Valuing Environmental Health Risk Reductions to Children

OPENING REMARKS BY

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A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE), NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER), AND OFFICE OF CHILDREN'S HEALTH PROTECTION; AND THE UNIVERSITY OF CENTRAL FLORIDA

October 20-21, 2003
Washington Plaza Hotel
Washington, DC

Prepared by Alpha-Gamma Technologies, Inc.
4700 Falls of Neuse Road, Suite 350, Raleigh, NC 27609

ACKNOWLEDGEMENTS

This report has been prepared by Alpha-Gamma Technologies, Inc. with funding from the National Center for Environmental Economics (NCEE). Alpha-Gamma wishes to thank NCEE's Kelly Maguire and Project Officer Nicole Owens for their guidance and assistance throughout this project.

DISCLAIMER

Remarks for Marianne L. Horinko
Acting Administrator of the U.S. Environmental Protection Agency
at the
Valuing Environmental Health Risk Reductions to Children Forum
Washington, D.C.

October 20, 2003

Thank you, Jessica (Furey), for that introduction. It is a pleasure to be here with you for the 9th Economy and Environment workshop – again highlighting a great partnership between EPA's Office of Policy, Economics and Innovation, Office of Research and Development, and our co-sponsors, the Office of Children's Health Protection and the University of Central Florida. For the second time, this series will focus on the importance of children's health protection – a topic that we are taking very seriously at EPA, especially as we recognize Children's Health Month during October. This month – and this forum – are excellent opportunities for us to discuss how we can use economic analyses to improve our decision making in the areas that affect children's health.

I'm not an economist, but those at EPA who are tell me that "environmental economists" approach the problem of valuing health risk reductions differently than "public health economists." I suspect that is true for children's risks as well, and it brings to mind what George Bernard Shaw once said: "If all economists were laid end to end they would not reach a conclusion." While they may not agree on a conclusion, economists provide vital information that informs policy decisions throughout the agency.

At EPA we consider economics a science, just as biology, toxicology, and chemistry are sciences. And, it is critical that we produce sound science that will help lead to quality decisions. Part of the scientific process is to engage in debate and disagreement. That is how progress is made, and it is why we are here. I encourage you to continue to engage on these critical issues, even when serious disagreement exists among - and within - branches of economics.

I will admit that I am frustrated when our economists say we lack the methods and research necessary to value specific benefit categories. Often times we use proxies or no valuation at all. We have to change that, and your work is crucial to gaining the information we need to do so. Your research provides the underlying information needed to support sound analyses and decision making. I am proud that our STAR grants program in the Office of Research and Development provides support to some of you to help us fill these critical knowledge gaps.

In the end, of course, there is far more agreement than disagreement. Indeed, the underpinnings of benefit-cost analysis, discounting, willingness-to-pay, and other economic concepts are now fundamental principles in textbooks. So it seems clear to me that tackling the problem of valuing health risk reductions to children is a situation where better communication among the various fields of economics will lead us to the quality decisions we want and need for our children. This conference will certainly get us closer to that goal. In fact, it is a goal that we have already been working toward for several years at EPA.

Protecting children is an important part of EPA's mission, and finding ways to value risk reductions for this vulnerable segment of society is critical to this work. As you may know, EPA does not account for age differences when estimating benefits for policy-making. However, we are committed to furthering our understanding of both the science and the valuation components of our decisions – which is why in 2003, EPA spent $18.4 million on children's health risk research.

We do know that children are not just little adults. As you know, their neurological, immunological, and digestive systems are still developing. They eat more food, drink more fluids, and breathe more air than adults in proportion to their body mass. And, children's behavioral patterns – such as crawling and placing objects in their mouths – may result in greater exposure to environmental contaminants. Because of these characteristics, children may not be sufficiently protected by regulatory standards that are based on risks to adults.

That does not mean that we have not made real progress in protecting children. For example, largely due to removing lead from gasoline, the median concentration of lead in blood of children under the age of 5 dropped by 85 percent between 1976 and 2000. This is important because lead exposure can result in lowered intelligence, impaired hearing, hyperactivity, and other adverse health effects. Building on the progress made by removing lead from gasoline, EPA spends $2.5 million annually on regulation development and public education to further reduce children's exposure to lead. Clearly, all of our efforts over the last three decades are working.

I hope that several years from now, the same will be said for our ongoing efforts to reduce childhood asthma. Between 1980 and 1995 the percentage of children with asthma doubled from 3.6 percent to 7.5 percent – today more than 6.3 million children under the age of 18 have this disease that forces them to miss 14 million days of school each year. The Clean School Bus USA initiative – which EPA launched last spring – will help clean up emissions from buses and reduce asthma symptoms by eliminating unnecessary idling, replacing older buses with new ones, and equipping buses with advanced emission control technologies. This program seeks to make sure that every public school bus on the road in all 50 states will be a clean school bus by 2010. They will emit less pollution, contribute to cleaner air, and – most importantly – keep our kids safe and healthy on the way to school.

Clean School Bus USA is the newest in a long line of EPA initiatives designed to improve the lives of children suffering the health – and social – impacts of asthma. Tools for Schools, Smoke Free Homes, and the President's Clear Skies Initiative – along with a request for a $3 million increase in the President's FY 04 budget for children's health research – will continue to help us combat this epidemic.

The cases of lead and asthma show that when it comes to environmental health risks, children need special attention. We have targeted children by focusing on things like school buses, ventilation systems, and educational initiatives for families – but we must go further. During my time as Acting Administrator – and in my former role as Assistant Administrator for OSWER – I have seen that it is tremendously difficult to reflect children's issues in our regulatory process – but I think we can all agree that we must continue to try.

As we work to develop better scientific data on how pollutants affect children, and better regulatory analysis addressing children's risks, it is important to keep track of how well children's health protection efforts are working. Earlier this year, EPA published the second edition of *America's Children and the Environment* – a ground breaking report that shows trends in children's environmental health. Today, I am pleased to announce the launch of the online version of *America's Children and the Environment* which will house new information and data as it becomes available and will be a valuable resource for researchers, concerned citizens, and policymakers. I am also pleased to announce the release of the *Children's Health Valuation Handbook*, which is a companion to EPA's *Guidelines for Preparing Economic Analyses* that was released in 2002. The *Handbook* is a reference tool for those conducting economic analyses of EPA policies that are expected to affect children's health, providing information on how we might incorporate the unique risks to children into our analyses.

This is where you come in. Your research and the work you are presenting over the next two days will be invaluable for our ability to further understand this process and ensure that we develop policies that are protective of everyone – not just adults. It is a true measure of our society how well we protect those who are the least able to protect themselves. I fully anticipate that your presentations will challenge and inspire us to continue tackling these difficult issues in an effort to improve public policy – and the lives of our children.

Thank you.

Valuing Environmental Health Risk Reductions to Children

PROCEEDINGS OF

SESSION I: THE STATUS OF CHILDREN

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE), NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER), AND OFFICE OF CHILDREN'S HEALTH PROTECTION; AND THE UNIVERSITY OF CENTRAL FLORIDA

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DISCLAIMER

These proceedings are being distributed in the interest of increasing public understanding and knowledge of the issues discussed at the workshop and have been prepared independently of the workshop. Although the proceedings have been funded in part by the United States Environmental Protection Agency under Contract No. 68-W-01-055 to Alpha-Gamma Technologies, Inc., the contents of this document may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

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Changes in the Lives of U.S. Children: 1990-2000

Kristin Smith
Robert Kominski
Julia Overturf

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Introduction

- Once every ten years, the decennial census provides the opportunity to generate snapshots of the population for very small geographic units. Much more than a complete count of the nation's population, the census provides important social, economic and housing detail about the population, allowing policy-makers and planners to see how characteristics have changed over time in cities, towns and neighborhoods.

- Over the past decade there has been renewed interest on the well-being of children. Spearheaded by federal activities such as the Federal Interagency Forum on Children and Families, much of the focus has been on identifying a variety of indicators of children's well-being.

- In this presentation, I present nine indicators of child well-being from the 1990 and 2000 decennial Censuses. What is unique about this presentation is that data for the items highlighted here are shown for all fifty states and the District of Columbia. Doing so allows one to see the variability that exists across the Nation, as well as providing details of change during the past decade.

Population and Family Characteristics

- Children living in married-couple families
- Children with difficulty speaking English
- Children who are foreign-born

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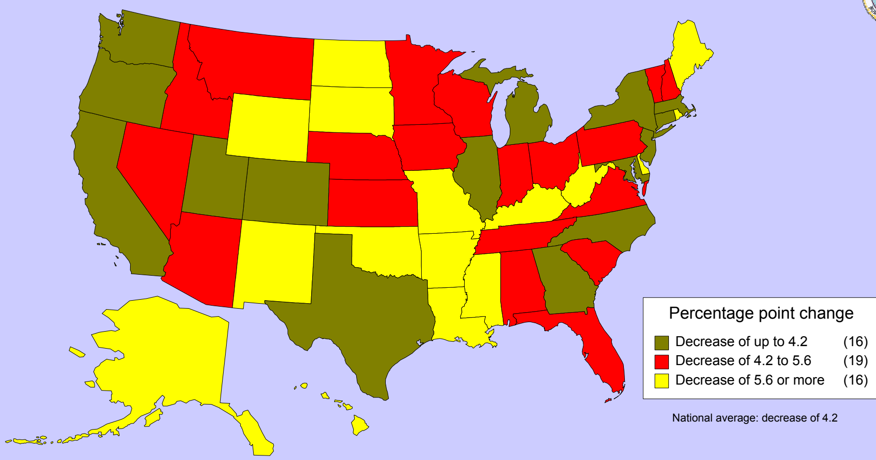
Children Living in Married-Couple Families
1990-2000 Change



NOTE: Includes children under 18 in households who are not householders, subfamily reference persons or their spouses. Children in married-couple families are the never-married biological, adopted, and step sons and daughters of a married householder or a married subfamily reference person.

SOURCE: U.S. Census Bureau, 1990 and 2000 Censuses.

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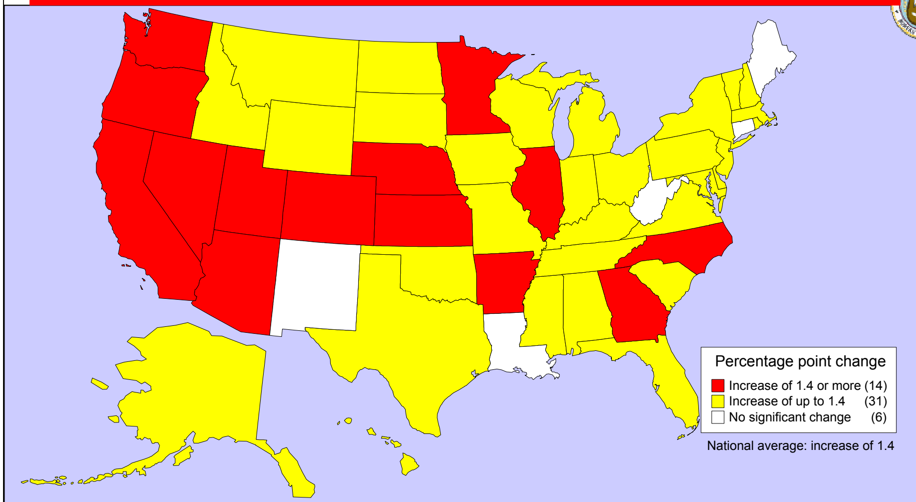
Children Living in Married-Couple Families

- In 2000, 68 percent of children under 18 years old lived in married-couple families, down from 72 percent in 1990.

- The decline in children living in married-couple families occurred in all states in the nation, with several states showing a decrease of about 7 percentage points. New Jersey had a small decrease (1.7 percentage points) from 74 percent in 1990 to 72 percent in 2000.

Children With Difficulty Speaking English
1990-2000 Change



NOTE: Includes children under 18 in households who are not householders, subfamily reference persons or their spouses. Children with difficulty speaking English speak a language other than English at home and speak English less than 'very well.' This includes those who speak English 'well,' 'not very well,' or 'not at all.'
SOURCE: U.S. Census Bureau, 1990 and 2000 Censuses.

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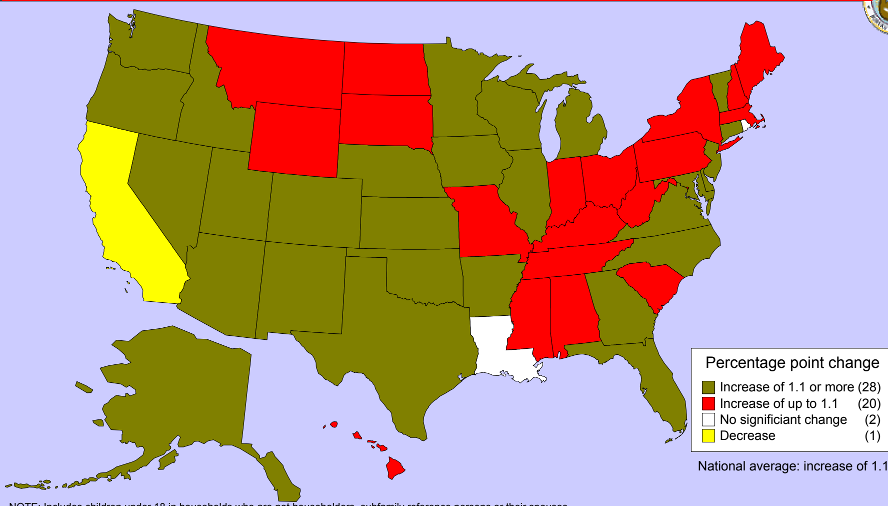
Children With Difficulty Speaking English

- Nationally, the proportion of children ages 5 to 17 with difficulty speaking English increased from 5 percent in 1990 to 7 percent in 2000.

- Most states experienced such an increase, with the largest percentage point increase occurring in Nevada, where it rose from 4 percent in 1990 to 9 percent in 2000.

Children Who Are Foreign-born
1990-2000 Change



NOTE: Includes children under 18 in households who are not householders, subfamily reference persons or their spouses.
Foreign-born children were not born in the 50 states, the District of Columbia, U.S. outlying territories, or abroad to American parents.
SOURCE: U.S. Census Bureau, 1990 and 2000 Censuses.

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Children Who Are Foreign-born

- In 2000, 4 percent of children living in the United States were foreign-born, up from 3 percent in 1990.
- Five states had increases of 2.5 percentage points or more in the proportion of foreign-born children: Arizona, Colorado, Nevada, Oregon and Washington – all of which were also states that saw their percentages of children with difficulty speaking English increase.

Economic Security

- Children in families in poverty
- Children in crowded housing
- Children living with a full-time employed parent

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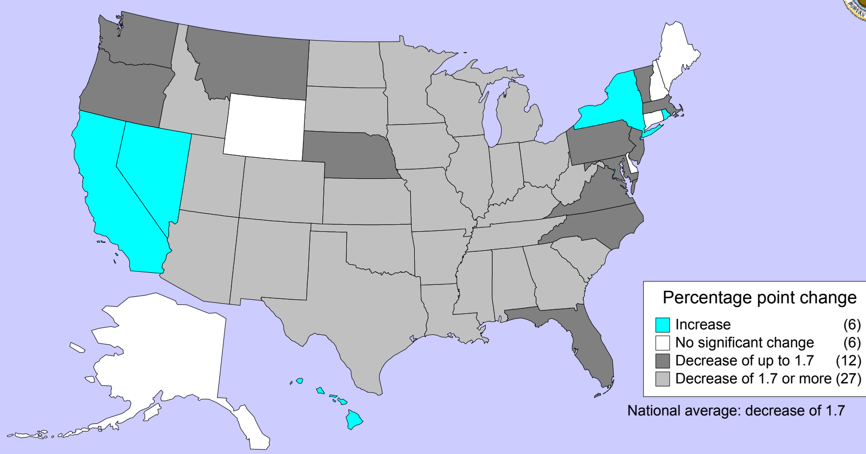
Children in Families in Poverty
1990-2000 Change



NOTE: Includes children under 18 in households who are not householders, subfamily reference persons or their spouses. Child poverty includes children living in households who are related to the householder and whose family income and family size put the child below the poverty threshold. Poverty data collected in the 1990 and 2000 censuses refers to poverty in calendar year 1989 and 1999, respectively. The average poverty threshold for a family of four was $12,674 in 1989 and $17,029 in 1999.
SOURCE: U.S. Census Bureau, 1990 and 2000 Censuses.

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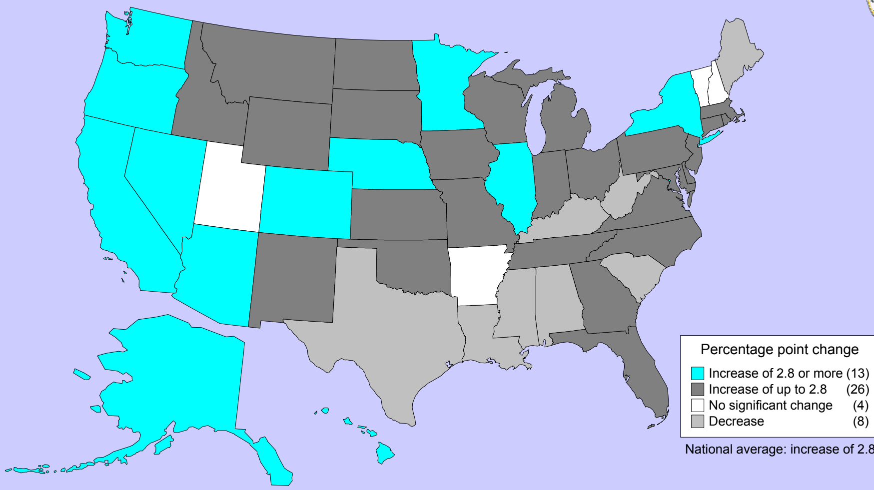
Children in Families in Poverty

- Child poverty decreased for the nation as a whole from 18 percent in 1990 to 16 percent in 2000.

- Louisiana and Mississippi had large declines in child poverty over the 1990s, even though they had the highest levels among the states in 2000. Despite a decrease in child poverty for the nation as a whole and for many individual states, child poverty increased significantly over the decade in five states and the District of Columbia.

Children in Crowded Housing
1990-2000 Change



NOTE: Includes children under 18 in households who are not householders, subfamily reference persons or their spouses.
Children living in crowded housing live in a house where the number of persons per room is greater than 1.
SOURCE: U.S. Census Bureau, 1990 and 2000 Censuses.

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Children in Crowded Housing

- In 2000, 19 percent of children lived in crowded housing, up from 16 percent a decade earlier.
- In Nevada, a rapidly-growing state, the proportion of children living in crowded housing increased 7.6 percentage points over the decade, from 19.7 percent in 1990 to 27.3 percent in 2000, the largest increase in the nation.
- However, the largest decrease was found in Texas, where the rate decreased from 25 percent in 1990 to 15 percent in 2000.

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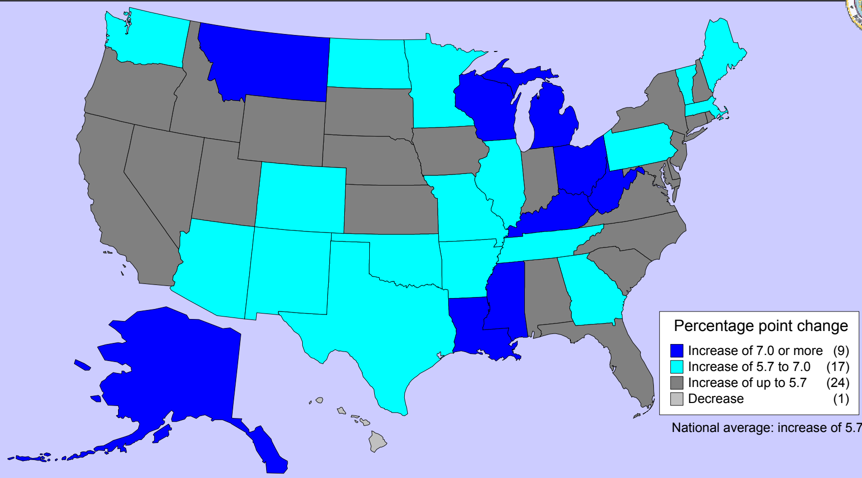
Children Living with a Full-time Employed Parent 1990-2000 Change



NOTE: Includes children under 18 in households who are not householders, subfamily reference persons or their spouses. Children living with an employed parent are the never-married biological, adopted, and stepsons and stepdaughters of a householder or a subfamily reference person, living with one or two parents who are employed and working at least 35 hours per week.
SOURCE: U.S. Census Bureau, 1990 and 2000 Censuses.

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Children Living with a Full-time Employed Parent

- In 2000, 83 percent of children lived in families with at least one parent employed full time, up from 77 percent in 1990.
- The largest gain in parental employment was found in Michigan where the rate of children living in families with an employed parent rose from 73 percent in 1990 to 84 percent in 2000.

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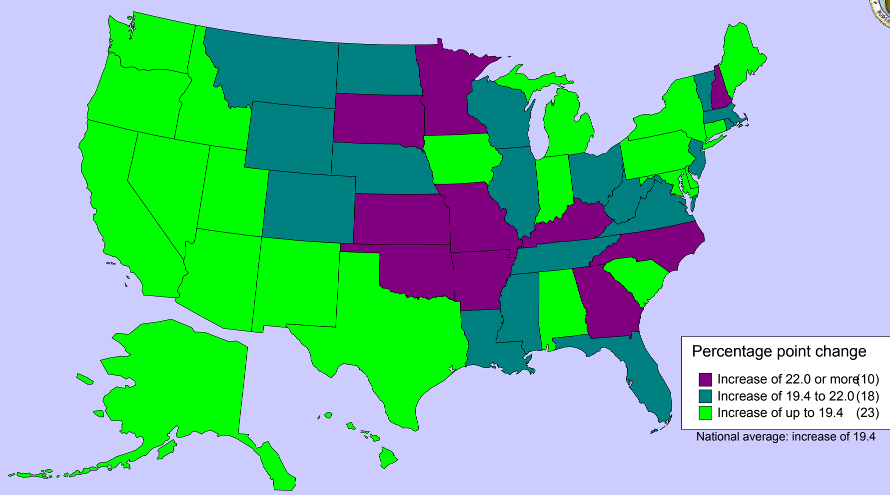
Education

- 3- to 5-year olds enrolled in school
- 18- to 24-year olds who have completed high school
- 16- to 19-year olds not working nor enrolled in school

3- to 5-Year Olds Enrolled in School
1990-2000 Change



NOTE: Includes only children 3- to 5-years who are living in households. Enrolled in school includes those in kindergarten, preschool, or nursery school.
SOURCE: U.S. Census Bureau, 1990 and 2000 Censuses

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3- to 5-Year Olds Enrolled in School

- Nationally, the proportion of children ages 3 to 5 enrolled in early education rose from 42 percent in 1990 to 61 percent in 2000, representing an increase of 19 percentage points.

- The figure clearly shows the geographic variation in early education among children ages 3 to 5, with most of the smaller increases clustered among the Western states. Georgia, a Southern state, had the largest increase from 41 percent in 1990 to 67 percent in 2000.

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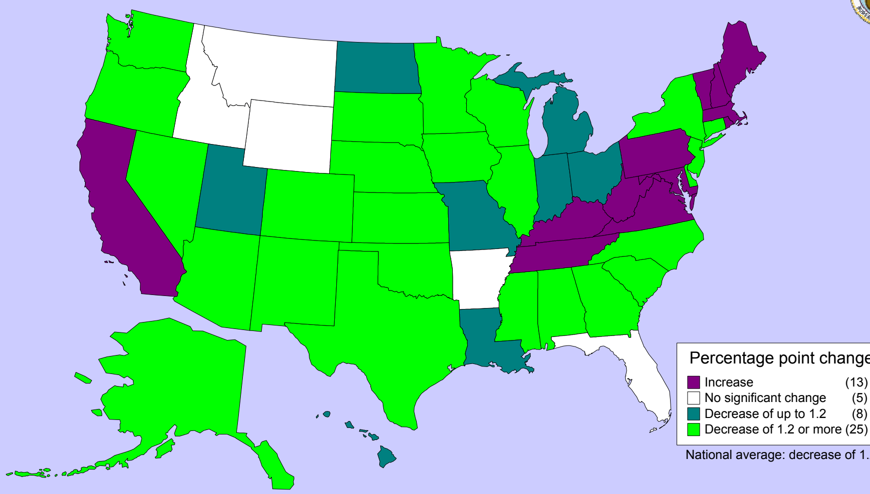
18- to 24-Year Olds Who Have Completed High School 1990-2000 Change



NOTE: Universe excludes those who are still enrolled in high school or below.
SOURCE: U.S. Census Bureau, 1990 and 2000 Censuses.

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18- to 24-Year Olds Who Have Completed High School

- Nationally, the percentage of people ages 18 to 24 who had completed high school dropped from 84 percent in 1990 to 82 percent in 2000. Part of this decrease was related to changes in the demographic composition of this age group, particularly with respect to the Hispanic population.
- Declines occurred in many states where the proportion of young Hispanics in the population increased, such as in Arizona, Colorado, Nevada, and North Carolina.
- Twelve states and the District of Columbia experienced increases in high school completion rates. The rates in California and West Virginia increased about 3 percentage points from 1990 to 2000.

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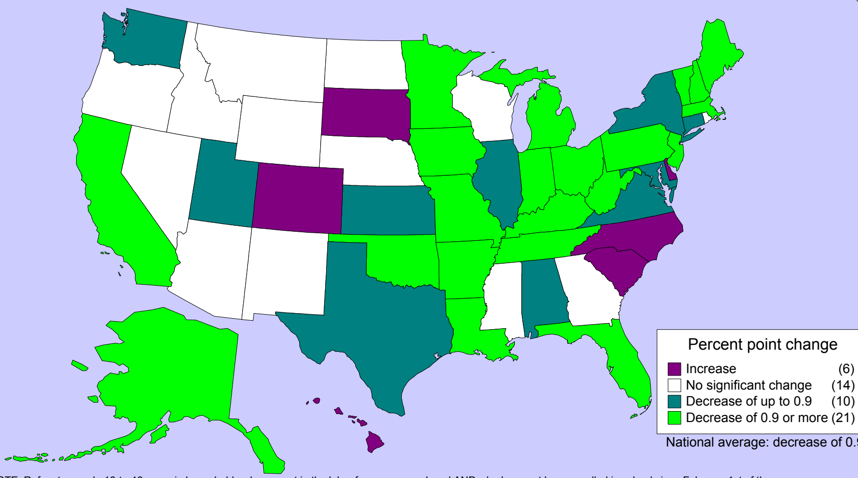
16- to 19-Year Olds Not Working Nor Enrolled in School 1990-2000 Change



NOTE: Refers to people 16-to-19 years in households who are not in the labor force or unemployed AND who have not been enrolled in school since February 1st of the survey year.
SOURCE: U.S. Census Bureau, 1990 and 2000 Censuses.

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16- to 19-Year Olds Not Working Nor Enrolled in School

- In 2000, 9 percent of youth ages 16 to 19 neither worked nor attended school, representing a decrease from 10 percent in 1990.

- Several states experienced decreases of around 2 percentage points. In contrast, the rate significantly increased in only six states (Colorado, Delaware, Hawaii, North Carolina, South Carolina, and South Dakota).

Additional Data

- Future U.S. Census Bureau reports on child well-being will build upon the data presented here today and incorporate other data to more fully portray changes in the lives of U.S. children.
  - Census report to be published by end of 2003, "Children and the Households They Live In: 2000" using Census 2000 data.
  - Census report to be published in 2004 comparing 1990 and 2000 Census data on more indicators.
- Many more indicators of child well-being are available for analysis at many geographic levels (Nation, State, MSA, county, tract, etc.).

Other available data

- Hispanic origin
- Foreign language spoken at home
- Recent immigrant
- Citizenship
- Metropolitan residence
- Home ownership
- Labor force status of parents
- Household utilities (incomplete plumbing or kitchen, no telephone or vehicle)
- Teen marital status
- Family structure and living arrangements

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Other available data

- Receipt of government assistance
- Multi-generational household
- Foreign-born parent
- Parent's educational status
- Living with a parent who is disabled
- Parent is a recent immigrant
- Living with a parent who speaks English less than very well

America's Children and the Environment:
Measures of Contaminants, Body Burdens, and Illnesses

US Environmental Protection Agency
Office of Policy, Economics and Innovation
Daniel A. Axelrad

1

America's Children and the Environment

- First edition - December 2000
- Second edition - February 2003
- Goals:
  - Identify environmental conditions and health outcomes of greatest relevance for children
  - Identify best available data
  - Develop most informative measures
  - Identify limitations, data needs, future directions

2

Topics Addressed

- Environmental Contaminants
- Body Burdens
- Childhood Illnesses

3

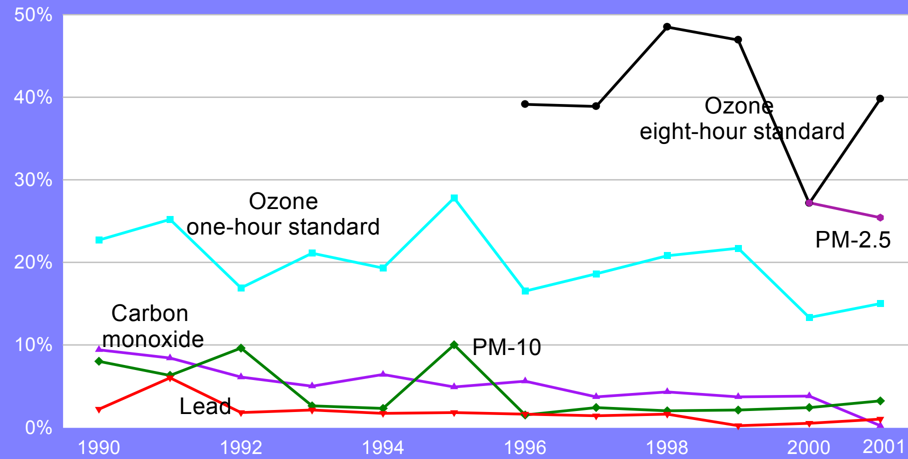
Environmental Contaminants

- Outdoor Air Pollutants
- Indoor Air Pollutants
- Drinking Water Contaminants
- Pesticide Residues
- Land Contaminants

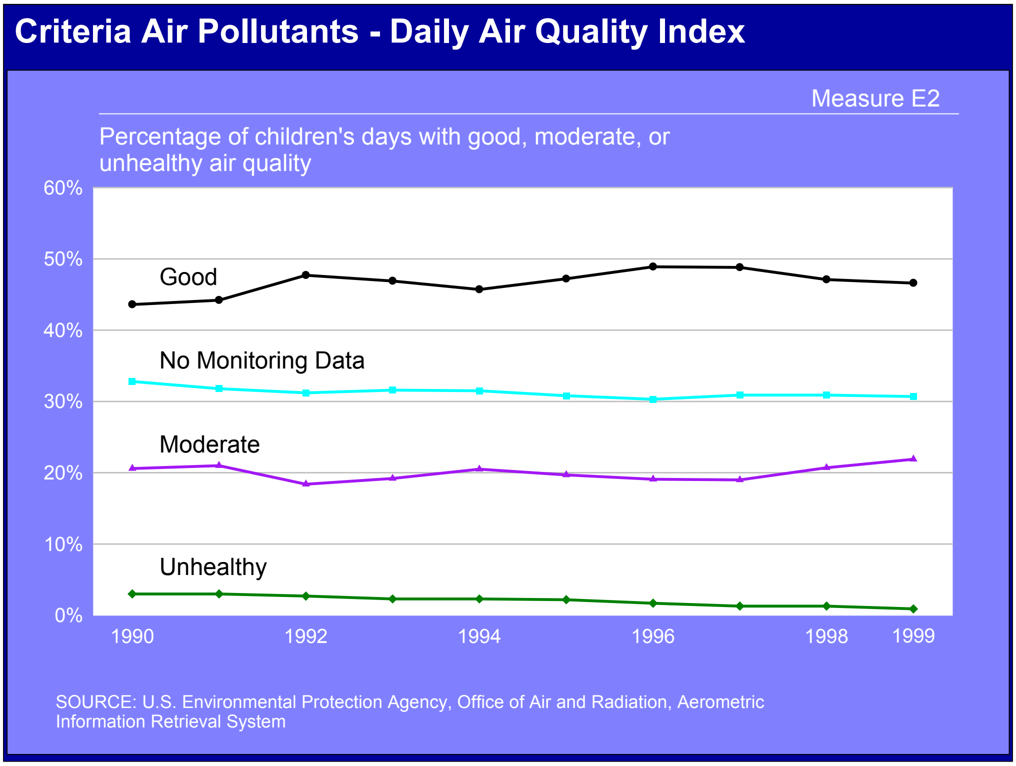
Criteria Air Pollutants - Exceedance of Standards

Measure E1

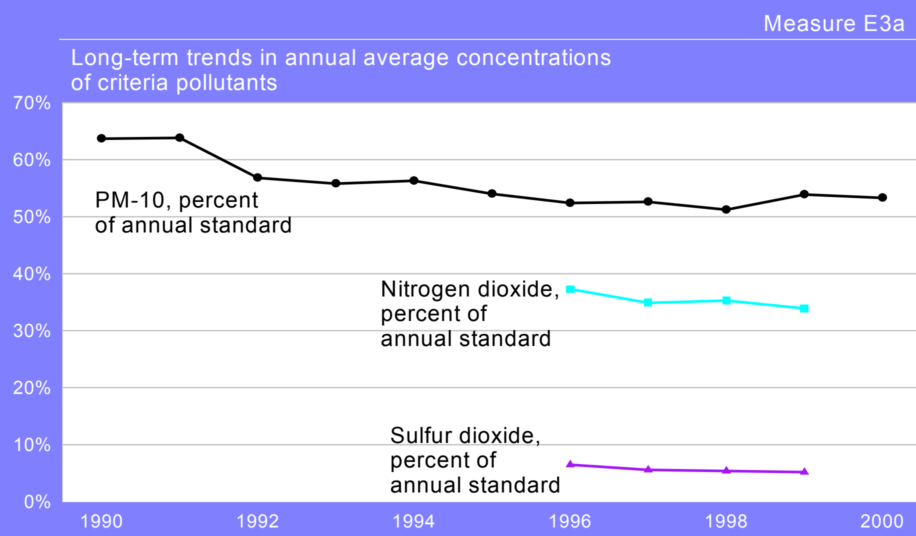
Percentage of children living in counties in which air quality standards were exceeded



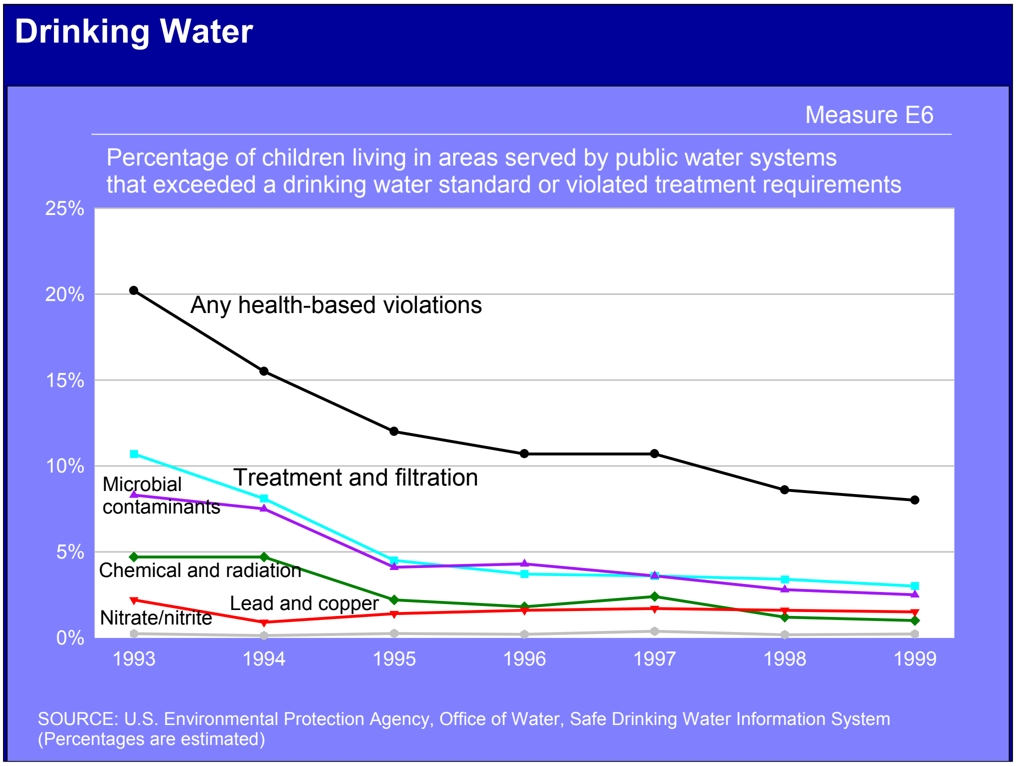
SOURCE: U.S. Environmental Protection Agency, Office of Air and Radiation, Aerometric Information Retrieval System


Criteria Air Pollutants - Daily Air Quality Index
Measure E2
Percentage of children's days with good, moderate, or unhealthy air quality
60%
50%
40%
30%
20%
10%
0%
Good
No Monitoring Data
Moderate
Unhealthy
1990
1992
1994
1996
1998
1999
SOURCE: U.S. Environmental Protection Agency, Office of Air and Radiation, Aerometric Information Retrieval System

Criteria Air Pollutants - Long Term



SOURCE: U.S. Environmental Protection Agency, Office of Air and Radiation, Aerometric Information Retrieval System



Drinking Water
Measure E6
Percentage of children living in areas served by public water systems
that exceeded a drinking water standard or violated treatment requirements
25%
20%
15%
10%
5%
0%
Any health-based violations
Treatment and filtration
Microbial
contaminants
Chemical and radiation
Lead and copper
Nitrate/nitrite
1993
1994
1995
1996
1997
1998
1999
SOURCE: U.S. Environmental Protection Agency, Office of Water, Safe Drinking Water Information System
(Percentages are estimated)

Body Burdens

- Concentrations of Lead in Blood
  - in children age 5 and under
- Concentrations of Mercury in Blood
  - women of childbearing age
- Concentrations of Cotinine in Blood
  - marker for exposure to Environmental Tobacco Smoke
  - in children under age 18

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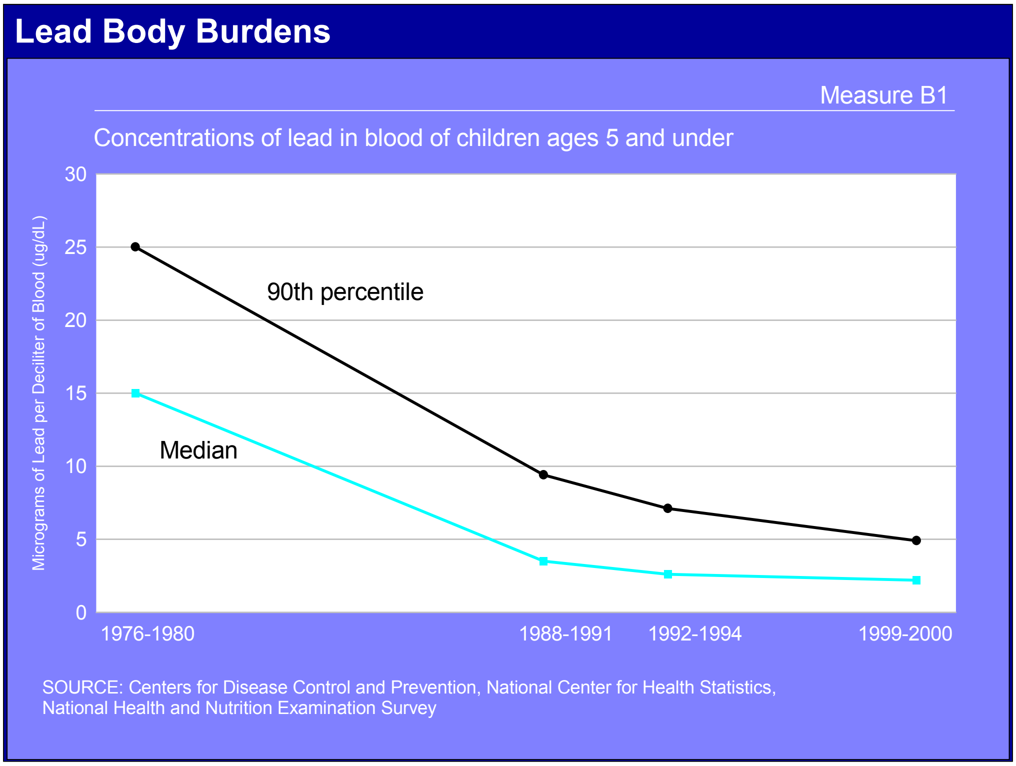
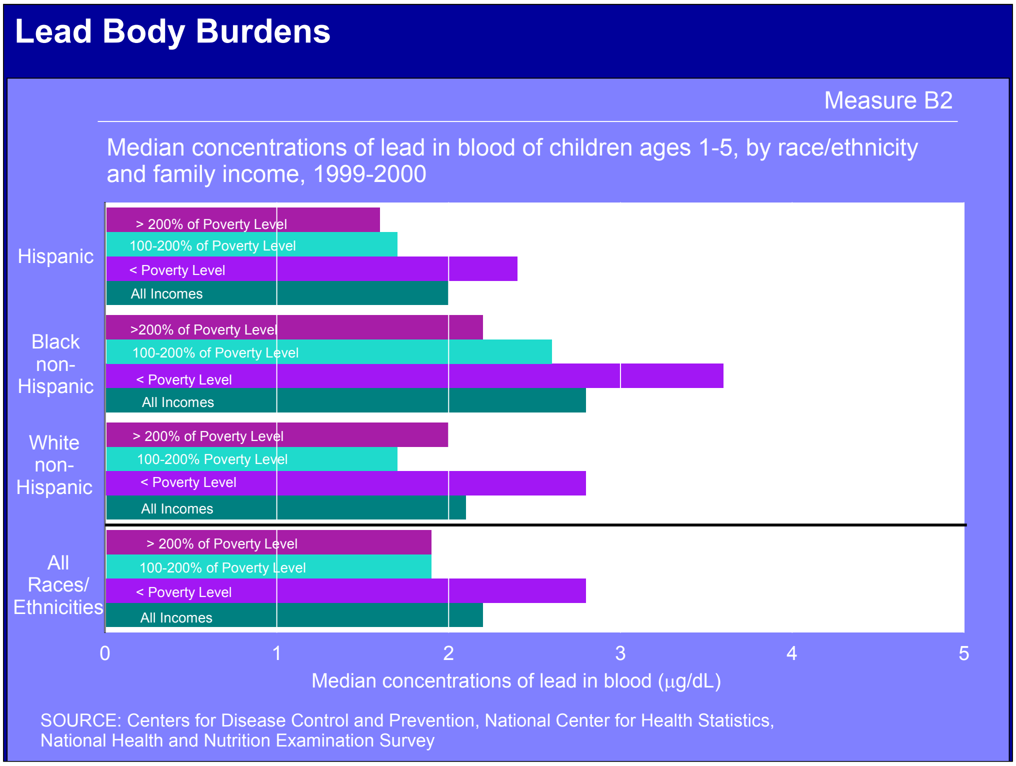

Lead Body Burdens
Measure B1
Concentrations of lead in blood of children ages 5 and under
Micrograms of Lead per Deciliter of Blood (ug/dL)
30
25
20
15
10
5
0
90th percentile
Median
1976-1980
1988-1991
1992-1994
1999-2000
SOURCE: Centers for Disease Control and Prevention, National Center for Health Statistics,
National Health and Nutrition Examination Survey

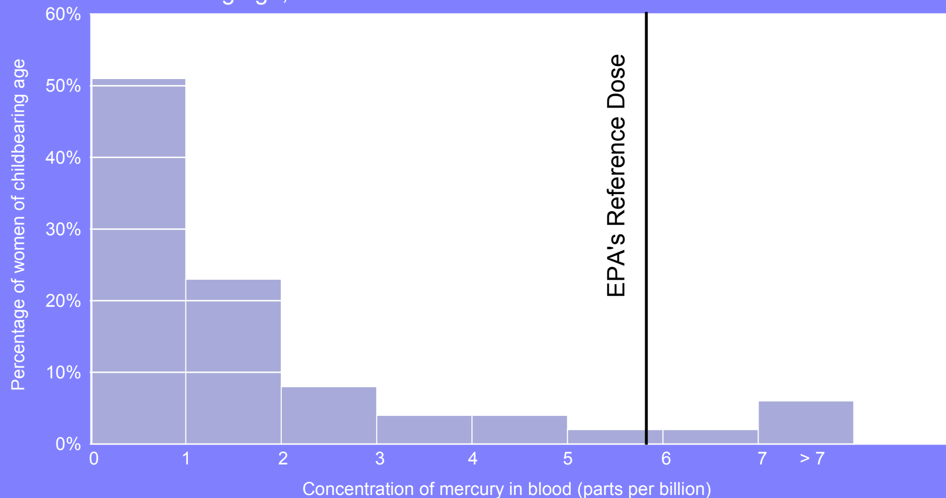


Lead Body Burdens
Measure B2
Median concentrations of lead in blood of children ages 1-5, by race/ethnicity and family income, 1999-2000
Hispanic
> 200% of Poverty Level
100-200% of Poverty Level
< Poverty Level
All Incomes
Black non-Hispanic
>200% of Poverty Level
100-200% of Poverty Level
< Poverty Level
All Incomes
White non-Hispanic
> 200% of Poverty Level
100-200% Poverty Level
< Poverty Level
All Incomes
All Races/ Ethnicities
> 200% of Poverty Level
100-200% of Poverty Level
< Poverty Level
All Incomes
0
1
2
3
4
5
Median concentrations of lead in blood (µg/dL)
SOURCE: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey

Mercury Body Burdens

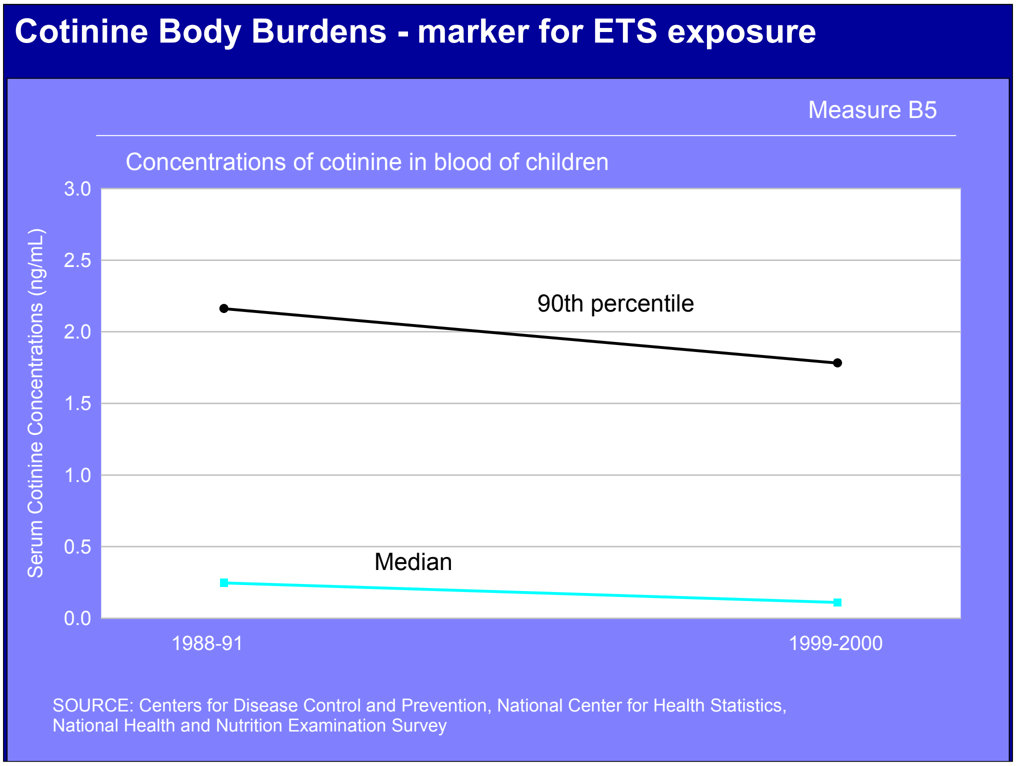
Measure B4

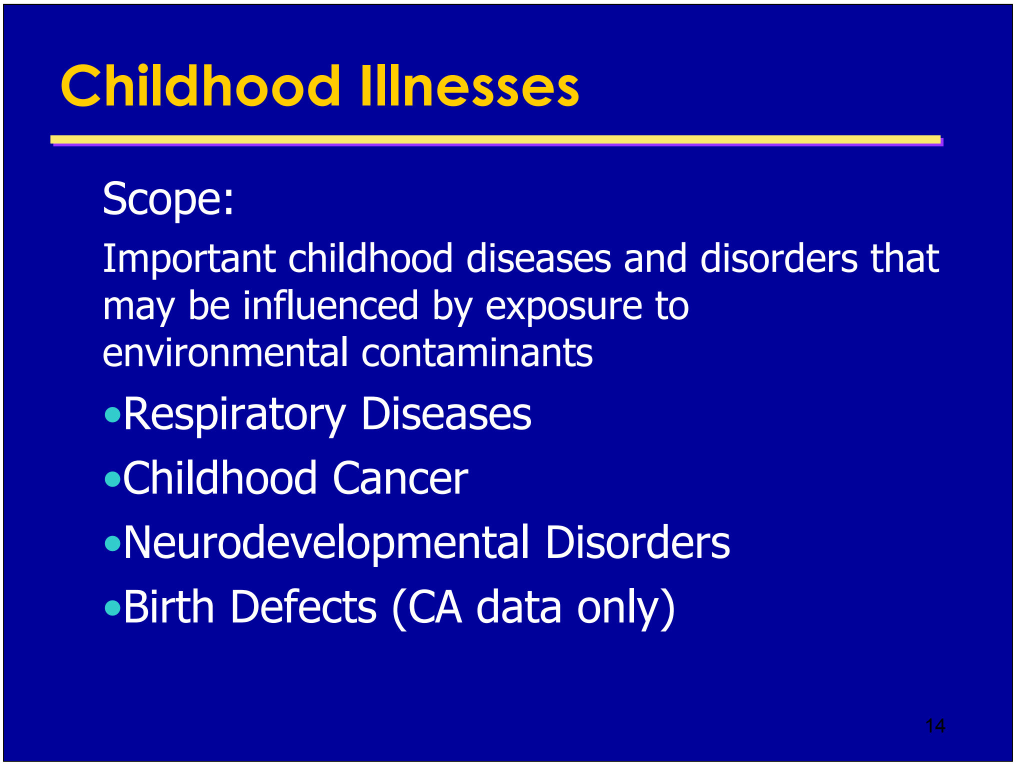
Distribution of concentrations of mercury in blood of women of childbearing age, 1999-2000

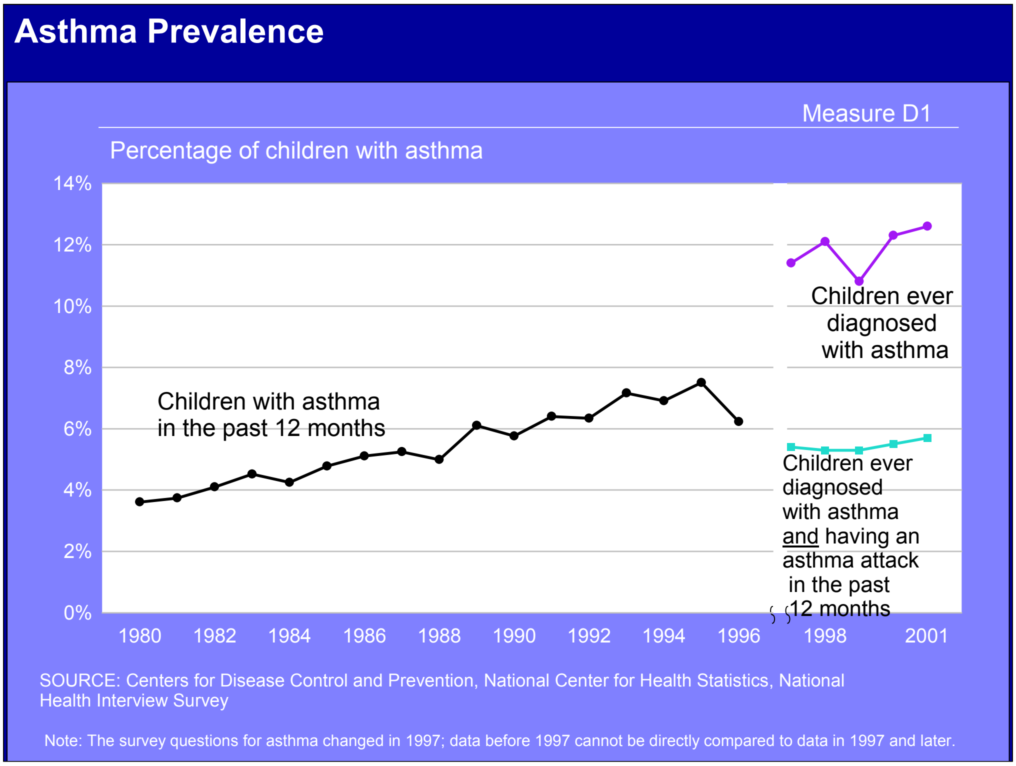


SOURCE: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey

Note: EPA's reference dose (RfD) for methylmercury is 0.1 micrograms per kilogram body weight per day. This is approximately equivalent to a concentration of 5.8 parts per billion mercury in blood.


Cotinine Body Burdens - marker for ETS exposure
Measure B5
Concentrations of cotinine in blood of children
Serum Cotinine Concentrations (ng/mL)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
90th percentile
Median
1988-91
1999-2000
SOURCE: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey


Childhood Illnesses
Scope:
Important childhood diseases and disorders that may be influenced by exposure to environmental contaminants
•Respiratory Diseases
•Childhood Cancer
•Neurodevelopmental Disorders
•Birth Defects (CA data only)
14



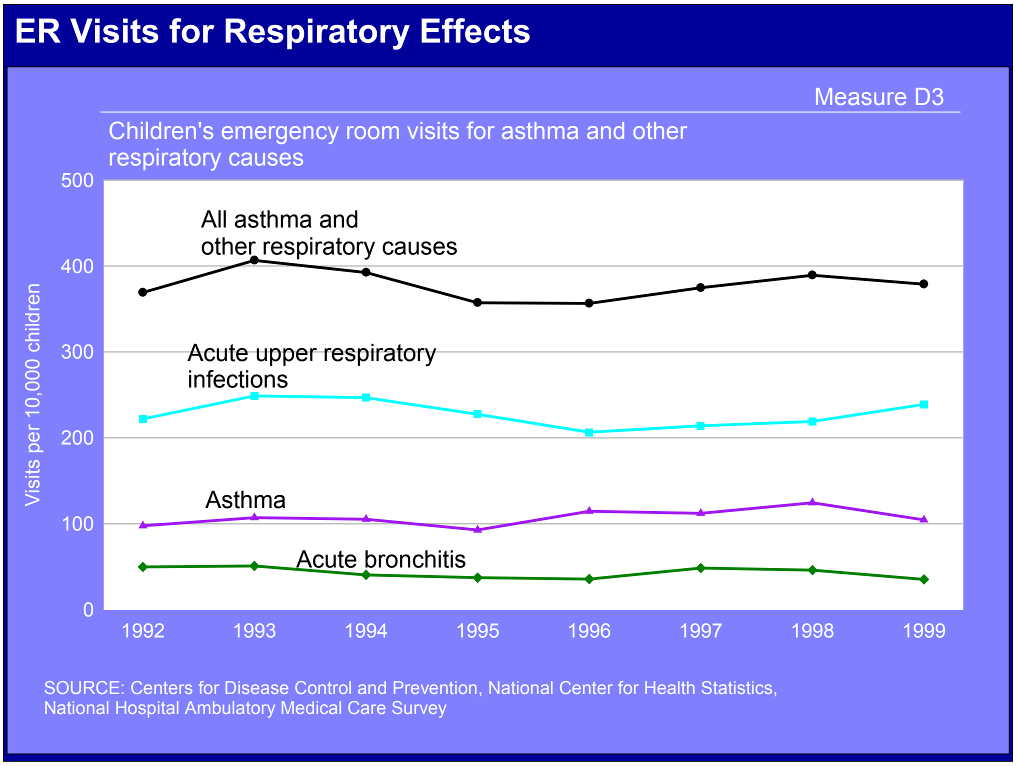
Asthma Prevalence
Measure D1
Percentage of children with asthma
14%
12%
10%
8%
6%
4%
2%
0%
Children with asthma
in the past 12 months
Children ever
diagnosed
with asthma
Children ever
diagnosed
with asthma
and having an
asthma attack
in the past
12 months
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2001
SOURCE: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health Interview Survey
Note: The survey questions for asthma changed in 1997; data before 1997 cannot be directly compared to data in 1997 and later.

Asthma Prevalence

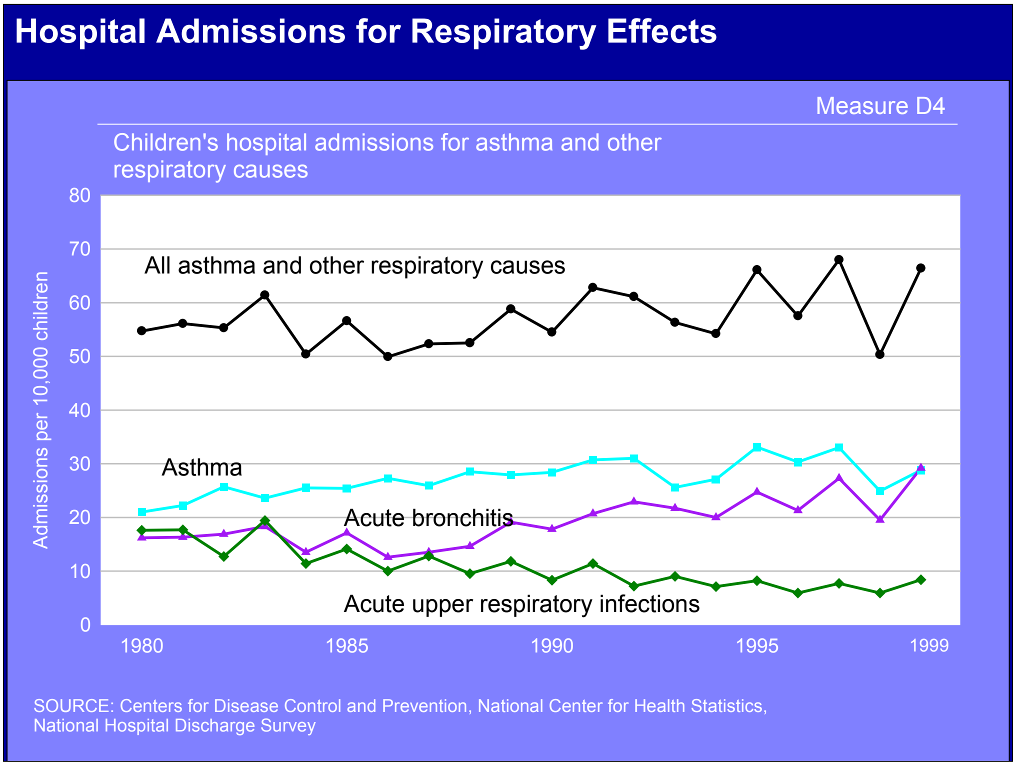
Measure D2

Percentage of children having an asthma attack in the previous 12 months, by race/ethnicity and family income, 1997-2000

SOURCE: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health Interview Survey



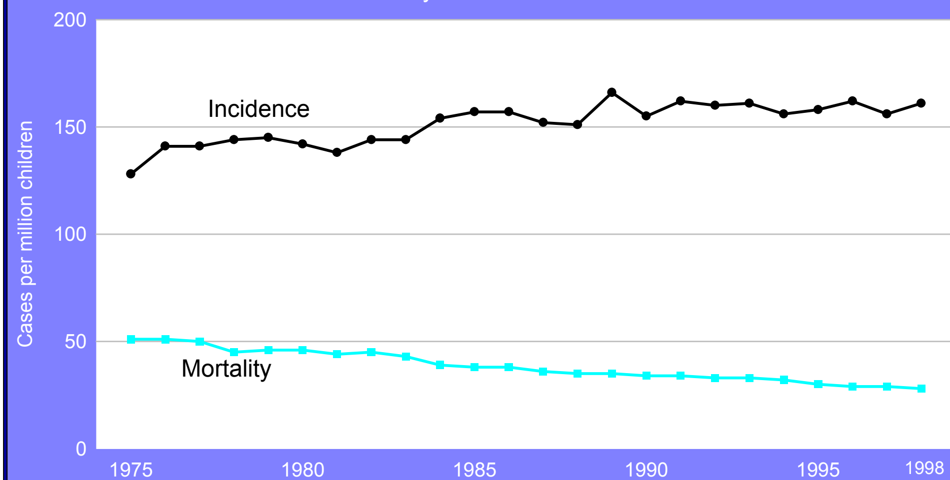
ER Visits for Respiratory Effects
Measure D3
Children's emergency room visits for asthma and other respiratory causes
All asthma and other respiratory causes
Acute upper respiratory infections
Asthma
Acute bronchitis
Visits per 10,000 children
500
400
300
200
100
0
1992
1993
1994
1995
1996
1997
1998
1999
SOURCE: Centers for Disease Control and Prevention, National Center for Health Statistics, National Hospital Ambulatory Medical Care Survey


Hospital Admissions for Respiratory Effects
Measure D4
Children's hospital admissions for asthma and other respiratory causes
Admissions per 10,000 children
80
70
60
50
40
30
20
10
0
All asthma and other respiratory causes
Asthma
Acute bronchitis
Acute upper respiratory infections
1980
1985
1990
1995
1999
SOURCE: Centers for Disease Control and Prevention, National Center for Health Statistics, National Hospital Discharge Survey

Childhood Cancer Incidence and Mortality

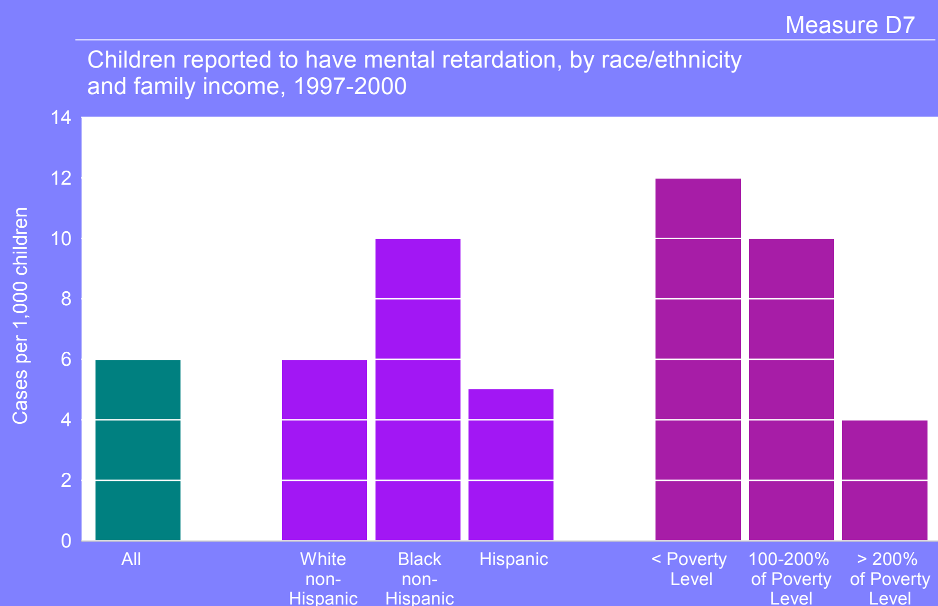
Measure D5

Cancer incidence and mortality for children under 20



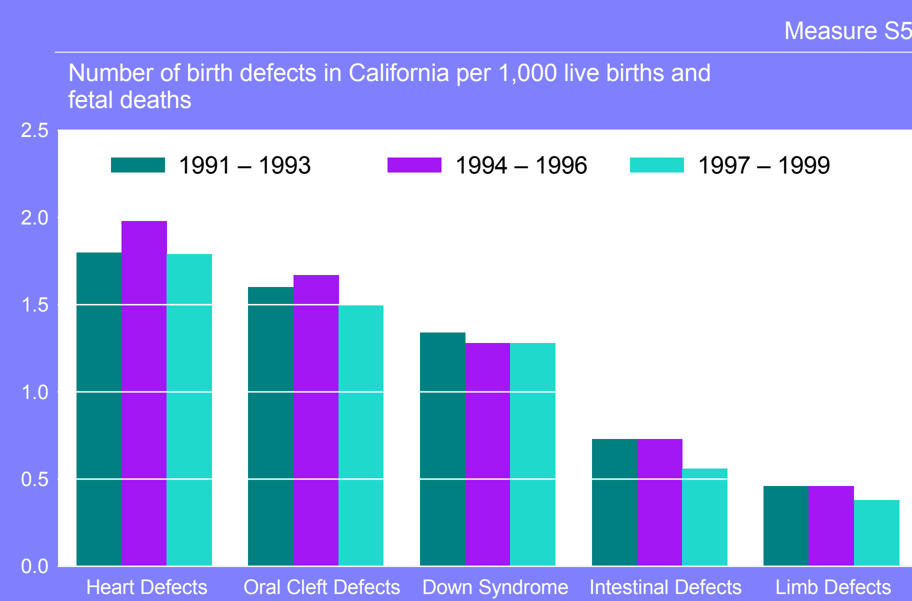
SOURCE: Incidence data from National Cancer Institute, Surveillance, Epidemiology and End Results Program; mortality data from Centers for Disease Control and Prevention, National Center for Health Statistics, National Vital Statistics System

Mental Retardation



SOURCE: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health Interview Survey

Birth Defects in California



SOURCE: California Birth Defects Monitoring Program

Conclusions

- Areas of improvement, including:
  - reduced blood lead levels and exposure to secondhand smoke
  - modest decreases in exposure to air pollutants and drinking water contaminants
- Areas of concern, including:
  - prenatal mercury exposure
  - rising prevalence of asthma
- Much remains to be learned about how pollutants affect children's health

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Acknowledgments

- Authors:
  - Tracey J. Woodruff, US EPA
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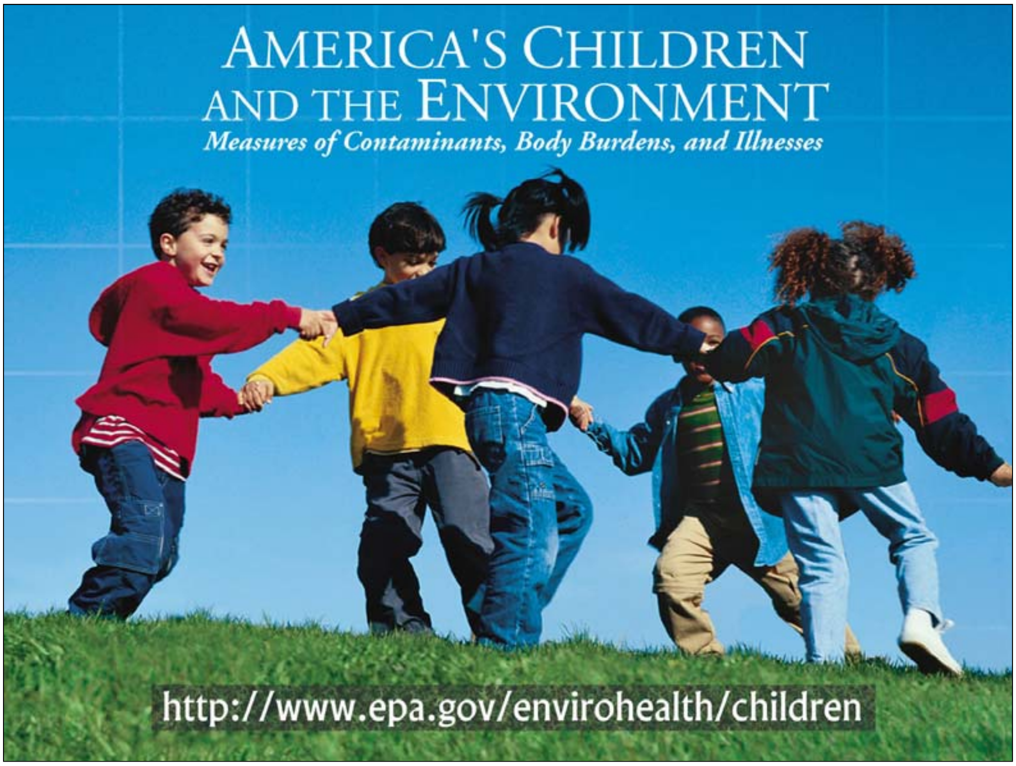

AMERICA'S CHILDREN
AND THE ENVIRONMENT
Measures of Contaminants, Body Burdens, and Illnesses
http://www.epa.gov/envirohealth/children

THE NATIONAL CHILDREN'S STUDY

Peter Scheidt

Program Office and Interagency Coordinating Committee

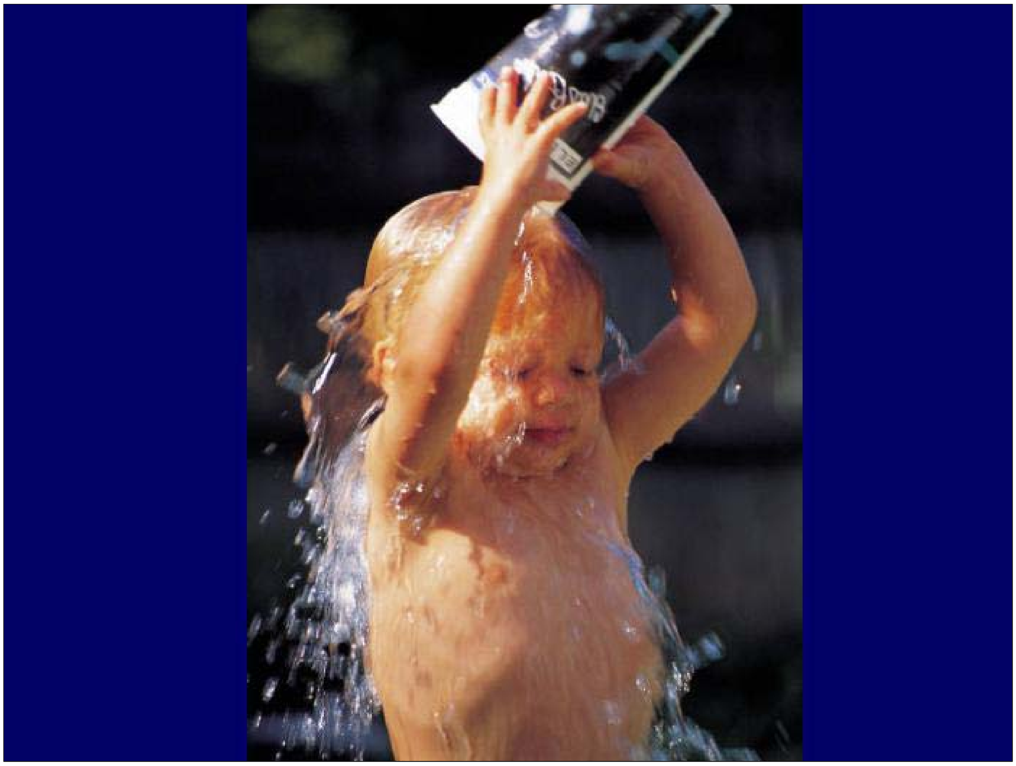
U.S. Department of Health and Human Services

NICHD, CDC, NIEHS

U.S. Environmental Protection Agency

Children have increased vulnerability to environmental exposures

- → Critical windows of vulnerability during development
- → Immature mechanisms for detoxification and protection
- → Differences in metabolism and behavior that may yield higher exposure in the same environments



Rationale for the National Children's Study

From The President's Task Force on Health Risks and Safety Risks to Children, 2000

- Compared to adults, children are especially vulnerable to environmental exposures – metabolism, behavior
- Exposures to some agents demonstrate potential for serious developmental effects – lead, prenatal alcohol
- Current known exposures of high frequency – pesticides, violence, media
- Numerous high burden conditions with suspected environmental contribution – learning disabilities, autism, diabetes, asthma, birth defects, premature birth
- Existing research too limited in size & scope to answer the questions
- Life-course (longitudinal) design needed to correctly link with multiple exposures and multiple outcomes

Why Now?

- Since the 1950s, many environmental factors have been introduced (chemicals in air, food, water, and soil) to increase the effects of the environment and its interaction with the genetic constitution of the developing fetus and the child. Others (DDT) have been decreased, at least in the U.S.
- Since the 1950s, many technological advances have been made (identifying biomarkers, mapping the human genome, computerization, etc.) that would contribute to the ability to identify environmental risks

PL 106-310
Children's Health Act of 2000

(a) PURPOSE- . . . to authorize NICHD to conduct a national longitudinal study of environmental influences (including physical, chemical, biological, and psychosocial) on children's health and development.

(b) IN GENERAL- The Director of NICHD shall establish a consortium of representatives from appropriate Federal agencies (including the CDC and EPA) to--

(1) plan, develop, and implement a prospective cohort study, from birth to adulthood, to evaluate the effects of both chronic and intermittent exposures on child health and human development; and

(2) investigate basic mechanisms of developmental disorders and environmental factors, both risk and protective, that influence health and developmental processes.

. . .

(e) AUTHORIZATION OF APPROPRIATIONS- There are authorized to be appropriated to carry out this section $18,000,000 for fiscal year 2001, and such sums as may be necessary for each the fiscal years 2002 through 2005.

Study Concepts

- Longitudinal study of children, their families and their environment
- National in scope
- Environment defined broadly (chemical, physical, behavioral, social, cultural)
- Study common range of "environmental" exposures and less common outcomes (n~100,000)
- Environment & genetic expression

Study Concepts (con't)

- →State-of-the-art technology – tracking, measurement, data management
- →Consortium of multiple agencies
- →Extensive public-private partnerships
- →National resource for future studies

Study Population - Issues

- → Generalizability to U.S. population
- → Additional study populations, e.g.
  - → Specific high-risk populations
    - → Agricultural
    - → Industrial
    - → Economically disadvantaged
  - → Women of child-bearing age - possible effects on fertility & pregnancy

Criteria for Core Hypotheses

- → No single hypothesis
- → Hypothesis required for costly elements
- → Important for child health & development (prevalence, severity, morbidity, mortality, disability, cost, public health significance)
- → Reasonable scientific rationale
- → Require the large sample size (~100,000)
- → Measurable with study of this size
- → Requires longitudinal follow-up

Priority Outcome Areas
(and example hypotheses)

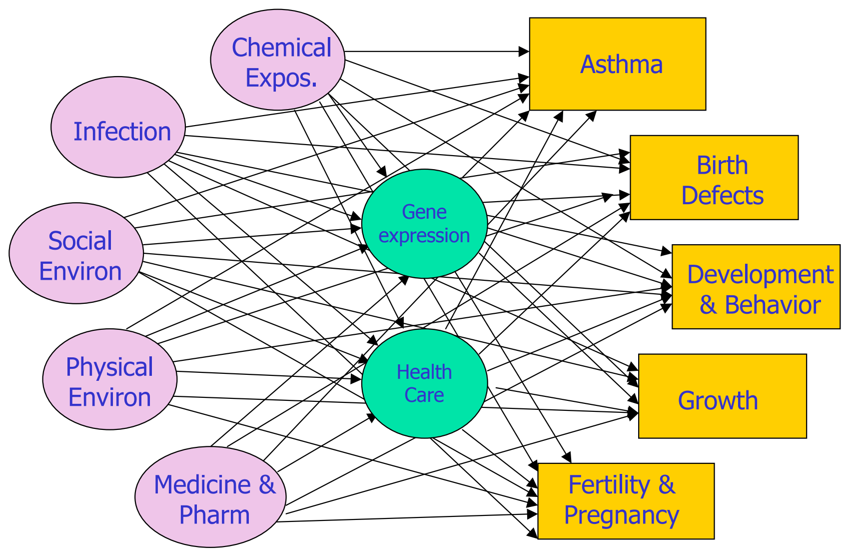
- → **Undesirable outcomes of pregnancy** (Infection and mediators of Inflammation during pregnancy are major factors associated with pre-term birth)
- → **Neurobehavioral development** (proposed - environmentally induced biochemical and physiological conditions of birth and infancy, including maternal hypothyroidism, neonatal hyperbilirubinemia, and others, are associated with learning and cogitative disabilities,.
- → **Injury** (Repeated head trauma w/o anatomic damage - cumulative adverse effects on neurocognitive development)

Priority Outcome Areas
(and example hypotheses)

→ **Asthma** (maternal stress during pregnancy is associated with the prevalence and severity of asthma in offspring)

→ **Obesity and physical development** (Obesity and insulin resistance is associated with impaired glucose metabolism in pregnancy and interacting factors in the physical and social environment)

Associations and Interactions in the National Children's Study



Measures Anticipated - Exposures

- → Environmental Samples: air, water, dust
- → Bio-markers for chemicals: blood, breast milk, hair, tissue, etc.
- → Interview and history
- → Serology and medical data
- → Housing & living characteristics
- → Family and social experiences
- → Neighborhood and community characteristics

Measures Anticipated – Outcomes

- Fetal growth and outcome of pregnancy
- Birth defects and newborn exam
- Growth, nutrition and physical development
- Medical condition and history: illness (e.g. asthma), conditions, & injuries
- Cognitive and emotional development
- Mental, developmental and behavioral conditions

Projected Time Line

2000-2004	Pilot study/methods development work
2001-2002	Form advisory committee and working groups
Periodically:	Meetings, peer reviews, consultations
Mid 2003	Finalize specific hypotheses, develop study design
Mid 2005	Select initial centers or alternatives and pilot test core protocol
Late 2005	Begin full study with vanguard centers
2005-2007	Enroll additional centers
2008-2009	First preliminary results available from pregnancy
2007-2030	Analyze data as collection continues, publish results throughout:

Potential Benefits of the NCS for Prevention of Diseases

Condition	Potential Reduction	Potential Annual Benefit
Pre-term Birth	10 %	$0.6 Billion
Asthma	25 %	$3.2 Billion
Obesity & Diabetes	12.5 %	$14.5 Billion
Juvenile Diabetes	15 %	$15 Billion
Injuries	10%	$39 Billion
Schizophrenia	33 %	$3.1 Billion
Learning problems One cause comparable to lead	8%	$100 Billion

NCS - Funding Status

- FY ’02 - $6 M
- FY ’03 – $10 M Proposed
- FY ’04 - $26 M Estimated need
- Funding for FY ’05 & beyond to NIH/HHS-EPA/OMB
- Congressional appropriation uncertain

The NCS will provide

- The **answer to concerns about known exposures** during childhood to potential toxicants
- The **power to determine absence of effects** or benefit of exposures to various products important for our economy
- **Causal factors for a number of diseases** and conditions of children with suspected environmental causes
- How **multiple causes** interact to result in **multiple outcomes**
- Large sample size required to **apply knowledge of the human genome** to understand multifactoral genetic conditions
- Identification of early life **factors that contribute to many adult conditions**
- A **national resource to answer future questions** by using stored biological and environmental samples and the extensive data for decades to come

Contact information

- Check the Web site: http://NationalChildrensStudy.gov
- Join the listserv for news and communication
- Contact us at ncs@mail.nih.gov

The End


Environmental Health Valuation
for Children:
Research in Europe
Pascale Scapecchi & Nick Johnstone
National Policies Division
OECD
OECD
1
OCDE

Context

- Much fewer studies in Europe than in the United States
- However, recent growth in interest in European countries
- OECD project on the valuation of environmental health risks to children

OECD 2 OCDE

European studies

- Very few economic European studies on the valuation of children's health
- Greater emphasis on epidemiological work
- Most European valuation studies estimate Health-related quality of life (HRQOL) measures
- Only one study which estimates WTP to protect children's health

OECD 3 OCDE

Valuation of Air Pollution in Europe

- Navrud (2001) estimates parental WTP to avoid ill-health episodes for their children.
- Health impacts considered: asthma attacks and coughing.
- Sample: parents of children under 17 years of age.
- Possibility of comparing parents' WTP for their own health with parents' WTP for their children's health.
- Mortality risk reduction is valued higher than morbidity risk reduction.
- Results show that WTP to prevent the child from illness is higher than WTP to prevent an adult from illness.

OECD 4 OCDE

16 D Questionnaire

- Apajasalo et al. (1996a) → health-related quality of life (HRQOL) measure of adolescent aged 12-15.
- 16 multiple choice questions representing one health-related dimension (e.g. mobility, vision, hearing, breathing, etc)
- Sample: “normal” and affected children (children waiting for organ transplantation, children with genetic skeletal dysplasias, and children with epilepsy).
- New approach: adolescents fill in the questionnaire by themselves, & questionnaire sent to their parents for comparison.
- Main Results:
  - The profiles differ significantly according to the diagnosis.
  - The measures obtained from the children and the parents differ
  - Differences between boys and girls.
- Conclusion: Reliable HRQOL measures of adolescents’ health should be based on data collected from the adolescents themselves.

OECD 5 OCDE

17 D Questionnaire

- Apajasalo et al. (1996b) → HRQOL measure for children aged 8-11 years.
- Based on the 16D questionnaire, they construct a measure consisting of 17 dimensions.
- Sample: affected and non-affected children.
- The children completed the questionnaire with the help of an interviewer.
- Similar results to the 16D study: the profiles vary according to the diagnosis.
- Reliable estimates of the HRQOL of children can be obtained when children fill in the questionnaire by themselves.
- However, recognition that limited cognitive capacities of young children.

OECD 6 OCDE

Children's QoL Assessment

- Manificat and Dazord (2002) assess quality of life (QoL) among 4 to 12 year old children.
- The questionnaire covers 27 items covering the main paediatric QoL domains, e.g. family life, social life, children's activities and health.
- Sample: ill and non-ill children.
- Children have to fill in the questionnaire by themselves.
- Results show differences across ages, health status and living condtions.

OECD 7 OCDE

Ongoing Work Programmes

- The Pan-European Programme assesses the evaluation of transport-related health impacts, with a particular emphasis on children. Countries involved: Austria, Switzerland, France, Malta, The Netherlands, and Sweden + WHO.
- Children's Environment and Health Action Plan for Europe (CEHAPE) undertaken by WHO, to tackle the environmental risk factors that most affect European children's health and providing concrete tools to address them. Countries involved: Member countries.
- The RANCH Project addresses the effects of noise on children's cognition and health. Countries involved: the Netherlands, Spain, Sweden and the UK.
- Work in Norway : projects referenced in the Norwegian Research Database (http://dbh.nsd.uib.no/nfi/english/)

OECD 8 OCDE

OECD Workshop

- Objectives:
  - Review the state of knowledge;
  - Assess the different valuation approaches; and,
  - Highlight the needs for further research and political action.
- Structure: 4 sessions:
  - general overview of differences;
  - conceptual and methodological issues;
  - comparison of methodologies; and,
  - policy perspectives.
- Key issues:
  - Unique challenges;
  - Availability of data;
  - Valuation methodology; and,
  - Benefit transfer

OECD 9 OCDE

Findings (1)

- **Overview of the differences between adults and children**
  - <u>Risk differences</u>
    - Children are not little adults
    - Heterogeneity between children
    - Great number of uncertainties
  - <u>Valuation differences</u>
    - 4 potential sources of valuation differences: age, risk preferences, context of valuation, and perspective.
    - Affect estimates
    - Estimated VSL of a child > Estimated VSL of an adult

OECD 10 OCDE

Findings (2)

- **Conceptual and methodological issues**
  - Formulation of children's preferences:
    - Parental perspective most appropriate
    - Application of intra-household allocation model (unitary vs. pluralistic)
    - Est'd WTP to reduce risk for children > Est'd WTP to reduce risk for adults.
  - Transfer of adults' values
    - Risk of under-estimation
    - Adjust adults' values with relevant marginal rate of substitution between adults' and children's health values.
  - Discounting children's health
    - Scarcity of relevant examples
    - Time-varying discount rate may be appropriate
    - Long term benefits accounted with care
  - Economic uncertainties
    - Key sources of uncertainty: risk context, time, irreversibility, formulation of children's preferences, valuation context and altruism.
    - Children's health value included in parent's health value.
    - Methodological concerns of greater importance.

OECD 11 OCDE

Findings (3)

- **Comparison of methodologies**
  - Stated vs. Revealed preferences techniques
    - Stated-preferences techniques more appropriate.
    - Revealed-preferences more demanding and difficult to implement, in particular in that context of valuation.
  - WTP vs. QALYs
    - WTP impose less restrictions on the structure of individual preferences but are more sensitive to the respondent thinking.
    - Any standard chosen is arbitrary
    - The choice will depend upon the setting
  - Health outcome measures
    - Studies conclude that perspective of children is preferred
    - Multi-attribute utility instruments provide reliable results
    - But what is the validity of the value obtained?

OECD 12 OCDE

Findings (4)

- **Policy perspectives**
  - Children are highly vulnerable to environmental degradation
  - Children are not little adults
  - Morbidity and mortality risks reduction greatly differ
  - Research on the valuation of children's health should be encouraged and supported
  - More comparative studies in different countries
  - Better risk and economic assessments are required

OECD 13 OCDE

Conclusions

- Misallocation of resources devoted toward children (and between children and adults)
- Linked to allocation (misallocation) of resources between morbidity and mortality
- Leads to wrong priorities being set across different impacts and wrong standards within individual impacts
- Much more information and research data are necessary to provide reliable policy advice

OECD 14 OCDE

Summary of Q&A Discussion Following Session I

Matt Clark (EPA/NCER) asked Dr. Scheidt whether there were any economists doing willingness-to-pay studies in association with the National Children's Study. When Dr. Scheidt responded "No," Dr. Clark suggested that a "wealth of data that would be very useful for policy matters" could be acquired for very little incremental cost, and he stated that similar joint efforts have been successful in the past. He strongly urged Dr. Scheidt to have economists participate and develop some survey materials that could augment the patient study.

Dr. Scheidt responded that the Study group was "very open to that kind of thing" and, in fact, has an economist/sociologist (Bob Michaels from the University of Chicago) involved on the advisory committee, although they've "not engaged in that level of economic study." He invited any interested economists to contact the Study group directly.

Glenn Harrison (University of Central Florida) asked two questions of Dr. Scheidt. He first stated that health economists can easily find studies that relate to the number of children who have hospital stays and diagnosis codes, etc., but they often can't find links to *cost* measures. Acknowledging that the costs are difficult to measure, he asked whether the Study was going to link to existing surveys that can actually give information on the *costs* of delivering healthcare. His second question concerned the issue that "surveys of children's health . . . very often start too late"—that is, they don't provide information on fetal deaths and infant deaths. The resultant "sample selection bias" can make a dramatic difference to the inferences one draws.

Dr. Scheidt responded that they definitely anticipate merging and linking to appropriate existing data sets (e.g., from the Census Bureau), and he stated that there is a white paper and workshop in the planning phase designed to examine all identifiable data sets relevant to the study which are candidates for linking. He said that this search is wide open, ranging "from social data to atmospheric air pollution" data being measured through satellite technology at NASA.

Dr. Scheidt acknowledged the concern with the question on fetal deaths and particularly with health risk issues from the critical period of early in the first trimester onward. Citing the logistical and economic difficulties of following the entire sample of those of child-bearing age from pre-pregnancy on, he stated that they at least hoped to track women whose children are enrolled in the study and who subsequently become pregnant.

Kerry Smith (North Carolina State University) commented on the difficulty, partly due to confidentiality reasons, in linking spatial data (i.e., latitude and longitude) to the households involved in the surveys, and he asked Dr. Scheidt to pay attention to getting economists access to that information, if possible. When, Dr. Scheidt asked for clues about how that might be accomplished, Dr. Smith clarified that what is needed is "a *convenient* way in which researchers can ask for the matching to take place by a third party." He acknowledged that certain for-profit entities allow linking to their databases, but this introduces the issue of cost.

Dr. Smith then asked whether in doing the design work there is "a provision to actually talk to household members about how they think about these choices" (i.e., the precautions parents take with their children). He suggested focus groups, cognitive interviews, etc. as means of ensuring that the right questions are being asked "as opposed to just itemizing what we *think* we'd like to know without talking to them."

Dr. Scheidt responded, "Yes, unequivocally," and mentioned that an extensive set of focus group discussions had begun and would be expanded as the protocol becomes clearer.

Dr. Smith asked whether the results of those discussions would be reported before the survey goes out, and Dr. Scheidt responded that information is posted on the website.

Rachel Nugent (NIH Fogarty International Center) called attention to the fact that both people and environmental contaminants move across borders and that "there are a lot of particularly vulnerable populations of children in the U.S. who may have foreign backgrounds or otherwise be influenced by other country backgrounds." She asked Dr. Scheidt to speak to the issue of coordinating the study with other countries.

Dr. Scheidt cited the Tri-National Commission's efforts in addressing the environmental impact of NAFTA and in urging Canada and Mexico to carry out "coordinated an parallel studies that would be quite an advantage to us to provide ranges of exposures that we would not otherwise have and potential sample size reductions." Dr. Scheidt acknowledged the potential problem of including participants from other countries who may migrate. In the study, they clearly anticipate including Spanish-speaking subjects and not excluding systematically any potential migrants, and they plan to provide long-term follow-up of anyone who does migrate. He stated that although the details of that had not yet been determined, they would do as much as is feasible.

Bryan Hubbell (EPA/OAQPS) brought up the issue of the limited network of monitors for many environmental contaminants. He wondered how the study was ensuring that "certain populations that don't happen to live where a monitor is" are not excluded and asked whether they planned to do additional monitoring.

Dr. Scheidt reiterated that the data from numerous sources (e.g., NASA) were being merged. He also stated that the study anticipated supplementing available data with "an extensive degree of monitoring" itself and was exploring the range of technologies available for doing this economically and efficiently. The study working groups and pilot studies are considering these issues.

J.R. DeShazo (UCLA School of Public Policy) stated that the household's totality of *response* to a perceived risk is important to factor into an evaluation of how households are economically responding to risk. He emphasized that remedial actions taken once a health outcome is expressed, and not just defensive mitigating actions, involve dedicating time and money resources by household members. He asked whether that consideration "was coming front and center in the survey instrument."

Dr. Scheidt asked for a clarification and Dr. DeShazo replied that "the fundamental issue is how parents evaluate the portfolio of health risks their children could face—the level of risk they perceive and what they do to defend and mitigate the risk of exposure to the child, and then once the child shows symptoms what kind of remedial behavior they undertake to reduce their level of risk . . ." in other words, the intra-household process of identifying and dealing with risks to children.

Dr. Scheidt responded that it was an "interesting question" and, saying that they had not focused on the decision-making dynamic in families, he wondered how they might go about doing that. He acknowledged that study participants, as a consequence of participating in the study, would learn a lot about health risks that their children face, or don't face, and that they are a bit concerned about the potential impact this will have on the long-term outcomes of the study. He closed by restating that they had not studied how parents process that information.

Ed Chu, the session moderator, closed the session by urging everyone to look at the study website, and he commented that one of the primary reasons for having Dr. Scheidt speak at the workshop was to stimulate economists' interest and involvement in the study.

Valuing Environmental Health Risk Reductions to Children

PROCEEDINGS OF

SESSION II: HOUSEHOLD DECISION MAKING

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE), NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER), AND OFFICE OF CHILDREN'S HEALTH PROTECTION; AND THE UNIVERSITY OF CENTRAL FLORIDA

October 20-21, 2003
Washington Plaza Hotel
Washington, DC

Prepared by Alpha-Gamma Technologies, Inc.
4700 Falls of Neuse Road, Suite 350, Raleigh, NC 27609

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DISCLAIMER

These proceedings are being distributed in the interest of increasing public understanding and knowledge of the issues discussed at the workshop and have been prepared independently of the workshop. Although the proceedings have been funded in part by the United States Environmental Protection Agency under Contract No. 68-W-01-055 to Alpha-Gamma Technologies, Inc., the contents of this document may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

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Benefit Cost Analysis and the Entanglements of Love

Theodore C. Bergstrom *

November 1, 2003

1 Introduction

Suppose that after careful thought, a parent reports that she is willing to pay up to $100 to save her child from one day of cold symptoms.[1] How can we use her answer and those of other parents to analyze the benefit of public projects that affect child health? Would it make sense to calculate the expected number of child days of cold symptoms that a project would prevent and to multiply this number by the average willingness to pay of a sample of parents?

But if a child has two parents, maybe we should value the child's health at the *sum* of the two parents' willingness to pay. Or, if the two parents' answers differ, perhaps we should use the maximum or perhaps the minimum of their two answers. And what of the child's own valuation on improved health? Why shouldn't we count that as well? To answer questions like these, we need to

*Aaron and Cherie Raznick Professor of Economics, University of California, Santa Barbara. This paper was prepared for a conference on Valuing Environmental Health Risk Reductions to Children, sponsored by the US EPA's National Center for Environmental Economics, the National Center for Environmental Research, and the University of Central Florida. I am grateful for helpful suggestions from Robin Jenkins of the EPA and Mark Agee of Penn State University.

[1] A series of carefully conducted studies have asked questions similar to this. Viscusi, Magat and Huber [25] interviewed individual parents who were asked their willingness to pay for hypothetical "safer" insecticides and toilet cleaners that would reduce health hazards for their children by specific amounts. Liu et al [16] found that a sample of Taiwanese mothers were willing to pay an average of about US $57 to avoid a cold for one of their children and about $37 to avoid a cold for themselves. (An earlier study by Alberini et al [1] asking Taiwanese adults about their willingness to pay to avoid colds for themselves found very similar values.) Dickie and Ulery [11] asked parents about their willingness to pay for the reduction of cold symptoms for a single child and for themselves. Dickie and Gerking [10] surveyed individual parents, asking their willingness to pay for a hypothetical sunscreen that reduced risk of skin cancer by a specified amount.

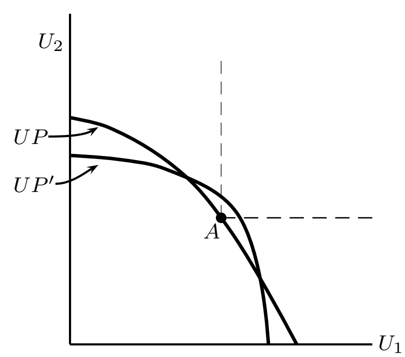
step back and examine the logic of benefit-cost analysis as applied to families in which some individuals care about the well-being of others.

2 What Can Benefit-Cost Analysis Do?

Without explicit instructions about how to compare one person's benefits with those of another, we can not expect benefit-cost analysis to tell us whether a public project should or should not be adopted. The best we can hope for from benefit-cost analysis is to learn whether a project is *potentially* Pareto improving. To see why this is so, it is useful to revisit a device found in Paul Samuelson's beautiful 1950 paper, "Evaluation of the Real National Income [23]. Samuelson introduces what he calls "the crucially important utility possibility function" to help us understand the logic of benefit cost analysis.

Consider a community with two people. A possible project would produce a public good valued by both persons. In order to produce it, community members will have to reduce their total consumption of private goods. If the project is not implemented, then alternative divisions of the total quantity of private goods will determine different utility distributions. These possible distributions generate a "utility possibility frontier" as described by the curve UP in Figure 1.

Figure 1: Utility Possibilities and Benefit Cost



If the project is implemented there will be less private goods to be distributed between the two people, but each will enjoy a higher level of public goods. This will generate a new utility possibility frontier UP'. Because the curves UP' and UP are not "nested" there is not an obvious way to determine which is the better situation. Some utility distributions are attainable only if the project is not implemented and others are attainable only if the project is implemented.

Suppose that we know that we know that if the project is not implemented, then the utility allocation will be the point A in the graph. We see from the figure that the curve UP' contains points above and to the right of A. This implies that it is possible to produce the public good and to divide its costs in such a way that both individuals are better off than they were at A. When this is the case, we say that the project is potentially Pareto improving. Stating this formally:

Definition 1 *A public project is potentially Pareto improving if it is possible to implement the project and to distribute its costs in such a way that in the resulting allocation some community member(s) are made better off and none are made worse off.*

In a suitably simple economy, benefit-cost analysis can determine unambiguously whether a project is potentially Pareto improving. One such "suitably simple economy" is the following: A possible public project produces a public good that benefits several individuals and harms none.[2] The economy has a single pure private good.[3] Implementing the project requires the input of a known amount of private goods.

If individuals are selfish, the logic of benefit-cost analysis in this economy is very simple. An individual's "willingness-to-pay" for the project is defined to be the maximum amount of private good that she would be willing to sacrifice in order to enjoy the benefits of the public goods provided by the project. The benefit-cost test compares the sum of all individuals' willingnesses-to-pay for the project to its cost. It is quite easy to see that for this simple economy, the sum of individual willingnesses-to-pay exceeds total cost if and only if the project is potentially Pareto improving.[4]

The relation between benefit cost analysis and potential Pareto improvement becomes more complex when some of the beneficiaries are children who are loved and supported by parents, and even more complex if the parents care about each others' happiness. In this paper, we try to untangle the logic of these attachments a few strings at at time.

[2] It is not hard to extend these principles to an economy where some individuals benefit and others are harmed. But this simpler model suffices to illustrate the principles.

[3] The single-good assumption is appropriate in a multi-good economy if adopting and paying for the project does not result in changes in the relative prices of the private goods.

[4] If the sum of willingnesses to pay exceeds total cost, then it is possible to pay for the project while assessing no individual a share of the cost smaller than her willingness to pay. Implementing the project and paying for it with any such assessment constitutes a Pareto improvement. Conversely, if the project is potentially Pareto improving, there is a way to assess the costs of the project so that nobody is worse off after the project is implemented. Each individual's assessment would, by definition be smaller than his willingness-to-pay. Since these assessments add to the cost of the project it follows that the project would pass the benefit-cost test.

In order to extend the principles of benefit-cost analysis to a family, we need to specify and apply a theory of household decision-making for that family. Of course the world is filled with a great variety of family structures, which differ in membership and in the distribution of decision-making authority. As we will see, the prescriptions for benefit-cost analysis can vary significantly with the family type.

As we extend benefit-cost analysis to multi-person households, we face the question of how to reinterpret the criterion of potential Pareto improvement. This paper takes the position that the government is not able to intervene in the distribution of private goods within the households. Thus we consider a project to be potentially Pareto improving if and only if there is a way to assign the costs to families so that *given the household decision structure in each family*, no individual is made worse off and at least one is made better off.

3 A Single-Parent Household

Suppose that an economy is made up of households consisting of a single parent and a dependant child. Assume that each parent cares about her own consumption and her child's health and consumption and is selfish with respect to those outside her household. Assume also that children care only about their own consumption and health. Consider a government project that uses private goods as inputs and produces a public good which increases the health of children. How can we determine whether or not the project is potentially Pareto improving?

Let each parent's utility function take the form:

$$U\left(x, v(k,h)\right) \tag{1}$$

where x and k are the amounts of private goods consumed by the parent and the child respectively and h is a measure of the child's health. The child has no income and receives consumption goods only from its parent. The parent has an after-tax income, m which she allocates between her own consumption and that of her child.[5] Then, contingent on the child's health being h, the highest utility that a parent can achieve with after-tax income m is

$$U^*(m,h) = \max_{x+k\leq m} U\left(x, v(k,h)\right). \tag{2}$$

Consider a public policy that would increase her child's health from h to h'. We will define the parent's willingness-to-pay for the project to be W, where W is determined by the equation

$$U^*(m-W,h') = U^*(m,h) \tag{3}$$

[5] A more general model could allow the parent to allocate some private goods directly toward improvement of the child's health.

Definition 2 *If the sum of all parents' willingness-to-pay for a project exceeds the cost of the project, it is said to* pass the benefit-cost test for parents*.*

We can show that if a project fails the benefit-cost test for parents, then it is not potentially Pareto improving. To say this in another way:

Remark 1 *In an economy with single-parent households, if a project is potentially Pareto improving, then it must pass the benefit-cost test for parents.*

The proof is simple, but instructive. If the project is potentially Pareto improving, it must be possible to implement the project and to assign its costs it in some way so that no parent is worse off and at least one is better off than if the project is not implemented. Suppose that a project fails the benefit-cost test. Then in order for the project to be funded, some parent must be assessed a cost greater than her willingness to pay. Since the parents have complete control of their family incomes, this means that the parent who is forced to pay more than her willingness to pay for the project will be worse off if the project is implemented. Therefore the project cannot be potentially Pareto improving.

From Remark (1), we see that even though the Pareto criterion accounts for the well-being of children, it would be misguided to measure benefits by adding the value that children place on their own health to the values that their parents place on it. Adding children's valuations to those of their parents would lead to acceptance of projects that do not pass the benefit-cost test for parents and which are therefore *not* potentially Pareto improving.

The converse of Remark (1) is not in general true. That is, there may be projects that pass the benefit-cost criterion for parental preferences, but which do not allow a Pareto-improving reallocation in which the well-being of children as well as parents is (weakly) improved. This is not very surprising, especially since it has not been assumed that parents agree with their children about what is good for them. But, more remarkably, the converse fails to be true, even if parents and children share the same preferences over alternative combinations of child consumption and child health.

Parent's preferences are said to be *benevolent* if the parent's preferences over the child's consumptions coincide with child's.[6] Stated more formally, we say that

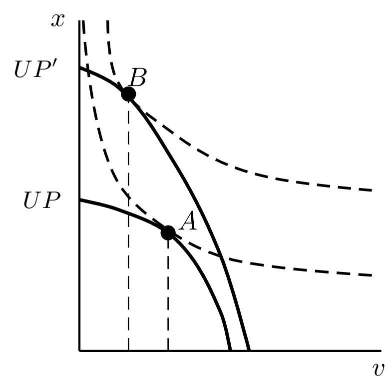
Definition 3 *A parent's preferences are benevolent if the parent's utility function is* $U_i\left(x_i, v_i(k_i, h_i)\right)$ *where* v_i *represents the child's preferences.*

Even if parents have benevolent preferences, it is possible that some projects that pass the benefit-cost test parental preferences will lead to outcomes that

[6]Though this usage is common in welfare economics, those who have been parents and those who have been children will recognize that parents who are "benevolent" by this definition would not always act in the best long-run interests of their children.

are worse for some children. This can happen because the child's health may be such a strong substitute for the child's income that with a healthier, the parent will reduce the amount of consumption goods transferred to the child by so much that the child is actually worse off after the transfer than before.

Figure 2: Parent's Consumption and Child's Utility



This effect is illustrated in Figure 3. The curves labeled UP and UP' shows combinations of parents' consumption and child's utility that are possible before and after a project is implemented. The point A on UP represents the preferred point of the parent if the project is not implemented and the point B on UP' represents the point preferred if the project is implemented. With the indifference curves that we have drawn, the parent will prefer B to A despite the fact that the child has a lower utility at B than at A. Notice that in Figure 3, the indifference curves drawn are consistent with parental benevolence, since the parents always prefer higher v to lower. One could imagine, for example, that for an impoverished family, an improvement in the child's health would induce the parents to require the child to earn its own food. Under these circumstances, despite their benevolence toward the child, the parents might favor an improvement in child health that is accompanied by such a large reduction in income transfers to the child that the child is worse off. Section 8.1 of the appendix, presents an algebraic example of preferences for which this is the case.

4 Lovebirds without Kids

Archie and Bess are a couple. They care about their own consumption of private goods and their own health. They also care about each other's happiness. Archie and Bess spend a good deal of time together and so each has become a good judge of the other's happiness, though this information arrives with a brief lag.

Let $x_A(t)$ and $x_B(t)$ be expenditures on consumption, and let $h_A(t)$ and $h_B(t)$ be measures of health for Archie and Bess respectively at time t.

Archie's happiness at time t is determined by the function

$$U_A(t) = v_A\left(x_A(t), h_A(t)\right) + aU_B(t-1) \tag{4}$$

and Bess's happiness is determined by the function

$$U_B(t) = v_B\left(x_B(t), h_B(t)\right) + bU_A(t-1). \tag{5}$$

Elsewhere [4] and [6], I show that this dynamical system is stable under plausible dynamics if and only if $ab < 1$. As these earlier papers explain, this stability condition limits the mutual intensity of their care for each other's happiness.

The government is considering a women's health project that will improve Bess's health by a known amount Δ. Archie and Bess are separately interviewed about their willingness to pay for this improvement. Bess realizes that if her health improves, this will have a direct effect on her happiness, which Archie will observe and enjoy, which in turn will make Bess herself happier, and so on *ad infinitum*. Can either Bess or Archie extract a reasonable answer to the interviewer's question from the blur of reflected happiness in this hall of mirrors?[7]

Equations (4) and (5) can be "inverted" to determine more conventional utility functions that depend only on the consumption and health of Archie and Bess. If consumptions and health levels are constant over time, equations (4) and (5) determine a time path of utilities for Archie and Bess that converges to equilibrium values. To find these equilibrium values, we set $U_A(t) = U_A(t-1)$, $U_B(t) = U_B(t-1)$ in Equations (4) and (5) and solve. Then $U_A^*(x_A, x_B, h_A, h_B)$ and $U_B^*(x_A, x_B, h_A, h_B)$ are the equilibrium utilities that result from the constant outcome (x_A, x_B, h_A, h_B). These utility functions are as follows:

$$U_A^*(x_A, x_B, h_A, h_B) = \frac{1}{1-ab}\left(v_A(x_A, h_A) + av_B(x_B, h_B)\right) \tag{6}$$

and

$$U_B^*(x_A, x_B, h_A, h_B) = \frac{1}{1-ab}\left(v_B(x_B, h_B) + bv_A(x_A, h_A)\right) \tag{7}$$

Let us call $v_A(\cdot)$ and $v_B(\cdot)$ the *private utility functions* of Archie and Bess respectively and let us call $U_A^*(\cdot)$ and $U_B^*(\cdot)$ their *social utility functions*. We assume that Archie and Bess are able to untangle their affections so as to find private and social utility functions as in Equations (6) and (7). There remain some tricky questions to answer. If know that their social utility functions

[7] Miles Kimball [15] suggested the hall-of-mirrors metaphor.

take this form, how can we use Archie's and Bess's reported valuations for improvements in Bess's health in a benefit-cost analysis? To answer this question, we need some assumptions about the way that Archie and Bess make family decisions.

4.1 Archie the Dictator

Gary Becker's famous "Rotten Kid Theorem" [2] operates on the assumption that family decisions are determined according to the preferences of a single benevolent household member.[8] Although this assumption is politically incorrect and, I believe, descriptively inaccurate for modern Western households, it remains worth studying for at least two reasons. First, the simplicity of this model makes it an instructive place to develop intuition and understanding that can be extended to other environments. Indeed since almost all economists interested in the economics of the family have cut their teeth on Gary Becker's patriarchal family [2], this model has become a benchmark against which alternative theories need to be tested. More importantly, not all of the households that interest us are modern and Western. Some of the most important applications of benefit cost analysis to public health programs are likely to concern traditional societies and highly patriarchal societies.

Assume that Archie has no direct control over his own health or that of Bess, but he is able to determine the amount of consumption expenditure that each receives, subject to a budget constraint. Then he chooses x_A and x_B to maximize his social utility function

$$U_A(x_A, x_B, h_A, h_B) = v_A(x_A, h_A) + a v_B(x_B, h_B) \tag{8}$$

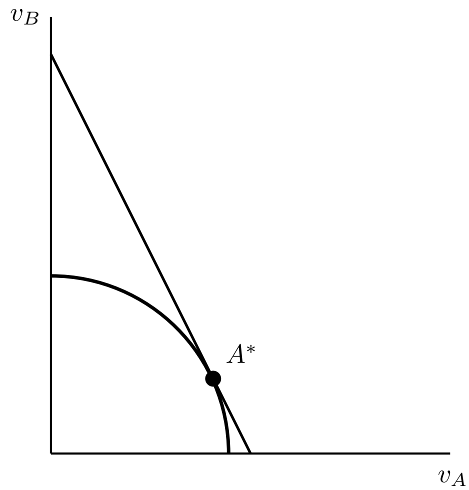
subject to the budget constraint $x_A + x_B = M$, where M is the family income. For given health levels and family income, the possible distributions of the private utilities, v_A and v_B are points lying on or below the curved line in Figure 4.1. Archie's indifference curves over these possible distributions will be straight lines with a slope of $-1/a$ and his preferred distribution of private utilities will be at the point marked A^*

Suppose that benefit-cost analysts interview Bess and ask her the following questions.

B.1 What is the largest amount of your personal consumption that you would be willing to give up in order to improve your health by Δ units?

[8] In Becker's treatment, although Archie is benevolent, Bess is selfish. I think he chose to do this not out of misogyny, but because he wanted to avoid the hall-of-mirrors complications of mutual affection.

Figure 3: Utility Possibilities



B.2 Given the way that Archie allocates income in your family, what is the largest amount of family income that you would want to give up in order to improve your health by Δ units?

Let us also suppose that they interview Archie and ask him:

A.1 What is the largest amount of family income that you would be willing to give up in order to improve Bess's health by Δ units?

When will the answers to these questions be different and when will they be the same? And how should we use the answers in benefit-cost analysis?

A Harmonious Case

Let us assume that Archie and Bess both have positive but diminishing marginal utility[9] for their own consumption of private goods and that Bess's private utility function is of the special form,

$$v_B(x_B, h_B) = f_B(x_B + kh_B) \tag{9}$$

[9] We have assumed that utility functions are additively separable between Archie's and Bess's private utilities. In the additive form, the v functions are unique up to positive affine transformations. The property of diminishing marginal utility for private consumption therefore has operational content in that it is preserved under all positive affine transformations.

where k is a constant and where the function $f_B(\cdot)$ displays positive but diminishing marginal utility. In this case Archie and Bess will be in perfect agreement about the value of an improvement in Bess's health. Bess's answer to question B.1 be will be the same as her answer to B.2 and also be the same as Archie's answer to question A.1.[10] In order to determine whether the health project is Pareto improving, a benefit-cost analyst could use this answer to represent the whole family's willingness to pay.

Remark 2 *If Archie and Bess both have diminishing marginal utility for private goods, if Bess's utility function is of the form $v_B(x_B, h) = f_B(x_B + kh_B)$ and Archie chooses the distribution of family income between private goods for himself and for Bess, then all three questions, B.1, B.2, and A.1 have the same answer, which is $k\Delta$. If the health project is implemented and Archie and Bess pay any amount less than $k\Delta$, both will be better off if the plan is implemented. If they must pay more than $k\Delta$,then if it is implemented, at least one of them will be worse off.*

It is easy to see that Bess's answer to question B.1 must be $k\Delta$. If she gives up $p < k\Delta$ of her own consumption and her health increases by Δ, the net effect is to increase her private utility and if she gives up exactly $p = k\Delta$ her private utility remains unchanged.

If the family spends p to improve Bess's health by Δ, Archie will allocate private consumption between himself and Bess by choosing x_A and x_B to maximize his utility, $v_A(x_A, h_A)+af_B(x_B+kh_B+k\Delta)$, subject to the constraint that $x_A+x_B = M-p$. If we define $y_B = x_B+h_B+k\Delta$, then we can restate this maximization problem as the equivalent problem: Maximize $v_A(x_A, h_A) + af_B(y_B)$ subject to $x_B + y_B = M + kh + (k\Delta - p)$. If the project is implemented and the family pays p, the net effect is seen to be the same as that of increasing Archie's budget by $k\Delta - p$. Thus Archie would be willing to pay any amount p up to $k\Delta$ for the project. Therefore Archie's answer to Question A.1 is $k\Delta$, which is the same as Bess's answer to B.1. Since we have assumed that both spouses have diminishing marginal utility of private consumption, it also true that an increase (decrease) in Archie's budget results in an increase (decrease) in both x_A and y_B and hence in Bess's private utility. Therefore Bess's answer to Question B.2 is also $k\Delta$.

Generous Archie?

With the utility function described in the previous section, Archie will agree to spend family funds on Bess's health if and only if she would be willing to pay for the increase entirely out of her own consumption. But if Bess's private

[10] This will be true for any positive a, that is, even if Archie is very selfish, so long as he cares a little about Bess's well-being.

utility function takes the additively separable form, $v_B(x_B, h_B) = f_B(x_B) + kh_B$ where Archie and Bess have diminishing marginal utility of private consumption, Archie will be willing to "share the cost" of an improvement in Bess's health. In this case, Archie's answer to Question A.1 is greater than Bess's answer to Question B.1 and equal to Bess's answer to B.2.

More generally consider the case where Archie considers Bess's health and her consumption to be complements, where complementarity is defined as follows.

Definition 4 *Person A regards the health and consumption of Person B as complements if for any distribution of consumption between A and B, an increase in Person B's health does not reduce A's marginal rate of substitution between B's consumption and A's consumption.*

A proof of the following result can be found in the Appendix.

Remark 3 *If Archie and Bess both have diminishing marginal utility for private goods and if Archie regards Bess's health and consumption as complements, then Archie's willingness to pay for an improvement in Bess's health exceeds the amount that she would be willing to pay for this improvement out of her own consumption.*

In the example discussed in Remark 2, Bess's health and consumption are not complements but substitutes. In this case, if Bess's health improves, Archie reduces the amount of consumption goods that she receives so as to leave her private utility unchanged. It is possible however, even where Archie is benevolent, that an improvement in Bess's health would induce him to reduce her allocation of consumption goods by so much that she is left worse off than he would choose her to be if she were less healthy. This is a case where he regards her health and her consumption as very strong substitutes. The example that we discussed in Section 3, where an improvement in child health led the benevolent parent to choose an outcome that is worse for the child can be reinterpreted to illustrate this case, with Archie cast in the role of parent and Bess in the role of child.

5 Non-dictatorial Outcomes

In modern Western societies, we do not expect either adult member of an ordinary household to have dictatorial power over the allocation of private goods. We consider two alternate theories of household allocation. One of these is a bargaining model in which the Nash cooperative bargaining solution to the household environment. The other is a model in which Archie and Bess reach unanimous agreement on outcomes based on a shared notion of fairness.

5.1 Fairness Norms and a Household Welfare Function

Suppose that in the course of their relationship, Archie and Bess build a mutually agreed notion of "household fairness" which governs their decisions. As Samuelson [24] suggests, this consensus might be expressed by means of a household "social welfare function which takes into account the deservingness or ethical worths of the consumption levels of each of its members." We could reasonably assume that this social welfare function would be an increasing function of each member's social utility as defined in Equations (6) and (7). Thus the household welfare function would be of the form

$$W\big(U_A^*(x_A, x_B, h_A, h_B), U_B^*(x_A, x_B, h_A, h_B)\big). \tag{10}$$

An appealing case can also be made that the household welfare function should be linear in its two arguments, so that we have

$$W\big(U_A^*, U_B^*\big) = \alpha U_A^* + (1-\alpha)U_B^* \tag{11}$$

for some α between 0 and 1.

A social welfare function with linear weights on individual social preferences would be implied if the couple formed their ethical preferences by "veil-of-ignorance" reasoning of the sort: "How would you want to divide household resources if there were an equal chance that I were you and you were me?" Although this kind of ethical reasoning can establish the existence of a social welfare function of the form of Equation (11), it is not sufficient to determine the parameter α that weights Archie's U_A^* relative to Bess's U_B^*. For example, our argument so far gives one no special reason to think that $\alpha = 1/2$ is more "fair" than any other α between 0 and 1. The scaling of the functions v_A and v_B is arbitrary and if these function are rescaled, then in order to preserve the same household preferences, the weight α would have to be altered.[11] As they cooperate with each other, Archie and Bess would need to develop a household consensus that determines the weight α that both regard as "fair". As Binmore [8] suggests, in the long run we might expect these weights to be close to the weights that would sustain a Nash cooperative bargaining solution for the household, since if there were a significant and persistent difference, the partner who could do much better with bargaining and threatening might defect from the social consensus expressed by the household social welfare function.

Recall from Equations (6) and (7) that the social utility functions are themselves linear combinations of the private utility functions, $v_A(x_A, h_A)$ and $v_B(x_B, h_B)$. In particular, we have

[11] Abram Bergson [3] introduced the notion of a social welfare function for an entire society. Harsanyi [14] proposed ethical foundations for such a function. Binmore [8] suggested that small, tightly-woven groups like families, may evolve a concept of group fairness that is well described by a household social welfare function.

$$W(U_A^*, U_B^*) = \frac{\alpha}{1-ab}\Big(v_A(\cdot) + av_B(\cdot)\Big) + \frac{1-\alpha}{1-ab}\Big(v_B(\cdot) + bv_A(\cdot)\Big) \qquad (12)$$

Since preferences determine utility functions only up to an increasing transformation, and since by assumption $ab < 1$, we have an equivalent household welfare function if we multiply the expression (12) by $1 - ab$. Doing this and combining terms, we have

$$W = (\alpha + b(1-\alpha))\, v_A(x_A, h_A) + (1 - \alpha + a\alpha)v_B(x_B, h_B). \qquad (13)$$

If Archie and Bess share a household social welfare function, then the interpretation of their answers to benefit-cost questions is really easy. If money is taken from household income to help pay for a public project that improves Bess's health, they both agree about how the cost will be shared in terms of their private consumption. Thus each of them would give the same answer to the question "How much would you be willing to pay for an increase of Δ in Bess's health?" The appropriate number for benefit-cost analysts to use is the number given by either of them. It would be a mistake to use the sum of their answers, since they both would agree that the sum as twice as much as they would want to pay.

5.2 Bargaining Equilibrium

The pioneering work on models of household bargaining was done by Marilyn Manser and Murray Brown [19] and Marjorie McElroy and Mary Horney [20], who proposed to model household decision making with the Nash cooperative bargaining model. In these papers, a marriage is modelled as a static bilateral monopoly. A married couple can either remain married or they can divorce and live singly. There is a convex utility possibility set S containing all utility distributions (U_1, U_2) that could possibly be achieved if they remain married. The utility of person i if he or she divorces and lives singly is given by V_i. It is assumed that there are potential gains to marriage, which means that the there are utility distributions (U_1, U_2) in S that strictly dominate the utility distribution (V_1, V_2). These papers propose that the outcome in a marriage will be the symmetric Nash bargaining solution where the "threat point" is dissolution of the marriage with both persons choosing to live singly. According to the Nash bargaining theory, the outcome in this household will be the utility distribution (U_1^*, U_2^*) that maximizes $(U_1 - V_1)(U_2 - V_2)$ on the utility possibility set S.[12] In this theory the outcome in a marriage is completely determined by

[12] This expression is sometimes known as the Nash product. John Nash [21] proposed a set of axioms for resolution of static two-person bargaining games such that the only outcomes that satisfy the axioms maximize the Nash product on the utility possibility set.

the utility possibility set and by the position of the threat point, (V_1, V_2). This theory has the interesting prediction that social changes that affect the utility of being single will affect the distribution of utility within the household and hence may change household spending patterns, even if they have no effect on the budget of the household, while changes in the apparent distribution of earned income within the household will have no effect on the distribution of utility in the household if they do not change the threat point from being single.

Shelly Lundberg and Robert Pollak [18], [17] propose an alternative Nash bargaining model. They suggest that for many marriages the relevant threat point for the Nash bargaining solution should be not divorce, but an "uncooperative marriage" in which spouses would revert a "division of labor based on socially recognized and sanctioned gender roles." The Lundberg-Pollak model makes predictions that differ significantly from the divorce-threat model. For example, in the Lundberg-Pollak model, if government child-allowances are paid to mothers rather than to fathers, the threat point shifts in favor of the mothers. Accordingly, the outcomes of cooperative bargaining within households are likely to be more favorable to women. By contrast, in the divorce-threat model, changing the nominal recipient of welfare payments when the couple is together will have no effect on the household outcomes if there is no change in the beneficiary in the event of a divorce.

To many married persons it seems unlikely that couples would resolve disagreements about ordinary household matters by negotiating under the threat of divorce. If one spouse rejects the other's proposed resolution to a household dispute, the expected outcome is not a divorce. More likely, there would be harsh words and burnt toast until another offer or counteroffer is made. It might even be that if the couple were to persist forever in inflicting small punishments upon each other, it would be *worse* both of them than a divorce. Nevertheless, the divorce threat may not be credible because divorce imposes large irrevocable costs on both parties, while a bargaining impasse need last only as long as the time between a rejected offer and acceptance of a counteroffer.

Nash's axiomatic approach to cooperative bargaining gives us no direct guidance about the appropriate threat points for bargaining in a marriage. But useful insight can be gained from Ariel Rubinstein's [22] model of noncooperative bargaining with alternating offers. Ken Binmore [7] extended the Rubinstein model to the case where each bargaining agent has access to an "outside option". Binmore's model is like the Rubinstein model, except that each person has the option of breaking off negotiations at any time and receiving a payoff of the value of an outside option.

The Rubinstein-Binmore model, as applied to marriage lends formal support to the Lundberg-Pollak notion of bargaining. The non-cooperative bargaining model predicts that household outcome will either be the Nash bargaining solution in which the threat point is delayed agreement and burnt toast so long as this Nash solution is better for both than divorce. Thus the divorce threat will influence the outcome only if the bargaining solution reached under the threat of burnt toast is worse than divorce for one of the partners. In case the divorce threat is relevant, one partner enjoys all of the surplus and the other is maintained at a point of indifference between being divorced and being single.

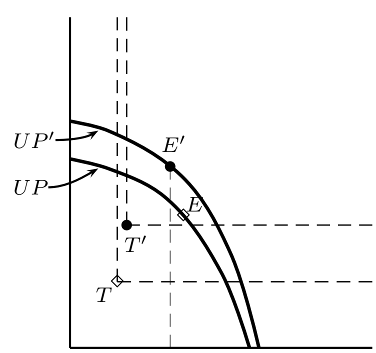
In our example with Archie and Bess, suppose that health levels are determined by public policy while the allocation of private goods is determined by bargaining. Suppose that the utility that each would obtain in the absence of agreement depends on total household income and on the health of each. Where x is total household income, let us represent these "threat point utilities" by the functions $T_A(x, h_A)$ and $T_B(x, h_B)$ The Nash bargaining theory predicts that the outcome of household bargaining will be an allocation of private goods that maximizes the Nash product

$$\left(U_A^* - T_A\right)\left(U_B^* - T_B\right). \tag{14}$$

subject to the constraint that $x_A + x_B = x$

For fixed levels of health, the Nash product in Expression (14) works like a utility function a household utility function in the sense that private goods are allocated in such a way as to maximize this function. If a public health project is implemented and their household is taxed, the utility possibility frontier for Archie and Bess will be altered and so will their threat points. The household bargaining theory predicts a new allocation of utility. Neither Archie nor Bess cares directly about the value of the Nash product, but only about his or her own utility in the solution to the bargaining problem. Therefore they will in general not agree on their willingnesses to pay for a specific change in health.

Figure 4: Health and Bargaining



In a bargaining environment, not only is it possible that Archie and Bess have differing willingness to pay for a public project. It may even be impossible to get them to agree to fund a project that strictly increases the set of possible utility allocations.[13] This can happen because the project may shift bargaining power and/or the shape of the utility possibility frontier in such a way that the bargaining outcome is worse for one of them, even though the project shifts the utility possibility frontier strictly outward. This effect is is illustrated fairly in Figure 5.2. The initial utility possibility frontier is shown by the curve UP and the initial threat point is located at T. The point that maximizes the Nash product (14) is labelled E. Now suppose that a public health project is introduced and a fixed amount of tax is collected from the Archie-Bess household. One result of the project and the tax is to shift the utility possibility frontier outward from UP to UP'. A second result is to move the threat point from T to T'. Then the Nash bargaining theory predicts that the equilibrium outcome for the family moves from E to E'.

We see that a curious thing has happened. The health project and associated tax seems to be an unambiguous boon for Archie and Bess, since their utility possibility frontier moves everywhere outward. But if the project is implemented, the actual outcome in the household must be the corresponding bargaining solution E' and as we see in the diagram, E' assigns a smaller utility to Archie than his utility in the initial equilibrium E. Therefore Archie would oppose this change.

Thus if we continue to use the benefit-cost test to ask whether a public health project is potentially Pareto improving, we would have to use the *minimum* of Archie's and Bess's valuations to evaluate the benefits to this household.

6 Couples with Kids

After all this foreplay, it is time to bring a child into the Archie-Bess household and contemplate how to apply benefit-cost analysis to projects that improve children's health. A natural starting point for this theory is to think of the child's health as a "public good" that is valued by both Archie and Bess. Let us assume that Archie and Bess care about each others' happiness, as well as the health and well-being of their child and about their own consumptions of private goods.

Suppose that they have social utility functions of the form

$$U_A^*(x_A, x_B, x_C, h_C) = v_A\big(x_A, v_C(x_C, h_C)\big) + av_B\big(x_B, v_C(x_C, h_C)\big) \qquad (15)$$

[13] Lundberg and Pollak [17] apply similar reasoning to suggest that in the absence of binding contracts, married couples may not be able to make efficient household decisions about matters that affect relative bargaining power.

$$U_B^*(x_A, x_B, x_C, h_C) = v_B\big(x_B, v_C(x_C, h_C)\big) + bv_A\big(x_A, v_C(x_C h_C)\big) \qquad (16)$$

where x_C is the child's consumption, h_C is the child's health and where $v_C(x_C, h_C)$ measures the child's well-being.

6.1 Father Archie Calls the Shots

Let us begin by considering the Beckerian assumption that Archie is dictator of the allocation of private goods. Then given the level of child health h_C and family income x, Charlie chooses the consumption levels x_A, x_B, and x_C so as to maximize Expression 15 subject to the family budget constraint, $x_A + x_B + x_C = x$. Archie's willingness to pay for a small improvement Δ in the health of the child is approximately Δ times his marginal rate of substitution between child health and his own consumption. Assuming that he chooses to spend a positive amount of the household income on the consumption goods for Beth and for the child, Archie's marginal utility of consumption for the child is equal to his marginal utility of consumption for himself and also equal to his marginal utility of consumption for Bess. Therefore, Archie's marginal rate of substitution between child health and his own consumption is equal to his marginal rate of substitution between the child's health and the child's own consumption. But this marginal rate of substitution is seen to be simply the ratio of the two partial derivatives of the function $v_C(x_C, h_C)$ that measures the child's health. Thus Archie's willingness to pay for a small increase Δ in the health of the child is approximately

$$W_A = \Delta\left(\frac{\partial v_C(x_C, h_C)}{\partial x_C} \div \frac{\partial v_C(x_C, h_C)}{\partial h_C}\right). \qquad (17)$$

Thus Expression (17) is Archie's answer to the question "How much money would you be willing to pay for an increase of Δ in the health of your child?"

Suppose that the child has the same perception of its welfare as do its parents and its preferences are represented by the same function $v_C(x_C, h_C)$ that appears as an argument in the parents' utilities. If the child is questioned about the amount of consumption that it would be willing to forego for an increase of Δ in its health, its answer would be Δ times its marginal rate of substitution between health and consumption. We see from Equation (17) that this is precisely the same as Archie's marginal rate of substitution between the child's health and family income. It follows that the child's answer would be the same as Archie's.

We seem to have a kind of "Rotten Kid Theorem" here, but does it extend to Bess? Given that Archie dictates the household allocation of consumption goods, how will Bess answer the question "How much of the household income would you be willing to surrender to pay for an increase of Δ in the health of your child?" Bess realizes that if family funds are paid to support child health, the resulting changes in private consumption by family members will be determined according to Archie's preferences. Given that Bess realizes this, the amount she would be willing to have the family spend to pay for an improvement of Δ in the child's health can be shown to be

$$W_B = W_A \left(\frac{\partial U_B^*}{\partial x_C} \div \frac{\partial U_B^*}{\partial x} \right). \tag{18}$$

where W_A is Archie's willingness and where $\frac{\partial U_B^*}{\partial x}$ is the marginal utility of household income to Beth, given her knowledge of how Archie will use it.

A simple calculation shows that

$$\frac{\partial U_B^*}{\partial x} = \frac{\partial U_B^*}{\partial x_A}\frac{dx_A}{dx} + \frac{\partial U_B^*}{\partial x_B}\frac{dx_A}{dx} + \frac{\partial U_B^*}{\partial x_C}\frac{dx_C}{dx}. \tag{19}$$

where dx_A/dx, dx_B/dx and dx_C/dx are the fractions of an incremental unit of income that Archie would allocate to the three household members.

From Equation (18) we see that Bess's answer to the benefit cost question will exceed Archie's answer if her marginal utility for the child's consumption is higher than her marginal utility for household income to be allocated according to Archie's priorities. This would be the case, if for example, Archie's distributional preferences lead him to allocate more private goods to himself and less to the child than Bess would like him to.

Which is the appropriate answer to use for benefit cost analysis? If we stick to the modest aim of identifying projects that lead to potential Pareto improvements and if Archie's willingness to pay is lower than Bess's, then we are forced to value the benefits at Archie's willingness to pay, which is the minimum of the two parents' answers. Using Bess's willingness to pay might also lead to a Pareto efficient outcome, but this outcome will not be Pareto superior to the initial situation, since Archie will be worse off.

6.2 Allocation with A Household Welfare Function

If household decisions are made by a shared household welfare function as discussed in Section 5.1, then as in our previous discussion, the situation is very simple. Archie and Bess would both agree in their rankings of possible alternatives for the family. Each would give the same answer to the question "How much household income would you be willing to spend for an improvement of Δ in your child's health. The answer given by either of them would represent the most that their household could pay in exchange for this gain without making them worse off.

6.3 Allocation with Divorced Couples

Suppose that after producing a child, Archie and Bess get a divorce. After the divorce, they have little affection for each other, but both care about the child's well-being. Bess has custody of the child and they set up separate household accounts, with each of them having a separate income. The only way that Archie can contribute consumption goods to the child is by giving money to Bess, who can allocate it as she chooses between herself and the child. Suppose that Archie makes no voluntary payments to Bess because only a fraction of the money that he gives her would be spent on the child's consumption.

In this situation, the appropriate measure for benefit cost purposes would be the sum of their two answers. If Archie is willing to pay an amount W_A and Beth an amount W_B for an improvement of Δ in the child's health, then both would benefit from implementing the project if amounts $P_A < W_A$ and $P_B < W_B$ are collected from the two parents. Thus their total willingness to pay is $P_A + P_B$. In this case, a benefit cost study that measured benefits of a child health project as the sum of the willingnesses to pay of a single parent for each child would underestimate the value of the project.

6.4 What About Grandparents and Aunts and Uncles?

A child's parents are not the only people who care strongly about its health and well being. Across almost all known societies, other close relatives besides parents are intensely concerned about the well-being of a child.

The theory of evolutionary biology gives us strong reason to expect that this must be true. The chances that our ancestors survived to reproduce successfully depended not only on the behavior of their own parents, but on the amount of help they got from their grandparents, uncles and aunts. If behavior toward one's near relatives is inherited, then the fact that we are products of successful evolution implies that humans can be expected to display significant willingness to care for their near relatives. In 1964, the great evolutionary biologist, William D. Hamilton [13] developed a theory that offers a systematic quantitative prediction of the extent to which individuals, on average, will care about their relatives. This prediction has come to be known as *Hamilton's Rule*.

Biologists define the "coefficient of relatedness" between two animals of the same species to be the probability that a rare "gene" found in one of these animals will also appear in the other. For sexual diploids if mating is between unrelated individuals, the coefficient of relatedness between two full siblings is 1/2, that between half-siblings is 1/4, that between an individual and a full sibling's child is 1/4, that between full cousins is 1/8, that between parent and offspring is 1/2, that between grandparent and grandchild is 1/4, and so on. Hamilton proposes that natural selection would produce individuals who try to maximize *inclusive fitness* where inclusive fitness is defined to be a weighted sum of one's own reproductive success and that of one's siblings, half-siblings, and cousins of various types, where the weights are coefficients of relatedness.[14] (Of course some care has to be taken to avoid double-counting of say, one's children's fitness and that of one's grandchildren.)

Hamilton stated his rule as follow:

> The social behaviour of a species evolves in such a way that in each behaviour-evoking situation the individual will seem to value his neighbor's fitness against his own according to the coefficient of relatedness appropriate to the situation.

Hamilton's rule implies that when faced with the option of sacrificing c units of its own reproductive success in order to increase the success of a relative whose coefficient of relatedness is k, by b units, the decision maker should make the sacrifice if it passes the benefit-cost test $kb > c$.

Should we add the willingness to pay of a child's grandparents and other relatives to that of its parents? Or does this amount to double-counting as we found to be the case if we added the willingness to pay of its two parents in an intact family? To answer this question in a really satisfactory way, we would need a theory of decisions for extended families. In extended families where transfers occur or are expected to occur between the grandparents and the parents of a child, it might be argued that the family operates under a single budget and that a parent's answers to questions about her willingness to pay for improvements in the child's health incorporate her understanding of the psychic benefits this improvement will confer on the grandchildren and her beliefs about how the costs of this improvement would be shared under family transfers.

On the other hand, it seems likely that in most Western families, adult siblings have independent family budgets with no significant sidepayments between families. In this case it is appropriate for benefit cost analysis to add the willingness to pay of a child's other relatives to that of its parents. As we argued in the case of a divorced couple, if changes in a child's health and in the tax burdens of its relatives do not otherwise affect the pattern of transfers between relatives, then a public project that improves a child's health and costs its relatives less than the *sum* of their willingnesses to pay allows a potential Pareto improvement.

[14]More recent theoretical work [9] [12] [5] has shown that Hamilton's rule is strictly correct only where the benefits and costs from interaction between relatives take a linear form.

7 Conclusion

We have tried to untangle some of the strings of familial affection in order to give practical guidance for benefit cost analysis. Some of these strings untie relatively easily. For example, the members of a single-parent household will not enjoy a Pareto improvement if the household is assessed a cost greater than the parent's willingness to pay. Thus adding willingness to pay of children to that of their parents would lead a benefit cost analysis to accept projects that are not potentially Pareto improving.

We showed that with reasonable restrictions, the reflected happiness between loving couples can be resolved into a well-defined household welfare function over allocations. If the household acts to maximize such a function, then the willingness to pay stated by either parent is an appropriate measure of the benefits to the entire household. If there are relatives outside of the household who also have significant willingness to pay, then a proper accounting of benefits from child health should include the valuations of these relatives.

For households with bargained outcomes or for divorced households, interpretation of parents' responses to questions about their valuation of a child's health can, in principle be more complex. We have shown that married couples who allocate private goods by bargaining may differ in the amount of household funds that they would be willing to spend on the child's health. In these cases, strict adherence to the principle of identifying potentially Pareto improving projects suggests using the smaller of the answers proposed by the two parents. The recommendation is quite different for divorced couples so estranged that the noncustodial parent makes no voluntary contributions to the custodial parent's household. In this case, benefit cost analysis should add the willingness to pay of the noncustodial parent to that of the custodial parent.

8 Appendix

8.1 An Example

Each parent i has an income $m > 1$ and a utility function of the form $U_i = x_i + 2v_i(k_i, h_i)^{1/2}$, where the function $v_i(k_i, h_i)$ is a utility function representing child i's preferences. There are two possible values for h_i. These are $h_i = 0$ and $h_i = 1$. where initially $h_i = 0$, and the public project is adopted, $h_i = 1$, and where $v_i(k, 0) = k$ and $v_i(k, 1) = k/2 + 4/9$. The total cost of the project is $N/6$, where N is the number of parents. Each parent allocates her income x_i and k_i so as to maximize her utility. When $h_i = 0$, this occurs where $k = 1$ and $x_i = m_i - 1$. Thus if the project is not adopted, each parent i has utility $m_i + 2 - 1 = m_i + 1$ and each child has utility 1. If the project is adopted, then the parent the parent optimizes by choosing $k_i = 0$ and $x_i = m_i$. In this case the utility of child i is $v_i = A = 4/9$ and the utility of the parent is $m_i + 2A^{1/2} = m_i + 4/3$. Each parent has a willingness to pay of 1/3 for the project to be implemented and so the sum of willingnesses to pay is $N/3$. Since the cost of the project is $N/6$, it passes the parental benefit-cost test. But, as we have seen, if the project is implemented, each child's utility will be reduced from 1 to 4/9.

Moreover, if the project is implemented, in order for children to be as well off as before the project, each child must receive at least $k = 10/9$. Any transfer scheme in which each child receives at least 10/9 and where parents pay a total of $N/6$ for the project must be worse than the outcome without the project for at least some of the parents.

8.2 Proof of Remark 3

Let x_A and x_B be the consumptions that Archie would choose for himself and Bess if the the health project is not implemented. Let p_b be the maximum amount that Bess would be willing to sacrifice out of her own consumption in order to improve her health by Δ. Then it must be that Bess is indifferent between her initial situation and the allocation in which her health is $h_B + \Delta$ and her consumption is reduced to $x_B - p_B$. If the family budget is reduced by p_B and Bess's health is improved by Δ, then since Beth has diminishing marginal utility of private consumption and since Archie views Beth's consumption and her health are complements, it must be that Archie's preferred allocation of private goods out of the new budget is one in which Bess's consumption is reduced by less than p_B.

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Preliminary research: Please do not cite

Weak Substitution, Environmental Vulnerability, and Choice
10/6/03

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I. Introduction

Feenberg and Mills' [1980] concept of weak substitution provides the basis for expanding the role of revealed preference methods in measuring individual willingness to pay to reduce pollution-related health effects. To support this argument we outline a graphical analysis of how weak substitution can enhance our use of models based on averting and mitigating behaviors. Moreover, the proposed structure offers an economic framework for describing why different groups might be considered more or less vulnerable to the health effects of pollution. Our discussion begins by summarizing Smith and Banzhaf's [2003] proposed approach to describe how weak complementarity and the Willig condition contribute to the estimation of the economic value for reducing pollution's impact on environmental amenities.

Discussions of the preference restrictions used to recover information about consumers' values for non-market goods largely ignore weak substitution. For example, after reviewing the concept in some detail in his 1992 book, Freeman [2003] reflected the apparent professional consensus and excluded weak substitution from his revised edition. He maintains that an assumption of less than perfect substitution is not especially

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informative without including a more detailed preference specification. Following Bartik [1988], Freeman argues that, at best, substitution offers upper and lower bounds for Hicksian welfare measures.[1] By contrast, our analysis suggests weak substitution may be comparable to weak complementarity in its ability to enhance the insights derived from revealed preference analysis of individual choice.

This paper provides a short primer on the logic underlying our arguments. We rely on graphical analysis and some simple analytical arguments but stop short of attempting to develop an empirical example. Section two outlines the first building block for understanding the link between weak substitution and choice. Our focus parallels Willig's [1978] use of weak complementarity. That is, we treat changes in environmental services as analogous to quality changes in private goods. This strategy redirects attention to selecting the private good whose price offers the most informative index of how a quality change affects consumer choice. Section three defines weak substitution and illustrates how a graphical analysis informs the structuring of economic models to recover preference information for the non-market resource with this restriction. By considering the price index capturing the effects of changes in environmental services, we isolate the private demands most likely to isolate an individual's non-market/market tradeoffs. Section four introduces a role for separability and with it a framework that demonstrates how an individual or household's economic circumstances, together with their physical (or health) conditions, contribute to a definition of their vulnerability to pollution. The last section describes how our logic relates to two past applications and

[1] Neill [1988] also discusses the prospects for substitution and complementarity relationships for groups of private commodities serving as bounds for willingness to pay measures.

how the framework might be used in new revealed preference (RP) or combined RP and stated preference research.

II. Analysis of Consumer Surplus with Indifference Curves

Following conventional discussions of Hicksian consumer surplus, we begin with the analysis of price changes. In analytical terms using indirect utility ($V(\cdot)$) or the expenditure function ($e(\cdot)$) with *m* designating individual (or household) income, *p* a vector of prices for market goods (*X*), *q* a non-market good, and *u* the utility level (e.g. $u^0 = V(m, p^0, q^0)$), the willingness to pay for a change in the price of *X* is defined implicitly in equation (1a) and explicitly in (1b).

$$V(p^1, m - WTP, q^0) = V(p^0, m, q^0) \tag{1a}$$

$$WTP = e(p^0, q^0, u^0) - e(p^1, q^0, u^0) \tag{1b}$$

Figure 1 provides the graphical interpretation that now finds its way into most undergraduate micro texts. Plotting the numeraire, *z*, on the vertical axis, a price reduction for good *X* from P_0 to P_1 corresponds to the pivot from AC to AD. WTP is the vertical distance AB.[2] This approach relies on changes in the prices of market goods and therefore has little bearing on non-market goods. As a result, many authors follow Lankford [1988] and adapt the early literature on rationing to deal with the WTP for non-market goods.[3]

In terms of expenditure functions, this strategy treats *q* as equivalent to a private good that is quasi-fixed. Letting *r* represent the price of *q*, we can define two expenditure

[2] It is labeled here with capital letters to distinguish it from the price vector.
[3] Freeman [2003] pp.74-81 has an excellent summary and graphical analysis.

functions– a conditional expenditure function that acknowledges the level of q can influence expenditures on X, labeled $e^*(\cdot)$, and an expenditure function which includes expenditures on q, labeled $e(\cdot)$. The following expression describes the relationship between $e^*(\cdot)$ and $e(\cdot)$:

$$e(p,q,r,u^0) = e^*(p,q,u^0) + r \cdot q \qquad (2)$$

Notice that in equation (2) q remains quasi-fixed in defining $e(\cdot)$. If $\frac{\partial e}{\partial q} = 0$ then we know the virtual price of q (i.e. $-\frac{\partial e^*}{\partial q}$) is equal to the exogenous price defined as r.

Figure 2 (adapted from Freeman's [2003] Figure 3.8) deals with this case where X is measured on the vertical axis and q on the horizontal axis. The WTP to realize a change in q from q^0 to q^1 is given in equation (3).

$$WTP = e^*(p, q^0, u^0) - e^*(p, q^1, u^0) - r(q^1 - q^0) \qquad (3)$$

Graphically, in Figure 2 the vertical coordinates of u^0 evaluated at q^0 and q^1 define WTP. The disparity in virtual expenditures (i.e. $r(q^1 - q^0)$) explains the difference between WTP and $e^*(p, q^0, u^0) - e^*(p, q^1, u^0)$.

To this point our discussion is a "garden variety" explanation that can be found in Freeman or other treatments of the concepts relevant to Hicksian welfare measurement. The logic used to explain welfare measures often outlines how some factor, exogenous to individual choice, affects the expenditures required to maintain a given utility level. Frequently invoked assumptions include the existence of prices and the inability of individuals to adjust freely. That is, the individual is often assumed to pay a per unit price for the good used to represent the environmental service. However, the choice process is described in a format that prevents her from actually choosing the amount desired at the available price.

As a rule, prices do not exist for environmental services. Thus, a comparison of Δe and Δe^{*} diverts attention from an issue that seems more relevant in models destined for empirical analysis. This issue concerns the selection of a private good (and hence a price) that provides the greatest insight into the importance of changes in q for an individual's observable choices. To develop this argument we need to consider a different way of describing the WTP for a change in q. This alternative entails selecting a single commodity and defining the price change that is *equivalent* to the change in q. We define this equivalence by specifying the changes in q and the selected good's price that require the same compensation (or payment) to restore the original utility level.

Thirty-five years ago, Fisher and Shell [1968] proposed a similar strategy in considering the issues associated with adjusting prices for quality changes. They demonstrate two results that seem underappreciated in the literature on non-market valuation.[4] The first of their results on price indexes relates to a quality change in a private good equivalent to augmenting the quantity of that good. This formulation of how quality influences preferences is the only one that allows the definition of a quality adjusted price (for the good experiencing the quality change) independent of the amounts of all other commodities being purchased. The second of their key theorems concerns another aspect of preference restrictions and focuses on conditions, other than simple repackaging (or equivalently quantity augmentation), that allow quality adjustment to the price of one or more goods <u>other</u> <u>than</u> the one experiencing the quality change.[5] Their examples for this type of preference restriction implicitly recognize a role for weak complementarity[6]:

> "…suppose there is a quality change in refrigerators. If this change simply makes one new refrigerator deliver the services of some larger number of older ones, then the simplest price adjustment in the cost-of-living index is indeed an adjustment in the price of refrigerators. On the other hand, if that quality change also increases the enjoyment obtained from a quart of ice cream, then an adjustment in refrigerator price will not suffice; an adjustment in the price of ice cream is also called for. **Indeed, if the *only* effect of a refrigerator quality change is to augment the enjoyment attained from ice cream, then the simplest adjustment is one made *only* in the price of ice cream, even though the quality change takes place in refrigerators.** In this case, an adjustment in the price of refrigerators can be made to suffice; the magnitude of that adjustment, however, will depend on the quantities demanded of all goods. An adjustment in the price of ice cream will also suffice; the magnitude of that adjustment, however, will only depend on the quantity of ice cream and the quantity of refrigerators" (p.123, bold highlights added).

The conditions that assure the quality change can be reflected in a subset of private goods' prices parallel the conditions required to recover estimates of the role of non-market services (quality) from consumers' choices of private goods. This link is consistent with our proposal to consider the equivalence relation between quality changes and price changes as a guide to revealed preference modeling.[7]

To develop this logic we reconsider the measurement of consumer surplus for a price change, first in Marshallian terms. Consider one of the private goods, *X*, and a

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[4] Banzhaf [2001] makes this point in discussing the adjustment of cost of living indexes for non-market environmental services.

[5] Hanemann [1984] addresses cases similar to this general idea in his evaluation of cross product repackaging for quality.

[6] This concept had not been defined at the time they developed their reasoning.

[7] As we noted, this argument is similar to Neill's [1988] use of substitution and complementarity restrictions for sets of private goods in relation to a non-marketed good to establish bounds for WTP.

change in the price of *X* from P_1 to P_0 (with $P_1 > P_0$). P_0TSRP_1 represents the change Marshallian consumer surplus (MCS) for an ordinary demand curve in panel a of Figure 3. Our argument is outlined for the linear case, but holds as an approximation for other cases. Equation (4) provides an algebraic description of P_0TSRP_1.

$$MCS = (P_1 - P_0)X_1 + \tfrac{1}{2}(P_1 - P_0)(X_0 - X_1) \tag{4}$$

Rearranging terms, we have equation (5):

$$MCS = \tfrac{1}{2}(P_1 - P_0)(X_1 + X_0) \tag{5}$$

Panel b of Figure 3 provides an alternative representation of this relationship. Assume the interior budget constraint corresponds to a price of *X* at P_1 and the exterior to P_0. The tangency at D corresponds to X_1 and at B to X_0. Marshallian consumer surplus for this linear case is exactly equal to the average of CD+BA. This is established directly once we recognize that, with numeraire good priced at unity, the following relations hold:

$$\begin{aligned} m_0 L &= P_1 X_1 \\ m_0 N &= P_0 X_1 \\ m_0 M &= P_0 X_0 \\ m_0 J &= P_1 X_0 \end{aligned} \tag{6}$$

As a result, CD=$m_0 L - m_0 N$ and AB=$m_0 J - m_0 M$. Substituting from equation (6) yields the relationship given in equation (7).

$$\begin{aligned} \tfrac{1}{2}(CD + AB) &= \tfrac{1}{2}\left[(P_1 - P_0)X_1 + (P_1 - P_0)X_0\right] \\ MCS = \tfrac{1}{2}(P_1 - P_0)(X_1 + X_0) &= \tfrac{1}{2}(CD + AB) \end{aligned} \tag{7}$$

To use this logic to illustrate the connection between changes in *q* and equivalent (in welfare terms) price changes, we assume weak complementarity. Let *X* and *q* be weak complements. The indifference curves for a given utility level <u>with different levels</u>

of q will intersect at R on the vertical axis (i.e. at zero consumption level for X) as in Figure 4, panel a. This feature follows from weak complementarity. That is, when there is no consumption of X the non-market good has no value to the consumer. We assume that $q_1 > q_0$. Quality improvements imply an inward fanning of indifference curves because the levels of the weak complement (X) and the numeraire (z) required to maintain the same level of utility decrease as q increases.

Now consider the definition of price change for X equivalent to the quality change in q. For the income level defined by the vertical intercept T in the figure, the budget constraints tangent to indifference curves labeled $V(q_0)$ and $V(q_1)$ at B and C, respectively, provide the equivalent price change. Moreover, the average of CD and AB in this case corresponds to the Hicksian willingness to pay for this price reduction (e.g. from the budget constraint tangent to $V(q_1)$ to the one tangent to $V(q_0)$) or *equivalently* the WTP for the increase in environmental services from q_0 to q_1. This conclusion follows because the utility level associated with these indifference curves is the same by construction (i.e. $V(q_0)=V(q_1)$). As in our earlier discussion of price changes, the argument holds exactly for the case of a linear Hicksian demand function and approximately with nonlinear demands.

Panel b of Figure 4 introduces a third indifference curve, $\bar{V}(q_1)$, corresponding to a quality level of q_1 but a different utility level. Comparisons of $V(q_1)$ and $\bar{V}(q_1)$ isolate the individual's choices holding income constant. We examine the case where prices correspond to the outer budget constraint. Therefore, $\frac{1}{2}(CD+EF)$ corresponds to the Marshallian consumer surplus for the Hicksian equivalent price change and thus for the change in environmental services as well.

Smith and Banzhaf [2003] use this relationship (i.e. between $\frac{1}{2}(AB+CD)$ and $\frac{1}{2}(CD+EF)$) to illustrate how weak complementarity and the Willig [1978] condition can be combined to recover Hicksian consumer surplus measures for the amenity values provided by enhanced quality. Here we argue that Willig's focus on the relationship between the Marshallian consumer surplus for a quality change relative to the level of consumption of a private good (that is a weak complement to quality) and the price adjustment for that good with respect to quality is another way of suggesting that the conditions required for quality adjusted price indexes parallel those needed to define welfare measures for changes in quality.

III. Weak Substitution

Feenberg and Mills [1980] define weak substitution as another form of demand interdependency that arises for private goods and environmental services when the relative prices of those interdependent private goods are "high". In the case of weak complementarity, the choke price of the private good is crucial to isolating the marginal value of an increase in the related non-market environmental service (see Smith and Banzhaf [2003] for details). In the case of weak substitution, the level of consumption of a private good is defined, but the interaction between the private good and quality (or non-market services) implied by this definition is different. That is, we assume there exists a level of consumption for the private good (the weak substitute) above which improvements in the non-market environmental service have no value. For price levels of the weak substitute above the level corresponding to this threshold, consumption of the weak substitute is below the threshold and quality improvements are valuable. Formally, if P_a defines the price that induces the threshold consumption level, X_a, as in equation (8), then the condition for weak substitution is given in equation (9).[8]

$$-\left.\frac{V_P}{V_m}\right|_{P=P_a}=X_a \tag{8}$$

$$\left.\frac{\partial V}{\partial q}\right|_{P=\hat{P}}=0\ \ \forall\ \hat{P}\le P_a \tag{9}$$

Figure 5 illustrates the fanning indifference curves associated with weak substitution. As in our discussion of weak complementarity, the level of utility is constant across the curves with the inward fanning denoting quality improvements. Figure 6 now combines the format used in our earlier analysis of weak complementarity to illustrate how the quality change can be translated to an equivalent price change in the presence of weak substitution.

Consider first panel b in Figure 6. We begin the analysis by selecting a price for *X*, denoted P_a, that will lead to X_a when there is no consumption of *z*. The pivot in the budget constraint from the outer budget line tangent to $V(q_0)$ at B to the inner constraint defines a relative change in the price of *z*. The constraint tangent at B corresponds to the lower price, $P_z(q_0)$, for the numeraire good *z* as given in Figure 6a. The inner budget constraint, tangent at C, relates to the higher price, $P_z(q_1)$. In this case, the weighted (by P_a) average of AB+CD (measured along the X-axis – i.e. the weak substitute) corresponds to the Hicksian surplus as detailed in equations (10a) through (10c).

[8] An important point that we discuss in more detail below concerns the fact that P_a is in fact a function defined by the specified level of X_a and the prices of other goods and income.

$$AB = \frac{1}{P_a}\left(P_z(q_1) - P_z(q_0)\right) \cdot z_0 \tag{10a}$$

$$CD = \frac{1}{P_a}\left(P_z(q_1) - P_z(q_0)\right) \cdot z_1 \tag{10b}$$

$$\frac{1}{2}(AB + CD) = \frac{1}{2}\left(\frac{1}{P_a}\right) \cdot \left(P_z(q_1) - P_z(q_0)\right) \cdot (z_1 + z_0) \tag{10c}$$

When P_a is normalized to unity, this relationship reduces to one that is comparable to our earlier description of the measurement of the Hicksian willingness to pay for a quality change. In this case however, we use the price of the numeraire and not the price for the private good serving as the weak substitute.

As in the case of our discussion of weak complementarity, introducing a third indifference curve, here at the level corresponding to a quality level of q_1 (labeled $\overline{V}(q_1)$ in Figure 6b), also yields the Marshallian measure of the quality change (or price change in z) as $\frac{1}{2} \cdot P_a \cdot (AB + FG)$ in the figure.

In some respects, our simple interpretation in Figure 6b may be misleading. The relative prices of X and z determine consumption levels of both goods. As we noted, Figure 6b assures that when z=0, consumption of X equals X_a, the threshold beyond which q no longer has value. The pivoting of the budget constraints at this point are intended to illustrate increases in the relative price of z in comparison to X, with the price for X remaining at P_a.[9] To some degree this representation is artificial because the diagram illustrates relative prices for a given income. Thus, P_a could be represented for a

[9] The actual slope of the budget constraint is $-\left(P_X / P_z\right)$. Increases in the price of z relative to P_a for X pivot the budget constraint inward.

different income level without pivoting at X_a. Figure 7 recasts the diagram starting the budget constraint at a position where $P < P_a$ when z=0. In this case, we also see that P_z can provide a price index for q. The combined results of Figures 6 and 7 suggests that the relevant condition is on relative prices. As Fisher and Shell suggest, we need to consider adjusting the price index of z and the level of consumption (or the price) for X. For the case of weak substitution (which was not explicitly discussed in Fisher and Shell's analysis), relative prices imply levels of consumption for X below X_a will be informative about the value an individual derives from changes in the amount of q. Our graphical illustration focuses on the price of the numeraire, z, to illustrate how this adjustment connects to the same Marshallian consumer surplus for a quality change discussed in the case of weak complementarity.

If we pivot panel b in Figure 6 and place X on the vertical axis with z on the horizontal, then the level of z corresponding to X_a (labeled as z_a in the figure) appears to correspond to what Smith and Banzhaf [2003] define as weak complementarity "at a point". This alternative interpretation of weak substitution provides a graphical illustration for Fisher and Shell's argument associated with improvements in the quality of refrigerators and ice cream. We can use the price of refrigerators to reflect quality changes (the price for the weak substitute in our example) but to do so requires that we incorporate consumption levels of all other goods. By contrast, when the effect is exclusively on ice cream we can use the price of ice cream and the consumption of refrigerators (our point X_a) to define a price index adjustment for quality. In this case we are implicitly assuming that for small levels of consumption of ice cream (i.e. levels at or below z_a) it is either not stored (and hence the quality improvement in the refrigerator is not important) or weak complementarity is associated with larger amounts of consumption that might be associated with specialty desserts (e.g. ice cream cakes that must be refrigerated for some period time).

These examples have been quite simple. As a result, we relegated all other goods to the background without really explaining how this outcome was accomplished. In short, *z* was implicitly a composite of all other goods. Our graphical strategy sought to focus on the properties of each of the two goods' prices as candidates for the quality adjustment. In the process we implicitly assumed that one of them was an index for everything else.[10] One way to take account of other goods' prices in developing restrictions that use weak substitution imposes separability. This next step is discussed below.

IV. Separability and Environmental Vulnerability

To limit our attention to the relationships between *z*, *X*, and *q* and allow a more explicit treatment of the remaining private goods, we introduce a new argument in the preference function, *r*, which designates a composite of all other goods. P_r represents its price (or price index).[11] Separability of *z*, *X*, and *q* from *r* implies we can write the indirect utility function as in equation (11).

$$V = V\big(v(P, P_z, q, m_v),\ \mu(P_r, m - m_v)\big) \tag{11}$$

Separability also assures that consumption choices can be described as if they were undertaken as part of a process that decomposes the budget into components for each set

[10] This was not what Fisher and Shell intended in their discussion of the problem.
[11] *r* can be a vector of goods and P_r a vector of prices. We do not need to be more specific here because our objective is to illustrate how separability allows the role of P_r to be limited to its influence on income effects.

of separable goods. Thus, we can specify m_v as the expenditures on X and z, given levels of q. m_v will be a function of all goods' prices (P, P_z, and P_r) as well as q and m.[12] This strategy "focuses" the patterns of influence. That is, separability allows us to distinguish the roles of the prices of goods in the sub-function, P and P_z, from all other goods' prices, P_r. All prices continue to affect the conditional demand for X and z. However, those outside the sub-function enter through reallocation of income about separable sets of goods. With this specification, the influence of both P_r and m are observed through the income effect. Perhaps more importantly the effects of q on the demands for other goods are observed exclusively through the reallocation of income (e.g. m-m_v) and their income effects. There are no separate substitution effects attributable to q with other private goods.

Consider now the definition of conditional weak substitution given in equations (12a) and (12b). Equation (12a) defines the conditional demand for X, given the budget allocation between X and z and all other goods implied by m_v.

$$-\left.\frac{v_P}{v_{m_v}}\right|_{P=P_a} = X_a \tag{12a}$$

$$\left.\frac{\partial v}{\partial q}\right|_{P=\hat{P}} = 0 \;\forall\; \hat{P} \le P_a^* \tag{12b}$$

We can simply recast the analysis of weak substitution in the previous section in terms of the indifference curves corresponding to the separable sub-function ($v(\cdot)$) in the direct utility function. An average of the changes in expenditures on the mitigating good, z, for a given budget allocation, measures the conditional compensating variation (CCV) (see

[12] See Blackorby, Primont, and Russell [1978], Theorem 5.5, corollary 5.5.1 and their discussion on pp.277-279.

Hanemann and Morey [1992]). $(P_z(q_1)-P_z(q_0))z_0$ evaluates initial consumption of z at the old and the new prices with $P_z(q_0)\cdot z_0$ representing initial expenditures and $P_z(q_1)\cdot z_0$ an estimate of the expenditures required to purchase z_0 at the new prices. $(P_z(q_1)-P_z(q_0))z_1$ considers analogous expenditure increments at the new level of z. The average of these two terms (adjusted by the price of X) provides the CCV for the quality change. This formulation makes explicit the dependence of P_a^* on the allocation of income to the activities we hypothesize to be included in $v(\cdot)$.

Prices, demographic features, or any variables that may affect the allocation process can change how X_a influences the derived value of P_a^*. Thus, we can explicitly describe how demographic and physical traits contribute to characterizing individuals who are differentially vulnerable to pollution (or equivalently to declines in environmental services). The physical attribute of vulnerability corresponds to increased sensitivity to the level of q. Health status, age (e.g. elderly groups or young children), or other non-economic variables can be specified to lead to different levels of X_a for each subgroup.[13] Equally important, this structure describes how economic conditions contribute to the implied price, P_a^*, associated with realizing this threshold level of consumption of the weak substitute.

The separability restriction provides a convenient functional specification that allows this logic to be incorporated with conditional demand models. An observed pattern of vulnerability for particular groups under this definition arises through both

[13] Conventional definitions of weak complementarity assume that the threshold for quality having an effect is confined to zero consumption. In this context it is not possible to distinguish separate reasons for

economic and demographic (or other) factors. Because the two considerations influence observed responses, efforts to isolate sensitive groups and measure their responses must resolve a difficult identification problem. The analysis must take account of the economic consequences of the threshold defining vulnerability.

Interpreting the separability restriction as a means of introducing household models illustrates an alternative use of the framework. For example, Chiappori's [1988] collective household model imposes budget decomposition on the allocation of income in the household through his structuring of the household decision process. Combining this preference assumption with a further restriction that different members of the household consume different goods, we extend the use of weak separability to develop some specific insights into the use of averting or mitigating behavior models within a household setting. To illustrate this point, consider a two-person household where changes in *q* only affect individual one. Each household member consumes an exclusive private good, represented by X_1 and X_2 respectively. In addition, assume that, for individual one, the exclusive consumption good, X_1, serves as a weak substitute for *q*. Chiappori's efficient household model yields budget decomposition similar to what we described in equation (12). However, the interpretation of the decomposition in the household setting is different.[14] In Chiappori's model, the expenditure groups represent consumption by different people in the household, rather than simply different groups of goods consumed by the same person as in our equation (12). Equation (13) clarifies the distinction. Let $\ell^1(\cdot)$ designate the first individual's indirect utility function viewed as

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environmental quality across individuals and use these physical or technical distinctions along with differences due to economic circumstances (since *X*=0 for all cases).

[14] See Smith and Van Houtven [2003] for a discussion of some of the welfare implications of the model.

the solution to Chiappori's efficient household. $\ell^1(\cdot)$ is a function of all goods' prices, income, and q. The left-hand side of equation (13) simply indicates that the indirect utility realized by individual one depends upon the prices for all the goods consumed by the household, q, and income. The right-hand side recognizes the exclusive goods consumed by each of the household members. As given here, individual one consumes the first good but not the second.

$$\ell^1(P_1, P_2, q, m) = V^1(P_1, q, s(P_1, P_2, q, m)) \tag{13}$$

$s(\cdot)$ represents the income available to individual one. The remainder, $m - s(\cdot)$, is the portion of household income available to individual two.

Equation (13) suggests two possibilities for defining the threshold level of commodity one implied by weak substitution, either in terms of $V^1(\cdot)$ or $\ell^1(\cdot)$. The central issue is whether the definition for X_{1a} implies that the income allocation is held constant. Equation (14a) uses Roy's identity for the Marshallian demand to define the price function for P_1 (e.g. labeled here as P_{1a}) that yields X_{1a} in terms of $V^1(\cdot)$.

$$-\left.\frac{V^1_{P_1}}{V^1_s}\right|_{P_1 = P_{1a}} = X_{1a} \tag{14a}$$

Equation (14b) defines weak substitution holding individual one's available income ($s(\cdot)$) constant.

$$\left.V^1_q\right|_{P_1 = \hat{P}_1} = 0 \quad \forall \quad \hat{P}_1 \leq P_{1a} \tag{14b}$$

Return to equation (13) and consider a change in q in terms of the expression that defines utility for individual one without the explicit separability. This process results in the identity given in equation (15).

$$\ell_q^1 = V_q^1 + V_s^1 \cdot s_q \tag{15}$$

Substituting from (14b) for $\hat{P}_1 \leq P_{1a}$ we have equation (16) for prices that satisfy this inequality.

$$\ell_q^1 = 0 + V_s^1 \cdot s_q \tag{16}$$

In other words, the model suggests that the tradeoffs we observe associated with individual one's choices in response to a change in *q* reveal any reallocation of income due to the change in *q*. This result holds provided we assume his (or her) income is held constant in defining P_{1a}.

In contrast, if we define weak substitution in terms of $\ell^1(\cdot)$, the model suggests that, for P_{1a} defined in this way, the incremental value of changes in *q* is counterbalanced by budget reallocation within the household. Equations (17a) or (17b) illustrate the result.

$$\ell_q^1 = 0 = V_q^1 + V_s^1 s_q \tag{17a}$$

$$\frac{V_q^1}{V_s^1} = -s_q \tag{17b}$$

At this level of analysis we are unable to select one of these descriptions as correct. Our point is to direct attention to the types of household information that should be collected and, potentially, to illustrate how the absence of some types of information may confound the process of isolating the effects of *q*.

Perhaps the most direct insight from this set of modeling alternatives is that if the analyst is to have any chance of recovering individual preferences for *q*, then empirical analyses must include information on the sensitive member of the household, his or her choices, and the responses of other household members to changes in some element of environmental quality or services. In the next section we discuss how the framework presented above relates to a few recent papers that sought to use household responses and specific sensitive populations to estimate individual willingness to pay for improvements in q.

V. Implications for Empirical Models

Weak complementarity has been *the* dominant restriction used in revealed preference approaches to measure the economic values for changes in non-market environmental services. More generally, complementarities between goods and services are important to the processes through which new goods (or services) generate improvements in individual well being. Bresnahan and Gordon [1997] developed this important insight in the introduction to their volume on incorporating new goods in cost of living measures. They used the example of artificial light to introduce their argument, noting that over the past century:

> "A series of new goods, such as whale oil for lamps, gaslight, and then the electric light bulb, rapidly lowered the costs of using artificial light, a commodity which is complementary to a wide variety of household and workplace activities. Thus, as artificial light grew cheaper, activities which had been economic only for short parts of the day spread to evening, activities confined to summer became year-round, and jobs became easier to perform" (p.3)

These types of complementarities have cascading effects – with cheap artificial light transforming the allocation of individual time throughout the day and creating a new mix of demands for goods and services – both new and old.

An important dimension of these effects is a set of discontinuities which was not emphasized by Bresnahan and Gordon and is central to Smith and Banzhaf's [2003] generalization ot weak complementarities. Relationships between goods and services may change substantially at different levels of consumption. Recognizing and using this information should be regarded as a preference restriction. Weak complementarity at a point and weak substitution are restrictions that provide a conceptual basis for developing these restrictions in ways that can be used in understanding individual choice.[15] That is, weak substitution's definition requires that we identify a point of discontinuity in the role for quality (or environmental services). As a result, it is adding more information than alternative specifications of substitution patterns (as might be associated with classes of preference functions, such as a constant elasticity specification).

To our knowledge, none of the empirical analyses of the costs of mitigating or averting behavior has imposed weak substitution. Moreover, while several papers have offered recommendations for future empirical analyses that follow the implications drawn from our combined models with separability and weak substitution, these studies do not suggest how the additional data would be used in estimation.[16] By specifying a formal structure, we believe the empirical implementation may be clearer. To illustrate this point we selected two applications that consider environmental impacts on family members – Agee and Crocker [1994] and Mansfield et al. [2002].

(a) Agee and Crocker [1994, 1996]

[15] We owe this observation to Dan Phaneuf who commented on the Smith-Banzhaf argument for weak complementarity by noting it created discontinuities and with them more information for revealed preference models.

[16] Shogren [2001] listed as his top two recommendations in a paper on valuing effects of environmental hazards on children's health: (a) "pay more attention to how decisions of intrahousehold resource allocation and distribution are made by caregivers; and (b) begin efforts to construct a systematic framework to help

Both Agee and Crocker papers investigate parental willingness to pay for risk information and therapy for children with differing confirmed levels of body lead. The focus of their analysis is on the decision to undertake chelation treatment given information about health risks, parental background (including education and labor market status), body lead levels, and household income. The authors are careful to include time costs in their estimates for the full costs of treatment (e.g. blood chelation). They consider average estimates for parental time commitment but do not have specific information on time allocations to the chelation activity or other activities for each family. The income, employment status, wage rates, family composition, and education levels are specific to each group.

Agee and Crocker find the chelation decision was related to parental education, family status (e.g. father present), lead levels, and measures of the full price. The results suggest more educated mothers and traditional families are less likely to choose the therapy. The authors suggest this outcome could imply a substitution of caregiving time for the therapy. Our framework would suggest that this behavioral response is exactly where one should expect to recover information about the economic value of reducing lead in the environment based on its impact on children. However, the information available to these authors provides no specific details on time allocation choices of parents, children's health status (that might serve as the threshold for a weak substitution effect), or reallocation of resources within the household. The authors correctly conjecture these issues are likely to be important but are unable to estimate a structural model without these details.

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organize how we think about the interaction of environmental threats and the behavioral choices of society, caregiver and children…" (highlights of author's summary, pp.7-8).

(b) Mansfield et al. [2002]

Mansfield et al. [2002] propose an ambitious diary study of families with asthmatic children to investigate parental responses to high ozone warnings. The authors hypothesize that changing the mix of activities undertaken by children offers a behavioral response to changes in air pollution. They use a national sample including asthmatics and non-asthmatics during times when high ozone might be expected so it seems reasonable to anticipate observed responses. The authors' preliminary results focus on total hours spent outdoors and the fraction of the day spent outside. Specifically, for each activity in which the child participated parents were asked to whether the activity was undertaken "totally indoors", "mostly indoors", "half indoors and half outdoors", "mostly outdoors", or "totally outdoors". Based on the time diaries, the authors calculated the total number of hours spent in each of these categories. The results do not adhere to one's a priori expectations. On average, parents of asthmatic children indicated that their children spent more time mostly outdoors more often than parents of non-asthmatics. Of parents who reported their child's time was spent "totally outdoors", the average hours were higher among parents of non-asthmatic children. However, as in the "mostly outdoors" category, the differences across the two groups were not large and did not appear to be significantly different. Multivariate analysis confirms the simple analysis – ozone warnings did not have a differential effect for the two groups.

The weak substitution framework suggests a potential explanation for this finding: the need to separate the sample with children distinguished by a health threshold. This partition might reflect parental judgments about when high levels of ozone are likely to be problematic in ways that are comparable to our weak substitution relationship. Our model also suggests that the household's capacity to reallocate resources among its members should affect the recoverability of the air quality effect. Our comparison of weak substitution defined as $\ell_q^1 = 0$ versus $V_q^1 = 0$ illustrated the importance of resource allocation. While our model focused on reallocation in terms of income, a reformulation to reflect time reallocation is a straightforward extension. The lesson for this analysis is, as Shogren suggested, greater attention to caregivers' time and monetary reallocations.

Overall, these two examples suggest that behaviors consistent with the weak substitution framework seem quite likely. What appears to be missing are data that include not only responses concerning the weak substitute, but other goods or services (or in the case of the household, the person) that a weak substitution model suggests is the best source for choice information.

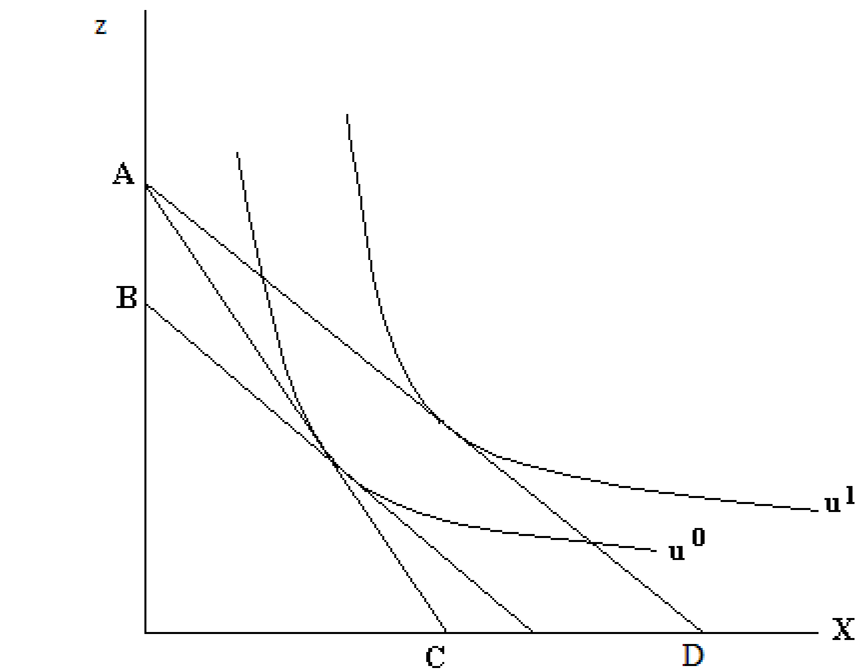
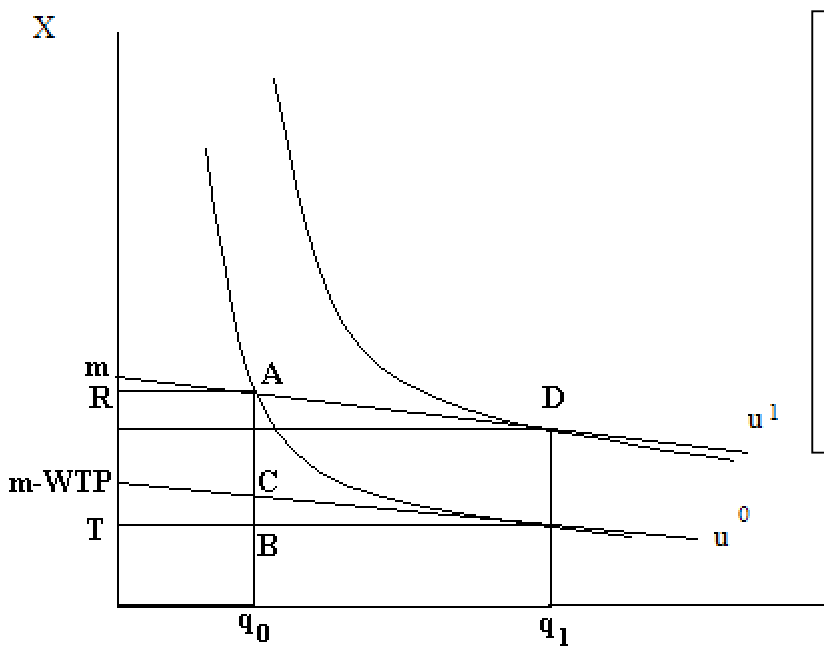


Figure 1: Conventional Description of Willingness to Pay – Price Reduction



Legend for Figure 2

m = income

WTP = willingness to pay for a change in the rationed good from q_0 to q_1

$\Delta q = q_1 - q_0$

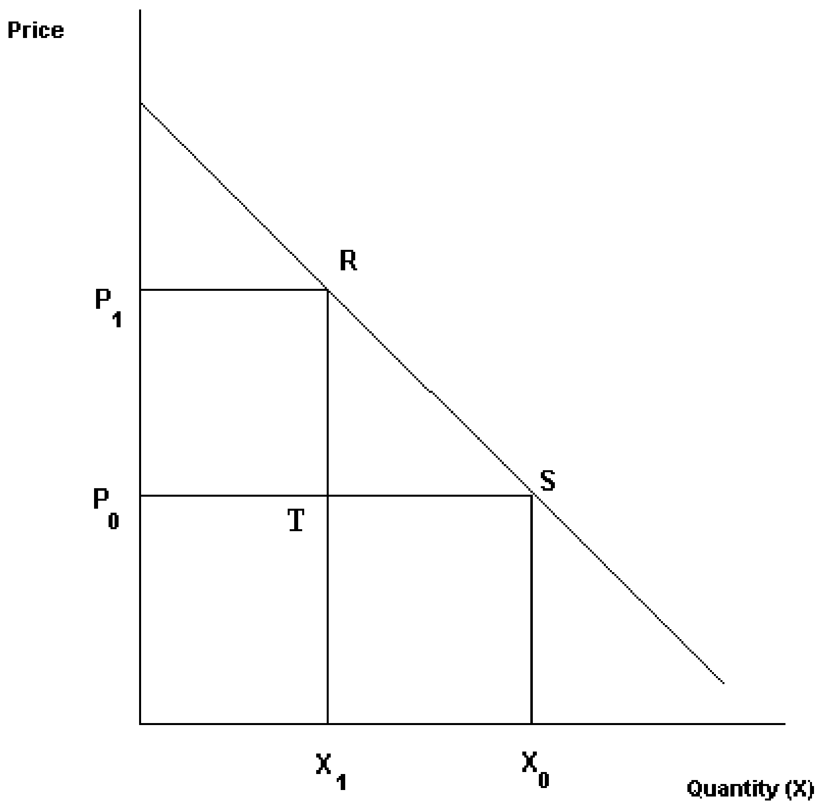
r = price of rationed good

A to $B = \Delta e^*$

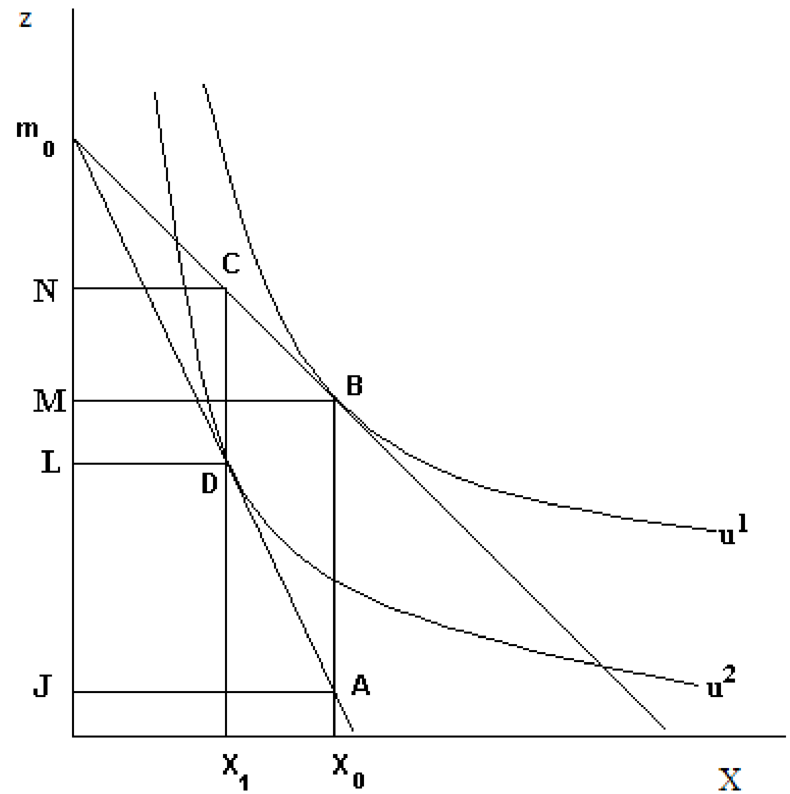
B to $C = r \cdot \Delta q$

m to $R = r \cdot q_0$

Figure 2: Freeman's Description of Lankford Model – Change in Rationed Goods

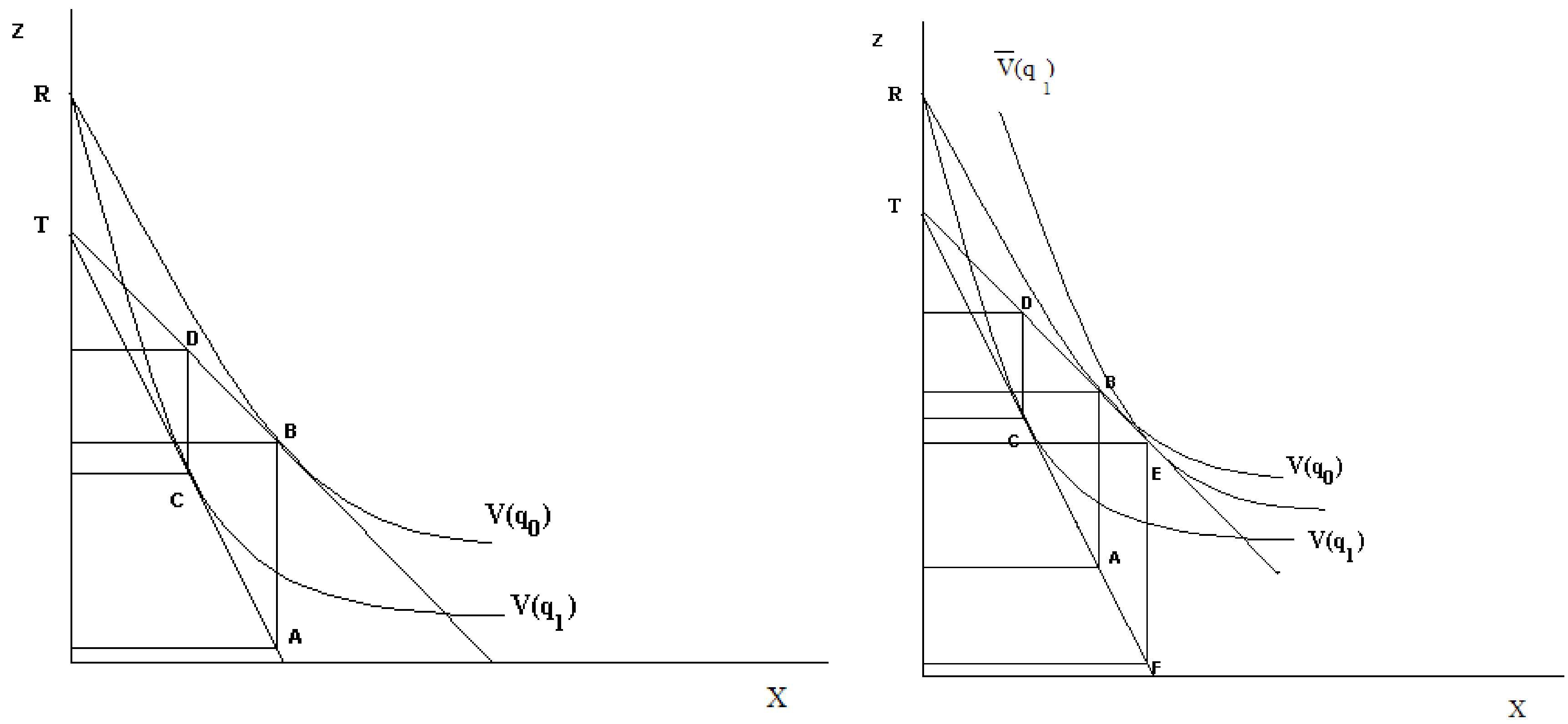


Panel a



Panel b

Figure 3: Marshallian Consumer Surplus for a Price Change



Panel a

Panel b

Figure 4: Illustrating Quality Change

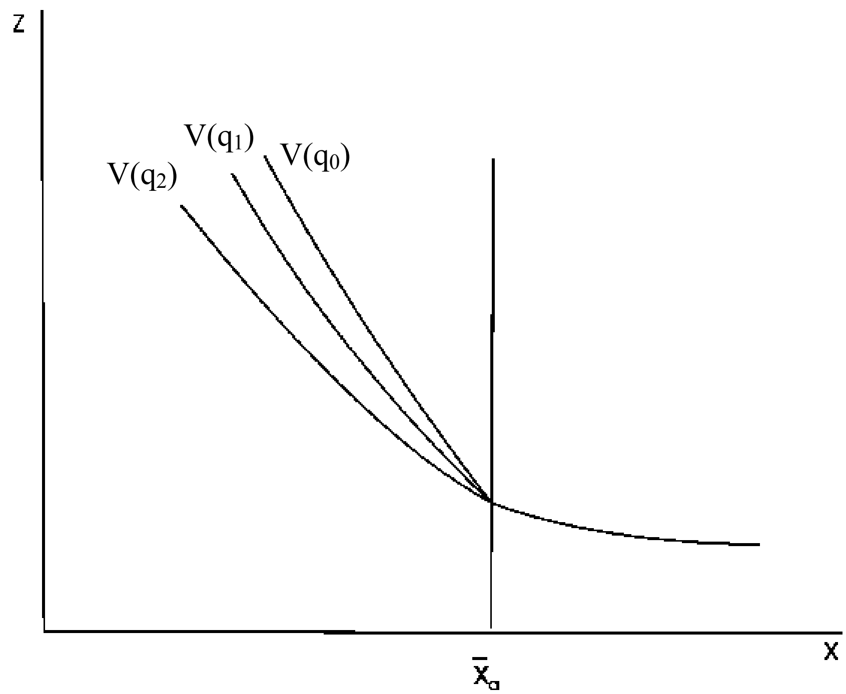


Figure 5: Weak Substitution

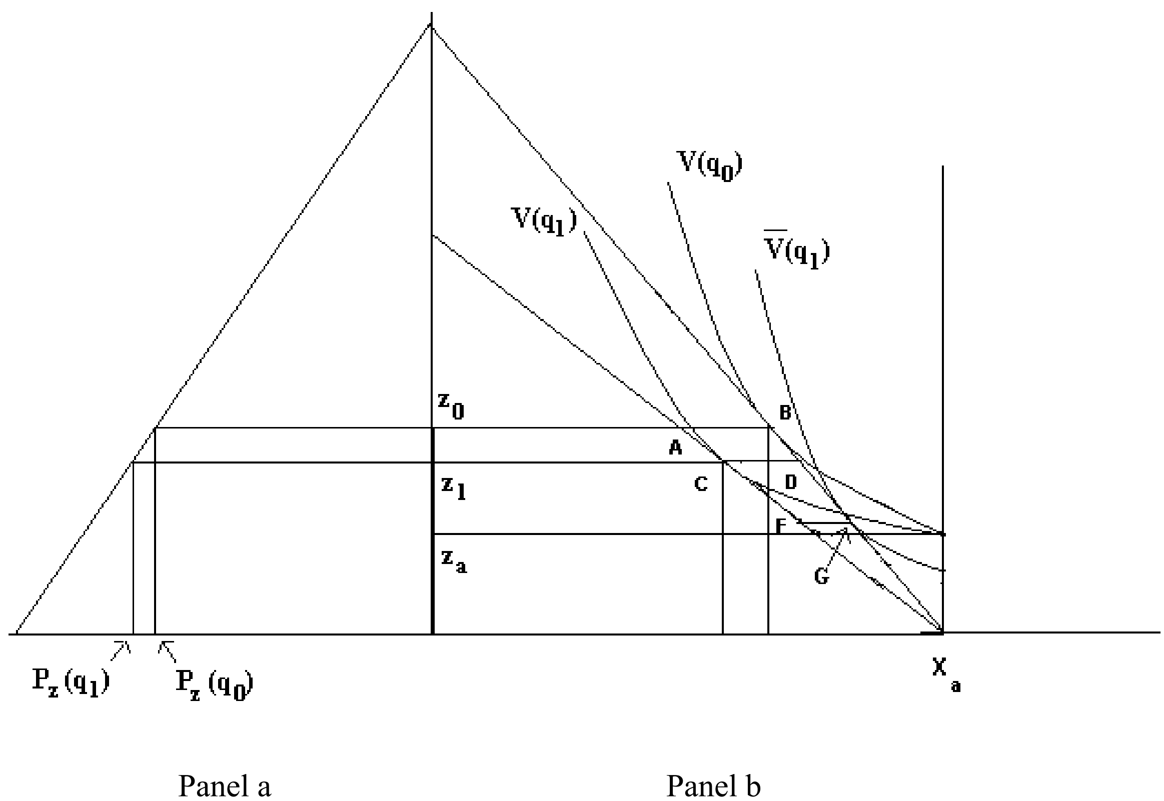


Figure 6: Weak Substitution and Hicksian Demand

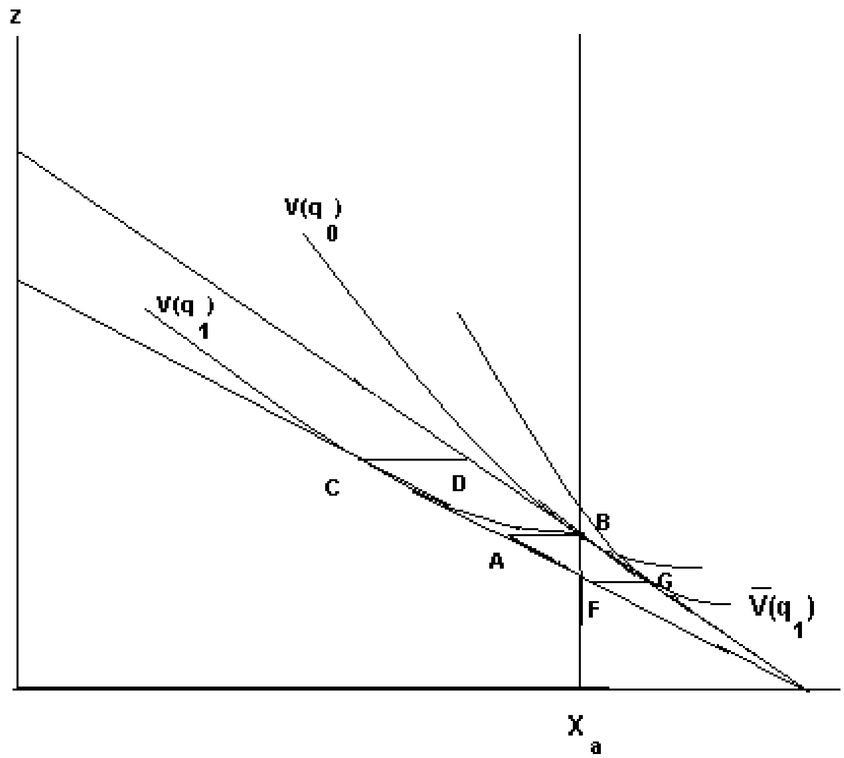


Figure 7: Weak Substitution with Alternative Relative Prices

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ABSTRACT

Family Decision Making and the Value of Preventing Childhood Developmental Impairment

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Objectives. This multi-disciplinary study has three objectives: (1) to provide more comprehensive valuation of reducing risk of childhood developmental impairment neurotoxins by estimating parental willingness to pay (WTP) to reduce lead-paint hazards; (2) to develop more accurate methods of eliciting parental WTP to protect children's health by testing the impacts of using intra-household resource allocation models rather than unitary household models; and (3) to develop more systematic approaches to designing non-market survey instruments by using mental models research to better understand the underlying decision processes.

Experimental Approach. Current research on parental WTP to protect children's health from environmental hazards models household choice as an action by a single decision-maker with a unitary utility function and a pooled budget. A large body of literature in economics and sociology of the family and in cognitive psychology suggests that these assumptions are flawed, and may lead to incorrect measures of parental WTP to protect children's health from environmental hazards. The study proposed here tests these assumptions.

Environmental neurotoxins can have permanent effects on children's intelligence, motor development, and attention. New research suggests that environmental exposure may be a larger contributor to developmental impairment than previously thought. Lead paint exposure will be used as the representative neurotoxin hazard. Lead paint abatement options provide an excellent vehicle for testing unitary versus bargained household models in estimating parental WTP to protect children's health. EPA currently relies on more limited cost-of-illness and human capital estimates of the benefits of protecting children from lead and other neurotoxin hazards.

This study has two phases. The first phase will elicit "mental maps" of parents' risk perceptions and decision making about reducing their children's health risks from lead paint. Thirty couples will be interviewed individually and as a couple about their risk perceptions, definitions of the decision problem and choice set, and roles in family decision making. Results from phase one will guide development in phase two of a attributed-based/conjoint contingent behavior survey of 250 couples to assess the influence of individual and shared parental risk perceptions and preferences on household choice of lead-paint abatement to protect children.

Expected Results. This research will produce estimates of individual and household willingness to pay for reduced risk of developmental impairment in children. It will also generate measures of the degree to which estimates from bargained and unitary household models differ. Insights into household decision making on environmental health risk issues from the valuation and mental model results will help guide future valuation efforts as well as neurotoxin risk communication programs.

Robin Jenkins's Policy Discussion of
"Benefit Cost Analysis and the Entanglements of Love"
Theodore C. Bergstrom, In progress, October, 2003 and
"Weak Substitution, Environmental Vulnerability, and Choice"
V. Kerry Smith, Mary F. Evans, H. Spencer Banzhaf, and Christine Poulos, October 6, 2003

I will discuss Prof. Bergstrom's paper, the Smith et al paper, and end with connections between the two.

Prof. Bergstrom's paper has two broad objectives. The first is to try to figure out how introducing an important aspect of real life into economic models will affect our interpretation of benefit-cost analysis (BCA). The important aspect is family relationships. How will accounting for the interdependencies of families affect how we conduct and interpret economic analysis?

Prof. Bergstrom's second objective is to simultaneously figure out whose willingness to pay (WTP) is valid when conducting BCA for families. (Should one examine the mother's, the father's or the child's WTP? Some combination thereof?)

Both of these objectives are important to policy-makers. EO 13045, issued by the Clinton administration in the late 1990s, directed policy makers to consider health risks to children. This introduced a new need for policy analysts to try to look separately at the impact of government policies on children. It turns out that this task is virtually impossible if one relies on the traditional tools of economics in which individuals maximize utility for themselves subject to a budget constraint. Children are not rational beings, they don't have access to the family budget and they don't operate as individuals. Children are inherently connected to family. Thus, a new question arose - how do we manipulate the tools of economics to find out whether we've improved the welfare of children? Prof. Bergstrom's paper is taking a stab at the answer. He's really asking how we use the traditional tools of economics (utility theory and BCA) in new, perhaps somewhat unconventional ways, in order to get at valid measures of the effect of policy on child and family welfare.

Prof. Bergstrom starts by reminding us what exactly we get from BCA, anyway. BCA tells us whether a project leads to a potential Pareto improvement (PPI), a situation where the winners could potentially compensate the losers. In the simplest model of an economy, to check for a potential Pareto improvement, one would just examine whether the sum of individuals' WTP exceeds the cost of the project.

Prof. Bergstrom suggests, however, that the relationship between BCA and potential Pareto improvements gets more complicated when you move away from the individual and try to model family relationships in which people care about one another's well-being. To understand the effect of family relationships he shows that we need a theory of household decision-making. He proceeds to examine households of different compositions and with different decision structures:

Household Compositions, Decision-Making and WTP		
Household Composition	**Decision-Making Structure**	**Whose WTP for BCA?**
Single parent	Dictator	Parental WTP
Child-free Couple	One is dictator	Dictator's WTP
	Unanimity	WTPm=WTPf
	Bargaining solution	Minimum WTP
Married couple with child	One is dictator	Dictator's WTP
	Unanimity	WTPm=WTPf
	Bargaining solution	Minimum WTP
Divorced couple with child (independent budget)	Separate dictators	WTPm + WTPf
Extended family (independent budget)	Separate dictators	Follow rule for nuclear family + WTP ext fam

Prof. Bergstrom offers a new criterion for passing BCA when family decisions are being accounted for: **The sum of parents' WTP must exceed project costs to pass the BC test for parents.** As he has worded it, the criterion clearly reveals whose perspective counts: parents. We don't add a child's WTP to parents or we'd end up accepting projects that don't meet this new criterion.

For each household construct, what he considers to get the third column, is a hypothetical government project that improves the health of children for the families with kids, or that improves the health of the female member for the families without kids. As the third column shows, to assess this criterion, depending on the composition and decision-making structure of the family, the policy analyst would collect WTP from different people. The following rule seems to fall out:

Rule for appropriate WTP:
"Interview all families who care about the child and operate with independent budgets. For each of those families,
a) if there is not unanimity between the adults, then count the WTP of the head (dictator) or, if there is not a head, count the WTP that is the lower of the two adults' WTP;
b) if there is unanimity, count the WTP from either individual."

This suggestion has immediate practical implications. For analysts relying on parental data, one must now acknowledge that parental WTP might overestimate if the un-interviewed spouse has a lower WTP, or for divorced couples, it might underestimate since really we should be adding in the WTP of the ex-husband/wife too.

In addition, if there are segments of the population that are more or less likely to be characterized by one or another of the family compositions or the decision-structures then those sub-populations might be systematically mis-represented. One can see how this is likely to be a real problem since culture is an important determinant of the prevailing power structure within the family. For example, the head-of-household model is probably more common among Hispanic families than non-Hispanic. In addition, certain family compositions are more likely among certain sub-populations – single parent families among inner-city African Americans. Thus the mis-representation of certain sub-cultures might follow from neglecting to model one or another of the possibilities in the table.

Prof. Bergstrom points out that in most of these models, a project could pass the BC test for parents, and children could experience a decline in utility. This is because of substitutability between the child's health and consumption. The parent might reduce the child's consumption by enough to offset an improvement in the child's health, so that the child's utility actually declines. Prof. Bergstrom offers a practical example of an impoverished family that requires a child to go to work once his health is restored. This is a disturbing possibility -- that by relying on parental WTP, policy makers might choose projects that ultimately lead to reductions in the direct utility and consumption of children.

This is a disturbing possibility and one to be aware of but, as Prof. Bergstrom himself points out, at least for western cultures, it seems like a remote one. In response to the child's improved health, the parent would have to reduce the child's consumption by an amount big enough to offset the improved health. I would assert that in Western families, health might be more realistically modeled as complimentary to consumption, since healthy kids probably eat more, are more concerned about social pressures regarding dress and play, and probably recreate and travel more too. In other words, improving children's health is not likely to decrease their direct utility for families in the U.S. at least not as a consequence of parents considering child health to be a substitute for child consumption of goods.

An interesting question is that as this paper develops, will there be more examples in which direct child utility declines even though a project passes the parental BC test -- examples more applicable to western cultures. Are there certain cases or circumstances where we should be concerned about this outcome? Clearly there are outlier parents – drug addicts, for example -- for whom we should be reluctant to rely on parental WTP to represent the well-being of children. But are there also broader cases or situations for which we should exercise caution when relying on parental WTP?

A final comment about the importance of Prof. Bergstrom's work. It goes beyond implications for the interaction of policy and child health. In fact, just as children are inherently family members, so too are most adults. In the final section of his paper, Prof. Bergstrom suggests adding together the WTP of divorced couples and adding to the WTP of a nuclear family, the WTP of extended family members with independent budgets. These suggestions imply that for adults we should also collect WTP for adult health from family members operating in households with independent budgets. For cultures like ours and most Western ones, where household budgets are fairly independent but there is a great deal of concern for extended family member's health, Prof. Bergstrom's work suggests that individual WTP probably understates society's valuation of health.

Turning to the Smith, Evans, Banzhaf and Poulos paper . . .

The major thrust of this paper is to propose a new framework for revealed preference research. As a policy analyst, after reading the first few paragraphs of this paper, I was excited about the significance of what they suggest. Clearly, analysts would find very useful yet another set of conditions under which we could tease out values of non-market goods or more specifically, for the EPA, environmental goods. The paper sets out to show that when certain conditions hold regarding the interrelationship between a private market good and a substitute environmental good, economists can study the demand for the private good and tease out valuation of the environmental one.

We are accustomed to thinking this way about complimentary goods – for years economists have been learning about the value of natural areas by examining recreation demand; e.g., the demand for fishing or for beach house rentals. As the authors of this paper highlight, Rick Freeman's much-cited text on Measuring Environmental and Resource Values covers the conditions surrounding weak complementarity. His latest version of the text, however, has all but eliminated discussion of weak substitutability. The authors intend, with this paper, to correct this oversight and to encourage economists to study, or at least be more aware of, this neglected category of market products – that is, substitutes for difficult-to-value non-market goods.

For weak complementarity, two conditions must be met. Together they suggest that when the price of the complementary market good is at or above its choke price (so that consumption is zero), changes in the environmental good have no welfare significance. Weak substitutability also requires that two conditions hold. Together they suggest that there exists a level of consumption for the private good (the weak substitute) above which improvements in the non-market environmental service have no value. In other words, if the price of the weak substitute is high enough, consumption of the market good is low and increases in the environmental good are valuable.

One can easily see how positing the conditions for weak substitutability might offend environmentalists. The hypothetical is that there is a market good that is a substitute for some set of environmental services. If the price of that market good drops low enough, then people no longer have a need for the non-market environmental services. Years ago when I taught an undergraduate environmental economics course, following Tom Teitenburg's text book, I would start the semester by exposing students to ideas of the "optimists" and the "pessimists." The citations to these schools of thought go back at least to the 1960s. The pessimists believed the world's population was growing at a rate that would outstrip resources and lead to a collapse with starvation and misery. The environmentalists in the classroom were sympathetic to these ideas. The optimists believed that advances in technology would outpace resource depletion and eventually replace the need for the natural world. Generally speaking, the optimists viewpoint was disliked by the environmentalists.

Drawing a connection to the paper, in general, studying goods that are complementary to nature, suggests that we have a continuing need for the natural world. These products complement or enhance our experience of the natural world. However, studying goods that substitute for nature, the very notion that goods can completely replace the demand for environmental goods, is in concert with the ideas of the optimists. The weak substitutability condition that there are prices of the market good below which changes in the quality of the environment are no longer valued might be more offensive to some people than the choke price assumption behind weak complementarity.

This leads to a practical question: Is the weak substitutability condition more restrictive or less representative of practical experience as well? I think not as long as one carefully characterizes the case under study. The private market good substitutes for a **specific subset of services** derived from an environmental good, and generally not for the entire set of services. The paper would do well to emphasize this caveat.

This point is illustrated by the examples identified by Smith et al in which weak substitutability might lend insight. Both are drawn from the existing literature and in both, the substitute goods are medical care and certain aspects of a cleaner environment. In other words, the consumer is substituting an averting or mitigating behavior for a cleaner environment, in both examples for their children. Agee and Crocker look at chelation therapy as a substitute for removing lead from a child's environment; Mansfield et al study removing children from the out-of-doors as a substitute for cleaning the air of pollutants that exacerbate asthma.

Certainly, if analysis of weak substitution can be as illuminating for environmental valuation as weak complementarity has, as the authors suggest, then the examination of averting and mitigating behaviors takes on a new importance. A simple application that comes to mind might be to examine purchases of bottled water as the route to valuing cleaner water.

I wanted to draw attention to an important connection between the two papers. In the final section of the Smith et al. paper, the authors highlight that in order to impose weak substitution in analyses of the costs of mitigating or averting behavior, analysts need more information about decision-making within the household . Clearly, Bergstrom's paper is a step in the right direction to fulfilling that need.

To close, both papers advance the state of knowledge regarding non-market valuation which ultimately is useful to policy-makers as an input into BCA; for analysts at the EPA for BCA of environmental policy. The Bergstrom paper gives insight into family decision-making and into the appropriate willingness-to-pay measures for children's health. The Smith, et al paper suggests a new approach to valuing environmental services, and in the examples they offer, the value stems from protecting human health. These papers make clear contributions to advancing policy-makers understanding of the benefits of human health protection.

Mark Agee's Comments on: "Weak Substitution, Environmental Vulnerability, and Choice," by V. Kerry Smith, Mary F. Evans, H. Spencer Banzhaf, and Christine Poulos.

This paper examines usefulness of identifying a threshold demarcating consumption and non-consumption of substitutes linked to an environmental amenity to assess Hicksian welfare changes associated with amenity improvements.

The paper provides an interesting and seeming applicable framework for use of revealed preference data to valuing environmental amenities. A highly desirable aspect of this framework is its focus on observable goods demands (i.e., does not necessitate specification/estimation of the consumers' underlying home production technologies) and the consumers' observed tradeoffs between these demands.

The first part of the paper lays out a detailed graphical portrayal of the concept of welfare measurement using weak substitution as another form of demand interdependency that arises for private goods and environmental services. I found the approach very interesting, and most of my comments/questions focus on my thoughts as to how the approach might be put in to practice.

Application-related questions/comments:

On page 14, z is referred to (from this point on) as a "mitigating good." Given this characterization, are we saying (or can we say) in effect that the separability notion is one of partitioning the classes of goods (averting and/or mitigating) that identify as substitutes in the individual's choice set—of which are then linked to the individual's utility and environmental amenity through perceived health, or risk to health, etc.? If so, then it seems that a binary choice model might be useful in identifying and estimating key thresholds of interest (you refer to these thresholds as points of discontinuity in the role for q) as well as identify the conditional demand for z?

- e.g., suppose X^a represents a substitute (averting) good such that, at a threshold, z (a mitigating good) is no longer demanded. A binary choice model similar to Agee and Crocker (1996) and Dickie and Gerking (1991) could be used to identify either positive or zero consumption levels of z by estimating:

- $v(P, P_z, P_r, q, \gamma, m)$ + error,

or

- $v[P_z, P, q, \gamma, m_v(P, P_z, P_r, q, \gamma, m)]$ + error,

where $v(\cdot)$ is an econometric specification of a conditional indirect utility function for z, and γ accounts for personal characteristics.

Estimation of the probability of "positive" consumption would also provide

- an estimate of P_a^*,

the price of X^a that reduces z to zero (or the individual's estimated choice index below the threshold), and

- an estimate of (the Marshallian) z as a function of prices, income and personal characteristics: $z(P_z, P, P_r, q, m, \gamma) = -\frac{\partial v(\cdot)/\partial P_z}{\partial v(\cdot)/\partial m}$ based on the analysis of the threshold of no consumption.

The paper also mentions the importance of demographic and physical traits that contribute to characterizing individuals who are differentially vulnerable to the environmental hazard in question. If the model can be estimated as a threshold of zero consumption, it seems that the level of q is also important in identifying key aspects of the price P_a^* since the relationship between goods linked to q can change as q changes:

- e.g., with reference to child lead exposure—there are burdens of body lead such that mitigation is not even considered; burdens such that mitigation together with exposure reduction are absolutely necessary (complementary goods); and burdens (likely close to the threshold) such that exposure reduction can suffice for chelation therapy (substitute goods).

- This of course would change the sign of the coefficient for P_a^* (i.e., only used, used with chelation, used as a substitute to chelation) in the estimated $v(\cdot)$ expression.

In these cases, it seems that a set of interactions between P_a^* and q (and between P_a^* and some of the personal characteristics) would be necessary to identify any critical thresholds for potential sign-changes of the P_a^* coefficient, as well as to correctly identify (calibrate) measures of z_0, z_1, and P_a^* for estimation of WTP.

Another estimation issue is encountered if X is multidimensional. If X is a vector, is it in general necessary to identify the entire vector of X in order to correctly specify z?

- e.g., z might denote (one-dimensional) medical care consumption that mitigates air pollution respiratory ailments; and X denotes exposure reducing activities that, at a point, may render mitigation either very improbable or unnecessary..

Can the problem of multidimensionality of P in z be dealt with adequately by estimating a specification of $v[\cdot]$ (e.g., like the second $v[\cdot]$ specification mentioned above) that includes each individual's observed fraction, m_v, of their budget allocated towards z and a single selected element of P (such as the price of air purifiers)? If so, since m_v is a function of all prices, q, income, and personal characteristics, it seems that one might want to account for possible correlation between m_v and the error term to avoid potential bias of the P and other coefficients in the binary choice regression (see e.g., Rivers and Vuong (1988) or Wooldridge (2002), p. 472 for cross section data; or Jones and Landwehr (1988) for panel data).

--or--

Might it be possible to construct a one-dimensional averting activities index (like intensity of use from a limited set of "most used" averting activities) with an accompanying averting cost index that condenses P to a single measure for estimation?

Sources:

Agee, Mark, and Thomas Crocker. 1996. "Parental Altruism and Child Lead Exposure: Inferences from the Demand for Chelation Therapy," Journal of Human Resources 31: 677-691.

Dickie, Mark, and Shelby Gerking. 1991. "Willingness to Pay for Ozone Control: Inferences from the Demand for Medical Care," Journal of Environmental Economics and Management 21:1-16.

Jones, J. Morgan and Jane T. Landwehr. 1988. "Removing Heterogeneity Bias from Logit Model Estimation," Marketing Science 7(1): 41-59.

Rivers, D., and Q.H. Vuong. 1988. "Limited Information Estimators and Exogeneity Tests For Simultaneous Probit Models." Journal of Econometrics 39: 347-66.

Wooldridge, Jeffrey M. 2002. Econometric Analysis of Cross Section and Panel Data Cambridge, Mass.: MIT Press.

Suppose X^a represents a substitute [averting] good such that—at a threshold—*z* [a mitigating good] is no longer demanded. A binary choice framework can identify either positive or zero consumption levels of *z* using:

- $v(P, P_z, P_r, q, \gamma, m)$ ***+ error***

--or--

- $v[P_z, P, q, \gamma, m_v(P, P_z, P_r, q, \gamma, m)]$ ***+ error***

where

$v(\cdot)$ **= specification of a conditional indirect utility function for *z***

γ **= personal characteristics**

Estimation of the probability of "positive" consumption provides

- **an estimate of** P_a^*
- **the price of X^a that reduces *z* to zero (the individual's estimated choice index below the threshold)**
- **an estimate of (the Marshallian) *z* :**

$$z(P_z, P, P_r, q, m, \gamma) = -\frac{\partial v(\cdot)/\partial P_z}{\partial v(\cdot)/\partial m}$$

Mark Agee's Comments on: "Benefit Cost Analysis and Entanglements of Love," by Theodore C. Bergstrom

This paper develops a creative approach to addressing some important questions about aggregation of willingness to pay (WTP) when WTP has altruistic connections between individuals within a family. Four specific questions are addressed:

- When considering a public project that increases children's health, would it make sense to calculate the aggregate value of that project by summing the average parent's WTP by the total number of parents; or
- if parents (within the same household) reveal WTP differences for the project, should the maximum or minimum of these values be used (exclusively) to represent the entire household's value; and
- should children's own values be accounted for and included; and
- should values of family members outside the immediate family be counted.

These questions are addressed within the frame of a specific criterion: is the project Pareto improving? That is:

- is it possible to implement the project and assign project costs to families in such a way that, given the household decision structure, no family member is made worse off and at least one member is made better off?

The initial part of the paper rearticulates this criterion by demonstrating that, if parents have complete control of their family incomes, if one parent is forced to pay more than his/her WTP for a project (implying project costs exceed the sum of parental WTP), then the project is not Pareto improving—and thus the benefit-cost test for parents provides a clear-cut gauge of satisfaction of the Pareto criterion.

The benefit-cost test is then applied to a variety of family structures involving one or two parents with and without a single child, and a variety of family preference and distribution structures common to the household decisionmaking literature. The paper acknowledges that the preference and distribution assumptions of some of the models do not accurately portray modern U.S. households. However, a few of these models had structural assumptions that came (somewhat) close to the frameworks found in the limited number of literature studies examining parental valuations of specific child health attributes. Specifically:

- A parent decisionmaker who allocates after-tax income between own utility-enhancing consumption and child utility-enhancing consumption;
- A parental utility function that derives utility from parental perceptions of child utility; and
- An exogenous index of child health that enhances parent utility through child utility.

Although the basic structure of these examples (within the context of the above assumptions) preclude the possibility of endogeneity of parental decisions regarding child health and child numbers, the paper demonstrates a result similar to prior studies:

- that parental WTP for a child's health improvement equals the health improvement times that adult's MRS between own consumption and child health, but it also finds that

- the parent *not* charged with income allocation may reveal a different WTP for the same child's health improvement—if this parent's marginal utility of child consumption exceeds her marginal utility her own income allocation,

in which case it is appropriate to

- use only the lowest of the two parents' WTPs to represent the family's WTP for the child's health improvement.

If a general household welfare function is used to link all family members' utilities, then:

- only one parent's WTP (which equals the other parent's and child's WTP) should represent the entire household's maximum WTP for the child health improvement.

However, if family utilities are disconnected (e.g., because of divorce or independent budget arrangements) then

- the sum of adults' WTP for the child health improvement satisfies the benefit-cost test.

These results suggest that aggregate WTP estimates of children's health improvements may inaccurately reflect true WTP if calculated simply as the "average" of parent's WTP multiplied by the number of U.S. parents. The paper highlights the importance of how specification of family allocation processes and the structure of family preferences can potentially impact aggregate WTP estimates. The question of whether to aggregate by U.S. family numbers, number of U.S. parents, or by U.S. parents categorized by their degree of "control" over household resources provides a good start to better understanding how aggregate WTP for children's health improvements can most justifiably be approximated. Listed below are some questions/comments that came to my mind upon several readings of the paper:

First, I'm not entirely convinced of the plausibility of the argument on page 4 regarding strong substitutability between parental income and child health and the potential for children being made worse off by their parents. The argument in the household utility function that seems to be missing here is parental own health, which has an intergenerational link (heritability) to child health. Would healthier parents (who likely have healthier children) necessarily behave in this fashion? The question closely parallels the discussion of parent and child endowments and parental investments in child human capital found in Becker and Tomes (*J. of Labor Economics.*, 1986, 4:S1-S39). Although children with better endowments are much more productive/efficient utilizers of human capital investments, better endowed parents still discount investments in their (better endowed) children at lower rates and invest more resources in them.

Second, does the current preference structure impose that parents treat their children as a "collective child" with an expressed, single willingness to pay for *their* improved health? An important question in my mind is—if we randomly select one child in a family would the parent's willingness to pay for that child's health improvement, multiplied by child numbers be the correct sum? For example, suppose expressions (10) and (11) in the paper incorporate a summation over *n* (predetermined) family members thus creating a household welfare function that varies also by *n*. With this (seemingly) minor change, would the appropriate number for benefit-cost analysts likewise be a single number representative of either parent or a single child—or would summing either parent's response across child numbers overstate aggregate WTP by a factor of n-2?

As an additional thought, the current preference structure has child utility nested in parental utility reflecting the concern each parent has for their child, i.e., the parental marginal utility of child utility. Perhaps child numbers could enter as in Becker, Murphy, and Tamura (*J. of Political Economy*, 1990, p.S12-S37) who assume that, with diminishing marginal utility of children, parental altruism is negatively related to child numbers (they also refer to parental altruism as an intergenerational discount rate applied by parents to the per capita consumption of their children). With this modification, how might diminishing marginal utility of children relate to the parents' determination of WTP for child health improvements, and does it provide any insights as to whether parental WTP is for $1/n$ or some other fraction of child numbers?

Finally, another question might be posed with reference to the role of child health in the determination of family utility. Certainly, the current exogeneity of child health in child utility enables ease of mathematical tractability; however, if child utility is modified such that parental allocations of child consumption goods also influence child health, would endogeneity of child health bring about any changes in your results?

Summary of Q&A Discussion Following Session II

Ronnie Leven (EPA, Region 1) stated that in addition to complications in the theory, there are complications in the cases being used, specifically the lead abatement studies. She went on to assert that "chelation therapy is not all good"and actually leads to a spike in blood lead levels and a correlating spike in brain lead levels. She also noted the spike in exposure after certain types of abatement that release lead paint dust into the air to be inhaled, and she listed encapsulation, replacement, delay, improved maintenance, and temporary removal as alternatives to immediate abatement. She ended by saying that the studies on purchasing bicycle helmets also had some complicating health issues.

Scott Grosse (Centers for Disease Control and Prevention) suggested this extension for Professor Bergstrom: Consider willingness to pay for health as a public good and not just as a private good. Dr. Grosse stated that "if we treat health as a private good, then you can't include the willingness to pay for the extended family members who also have children of their own."

Professor Bergstrom responded by saying that he was thinking about how a particular questionnaire related to a specific project should be framed ("it might be a local community project, it might be a national whole airshed, or it might be a national project"). To him it seems reasonable to ask someone, "How would you feel about an improvement in the health of your child?" or, in fact, "How would you feel about an improvement in the health of *each* of your seven children?" and then on to, "How would you feel about an improvement in the health of your nephew?" Professor Bergstrom said that he would propose evaluating that project then by building up from these micro-answers.

Grosse: "But, it may be that people are not willing to spend "n" times as much to help "n" children."

Professor Bergstrom reiterated that you would ask a sequence of questions–regarding the valuation of the health of one's own children, and then on to a relative's children, and even on to a stranger's children–as the building blocks to constructing a policy.

Ellen Post (Abt Associates, Inc.) told Professor Bergstrom that she was bothered by the fact that assigning the willingness to pay value entirely to the dictator parent in a dictatorial household model (and thereby ignoring the other parent because that person, though possibly willing, has nothing to pay with) basically incorporates *intra*-household politics into the policy assessment. She further stated that the belief "if one person controls the budget then only that person's willingness to pay should be counted" would be true for all similar situations of valuing non-market goods.

Professor Bergstrom replied, "Yes, we'll be a little careful about the "should," of course, but essentially if you believe that your policy will not change the structure of household decisions, then it seems to me a realistic assessment of policy is the consequences of the policy given the household structure." He also provided the reminder that, at least in theory, this is "a benevolent dictator who buys the flavor of ice cream that his children want, and so on," and clarified that "whether that theory is an accurate theory is yet another question."

Post: "I guess I was just saying that the idea of saying that there are different kinds of families with different intra-family politics which determine people's budgets–that has a lot wider implications than, say, just children's health risks.

Bergstrom: "Indeed, I agree."

Laurie Chestnut (Stratus Consulting, Inc.): stated that she was "alarmed" at the suggestion that we should be seeking to determine various relatives' willingness to pay for a particular child's health. Citing a paper concerning altruism from a few years ago by Jones Lee, she said it was her understanding that "if what people care about is other people's utility, then the optimal allocation is just adding up everyone's willingness to pay for their own utility change, and that takes care of everybody." She further stated that it's only in the case where one cares about another's *consumption* of a specific thing that the willingness to pay issue gets more complicated. She closed by saying, "what we care about is each other's happiness, which I think is the primary model of families caring about each other."

Professor Bergstrom responded that it's a bit tricky with a divorced family, where the money transferred from the non-custodial parent to the custodial parent does not go directly to the child–but, a health benefit does. He stated that if a divorced parent voluntarily transfers money to the custodial parent, then one can presume that they had come to an agreement about where marginal money should go.

Chestnut: "So, health might be a special case in some circumstances . . ."

Professor Bergstrom replied that he had put a lot of thought into the relatives issue and concluded that if you're not willing to give your brother some money and say "go buy your child some medicine," maybe that suggests that you find no extra valuation in that. "On the other hand, it may be that institutions aren't well set up."

Don Kenkel (Cornell University) asked this of Robin Jenkins, referring to her discussant presentation of Ted Bergstrom's paper: "Is the potential Pareto improvement criterion really consistent with the Executive Order?–sort of plucking out children and saying, "This deserves *special* attention."" Is this suggesting that even if the social welfare function *doesn't* pass the sufficiency test, we should still worry about children's welfare?"

Robin Jenkins: "In other words, do we want transfers to children?

Kenkel: "Even if the parents don't want them."

Spencer Banzhaf (Resources for the Future) followed with a comment that he said is actually very similar, and he pointed out that toward the end of Ted Bergstrom's presentation, wasn't it ironic that there was clearly a potential for Pareto improvement, but "the husband was made worse off because of the reallocation in the family?" He concluded that "that irony raises this doubt about the usefulness of potential Pareto criteria when the agency in charge of the policy does not actually have the power to reallocate wealth . . ."

Kerry Smith (North Carolina State University) said that he had a different take: "If we take the way Ted characterized the household model and different views of it and look at what he's doing . . . In environmental economics we have sort of two ways we've approached looking at environmental policy: One way has been to present people with programs, and we've said, "Here's a program to do this–or do something else, on a national level." So the commodity that was actually in preferences was however they conceived of the program, and there were all sorts of questions raised with respect to "Well how should people have preferences about programs?" He's actually proposing to commoditize programs, and so he's basically saying, "We're going to introduce a program that has these kinds of consequences and let's be very, very specific about what those consequences are–it would improve the health of child #1 this much, child #2, the wife, and so forth. . . . But the challenge then becomes converting programs into what commodities would change, so that now we have, if we get very, very specific, with individuals–my nephew's health is going to improve; my niece is going to go down the rathole or something–I then have to think about exactly how is that going to be accomplished with the policy or with the program. So, we don't get around the challenge of connecting policy to commodity outcomes–we simply do a better job of identifying the features and preferences that we can recover from behavior and what we can't recover from behavior, whether it's stated or revealed."

Professor Bergstrom responded that if people are asked how they feel about a policy that they don't understand very well (which is typical), "their answer will be of some interest to politicians, of course, but to welfare economists of less interest I suppose. The point is, it always seems to me a useful thing to map policies to consequences as well as possible."

Glenn Harrison (University of Central Florida) directed his comment at Professor Bergstrom but said it was motivated by Robin's "paternalistic"comment that kids are not rational. He said he was disappointed that Professor Bergstrom didn't address the issue of how kids form preferences, and he lamented that all of the discussion so far in the workshop totally ignored the kids preferences and went straight to the parents. "Now, I understand the simplicity of doing that–I understand the logistic ease of doing that, but it's a pretty sloppy way of thinking about the social welfare function. Just because kids are vertically challenged, we disenfranchise them." He summarized Robin's viewpoint as being that kids don't have well-formed preferences so we can't rely on them, and then he posed the question: "Shouldn't we be thinking about kids' preferences as state-dependent, broadly defined, where the state is the information they have and at a certain age and with a certain information load, they act more consistently over time? And the question, then, is what implications does that have when you start thinking about *social* willingness to pay as distinct from aggregating up from an individual willingness to pay? And indeed, arguably we're interested in social willingness to pay."

Professor Bergstrom replied that it was "a lovely question" that he was reluctant to tackle at the time due to the upcoming lunch break. He offered to speak to Dr. Harrison on the subject later.

J.R. DeShazo (UCLA) commented, "Ted's presentation, I think, illustrates that when we elicit values from parents what we're really eliciting are household preferences for investments in children's health and the benefits that accrue to children as perceived by the households, so that households can express the schedule of values for the children as a function of the number of children they have, as a function of the governance structure within the household. I simply want to point out that this approach misses the fundamental theoretical construct that we're trying to recover, which are the net benefits to the child of the policy. I think we should just recognize the disconnect between what we can measure and theoretically what we optimally would like to know in order to set the optimal policy."

Professor Bergstrom replied, "That is a technical issue that in a sense I *did* address. The question is to what extent do the parents' evaluations of the child help represent the child's interests. . . If there's complementarity between the child's health and the child's conception, then definitely the parent will *always* be acting in the child's interest, and if there's not, there are cases where indeed the parent will *not*, despite the fact that the parent cares about the child's interests. I can't give you magical answers, you know."

Sandra Hoffman (Resources for the Future) said, "It seems to me that there is a logical inconsistency in the discussion we're having here, because on the one hand we're saying that children do not have well-formed preferences–they haven't developed the judgment that's able really to express preferences–and yet when we look at parents' preferences, we're looking at the child's utility entering the parent's utility function. So there's a transformation going on there. We're not directly measuring the child's benefits, and maybe we don't want to. So it seems to me that J.R.'s point still stands–we're at best getting at a transformation, and perhaps . . ."

Professor Bergstrom clarified that this is not such a difficult issue–the parent's and the child's notions of what's good for the child "needn't be identical–it's as simple as that."

Glenn Harrison said, “But no one here has assumed that the child does not have well-formed preferences.”

Professor Bergstrom responded, “I’ve never made such an assumption. I think it’s a very interesting issue, but again, I don’t want to spend our lunchtime here.”

Valuing Environmental Health Risk Reductions to Children

PROCEEDINGS OF

SESSION III: VALUING FETAL AND INFANT HEALTH EFFECTS

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE), NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER), AND OFFICE OF CHILDREN'S HEALTH PROTECTION; AND THE UNIVERSITY OF CENTRAL FLORIDA

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DISCLAIMER

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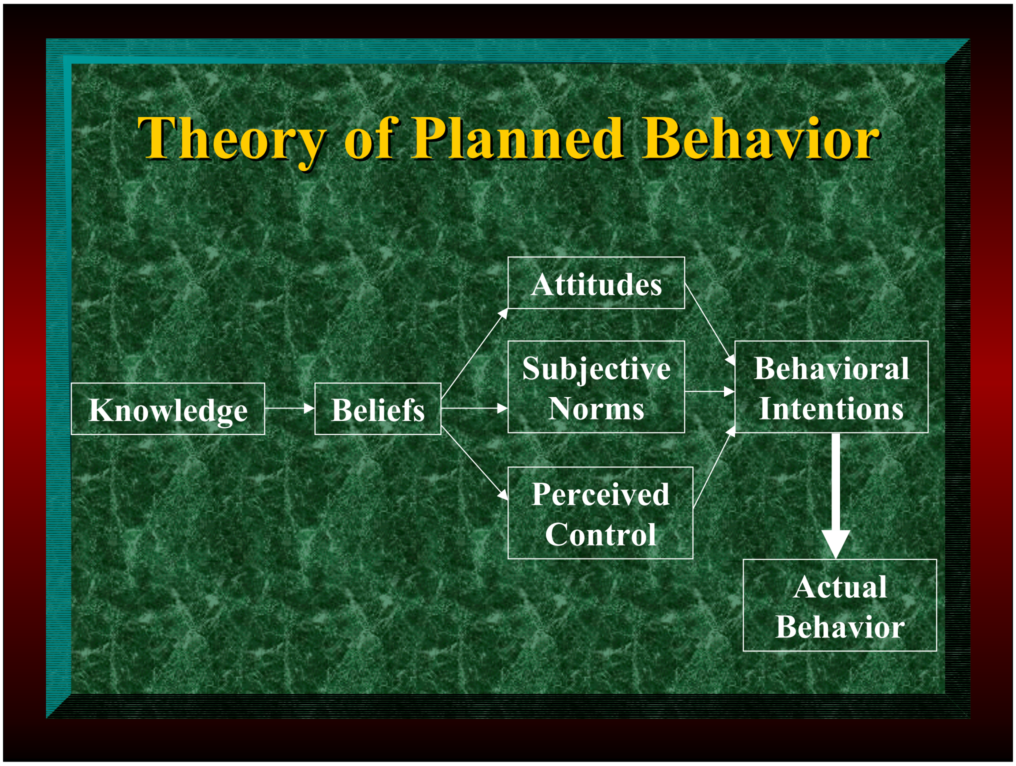
Combining Psychological and Economic Methods to Improve Understanding of Factors Determining Adults' Valuation of Children's Health

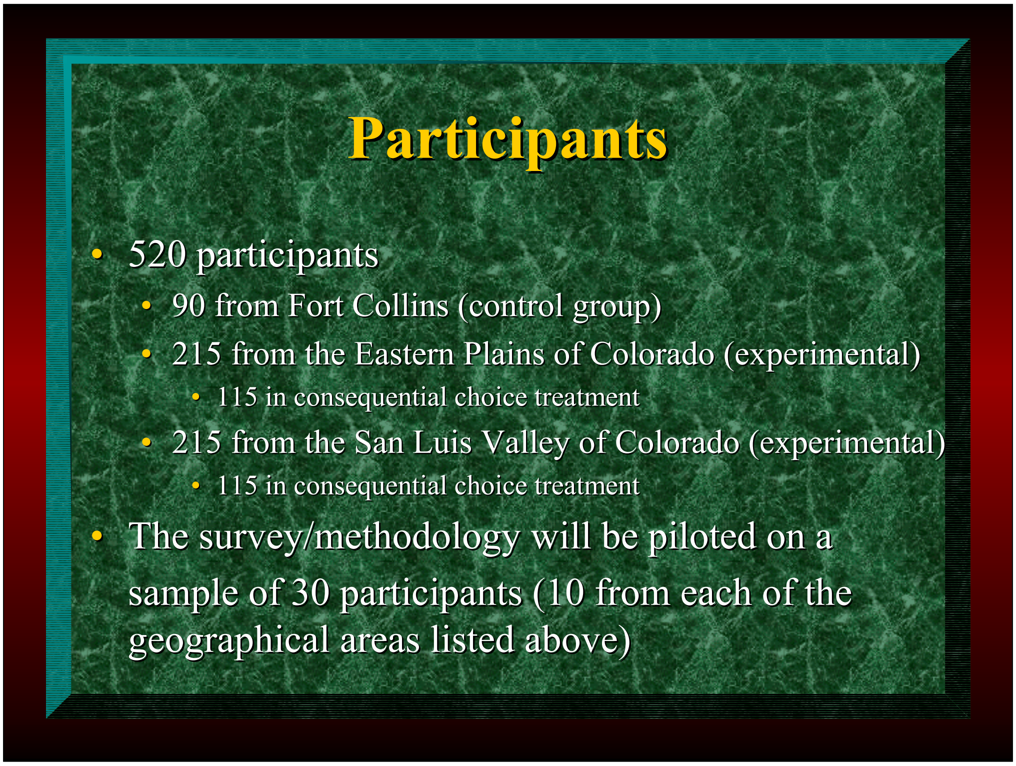
Cheryl Asmus, Paul Bell, John Loomis, and Helen Cooney
Colorado State University

Research Question

- What are the factors that influence adults' willingness-to-pay to avert risks to children's health?
  - Stressor → Nitrate (NO_3) contaminated drinking water
  - Model → Theory of Planned Behavior
  - Method → Survey and choice task



Theory of Planned Behavior
Knowledge
Beliefs
Attitudes
Subjective Norms
Perceived Control
Behavioral Intentions
Actual Behavior


Participants
• 520 participants
• 90 from Fort Collins (control group)
• 215 from the Eastern Plains of Colorado (experimental)
• 115 in consequential choice treatment
• 215 from the San Luis Valley of Colorado (experimental)
• 115 in consequential choice treatment
• The survey/methodology will be piloted on a sample of 30 participants (10 from each of the geographical areas listed above)

Procedure

- Survey will assess various components of TPB with respect to the stressor and the various behavior options
- Respondents will be presented with a contingent valuation task

Contingent Valuation Task

	Do Nothing	Purchase Bottled Water
Trips to Store		
Risk of Severe Health Effects		
Risk of Moderate Health Effects		

Procedure (cont.)

- Half of the respondents in the two experimental conditions will be instructed that one of the decisions they make in the contingent valuation task will be binding

Current Status

- Expert Advisory Groups
  - Survey development
  - Construction of option/attribute tables for contingent valuation task

Nitrate Advisory Group

- Survey should assess knowledge of different potential sources of nitrate contamination
- Survey should assess knowledge of how responsibilities differ for public and private water supplies
- Items regarding source reduction strategies should be broad

Nitrate Advisory Group

- Survey wording should avoid "test-like" quality
- Providing some participants with a reverse osmosis filter would be problematic

Health Advisory Group

- Should determine if the communities under investigation have had cases of blue baby syndrome
- Determine if each community has problems with contaminants other than nitrate
- Survey should include items pertaining to pre-natal exposure

Health Advisory Group

- Items should be framed in terms of both the respondents' own infants and infants in the community

Methodology Advisory Group

- Choice task should be simplified
- The different behavior options should be more compatible
- A practice round would be helpful in the consequential choice treatment
- Survey should provide information acknowledging that the options may be beneficial for other reasons

Methodology Advisory Group

- Costs for the different options should be constructed to be credible and to ensure that some participants will actually purchase the option

Next Steps

- Complete survey development
- Translate survey into Spanish
- Collect pilot data

September 2003

Pregnant Mother's Valuation of Own and of Child Health*

by

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JEL Classification: D1; Q2

Keywords: Benefit transfers; birthweight productivity.

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ABSTRACT

The value an adult attaches to own health relative to child health is estimated when adult health inputs are choice variables and adult health is an input to child health. Mothers' weight gains during pregnancy and children's birthweights respectively measure adult and child health. Estimates suggest mothers value child health about six times more than own health, and that this relative value declines with number of siblings, increases with family income, and varies with maternal consumption patterns.

I. INTRODUCTION

This paper uses a pregnant woman's own - consumption in its various commodity - specific forms to estimate the value she attaches to own - health relative to the health of the fetus she carries. The current U.S. federal agency practice of transferring widely available adult health benefit measures unadjusted to children's health gives the issue policy relevance.[1] Also, except insofar as it reduces household resources available to a child, the "child development" influence of the commodity - specific particulars of a parent's own - consumption have been little studied in economics. Yet parents engage in many activities which directly or indirectly give them utility while simultaneously producing consequences for their children. Thus, for example, a parent may drink alcohol excessively and subsequently abuse or neglect her child, or a pregnant woman may indulge a diet which adversely affects the health of her fetus.

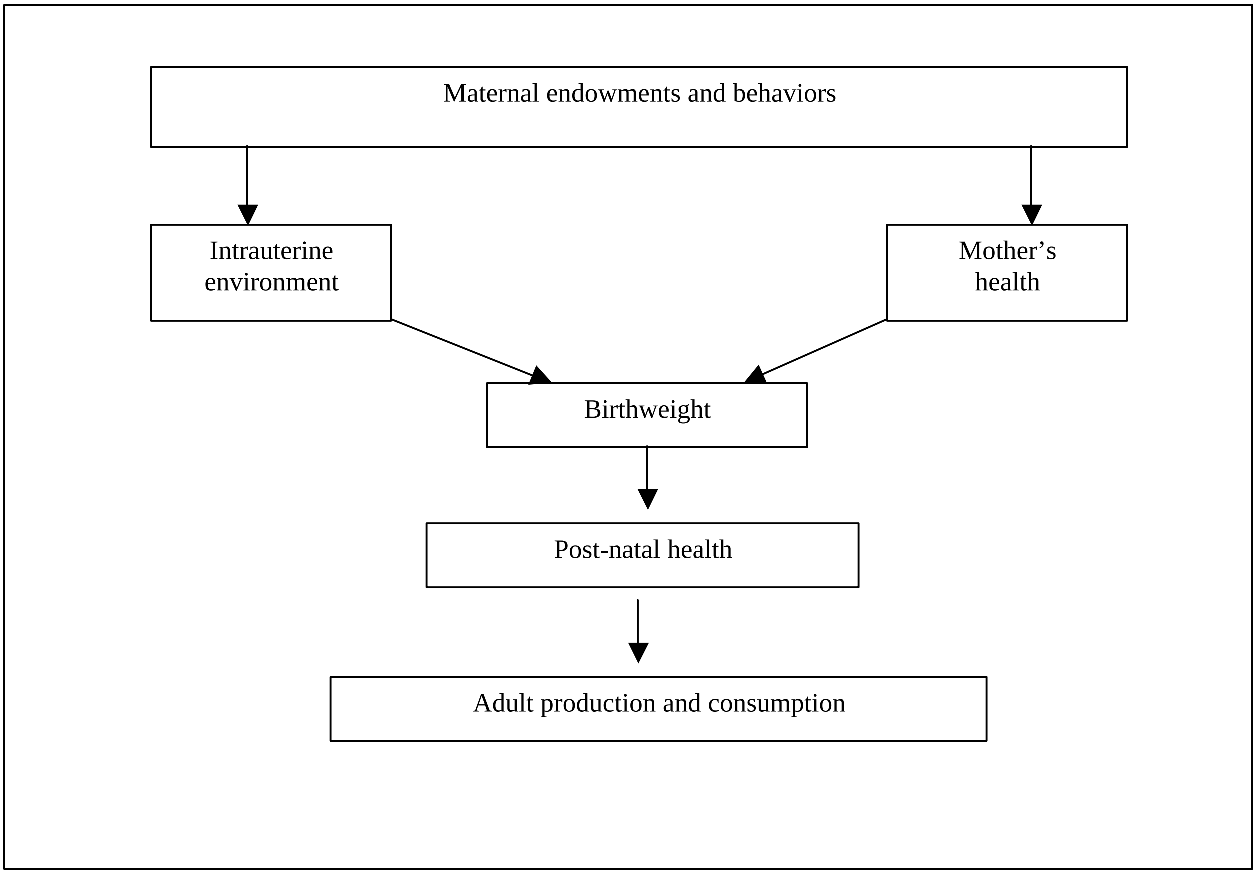
Because adults do not resemble children either biologically or economically, the current U.S. federal agency practice of using unadjusted adult health economic benefit measures to assess the benefits of improving children's health is suspect. Differences between the biological responses of adults and children to many identical environmental stressors are widely acknowledged. And children live with adults whose internal household allocation and investment behaviors can amplify or temper these biological responses. The degree of amplification or tempering many differ between adult and child because of differences in the choices adults make for themselves and for their children. For example, the scope of the activities adults choose for themselves is commonly less restricted than those they choose for their child. Also, adult investments in children's health can be riskier and thus the return to human capital investments less than equivalent own - health investments, given that children

[1]See, for example, the health benefit transfer procedures propounded in Kuchler and Golan (1999), and in U.S. Environmental Protection Agency (2000).

have no performance records indicative of potential investment payoffs. Markets to insure against this risk are more incomplete for children than for adults. But children have longer expected life spans than do adults, which allows them to accumulate more human capital than an adult whose capital stock is already largely built. Given the concavity of health investments (Grossman, 1972) in producing human capital, the marginal productivity of investments in children will exceed that of genetically similar adults. In general, the value to adults of own relative to children's health improvements is an empirical question influenced by the relative prices and the properties of the not always identical health hazard risk - reduction technologies applied to adults and to children. Thus a similar health hazard exposure may induce quite different marginal benefits and marginal costs for adult and for child health -- physical, intellectual, and emotional.

To estimate the relative value adults attach to own health relative to child health we focus on the intrauterine environment a pregnant woman provides her fetus. The impact of the intrauterine environment upon child health and development and ultimately upon that child's adult well-being is a recent concern in economics that has a very large literature in other disciplines. This noneconomic literature suggests the health of a fetus and its adult well-being are connected through the causal chain depicted in Figure 1 involving both adult caretaker behaviors and biological processes. The starting point is maternal health endowments and behaviors. Maternal endowments and behaviors are linked to the intrauterine environment and fetal growth, and to contemporaneous maternal health. The intrauterine environment and the mother's contemporanceous health positively affect birthweight, which is positively linked to the child's post-natal health (Institute of Medicine, 1990). Post-natal health is a significant positive

Figure 1. A Causal Chain



determinant of the child's ultimate adult production and consumption and of its societal contribution (Becker and Murphy, 1992).

For two reasons, our attention here is limited to the first three levels of Figure 1. First, as Figure 1 suggests, there is evidence that the effects of lower birthweight are long-term, even intergenerational (e.g. Hack et al., 1995; Barker, 1998; Currie and Hyson, 1999; Henriksen, 1999; Agee and Crocker, 2002). Lower birthweight children are less healthy than their peers, and they do less well in school. Increasing birthweight increases adult earnings and schooling (Behrman and Rosenzweig, 2001). Given that birthweight drives post-natal child health, it is plausible that an adults' relative valuation of own to post-natal child health reflects the in utero investment the pregnant mother made. If so, an estimate of the own/fetus health valuation will be predictive of the evolution of her own/child health valuation.

Second, maternal health has positive and negative impacts on post-natal child health. In the post-natal setting, increased parental consumption or investments in own health impact the household budget constraint, implying that child health and parent health are substitutes. Better parent health or more consumption then implies lesser child health. But better parent health frequently means the parent can provide the child a better quality of care, resulting in enhanced child physical, intellectual, and emotional health. For the young child the net effect of an increase in parental consumption or health investment depends on the sign of the sum of these two factors. This sign is an empirical question dependent upon the mix of phenotypes of individual household members and upon the determinants of intrahousehold resource allocations to these members. Grasping the complexities of the mix and the determinants can be a daunting analytical and empirical task, especially if adult and child behaviors are jointly determined or if household public goods are present. In contrast, the sign of the connection between maternal health and fetal child health is unambiguous: it is positive and unidirectional from mother to fetus.[2] This positive and unidirectional linkage is widely recognized in the medical literature.[3] A mother's morbidity and poor health habits result in growth retardation in utero, and, consequently, a

[2] See, however, The Economist (2003) which reviews literature suggesting that the fetus, when stressed, allocates a greater share of available resources to brain development. No evidence exists that this reallocation fully compensates for poor maternal health or health practices in all dimensions of post-natal child health.
[3] ACC/SCN (2000) provides a thorough review. Other reviews are to be found in Battaglia and Simmons (1979) and in Kramer (1987). This same literature presents evidence consistent with the marginal products of many post-natal inputs for lower birthweight children being less than those for normal birthweight children. Thus the disadvantage of lower birthweight may become progressively greater with age.

reduced birthweight for her child.[4] The health of the fetus defined in terms of its realized birthweight for a given gestation period is the result only of its genotype and the contemporaneous health behaviors and health state of its mother. No other intervening or mediating influences enter.

Both the biomedical health and the health economics literatures report the results of extensive research on the determinants of birthweight.[5] The economics literature can be distinguished from the biomedical literature by the emphasis of the former on the endogeneity of many health inputs, unobserved heterogeneity, and selectivity of women who become pregnant and who produce live births. This paper extends the previous economics literature in two ways. First, while continuing to account for input endogeneity and selectivity, it treats the pregnant mother's health as endogenous. Second, this treatment of the health of the pregnant mother as endogenous permits derivation of the value this mother attaches to own health relative to the health of her fetus. We find the contemporaneous, endogenous health of the pregnant mother to be a significant determinant of the health of her fetus, where fetus health is defined as its live birthweight. Our representative mother values the health of her fetal child about six times more than she values her own health.

The next section discusses the implications of the endogeneity of contemporaneous maternal health for estimates of birthweight production functions. A third section develops a model of birthweight production which provides restrictions for an econometric specification. The data used to estimate the birthweight production function are described in a fourth section

[4] The medical literature defines low birthweight (LBW) as a weight at birth less than 2500 grams, about 5.5 pounds. LBW results from premature birth and intrauterine growth retardation. This purportedly universal threshold fails to consider variations in genetically determined normal birthweights.

[5] Economic interest in the issue appears to have first appeared with Rosenzweig and Schultz (1982). Representative subsequent treatments in the economics literature include Grossman and Joyce (1990), Rosenzweig and Wolpin (1991), Levinson and Ullman (1998), Warner (1998), Evans and Ringel (1999), Joyce (1999), and Abevaya (2001).

and estimation results take up the fifth section. A summary of and caveats about results conclude.

II. THE ENDOGENEITY OF MATERNAL HEALTH

Epidemiological research (e.g., Kirchengast and Hartman, 1998; Shapiro et al., 2000) unequivocally concludes that a mother's weight gain during her pregnancy has a strong positive influence on her child's birthweight. This weight gain is a function of her preconception health endowment and her nutritional and morbidity state while pregnant (Institute of Medicine, 1990). Her nutritional and morbidity state while pregnant is influenced by her contemporaneous health input behavior (Osami and Sen, 2003). That is, the pregnant mother's health as measured by her contemporaneous weight gain is an endogenous input to her child's birthweight. Physicians recognize this as they recommend behaviors for individual mothers which they think will result in a weight gain for her conforming to guidelines recommended by the American College of Obstetrics and Gynecology (1998).

Although development economists (e.g., Strauss, 1986; Devlalikar, 1988) frequently treat weight as an endogenous variable in studies of labor productivity, none of the economics literature dealing with birthweight takes account of the possible endogeneity of the pregnant mother's health as measured by her pregnancy weight gain.[6] To see the consequences of this neglect for acquiring accurate insights into the determinants of birthweight, let the pregnant mother's health (her pregnancy weight gain), h^m, be determined by

$$h^m = h^m(z, y, v^m) \quad (1)$$

[6] Nor does it even account for the mother's anthropometry. Warner (1998) is an exception but he treats the mother's weight gain as exogenous.

where v^m is the mother's phenotype (her genetic and social inheritances), y represents the health infrastructure (predetermined or exogenous social, environmental, and economic factors such as her marital status, employment, income, education, and access to health services), and z is a vector of endogenous inputs such as prenatal care.

The health technology of the child (its birthweight) h^c is described by

$$h^c = h^c(h^m, z, y, v^c), \tag{2}$$

where v^c is the child's genotype. The relationship between the mother's and the child's health is made explicit in (2) by including the mother's health, h^m, as an argument in the child's health technology. This same relation between parent and child health also holds for a young child,[7] but it is most vivid for a fetus.

The effect of a marginal improvement of the exogenous health infrastructure, y, and of the endogenous health inputs, z, on the child's health is:

$$\frac{dh^c}{dy} = \frac{\partial h^c}{\partial y} + \frac{\partial h^c}{\partial h^m}\frac{\partial h^m}{\partial y} \tag{3}$$

$$\frac{dh^c}{dz} = \frac{\partial h^c}{\partial z} + \frac{\partial h^c}{\partial h^m}\frac{\partial h^m}{\partial z} \tag{4}$$

The differences between reduced forms that ignore the endogeneity of maternal health in the child's health technology and a structural system which accounts for endogeneity are the second terms in expressions (3) and (4). That is, the marginal products of changes in y and in z depend upon their direct biological effects, the $\partial h^c/\partial y$ and the $\partial h^c/\partial z$, and the indirect effects, the $(\partial h^c/\partial h^m)(\partial h^m/\partial y)$ and the $(\partial h^c/\partial h^m)(\partial h^m/\partial z)$, representing the mediating influence of the mother's health. To neglect these indirect effects is to presume that parents ignore the effect of

[7] For example, an ill parent can engage in fewer activities with her child. She is able to do less with and for her child.

own-health on child health. If the presumption is incorrect, then, for example, the negative effect of a decline in exogenous health infrastructure or in positive endogenous health inputs on child health will be understated. The decline directly reduces maternal health as well child health and the decline indirectly reduces child health via its effect on maternal health. Similarly, the presumption will understate the effectiveness of an infrastructure or chosen input increase since an improvement in the mother's health improves the child's health.

III. MODEL AND ECONOMETRIC PROCEDURES

A. Model

Let a cooperative equilibrium exist between parents such that household preferences can be described by a single preference function. Consider a two-period model, j = 1,2, where in the first period the resolution (abort, carry) of the pregnancy is determined. In the second period the fetus is carried to birth. The mother chooses the quantity of health inputs, z_j, to allocate to own and to child health in each period. She also chooses own consumption of a composite good, x_j. Her maximal expected two-period utility is then:

$$V = \max_{z_1, x_1} U(h_1^c(h_1^m(\cdot), z_1, y, v_1^c), x_1) + d\,(q\,(h_1^c)V^1(z_2^{1^*}, x_2^{1^*}) + (1 - q\,(h_1^c))V^2(x_2^{2^*})), \tag{5}$$

where

$$V^1 = \max_{z_2^1, x_2^1} U(h_2^c(h_2^m(z_2^1, y, v_1^m), z_2^1, y, v_2^c), x_2^1) \tag{6}$$

$$V^2 = \max_{x_2^2} U(0, x_2^2), \tag{7}$$

and

$$q\,(h_1^c) \in [0,1] \tag{8}$$

$$I_j = p_{x_j} x_j + p_{z_j} z_j . \qquad (9)$$

I_j is income in period j, δ is the mother's fixed discount rate, and $q(h_1^c)$ is the probability that the child is born alive. It is assumed that the mother does not die with the birth of the child. The superscripts on z and x are 1 for a live birth of the child and 2 otherwise. $q(h_1^c)$ is a monotonically increasing continuous function of the child's first-period health. The mother's health is a pure investment commodity in that she values own health only as an input into her child's health (Grossman, 1972). While pregnant, the mother makes first-period allocations of health inputs based on her expectations of the child's survival, the health endowments, v^c and v^c, health input prices, p_z, social, environmental, and economic factors, y, and income, I, in both periods. In the second period, the child is born or not, uncertainty is resolved, and the allocation problem is static. The maximal expected utility for the live birth state is $V^1(z_2^{1^*}, x_2^{1^*})$, and $V^2(x_2^{2^*})$ otherwise. If the fetus is not born, its health is normalized to zero in the second period and the optimum is $x_2^{2^*} = \frac{I}{p_{x_2}}$. First-order conditions are derived in the Appendix.

Given a live birth, the mother's valuation of her child's health can be derived from the dual of her second-period allocation problem. Presuming that the expenditure function associated with this dual is continuous, strictly increasing, and unbounded above in U, as well as nondecreasing, homogenous of degree one, concave, and differentiable in prices, this problem can be written as

$$\min_{z_2^1, x_2^1} \; p_{x_2^1} x_2^1 + p_{z_2^1} z_2^1 \qquad (10)$$

subject to:

$$U_2^1 = \overline{U}_2^1 , \qquad (11)$$

where $\overline{U}_2^1$ is the mothers maximal utility in the second period, given a live birth. Efficiency requires

$$U_2^1 - \overline{U}_2^1 = 0 \tag{12}$$

$$p_{x_2^1} + \lambda U_{x_2^1}^1 = 0 \tag{13}$$

$$p_{z_2^1} + \lambda \frac{\partial U_2^1}{\partial h_2^c}\left(\frac{\partial h_2^c}{\partial z_2^1} + \frac{\partial h_2^c}{\partial h_2^m}\frac{\partial h_2^m}{\partial z_2^1}\right) = 0, \tag{14}$$

where λ is the Lagrange multiplier.

With a live birth, solution of the problem in (10) and (11) yields parental demand functions for consumption, x_2^1, and the health inputs, z_2^1, which, when substituted into the budget constraint, yield the expenditure function for the second period

$$e_2^1(p_2, y, v_2, U_2^1) \tag{15}$$

By the envelope theorem, the mother's valuation of a change in the health infrastructure is:

$$\begin{aligned}\frac{\partial e_2(\cdot)}{\partial y} &= \lambda \frac{\partial U_2^1(\cdot)}{\partial y} \\ &= \lambda\left(\frac{\partial U_2^1}{\partial h_2^c}\frac{\partial h_2^c}{\partial y} + \frac{\partial U_2^1}{\partial h_2^c}\frac{\partial h_2^c}{\partial h_2^m}\frac{\partial h_2^m}{\partial y}\right)\end{aligned} \tag{16}$$

Substituting for λ from expression (14):

$$\frac{\partial e_2(\cdot)}{\partial y} = -p_{z_2}\frac{\dfrac{\partial h_2^c}{\partial y} + \dfrac{\partial h_2^c}{\partial h_2^m}\dfrac{\partial h_2^m}{\partial y}}{\dfrac{\partial h_2^c}{\partial z_2^1} + \dfrac{\partial h_2^c}{\partial h_2^m}\dfrac{\partial h_2^m}{\partial z_2^m}}, \tag{17}$$

which says that, given a live birth, a mother's marginal valuation of an exogenous improvement in health infrastructure is her monetized marginal rate of substitution between y and z.

A mother's marginal valuation of her child's health is:

$$
\begin{aligned}
\frac{\partial e_2(\cdot)}{\partial v_2^c} &= \lambda \frac{\partial U_2^1}{\partial h_2^c}\frac{\partial h_2^c}{\partial v_2^c} \\
&= \left(\frac{-\pi_{z_2^1}}{\dfrac{\partial h_2^c}{\partial z_2^1} + \dfrac{\partial h_2^c}{\partial h_2^m}\dfrac{\partial h_2^m}{\partial z_2^1}} \right) \left(\frac{\partial h_2^c}{\partial v_2^c} \right),
\end{aligned}
\tag{18}
$$

that is, a mother's marginal valuation of an improvement in her child's health is defined as the tradeoff between family income and the marginal improvement. Similarly, a mother's valuation of own health is:

$$
\begin{aligned}
\frac{\partial e_2(\cdot)}{\partial v_2^m} &= \lambda \frac{\partial U_2^1}{\partial h_2^c}\frac{\partial h_2^c}{\partial v_2^m} \\
&= \left(\frac{-\pi_{z_2^1}}{\dfrac{\partial h_2^c}{\partial z_2^1} + \dfrac{\partial h_2^c}{\partial h_2^m}\dfrac{\partial h_2^m}{\partial z_2^1}} \right) \left(\frac{\partial h_2^c}{\partial h_2^m}\frac{\partial h_2^m}{\partial v_2^m} \right),
\end{aligned}
\tag{19}
$$

A mother's value of own health relative to her value of child health is then

$$
\frac{\dfrac{\partial e_2}{\partial v^m}}{\dfrac{\partial e_2}{\partial v^c}} = \frac{\partial h_2^c}{\partial h_2^m}\frac{(\partial h_2^m / \partial v_2^m)}{(\partial h_2^c / \partial v_2^c)}, \tag{20}
$$

which is the marginal improvement of own health relative to the marginal improvement in child health.

B. Econometric Procedures

In contrast to the great bulk of the biomedical literature, the economic literature on the household production of health emphasizes that technical processes together with prices and income condition a person's or a family's health input choices. Thus simple correlations between inputs and health outcomes cannot be used to determine causality. Specifically, unbiased estimates of technical family health relationships such as those derived above must be obtained from a behavioral framework in which health inputs are endogenous. To account for heterogeneity in the production of mother's and of child's (fetus') health, we propose the following four equation system: 1) the child's health production to determine survival selection through the first period; 2) the mother's health in the second period for children who survive the first period; 3) the surviving child's health in the second period; and 4) the mother's demands for health inputs in both periods.

Given the mother's utility maximizing quantities of health inputs, a linear representation of the child's period one health production is

$$h_1^c = (y, p_1, p_2)'a_1 + (I_1, I_2)'a_2 + m^c a_3 + h_1^m a_4 + e_1^c, \tag{21}$$

where $m^c + e_1^c = v_1^c$. m^c is the child's observable endowment, and e_1^c is that facit of the endowment known to the mother but unobservable to anyone else. The $(y,p_1, p_2)'$ and $(I_1, I_2)'$ vectors determine the mother's utility-maximizing equilibrium quantities of the z_i. Second period prices and income appear in (21) because the child's first period survival depends on the mother's expected second period behaviors. For $h_1^c \leq 0$, the mother expects the child will not survive or a spontaneous abortion occurs. With $h_1^c > 0$ the mother carries the child to birth. The child's first period health is therefore an indicator variable taking a zero if the child is not born and one if it is born. Failure to account for selection in the resolution of pregnancies will bias estimates of the consequences of the mother's second period decisions (Grossman and Joyce, 1990). Unacknowledged adverse selection, where women who make relatively small investments in health care are more likely to give birth, will bias downward the estimated productivity of health investments. Favorable selection, which refers to women who are more likely to give birth when they make large investments, will, when unacknowledged, impart an upward bias.

The mother's second period health is

$$h_2^m = \hat{z}_2 b_1 + y b_2 + m^m b_3 + e_2^m, \tag{22}$$

and the surviving child's second period health is

$$h_2^c = \hat{z}_2^1 b_4 + y b_5 + \hat{h}_2^m b_6 + m^c b_7 + e_2^c. \tag{23}$$

Given that the child survives the first period, the estimating equation of the mother's second period decision rule for the z_2^1 is

$$z_2^1 = (p_2, I_2)' g_1 + (m^c, m^m)' g_2 + y g_3 + f_2, \tag{24}$$

where $f_2 = (e_2^c, e_2^m)$.

Our empirical strategy proceeds by obtaining first-stage estimates of the $\hat{z}_j$ and then applying the fitted values of these quantities to estimate the h_j^c and the h_2^m. First period health for the mother is considered to be predetermined. This is reasonable given that this first period corresponds to the three months immediately after conception. The four equation system is expressions (21) through (24) applies to our entire sample of pregnant women but expressions (22) and (23) are observed only for women for whom $h_1^c > 0$. Moreover, some health inputs such as prenatal care visits will be influenced by whether or not $h_1^c > 0$. These truncations imply that the error terms among expressions (21), (23), and (24) will be correlated since some of the same health input factors that influence first period child survival also influence second period child health. We correct for this problem by assuming that the joint distributions of (e_1^c, e_2^c) and of (e_1^c, f_2) have bivariate normal densities which allows application of Heckman's (1979) two-stop selection correction procedure. Following Grossman and Joyce (1990), we implement the procedure by estimating expression (21) as a bivariate probit function, compute the inverse of the Mills ratio, and then insert this inverse as a regressor into expressions (22), (23), and (24).

IV. DATA DESCRIPTION

Our data come from the 1988 National Maternal and Infant Health Survey (NMIHS), a data set specifically designed to acquire information on pregnancy outcomes for American women. After eliminating 13,479 observations with incomplete data, and data referring to adolescent mothers, mothers more than 35 years old, gestations less than 20 and more than 45 weeks, and birthweights less than 400 and more than 6,000 grams, our full sample of 12,876 mother/child observations remained with 10,644 live singleton births.[8] The NMIHS data was augmented with physician visit costs and with cigarette price per pack for each of 48 states (Montana and South Dakota refused to participate in the NMIHS).[9] About 25 percent of the sample mothers are homemakers exclusively. Their reservation wages were calculated using the 1983 estimated reservation wage equation of Hofler and Murphy (1994) inflated to 1988 by the U.S. Consumer Price Index. The wages variable thus represents observed wages for working mothers and calculated reservation wages for homemakers.

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[8] Grossman and Joyce (1990) and Werner (1998) employ similar elimination criteria.

[9] Physician visit costs are calculated from the 2000 Medicare Physician Fee Schedule as the Nonfacility Fee Amount deflated to 1988 by the U.S. Bureau of Labor Statistics' Consumer Price Index. Cigarette prices include all applicable state taxes for 1988, as cited in the Tobacco Institute (1997).

Table 1 provides summary statistics and descriptions of the data we employ. A Durbin-Wu-Hausman test (Greene, 2000) suggested endogeneity for the mother's number of prenatal care visits while pregnant and the number of weeks she delayed her initial visit after her last menstrual period. If no care was sought, a delay of 45 weeks was assumed. This delay variable is thus a negative correlate of the quantity and quality of care and should thus have a negative coefficient in the probability of survival and birhtweight production function estimates. In addition to the mother's health, other variables the test proposed as potentially endogenous in one or more estimated expressions are the order of birth (parity) and smoking during the pregnancy.

A long list of variables finally treated as exogenous appears in one or more estimated expressions. Included among them are distance in minutes to a prenatal care facility and the days not engaged in paid work while pregnant as measures of the time sacrifices the mother made. The days the mother took off from work are thus treated as a medical necessity. Price measures include the mother's wages and the cost of a pack of cigarettes. Her anthropometric and sociodemographic features are represented by the mother's race, age, marital status, number of household children, number of household smokers, prior smoking habits, number of prior induced and spontaneous abortions, and prepregnancy body mass index (weight in kilograms divided by height squared in meters), and the child's gender. Attributes of the mother's pregnancy include the number of nights she was hospitalized while pregnant, gestation, and dichotomous variables to indicate whether or not general pregnancy problems/complications existed and whether efforts had to be made to prevent a premature delivery. The mother's education, household income, WIC support, Medicaid or insurance coverage, drug use, residence in a metropolitan area, mental health (CES Total Scale) while pregnant, and whether or not the pregnancy was wanted are included to reflect the mother's health knowledge, stress and attitudes, and her propensity to seek medical care.

Our objective is to estimate expression (20), the marginal contribution of mother's health to her child's health. Expression (20) says that this is simply the utility-maximizing marginal product of a one unit change in mother's health upon child health. Thus, a meaningful comparison of a change in mother's health (weight gain) relative to an improvement in child health (birthweight) induced by a common source requires a common measure. This is accomplished via a linear monotonic transformation of the distribution of mother's weight gain and child's birthweight such that these distributions have identical means and variances. The two transformations are:

$$h_i^c = \frac{birthweight\ in\ grams}{s\tan dard\ deviation\ of\ birthweight} \tag{25}$$

$$h_i^m = \frac{weight\ gain\ in\ grams}{s\tan dard\ deviation\ of\ weight\ gain} + \left(\overline{h}^c - mean\left(\frac{weight\ gain\ in\ grams}{s\tan dard\ deviation\ of\ weight\ gain}\right)\right). \tag{26}$$

The i subscript refers to a sample child or mother and $\overline{h}^c$ is the sample arithmetic mean for expression (25).

V. RESULTS

The potential selectivity bias in a straightforward estimate of the birthweight expression in (23) is quite strong since almost 18 percent of the pregnancies in our sample were aborted. If the mother's second period utility is positively correlated with the child's birthweight, then abortions, which cause birthweight to be observed only for live births, push the observed distribution of the mother's utility to the right. Following Heckman (1979), we correct this bias by estimating expression (21) in linear form for the full sample, using two-stage probit (Lee et al., 1980) while assuming a bivariate normal form. We then computed a correction factor, the inverse Mills ratio, for each of the sample women who gave birth. This ratio, which had an arithmetic mean of 0.3079, and a standard deviation of 0.0963, was then inserted as a regressor in expression (22), (23), and (24). As a regressor, this selection correction factor can be interpreted as proportional to the inverse of the probability that a pregnancy is terminated.

Because epidemiological evidence suggests that almost none of the mother's weight gain occurs in the first trimester (Kramer et al., 1992), mother's first period health is treated as exogenous in the birth probability equation and is measured by her anthropometric and sociodemographic endowments. A Durbin-Wu-Hausman test (Greene, 2000) suggested endogeneity of smoking, parity, the number of prenatal care visits, and delay of the first such visit in the birth probability equation. Reduced form demand functions for these variables were estimated by OLS for the full sample of 12,876 mother/child observations. All of the previously mentioned exogenous variables were treated as regressors except for all of the variables describing the mother's pregnancy attributes, prior abortions, drug use, and mother's body-mass-index (BMI) immediately before her current pregnancy. The fitted values for these four endogenous variables were then entered as regressors in the birth probability equation along with mother's age, mother's wantedness attitude, and the immediately aforementioned exogenous variables that were excepted from the demand estimates. Fitted versions of the number of prenatal care visits, delay of the first such visit, and parity were statistically significant positive correlates of birth probability and smoking was a statistically significant negative correlate. Of the exogenous variables entered in the birth probability equation, only the coefficients for mother's age and for her BMI were significant at less than 5 percent. Both exhibited negative signs.

Table 2 presents OLS estimates for the endogenous regressors in period 2. Since birth selection for the current pregnancy cannot affect parity and is presumed not to affect period 2 smoking behavior, the demand expressions for these two variables do not include the Mills correction and thus apply to both periods 1 and 2. Among the more notable of the results for the smoking expression is the positive impact of prior smoking or smoking while pregnant and the statistical insignificance of the impact of cigarette price upon smoking while pregnant. These results are consistent with an addiction to smoking.[10] The elasticity of the mother's smoking while pregnant with respect to prior smoking is 0.967. Her education has an elasticity of -.379, implying that she chooses to consume about 8 fewer daily cigarettes while she is pregnant when she has an additional year of education.

Consistent with Rosenzweig and Schultz (1983), more educated women who earn higher wages experience fewer pregnancies and have them later in life. However, the Table 2 finding that women living in urban environments have higher fertility is contrary to Rosenzweig and Schultz (1983). Black mothers and mothers who are depressed get pregnant less frequently, all else equal.

[10] Another source of addiction is alcohol intake. Rosenzweig and Wolpin (1991) and Warner (1995) find that alcohol use is not a significant influence upon birth weight. Our preliminary birthweight regressions confirmed this result, perhaps because more than 90 percent of the pregnant mothers in our full sample drank less than one alcoholic beverage per month. Some 83 percent of the full sample were nondrinkers while pregnant and only 1.1 percent drank more than one drink daily. Our NMIHS full sample is likely not rich enough to capture any birthweight effect from alcohol.

The estimated demand equations for the number of prenatal care visits (xvisit) and the delay in the initial visit (visit) exhibit favorable selection, contrary to Joyce (2001). Most other results are consistent with those obtained by Grossman and Joyce (1990). However, the Table 2 result that married women who are pregnant have lesser delays for their initial prenatal care visit contradicts Grossman and Joyce (1990). The Table 2 finding that an unwantedness attitude and a depressed state of mind reduce and delay prenatal care suggest that convincing pregnant women to seek medical help is more than a matter of simply manipulating economic and easily observed sociodemographic factors.

Table 3 presents 2SLS estimates for the mother's period 2 health (mother's weight gain, transformed). Only visit-hat is endogenous. It thus represents fitted values from the visits equation in Table 2. The Mills correction for selection is statistically insignificant. Most Table 3 explanatory variables, including visit-hat, are also insignificant but weight gain is positively responsive to black mothers and to women who were big before becoming pregnant, and negative with respect to mother's age. The positive and statistically significant result for wages is consistent with numerous biomedical and economic results (e.g., Grossman, 1972) indicating a positive association between health and wealth. The positive signs attached to the statistically significant coefficients for depression (ces-total) and drug use defy ready explanation.

Table 4 presents birthweight equations estimated by TSLS. Each column of Table 4 represents a combination of the endogeneity or the exogeneity of weight gain for mothers who gave live births, h_2^m, and a correction or lack of such for selection via the termination of a pregnancy. When a selection correction is made as in Columns (1) and (2), because the inverse Mills ratio is a non-linear function of the variables included in the first-stage probit model, the second-stage model is identified even if the regressors in the first and second stage models are identical. Nevertheless, as an extra identification precaution, two exclusion restrictions were imposed. First, there is at least one covariate in the first-stage not in the second-stage; second, there is at least one variable in the instruments for each endogenous variable that does not appear in the second-stage. Basically, enabling variables such as income, insurance, etc., were assumed to affect birthweight only indirectly through the mother's weight gain.

A version of Sargan's (1976) test, known as the Pagan-Hall (1983) test, for misspecification in models with instrumental variables failed to reject at the 1 percent level the hypothesis of no misspecification for our complete set of instruments.[11] However, a Breusch-Pagan (1979) test revealed heteroskedasticity between the error terms in the mother's weight gain and the child's birthweight equations. Consequently, three-stage least squares estimates were obtained. These 3SLS estimates caused the Mills selection correction variable to become insignificant in the birthweight equation and reduced the magnitude of the coefficient for the number of prenatal care visits without altering its statistical significance. Coefficient estimates and levels of statistical significance for the other covariates in Table 4, including especially the endogenous and the exogenous versions of the variables for mother's health, were essentially unchanged.[12] Given the focus of the paper upon the mother's value of own relative to child health, the following discussion centers upon Table 4 and its value implications.

All columns of Table 4 indicate that mother's pregnancy weight-gain is a positive and statistically significant influence upon the child's health. More importantly, by treating the

[11] See Godfrey (1988, pp. 174-176) for a succinct exposition of these tests.

[12] For example, the 2SLS estimate for $h_2^m - hat$ with selection is .160 with a standard error of .014; for the 3SLS estimate it is .170 with a standard error of .019.

mother's weight gain as endogenous, one increases this positive influence by a factor of three. Failure to take into account the indirect effect of the mother's health upon the child's health greatly underestimates the importance of the mother's health behaviors to the child's health.

Apart from mother's health, there are only very minor differences across columns in the coefficients for the Table 4 regressors. However, there are substantial differences for the selection and no selection results for the case of mother's health endogeneity as well as that for exogeneity. The effect of the number of prenatal care visits is two times higher with than without selection, as is the effect of parity. An accounting of selection has little effect upon the birthweight influence of drugs, smoking, gestation, or gender.

Expression (20) implies that the coefficient on $h_2^m - hat$ in Table 4 measures the mother's value of own relative to her child's health. For the case of no selection, $h_2^m - hat$ has a value of .170, implying that the representative mother values her child's health about six times more than her own health. Thus four conclusions emerge from Table 4: 1) pregnant mothers value child health more than own health; 2) mother's health and child health are complements; 3) the indirect effect of maternal behaviors increases the estimated contribution mother's health makes to child health; and 4) selection due to pregnancy termination does not affect the estimated contribution of maternal health to child health.

The contribution of maternal health to child health and thus the mother's value of own to child health was also estimated for subsamples of the NMIHS women who gave live births. Table 5 gives the results. The most striking difference emerges for nulliparous women (this pregnancy is their first child) and women who already have at least one child. If mother's health is endogenous, nulliparous women value their child's health relative to their own health more than twice as much as do other women who have had children. This result is consistent with the tradeoff between the quantity and the "quality" of children emphasized by Becker and Lewis (1973). Nonsmoking mothers appear to value their children more highly than do smokers. More income, as reflected in the income, medicaid/no medicaid, and married/not married subsamples seems to increase the relative value of child health. Education also increases this relative value, perhaps because of the opportunity costs of the time a mother expects she will subsequently have to devote to a born child.

VI. SUMMARY AND CONCLUSIONS

We have presented a framework suitable for estimating the value an adult attaches to own health relative to child health when health inputs are endogenous and adult health is an input to child health. Heretofore, no research has specifically examined the impact of adult behaviors on own health and thence upon child health. Though our focus is upon pregnant woman and the child they carry, the framework could, likely at considerable cost in analytical and empirical complexity, be extended to the care adults provide post-natal children. A parent's discretionary behaviors affect her contemporaneous health and this health impacts what she can do with and for her child. What she does with and for her child influences its health. By aiding her own health, the mother helps her child's health.

When the maternal health input to child health is treated as endogenous our empirical results indicate that, on average, pregnant mothers value the prospective health of their as yet unborn children about six times more than they value own health. Treatment of the maternal health input as exogenous will reduce the estimated impact of this input upon child health relative to the impact when it is treated as endogenous. Consequently, for a given observed child health improvement, part of the contribution of maternal health to this improvement will be attributed to other health inputs, thus reducing the estimated value of maternal health relative to child health.

Our empirical results also suggest that the mother's relative valuation of own and of child health is sensitive to her personal and family characteristics and behaviors such as number of siblings for the child, family income, and maternal consumption patterns (e.g., smoking).

The result that pregnant mothers value own health considerably less than they value child health promotes skepticism about the one-to-one transfer of adult health benefits measures to children. Whatever the average relative valuation employed, they also promote caution about use of a one-size-fits-all constant for these transfers.

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Table 1. Summary statistics, n=12,876

Variable	Mean	Std. Dev.	Description of variables
abortions	.4344517	.9231301	Number of previous abortions, induced and spontaneous
alive	.8265219	.3786747	Dichotomous: 1 if child was born alive
attitude	.4558356	.498065	Dichotomous: 1 if pregnancy was not wanted
bweight	2579.276	1111.054	Baby's birth weight in grams
ces_total	13.99845	12.10674	CES Depression scale for pregnant mother
children	1.180147	1.384186	Number of children in the household
cigprice	130.9913	9.75674	Price of one packet of cigarettes, including all taxes in cents (1988 US dollars)
distance	20.40993	16.35411	Distance in minutes to prenatal care provider
drugs	.0755332	.2642599	Dichotomous: 1 if mother used drugs in the 12 months before delivery
gender	.4740597	.499346	Dichotomous: Baby's gender 1 if female
gestation	35.97053	5.837431	Length of gestation in weeks
health_child	2.321469	1	Child's health index, transformation of child's birth weight
health_mother	2.321469	1	Mother's health index, transformation of mother's weight gain
income	25672.04	21067.1	Total annual household income, whole dollars (1988 US dollars)
insurance	.6350523	.4814341	Dichotomous: 1 if mother had health insurance at delivery time
mage	26.57325	4.242554	Mother's age in years
marital	.6201629	.485365	Dichotomous: 1 if married
mbmibefore	28.04287	5.512001	Mother's Body Mass Index before pregnancy
medicaid	.3010469	.4587308	Dichotomous: 1 if covered by Medicaid
meduc	12.59558	2.318349	Mother's education in years
metro	.777027	.4162565	Dichotomous: 1 if family lives in metropolitan area
nights	7.8185	13.80952	Number of nights hospitalized during pregnancy (excluding delivery)
parity	.8675456	1.428883	Number of previous pregnancies
premature	.3535259	.4780827	Dichotomous: 1 if action was taken to prevent premature delivery
prenatalcost	361.44	27.406	Cost of prenatal care visit, whole dollars (1988 US dollars)

Table 1. Summary statistics (cont.)

priorsmoke	5.077975	9.224811	Number of cigarettes smoked by the mother prior to pregnancy, per day
problems	.8952314	.3062669	Dichotomous: 1 if complications with pregnancy
race	.528425	.499921	Dichotomous: 1 if mother is black
smokers	.480817	.8589116	Number of smokers in the household
smoking	3.065995	6.889637	Number of cigarettes smoked by the mother during pregnancy, per day
totaldays	66.40775	110.6519	Total days the mother did not work
visit	10.41171	8.45774	Weeks since pregnancy started before first prenatal care visit
wages	37043.31	23570.97	Mother's wages annually, whole dollars (1988 US dollars)
wgain	9586.068	9881.782	Mother's weight gain during pregnancy, in grams, after birth
wic	.3422257	.4744731	Dichotomous: 1 if WIC food aid provided during pregnancy
xvisits	11.23893	6.130369	Number of prenatal care visits

Note: The mother's and the child's health index transformation is explained in the text. The WAGES variable also includes reservation wages for homemakers, as explained in the text.

Table 2. Demand Estimates

	visit		xvisit		smoking		parity	
	Coefficient	t	Coefficient	t	Coefficient	t	Coefficient	t
distance	-.085	-18.12	.027	7.64	-.005	-2.14	-.003	-3.98
attitude	3.202	14.27	-1.381	-8.09	.189	2.37	.054	2.27
children	.535	8.38	-.273	-5.64	.231	8.00	.368	42.46
wic	-2.185	-9.95	1.440	8.63	-.121	-1.30	-.054	-1.94
insurance	-1.482	-7.01	.653	4.06	-.190	-2.09	-.318	-11.63
marital	-1.386	-6.92	.872	5.73	-.309	-3.23	-.010	-0.35
mage	-.123	-5.78	.046	2.84	.034	3.75	.034	11.71
race	-2.978	-9.20	2.463	10.00	-.068	-0.78	-.288	-11.14
meduc	-.227	-5.87	.208	7.07	-.092	-5.01	-.073	-13.19
wages	-.103e-04	-2.70	.688e-07	2.37	.476e-07	2.83	-.336e-07	-6.65
income	.266e-04	-5.36	.128e-04	3.39	-.930e-07	-3.96	.299e-08	0.42
medicaid	.929	4.01	-.460	-2.61	.084	0.81	.120	3.84
total days	.225e-04	0.03	.002	2.96	-.001	-1.98	.162e-07	0.02
metro	-.485	-2.46	.247	1.65	.063	0.68	.142	5.12
cigprice	.011	1.28	-.014	-2.17	-.002	-0.49	-.047e-03	-0.04
ces_total	-.073	-4.70	.060	5.06	.006	1.97	-.005	-5.09
prenatal cost	-.004	-1.33	.005	1.95	.001	0.50	.002	4.36
priorsmoke	.045	5.23	-.007	-1.13	.584	142.20	.012	10.12
mills	22.689	8.37	-17.234	-8.36	----	----	----	----
Constant	15.350	9.80	9.028	7.58	.349	0.50	.153	0.73
Observations	10,644		10,644		12,876		12,876	
F-statistic	102.42		48.30		1293.63		247.29	
R^2	.1548		.0795		.6443		.2572	

Note: All estimates were obtained by ordinary-least-squares.

Table 3. Mother's Period 2 Health (Weight Gain)

h_2^m	Coefficient	t
distance	-.001	-0.51
attitude	-.003	-0.08
children	.008	0.97
wic	-.074	-1.50
insurance	-.058	-1.50
marital	.002	0.05
mage	-.014	-5.58
race	.010	4.29
meduc	.005	0.84
wages	.126e-07	3.14
income	.123e-07	1.78
medicaid	-.003	-0.11
total days	.146e-03	-1.69
metro	-.032	-1.32
cigprice	-.458e-03	-0.48
ces_total	.004	4.35
prenatal cost	.001	1.67
priorsmoke	-.848e-04	-0.08
mbmibefore	.074	45.11
gestation	.003	2.08
drugs	.111	3.17
visit-hat	-.008	-0.56
mills	.161	0.76
Constant	.208	0.63
Observations	10,644	
F-statistic	99.45	
R^2	.1708	

Note: Estimated by two-stage-least-squares. Variables denoted with a "-hat" are endogenous.

Table 4. Child's Period 2 Health (Birthweight)

h_2^c	(1) Endogenous/ Selection		(2) Exogenous/ Selection		(3) Endogenous/ No Selection		(4) Exogenous/ No Selection	
	Coefficient	t	Coefficient	t	Coefficient	t	Coefficient	t
visit-hat	.018	1.49	.019	1.74	.008	1.70	.007	1.51
xvisits-hat	.051	5.07	.055	5.47	.029	3.20	.028	3.09
parity-hat	.039	3.96	.040	4.05	.020	2.18	.016	1.77
smoking-hat	-.012	-9.98	-.012	-10.29	-.010	-8.95	-.010	-8.95
drugs	-.071	-3.28	-.066	-3.03	-.068	-3.13	-.062	-2.83
$h_2^m - hat$	.160	11.51	----	----	.170	12.32	----	----
h_2^m	----	----	.055	9.76	----	----	.057	10.11
mills	.346	4.88	.423	6.00	----	----	----	----
gestation	.134	144.49	.136	147.20	.134	144.20	.136	147.00
gender	-.104	-9.45	-.104	-9.45	-.106	-9.60	-.106	-9.63
Constant	-3.639	-20.34	-3.530	-19.75	-3.185	-20.82	-2.956	-19.55
Observations	10,644		10,644		10,644		10,644	
F-statistic	2546.65		2533.73		2855.86		2836.60	
R^2	.6831		.6820		.6824		.6809	

Notes: All estimates were obtained by two-stage-least-squares. Variables denoted with a "-hat" are endogenous. The columns denote whether or not h_2^m was treated as endogenous, and whether or not a selection correction was made.

Table 5. Mother's Value of Own Relative to Child Health.

		With endogeneity			Without endogeneity		
Subsample	Observations	Coefficient	z	R^2	Coefficient	z	R^2
Whites	5234	.1546	5.19	.5189	.0552	6.25	.5558
Blacks	5410	.1789	6.38	.7000	.0527	7.14	.7165
No other children	3967	.1005	3.08	.6622	.0524	5.72	.6777
One or more children	6677	.2254	8.52	.6261	.0601	8.16	.6524
Pregnancy wanted	5628	.1621	5.42	.6562	.0531	6.78	.6688
Pregnancy not wanted	5016	.1810	6.45	.6211	.0604	6.82	.6319
Not insured	3922	.1717	5.32	.6125	.0658	5.97	.6200
Insured	6722	.1700	6.60	.6759	.0489	7.17	.6936
Unmarried	4158	.1902	6.40	.5650	.0712	6.88	.5925
Married	6486	.1561	5.05	.6842	.0458	6.52	.6971
Not on Medicaid	7344	.1589	5.95	.6863	.0535	8.05	.6940
On Medicaid	3300	.2065	6.01	.4565	.0663	5.83	.4897
Live outside metropolitan area	2312	.1955	3.29	.6234	.0813	6.30	.6279
Live inside metropolitan area	8332	.1673	7.83	.6038	.0509	7.84	.6134
Nonsmoker	7808	.1440	5.99	.6703	.0475	7.20	.6823
Smoker	2836	.2381	5.26	.4572	.0811	6.80	.4632
Education<=12 years	6458	.1864	6.85	.6240	.0614	7.62	.6388
Education >12 years	4186	.1391	4.58	.7044	.0472	5.37	.7132
Homemaker	4014	.1833	5.97	.5411	.0591	5.84	.5688
Employed	6630	.1718	6.41	.6939	.0563	8.13	.7060
Income<10000	3250	.1960	4.61	.4428	.0724	5.19	.4801
Income <=50000	6925	.1640	6.68	.6610	.0563	8.07	.6729
Income >50000	1059	.1497	3.74	.6747	.0196	1.21	.6852

The results are based on two-stage least squares without selection.

Appendix

Appendix

The problem of the parent is to maximize her expected "lifetime" utility. Her maximal expected "lifetime" utility in the first period is:

$$V = \max_{z_1, x_1} E\{U(h_1^c[h_1^m(.), z_1, y, v_1^c], x_1) + \tag{A.1}$$

$$d[q(h_1^c)V^1(z_2^{1^*}, x_2^{1^*}) + [1 - q(h_1^c)]V^2(x_2^{2^*})]\}$$

$$V^1 = \max_{z_1^2, x_2^1} U\left(h_2^c\left(h_2^m(z_2^1, y, v_2^m), z_2^1, y, v_2^c\right), x_2^1\right) \tag{A.2}$$

$$V^2 = \max_{x_2^2} U(0, x_2^2) \tag{A.3}$$

$$q(h_1^c) \in [0,1] \tag{A.4}$$

$$I_j = p_{x_j} x_j + p_{z_j} p_j \tag{A.5}$$

where x_j is period j parental consumption, I_j is period j income, δ is the parent's discount rate and θ is the probability of a "normal" pregnancy. We assume that each period's income is predetermined (labor supply decisions for the mother are exogenously determined), the parent's discount rate δ is fixed and the probability of the child born alive θ is a monotonically increasing continuous function of the child's health in the first period. Superscripts on x and z in equation (A.5) are omitted for notational simplicity. The mother chooses x_2^1 and z_2^1 at the beginning of period one.

Substituting the budget constraint (A.5) into equations (A.1), (A.2) and (A.3), the system becomes:

$$\begin{aligned} V = \max_{z_1} E\{&U(h_1^c(h_1^m(z_1, y, v_1^m), z_1 y, v_1^c), I_1 - p_1 z_1) + \\ &d[q(h_1^c(h_1^m(z_1, y, v_1^m), z_1 y, v_1^c), V_1(z_2^{1^*}) + (1 - q(h_1^c(h_1^m(z_1, y, v_1^m), z_1 y, v_1^c),)))V^2(z_2^{2^*})]\} \end{aligned} \tag{A.6}$$

$$V = \max_{z_2^1} U(h_2^c(h_2^m(z_2^1, y, v_2^m), z_2^1 y, v_2^c), I_2 - p_2 z_2^1) \tag{A.7}$$

$$V^2 = \max_{z_2^2} U(0, 1_2 - p_2 z_2^2) \qquad \text{(A.8)}$$

The optimal z_2^1 is the solution to equation (A.6). Efficiency requires that:

$$V^1 : \frac{\partial U}{\partial h_2^c}\frac{\partial h_2^c}{\partial z_2^1} + \frac{\partial U}{\partial h_2^c}\frac{\partial h_2^c}{\partial h_2^m}\frac{\partial h_2^m}{\partial z_2^1} = p_2 \frac{\partial U}{\partial c_1} \qquad \text{(A.9)}$$

The first term in equation (A.9) is direct effect on utility of a change in z on the child's health, as would be predicted if only the "reduced-form" effect was considered, and the second period, given that the child does not survive, the mother does not consume any health inputs for the child, therefore:

$$V^2 : x_2^2 = \frac{I_2}{p_{x_2}} \qquad \text{(A.10)}$$

Equation (A.8) states the familiar result of consumer theory that in order to maximize utility, the parent must allocate resources so as to make the ratios of marginal utilities equal to the ratios of prices.

Efficiency for equation (A.6) requires that:

$$\frac{\partial EU}{\partial h_1^c}\frac{\partial h_1^c}{\partial z_1} + \frac{\partial EU}{\partial h_1^c}\frac{\partial h_1^c}{\partial h_1^m}\frac{\partial h_1^m}{\partial z_1} - \frac{\partial EU}{\partial c_1}\frac{\partial c_1}{\partial z_1} p_1 + d\left[\frac{\partial q}{\partial z_1}V^1 - \frac{\partial q}{\partial z_1}V^2\right] = 0 \qquad \text{(A.11)}$$

where

$$\frac{\partial q}{\partial z_1} = \frac{\partial q}{\partial h_1^c}\left(\frac{dh_1^c}{dz_1} + \frac{\partial h_1^c}{\partial h_1^m}\frac{\partial h_1^m}{\partial z_1}\right) \qquad \text{(A.12)}$$

Equation (A.11) is the marginal change in the probability of survival in the second period from a change in z. The solution of the problem comes from solving the first-order condition (A.8), and then (A.10).

Valuing Fetal and Infant Health:
What Can Be Learned from Empirical Health Economics Research?

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I. Introduction

Despite many encouraging trends in environmental quality, serious environmental health threats to fetal, infant, and child health remain. For example, some research suggests that particulate matter air pollutants may be associated with higher infant mortality.[1] In 2001 approximately 25 percent of children lived in counties that exceeded the annual standard for particulate matter (US EPA 2003). This suggests a similarly large fraction of all pregnant women may be exposed to unhealthy levels of particulates The importance of fetal and infant health is underscored by the inclusion of data on birth defects in California as a Special Feature in the most recent EPA (2003) report on America's Children and the Environment. As the EPA notes, "birth defects are leading cause of infant death in the first year of life, accounting for about 20 percent of infant deaths in 1999." Although some birth defects are inherited, environmental and public health policies may be able to reduce nongenetic risk factors for birth defects, and improve fetal and infant health more generally.

Benefit-cost analysis of policies to improve fetal, infant and child health requires valuation of those health improvements. A number of studies extend market and non-market approaches to estimate willingness to pay for child health. Because children are not in the labor market and do not make independent consumption decisions, the studies focus on parents' decisions that affect the health and safety of their children. Analysis of parents' child safety seat use, automobile purchases, and bicycle helmet purchases provides estimates of willingness to pay

[1]In addition to the references in US EPA (2003), Chay and Greenstone (1999, 2001) analyze data on infant mortality, birthweight, and air quality improvements in the early 1970s and the early 1980s. Their findings suggest a strong relationship between air quality as measured by total suspended particulates and infant mortality rates, and a somewhat weaker relationship between air quality and birthweight.

for child mortality risks , summarized as the value of a statistical life for a child (Carlin and Sandy 1991; Mount *et al.* 2000; and Jenkins, Owens and Wiggens 2001). Other child health effects valued include: child lead exposure (Agee and Crocker 1996); colds (Liu *et al*. 2000); risks of non-melanoma skin cancer (Dickie and Gerking 2001); lifetime cancer risks (Maguire, Owens and Simon 2001); and child health effects related to secondhand smoke exposure (Agee and Crocker 2001). However, there seem to be few if any existing estimates specific to the value of fetal and infant health.[2]

The goal of this paper is to examine the implications of empirical health economics research for the valuation of fetal and infant health. Section II sets the stage by reviewing illustrative empirical evidence on the various ways parents invest in prenatal health, including market purchases such as medical care, and lifestyle changes such as smoking cessation. Section III presents a simple version of the standard household health production model, to serve as the theoretical framework for the valuation expressions and the empirical research to be reviewed. Section IV reviews health economics research that estimates infant health production functions. Combining the estimates of the marginal product of prenatal care with estimates of the full price paid yields estimates of parental marginal willingness to pay for infant health. Section V reviews studies of maternal demand for cigarettes and alcohol during the pre-natal period, and discuss the implications for fetal and infant health valuation. Section VI discusses health economics studies

[2]In the recent review by Neumann and Greenword (2002), all of the studies of effects associated with prenatal exposure use the cost-of-illness approach. The review includes estimates of willingness to pay to reduce infants' mortality risks, based on Dickie and Nestor's (1999) analysis of the results of Joyce, Grossman and Goldman (1989).

that estimate the impacts of public policies on fetal and infant health, and explores whether these can be used to shed light on the health valuation question.

At the outset, limitations of the scope of this paper should be noted. The emphasis of the paper is on lessons from health economics, so the environmental economics research literature is not reviewed in depth. The valuation approach is to infer parents' willingness to pay for fetal and infant health based on their preferences as revealed in the markets for medical care, cigarettes, and so on. The paper does not review studies from three other approaches that shed light on health valuation: the cost-of-illness approach; the contingent valuation or stated preference approach; or the quality-adjusted life year approach used in cost-effectiveness analysis. To date, most evaluation studies relevant to fetal and infant health follow the cost-of-illness approach; for summaries of these studies see Neumann and Greenwood (2002). Cost-of-illness estimates provide a lower bound to willingness to pay (Berger *et al*. 1987, Kenkel 1994), so these estimates are a way to check the plausibility of willingness to pay estimates from other approaches. Two contingent valuation studies estimate willingness to pay related to infertility risks (Neumann and Johanneson 1994, Smith and Van Houten 1998), but the implications for the value of fetal and infant health are not clear. Finally, in principle it should be possible to follow the common approach in cost-effectiveness analysis and estimate the number of quality-adjusted life years lost from fetal and infant poor health and death. For example, the Harvard Catalogue of Preference Scores includes weights to calculate the quality-adjusted life years for children with a range of neurologic disabilities. However, in all of the cases the preference scores were measured based on author or clinical judgement, and so may not reflect either parental or societal preferences over these health states.

II. Parental Investments in Prenatal Health: An Overview

Table 1 provides an overview of maternal investments in prenatal health. The data are from the National Maternal and Infant Health Survey (NIMHS) 1988, conducted by the National Center for Health Statistics. The 1988 NMIHS consists of three independent national files of live births, fetal deaths and infant deaths. The full sample consists of 18,594 mothers who had a live birth, fetal death or infant death in 1988. Of these 18,594 mothers, 9,953 women had live births, 3,309 had late fetal deaths and 5,332 had infant deaths.[3] Table 1 presents the patterns of prenatal investments for the full sample and for each of the sub-samples.

As can be seen in Table 1, during the prenatal period women invest both money and time to improve fetal health. Virtually all (98 percent) of pregnant women in the U.S. receive prenatal medical care, and on average make almost 13 prenatal visits. Additional data from the NMIHS (not reported in Table 1) indicate that about a third of the women report paying for the prenatal care out of their own income. In addition, some of those whose care was covered by private insurance or Medicaid still incurred out-of-pocked costs due to copayments or coinsurance, although data on this was not collected in the NMIHS. Women also incurred time costs to travel to and receive prenatal care; the average travel time to prenatal care for NMIHS respondents was about 21 minutes.

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3 In 1988, there were 3,898,922 live births to women between 15 and 49 years of age, 15,259 fetal deaths of 28 weeks or more gestation, and 38,917 infant deaths to United States residents. The overall probability of the 1988 NMIHS selection was about 1 of every 354 live births, 1 of every 4 fetal deaths and 1 of every 6 infant deaths. The overall response rate for the national file of 18,594 mothers is 71%; it is 74% for live birth mothers, 69% for fetal death mothers, and 65% for infant death mothers.

In the full sample, 38 percent of pregnant women also attend prenatal childbirth class, but fewer women in the fetal death and infant death samples attend such classes. About 80 percent of pregnant women take multivitamins and/or minerals at least three days a week after they found out they were pregnant, up from about 25 percent of women who took vitamins before they found out they were pregnant.

Women also commonly make lifestyle changes after they find out they are pregnant. In the 1988 NIMHS, pregnancy is associated with a drop in the prevalence of smoking from 30 percent to 22 percent. Even those women who continue to smoke while pregnant still on average report that they decreased the amount, from about 16 cigarettes per day to 12 cigarettes per day. Pregnancy is also associated with a drop in the prevalence of drinking alcohol, from 45 percent to 21 percent. And those women who continue to drink while pregnant on average report that they decreased the amount, from 9 drinks per month to about 3 and a half drinks per month. The only exception to these patterns is that is somewhat more common for women to quit exercising after they discover that they are pregnant than it is for women to start exercising.

The data in Table 1 are presented to make the broad point that during the prenatal period women make substantial investments in fetal health. Table 1 neglects some investments, such as changes in maternal diet and illicit drug use, as well as all paternal investments in fetal health. On the other hand, because the data are self-reported, the changes in maternal behavior may be over-stated. It also should be noted that while women invest in fetal health, in many cases their choices are not optimal from the public health viewpoint, i.e. their choices do not maximize fetal health. For example, public health goals call for increasing the proportion of women who receive early and adequate prenatal care from its 1998 level of 74 percent to a 2010 target level of 90 percent (USDHSS 2000). Nevertheless, it is clear that many women are willing to sacrifice money, time, and cigarette and alcohol consumption to improve the health of their unborn children. The next section outlines the standard economic approach to modeling this behavior.

III. Conceptual Framework

This section considers a highly simplified one-period version of Grossman's (1972) household production model of the demand for health and health-related goods. Assume the mother receives utility from consuming a numeraire good X, her infant's health IH, and from smoking cigarettes S: U = U(X, IH,S). The mother may purchase in the market prenatal medical care (M), which does not provide utility directly, but is used to produce the commodity infant health according to a household production functions. Infant health is also assumed to depend on maternal smoking, and exogenous influences such as environmental quality, E: IH = IH (M, S, E).

The mother chooses X, S, and M to maximize her utility subject to a standard budget constraint and the household production function. The first order conditions for this maximization problem implicitly define goods demand functions for X, S, and M as functions of market prices, income, and the parameters that describe preferences (U (.)) and the technology of household production (IH (.)). Formally, the model also includes a commodity demand function for infant health, which is conceptually distinct from the infant health production function.

Before discussing empirical applications, some brief comments on this theoretical model are in order. Grossman's (1972) seminal model contains two key features: first, that health is a commodity produced in the household; and second, that health is a form of human capital. The focus here is on behavior during the prenatal period and the production of fetal and infant health, so the model is simplified to one period and abstracts from the dynamics of health capital over the life cycle. Grossman (2000) provides a comprehensive review of theoretical and empirical work based on his human capital model of health, while Currie (2000) contains an intertemporal model of parents' investments in child health. By focusing on the mother's utility function, the model also abstracts from the more complex problem of decision-making within the family. This extension is discussed in a series of recent health economics papers (Jacobson 2000, Case and Paxson 2001, Bolin, Jacobson and Lindgren 2001, 2002), as well as by Bergstrom (2003).

The general structure of the household production model of health provides the conceptual framework for a great deal of empirical research in health economics. One approach is to estimate a structural health production function as a function of endogenous health inputs and exogenous factors. Section IV of this paper reviews research on the household production of infant health in the U.S. , but the approach has also been commonly used in the context of low-income countries (e.g., Barrera 1990, the Cebu Study Team 1992).

The Grossman model also provides the explicit or implicit framework for empirical studies of the demand for various health-related goods. Section V of this paper reviews some recent research on the demand for cigarettes and alcohol by pregnant women. These papers are extensions of an extensive empirical literature reviewed in several chapters of the *Handbook of Health Economics:* Chaloupka and Warner (2000) review empirical studies of the demand for cigarettes; Cook and Moore (2000) review empirical studies of the demand for alcohol; and Kenkel (2000) reviews empirical work on the demand for prevention broadly defined. As Kenkel (2000, p. 1685) points out, while some empirical studies have tight links between the structure of the theoretical model and the empirical specification, more commonly the theoretical model only provides general guidance for the empirical investigations, for example in terms of the explanatory variables to be included in a demand model.

A number of recent studies take one step further away from structural models, and focus on reduced-form estimates of the impacts of public policies on health, including the impact of so-called "natural policy experiments." This approach can be used to study the impact of policy changes on health outcomes and on the use of health inputs. For example, Currie and Gruber (1996) examine the impact of Medicaid expansions on infant mortality; Currie and Grogger (2002) examine the combined impact of Medicaid expansions and welfare reform on both the use of prenatal care and fetal deaths. However, it is not in general appropriate to interpret the estimated equations as either structural production functions or demand functions. As Rosenzweig and Schultz (1983) demonstrate, the estimated coefficients from such hybrid equations will generally be mixtures of preference and technology parameters. Section VI discusses some examples from this body of research.

IV. Health Production Function Estimates and the Value of Infant Health

Willingness to Pay Expression

The health production function approach is a well-established method in environmental economics research on the valuation of health as a non-market commodity (Freeman 1993, pp. 344-360). It is a revealed preference approach to valuation, where consumers' demand for a health input reveals the value they place on the health output. The model in section III can be used to derive the standard expression for marginal willingness to pay ($MWTP_E$) for a health-improving change in environmental quality (E). To complete the model sketched above, assume a simple goods budget constraint: $Y = X + p_M M + p_S S$; where Y is income and p_M and p_S are the money prices of medical care and cigarettes. (Recall that X is the numeraire good so its price is normalized to one.) To find the $MWTP_{E,}$ set the total derivative of the utility function equal to zero and substitute in the first order conditions. After some manipulations, the change in income necessary to hold utility constant after a change in environmental quality can be expressed as a ratio of the technological parameters of the production function, which can be interpreted as the marginal rate of technical substitution between E and M in producing infant health:

$$MWTP_E = d Y / d E = (IH_E / IH_M)\, p_M$$

As Freeman (1993, p. 349) stresses, one of the advantage of this expression is that on the right hand side "all of the measures are functions of observable variables that can be calculated given knowledge of the production function." Strictly speaking, the valuation expression involves the individual's perceptions of the parameters of the health production function. It is therefore typically assumed that, at least on average, individual perceptions are correct, so econometric knowledge of the production function translates into knowledge of consumers' perceptions of the production function. Unless extra data are collected on individual perceptions, this type of assumption is common in the revealed preference approach. For example, many studies of the value of a statistical life make comparable assumptions about the risks associated with labor market and consumption decisions (e.g. Viscusi 1992a, Jenkins, Owens, and Wiggins 2001).

The household health production approach has been used to estimate marginal willingness to pay for air quality-related health improvements for adults (Gerking and Stanley 1986) and infants (Joyce, Grossman and Goldman 1987). Dickie and Gerking (1991) extend the analysis to consider multiple symptoms, i.e. multiple health outputs. If the number of health inputs exceeds the number of symptoms to be valued, it is still possible to express the marginal willingness to pay for each symptom as a ratio of the technological parameters of the household health (symptom) production function. Agee and Crocker (2001) provide a recent example of the approach with multiple health outcomes, namely child and adult health. They use cross-sectional data on parents who are smokers from a 1991 follow-up of the 1988 National Maternal and Infant Health Survey (NMIHS). Each household in the sample has a three-year-old child. Agee and Crocker use these data to estimate a structural household production model of parents' smoking behavior, adult health, child secondhand smoke exposure, and child health.

The expression for $MWTP_E$ relies on the assumption that prenatal care is only demanded as an input into infant health production. In many cases, important health inputs either provide utility directly, such as cigarette smoking in the model sketched above, or enter some other household production function.[4] When an input like S is jointly demanded for several reasons, the $MWTP_E$ can not be expressed as the marginal rate of technical substitution between E and S. Instead, unobservable utility terms remain in the expression. Section V below discusses an approach to health valuation in this situation.

The approach in previous environmental economics studies is to estimate directly the necessary parameters of the health production function, including the marginal product of environmental quality on health (IH_E). As is noted elsewhere (Freeman 1993, p. 349, Dickie 1999), implementing this approach is thus very demanding of the data. Of particular relevance to

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4More accurately, cigarette smoking jointly enters the infant health production function, enters the mother's utility function directly, and enters the health production function of the mother. This extension is sketched below in section V.

the current literature review, health economics data sets often lack the necessary measures of environmental quality. However, marginal willingness to pay for an improvement in fetal and infant health ($MWTP_{IH}$), i.e. the marginal rate of substitution in consumption between X and IH, is not as demanding. It can be shown that:

$$
\begin{aligned}
MWTP_{IH} &= U_{IH} / U_X \\
&= (d\,Y / d\,E) / IH_E \\
&= p_M / IH_M
\end{aligned}
$$

The $MWTP_{IH}$ thus requires only an estimate of IH_M from health economics research on infant health production functions, and a corresponding measure of the price of prenatal care. The $MWTP_{IH}$ can be thought of as the value of a standardized improvement in environmental quality or any other exogenous change that yields a marginal change in infant health. It can be used to value any public policy change that improves infant health at the margin, assuming, of course, that the policy analyst has an outside estimate of the infant health improvement (i.e., a term analogous to IH_E).

Empirical Estimates of Infant Health Production Functions

Table 2 lists eleven studies that estimate the marginal product of prenatal care in improving infant health. Seven of the studies use microdata and measure infant health by birthweight in grams. Three studies use county- or state-level aggregate data and measure infant health by the percentage of infants born at a low birthweight (below 2500 grams); one study uses county-level data on neonatal mortality rates. The use of prenatal care is usually measured in terms of whether it was initiated in the first trimester of pregnancy or delayed. In addition to measures of prenatal care, all of the studies include endogenous health inputs such as maternal smoking and other variables such as maternal age and schooling.

The research on infant functions addresses a number of specification issues. The functions are generally specified to be linear, although Rosenzweig and Schultz (1983, 1988) also estimate Cobb-Douglas specifications, and Warner (1988) also estimates linear with interaction terms, quadratic, and square root specifications.[5] As might be expected, specifications have evolved over time to address new research questions. Several of the studies suggest that the parameters of the infant health production function vary significantly by race. In another extension, Warner (1998) emphasizes the importance of maternal anthropometric measures such as height and weight. Warner (1995, 1998) also explores whether subsequent more frequent prenatal visits substitute for delaying pre-natal care after the first trimester.

The research on infant health production also addresses a number of econometric issues. Following Rosenzweig and Schultz (1983), a central concern has been the endogeneity of the health inputs. Rosenzweig and Schultz show that with individual heterogeneity that is known to the mother but unobservable to the econometrician, ordinary least squares (OLS) yields biased estimates of the parameters of the health production function. Their empirical results suggest that women with health problems may seek prenatal care earlier to compensate, causing OLS to underestimate the productivity of prenatal care. Rosenzweig and Schultz and most subsequent studies use two stage least squares or a related instrumental variables technique to treat prenatal care and other health inputs as endogenous. This approach generates a research debate across the

5Rosenzweig and Schultz (1983) also consider the translog specification, but it is rejected in favor of the Cobb-Douglas.

studies about the validity of the identifying exclusion restrictions and the explanatory power of the instrumental variables as predictors of input demand.

Grossman and Joyce (1990) argue that in addition to treating health inputs as endogenous, it is important to control for self-selection in the resolution of pregnancies as live births or induced abortions. The selectivity bias could be in either direction. They find strong selection effects for blacks but not whites, with the results suggesting that among blacks the unobserved factors that increase the probability of a live birth are correlated with unobserved factors that increase use of prenatal care and increase birthweight. Subsequent studies that use vital statistics data also control for selectivity bias (Joyce 1994, Liu 1998). However, other recent studies such as Warner (1998) that use data from surveys of mothers can not, because the data necessary to estimate the selection equation are lacking.

Because of the variety of specifications, econometric methods, and data sets used, it is difficult or impossible to determine a single 'best' estimate of the marginal product of prenatal care in improving health. There is a strong consensus in the research that prenatal care is productive, but the precise magnitude varies. A few examples illustrate typical results. After controlling for the endogenous choice of health inputs, Rosenzweig and Schultz (1983) results imply that prenatal care delay decreases birthweight by approximately 50 grams. Warner (1995) estimates a monthly delay productivity of between 25 and 30 grams for black mothers. After controlling for both endogeneity and selectivity bias, Liu (1998) estimates that each month of prenatal care delay decreases birthweight by 76 grams. To consider a different health outcome measure, Corman, Joyce and Grossman (1987) estimate that prenatal care reduces black mortality by 1.82 deaths per 1000 live births, but reduces white mortality by only 0.30 deaths per 1000 live births.

Illustrative Calculations of Willingness to Pay for Infant Health

Marginal willingness to pay for infant health can be calculated by combining an estimate of the marginal productivity of prenatal care in improving infant health with an estimate of the price of prenatal care. Ideally, the price should be specific to the sample used to estimate the infant health production function, in terms of both geographic area and time period. In addition, although the simple model presented above abstracted from these complications, price should be measured as the out-of-pocket cost paid by the mother after insurance, plus additional travel and time costs incurred to receive the care. In practice, developing such a price measure is challenging, so the following calculations should be viewed as illustrative.

Suppose the full price (out-of-pocked monetary costs plus travel and time costs) of reducing one month of prenatal care delay is $300. From the studies reviewed above, this reduction in delay might increase birthweight by 25 to 76 grams. Assuming the increase is 50 grams, the implication is that maternal marginal willingness to pay is about $6 per extra gram of birthweight.

As another illustrative calculation, combining the cost of prenatal care with the estimate from Joyce, Grossman and Goldman (1989) of the marginal product of prenatal care in reducing neonatal mortality yields the willingness to pay for a small reduction in neonatal mortality risks. As is conventional, this can be conveniently summarized as the value of a statistical life. Dickie and Nestor (1998) conduct the needed calculations to derive the per birth value of $43,000 to $750,000 for whites and $59,00 to $1,450,000 for blacks.

V. Demand Function Estimates and the Value of Infant Health

Willingness to Pay Expression

The model sketched in section III can be extended to focus on mothers' consumption choices that affect both their own health and fetal health. Suppose now that the parent receives utility from consuming S, X, and her own health H, and additional utility from her child's health IH. Assume the parent's utility is a separable function of consumption utility (U) and utility (W) from child health: utility = U (X, S, H) + W (IH). Parent health and child health are produced according to household production functions: H = H(S) and IH = IH (S). (This abstracts from the use of prenatal care, to simplify the presentation). A smoking parent chooses S and X to maximize her utility subject to a standard budget constraint and the household production functions; call these optimizing choices S* and X *, with the corresponding parental and child health consequences H* and IH*. For the parent who finds it optimal to quit smoking, call her optimizing choices of consumption S** = 0 and X**, with the corresponding parental and child health consequences H** and IH**. The net benefits of quitting smoking are therefore given by:

$$(1) \qquad NB = \{U [0, X^{**}, H^{**})] + W [IH^{**}]\} - \{U [S^*, X^*, H^*] + W [IH^*]\}$$

Equation (1) can be seen as the motivation for the empirical research on smoking during pregnancy discussed below. If NB > 0, the individual is observed to quit smoking; otherwise the individual remains a smoker. Equation (1) provides the basis for comparative static predictions about the determinants of smoking cessation. Pregnancy increases the net benefits of smoking cessation through the W[ ] terms in equation (1). Standard arguments suggest that cigarette prices, income, and various demographic characteristics and life cycle events also enter as possible determinants of NB.

To derive the implications of maternal smoking decisions for valuing infant health, consider a smoker who quits because of pregnancy or a new child. Before children her optimal choice was to smoke, so the parent's direct utility from consumption is lower when she quits to improve child health:

$$(2) \qquad ?\ U = U(0, X^{**}, H^{**}) - U(S^{*}, X^{*}, H^{*}) < 0$$

Measured in utility units, ? U is the net consumption utility foregone in order to invest in infant health. But for the smoker who finds it optimal to quit, NB > 0, which implies:

$$(3) \qquad ?\ U < ?\ W = W[IH^{**}] - W[IH^{*}]$$

From (3), the consumption utility foregone is generally a lower bound to the parent's utility gain from the infant health improvement due to smoking cessation. For the marginal quitter, the consumption utility foregone will just equal the utility of the child health improvement. Thus, an estimate of the dollar value of the consumption utility foregone provides a measure that is a lower bound to the value of the infant health improvement from maternal smoking cessation.

Methods from applied welfare economics provide a precise definition of the value of the consumption utility foregone from maternal smoking cessation. To account for the dollar value of this utility loss, the framework can be re-stated in terms of the indirect utility function. Let v (p, Y) be the indirect sub-utility function for parent's consumption of S, X and H. Given prices ps0 , px0 and income Y^0 , define the indirect sub-utility from consumption before child health concerns with choices S*, X* and H* as v* = v(ps0, px0, Y^0). Given the same prices and income, but rationing the consumer to S** = 0, let her indirect sub-utility be given by v** = v(ps0, px0, Y^0; s** = 0). A dollar-valued measure of the utility from goods consumption foregone to invest in health is the compensating variation (CV) in income implicitly defined by:

$$(4) \qquad v(ps0, px0, Y^0) = v(ps0, px0, Y^0 + CV; S^{**} = 0)$$

This compensating variation is the amount the consumer would have to be paid after she has quit smoking to give her just as much consumption utility as she received when she was a smoker. Because the parent quit smoking due to infant health concerns, CV will be the operable definition of the parent's willingness to pay for infant health.

The CV can be approximated using standard methods from applied welfare economics (Deaton and Muellbauer 1980, Varian 1978). In that approach, the CV implicitly defined by equation (4) can be related to an area of consumer's surplus measured to the left of a compensated (utility-held-constant or Hicksian) demand curve for cigarettes. The appropriate area is measured with reference to a "virtual price" of cigarettes, ps1 that would convince the consumer to quit smoking even before child health concerns (see Neary and Roberts 1980, and a similar application by Kenkel 2002). The empirical estimates reviewed below provide measures of the effect of pregnancy, a new child, and cigarette prices on the decision to quit smoking. The estimated effects can be used to calculate the virtual price increase that has the same effect as a pregnancy or new child. Consumers' surplus can then be calculated using estimates of the price elasticity of smoking. Although the price elasticity estimates will correspond to an ordinary demand curve, the area CV measured with an ordinary demand curve approximates the exact measure of compensating variation (Willig 1976).

The simple model used to derive parents' willingness to pay for infant health abstracts from addiction, a potentially important aspect of decisions about cigarette and alcohol consumption. Consumers' surplus needs to be carefully interpreted in the context of an addictive good. Most smokers report a desire to quit, but this does not invalidate economic models of smoking (Viscusi 1992b). The fact that they continue to smoke despite a stated desire to quit means that quitting is costly; addiction may mean that this cost is better interpreted as the pain of quitting rather than the foregone pleasure of smoking. Regardless how this cost is interpreted, estimates of the costs smokers incur to quit smoking when pregnant reveal their willingness to pay for child health.

Another concern is that estimates of smokers' or drinkers' willingness to pay for infant health underestimate the average parents' willingness to pay. Research suggests that smokers have different risk preferences from nonsmokers (Hersch and Pickton 1995, Viscusi and Hersch 2001). Assuming their willingness to pay for child health shows the same patterns, the estimates of average smokers' willingness to pay will be a lower bound to average parents' willingness to pay for child health. A related issue is that smokers appear to process risk information differently (Viscusi, Magat, and Huber 1999). Smokers may have placed a low weight on reports linking secondhand smoke to child health. In this case, smokers may be relatively unwilling to change their behavior partly because they are using low risk assessments. These limitations should be kept in mind.

Empirical Estimates of Maternal Demand for Cigarettes and Alcohol During Pregnancy

Table 3 lists six empirical studies of the demand for cigarettes and alcohol during pregnancy. Four of the studies explore the determinants of pregnant women's smoking participation, i.e. whether or not they are regular smokers. One study explores the determinants of both smoking participation and the daily consumption of cigarettes conditional on being a current smoker; another study explores the determinants of drinking participation and the monthly consumption of alcohol conditional on being a drinker. Three of the studies of smoking participation use data from the national natality files, which starting in 1989 include an indicator of whether the mother smoked during pregnancy. The first such study by Evans and Ringel (1999) uses a sample of over 10 million births between 1989 and 1992, and the subsequent studies by Ringel and Evans (2001) and Gruber and Koszegi (2001) increase the sample size further by extending the sample period. Colman, Grossman and Joyce (2003) use an alternative data set overseen by the CDC, and by pooling together data from 10 states over the years 1993 - 1999 obtain a sample of 115,000 women. The remaining two studies – Bradford's (2002) study of smoking and Kenkel and Lin's (2003) study of drinking – use a sample of about 6,000 women from the 1988 NMIHS, and its 1991 Followup. Although it is a smaller sample over a limited time period, the NMIHS provides much more detailed information about smoking and drinking behavior and the women's circumstances.

The main focus of research on the demand for cigarettes and alcohol during pregnancy is to estimate the price-elasticity of demand, to explore whether higher taxes might be effective to change these prenatal behaviors and thus improve health. For example, Ringel and Evans (2001) estimate a price elasticity of -0.7, which suggests that cigarette taxes may be a powerful tool to reduce smoking during pregnancy. However, as Corman, Grossman and Joyce (2003) point out, their estimate may be too optimistic: real cigarette prices have risen 60 percent since 1997, but smoking during pregnancy dropped by only 7.6 percent, not the 42 percent drop implied by a price elasticity of -0.7.

Bradford (2002) uses data from the 1988 NMIHS and its 1991 Followup to conduct a more in-depth study of smoking behavior during pregnancy. Kenkel and Lin (2003) also use the NMIHS data to conduct a similar study of drinking behavior during pregnancy. The NMIHS is a sample of women who were pregnant in 1988, and some but not all of these women were again pregnant when they were re-surveyed in the 1991 Followup. As a result, these studies are able to estimate the impact of both pregnancy and prices on maternal behaviors. For example, Bradford finds that during pregnancy light smokers reduce consumption by 1.6 cigarettes per day, moderate smokers reduce their consumption by 3.4 cigarettes per day, and heavy smokers reduce their consumption by 5.7 cigarettes per day. Analogously, Kenkel and Lin estimate that during pregnancy, a drinking mother reduces her alcohol consumption by 4.5 drinks per month, and again there are differences in the response of light and heavy drinkers. Because they also estimate the price elasticity of cigarette and alcohol demand by pregnant women, the studies by Bradford (2002) and Kenkel and Lin (2003) can be used to implement the valuation approach based on consumers' surplus calculations.

Illustrative Calculations of Willingness to Pay for Infant Health

To illustrate the approach to infant health valuation, this section presents back-of-the-envelope calculations of the values that are revealed by smoking and alcohol consumption decisions. Bradford (2002) estimates that light smokers voluntarily forego from $610 to $800 in consumers' surplus in response to pregnancy, while heavy smokers having their first child forego over $2,800 in surplus during pregnancy. According to information from the USDHSS (2001), smoking during pregnancy increases the rate of perinatal mortality (still births and neonatal deaths) from about 8 per 1,000 births to about 10 per 1,000 births. A heavy smoker who quits while pregnant therefore gives up $2,800 to reduce perinatal mortality risks by 0.002. Together these numbers imply that the value of a statistical life for an infant is $1.4 million. While many caveats obviously apply, this back-of-the-envelope estimate compares reasonably well to other estimates of the value of life of adults and older children.

Analogously, Kenkel and Lin (2003) calculate the consumers' surplus drinking mothers give up during pregnancy. On average, during the entire pregnancy, the forgone consumer surplus for an average drinking mother is about $37.8.[6] However, this average obscures important differences between three groups of drinking mothers: light drinkers, moderate drinkers, and heavy drinkers. It is useful to explore the surrendered consumer surplus for sub-populations since studies have shown that heavy drinking mothers impose higher risks on their unborn children than moderate and light drinking mothers do.[7] A drinking mother with less than 31 drinks monthly is defined as a light drinker; one with 31 to 59 drinks monthly is defined as a moderate drinker, one with at least 60 drinks monthly is defined as a heavy drinker. This definition is the same as that in most alcohol studies. On average, a heavy drinking mother surrenders $451.3 in consumer surplus; a moderate drinking mother surrenders $ 247.9 and a

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6 For those drinking mothers who choose to quit during pregnancy, the surplus foregone can only be viewed as a lower bound of their perceived value to invest in their unborn child's health.

7 In Quelette et al. (1977), babies born to heavy drinkers had twice the risk of abnormality over those born to abstainers or moderate drinkers. They find that 32% of infants born to heavy drinkers demonstrated congenital anomalies; as compared to 14% in the moderate group and 9% in the abstinent group.

light drinking mother surrenders $24.2. Heavy drinkers, compared to moderate and light ones, give up much more in consumer surplus since they perceive a larger benefit from reducing alcohol consumption during pregnancy. A conservative incidence rate is that among heavier drinking women the incidence of Fetal Alcohol Syndrome (FAS) is 1 in every 1000 live births.[8] Because an average heavy drinking mother reveals her willingness to pay to reduce probability of FAS by 1/1000 is $451.3, this implies the value of a statistical case of FAS is $451, 300. By way of comparison, the cost of illness estimates of Harwood and Napolitano (1985) value a case of FAS at about $347,000 (in 1990$).

VI. Impact of Public Policies on Infant Health and Implications for Valuation

Willingness to Pay Expression

There are at least two challenges to estimating willingness to pay from empirical studies of the impact of public policies on infant health. First, it may not be possible to recover the necessary structural parameters from the reduced form equations estimated. Second, in many cases a change in public policy represents a non-marginal change. The first point is similar to Rosenzweig and Schultz's (1983) criticism of what they term "hybrid" health equations. In a so-called hybrid equation, one input, for example prenatal care, and variables like income and prices that are the determinants of the other inputs, are regressed against a measure of health. The results are often interpreted as the causal effect or marginal product of prenatal care. However, Rosenzweig and Schultz (1983) argue that this interpretation is invalid: they show that the

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8 Estimates of FAS prevalence vary from 0.5 to 3 per 1000 live births in most populations. However, the prevalence rate in some American Indian communities is as high as 9 per 1000 births.

estimated effect of prenatal care on health from such an equation embodies both technology parameters of the health production function and preference parameters of the utility function.

Even compared to a hybrid health equation, the approach of many empirical health economics studies is further away from structural estimation of the household health production function. For example, Currie and Gruber (1996) estimate the impact of Medicaid expansions on infant mortality. In essence, Medicaid as a determinant of the use of prenatal care has been substituted into the hybrid equation. The resulting reduced-form equation may be a desirable approach to estimate the impact of the specific policy change. But the estimated effect of Medicaid now combines the impact of Medicaid on the use of prenatal care (a demand effect) and the impact of the use of prenatal care on infant health (a production function effect). It might be possible to use additional information or assumptions about some of the structural demand parameters to disentangle the effects. If the policy change can be treated as a marginal change, it would be then be possible to derive estimates of the marginal product of prenatal care in producing infant health. Such an estimate could be used in the expression derived above for the marginal willingness to pay for infant health.

However, as has been already noted, in many cases discrete policy changes represent non-marginal changes. Bockstael and McConnell (1983) suggest that it may be possible to value such changes with reference to the areas behind appropriate marginal value and marginal cost curves. Bockstael and McConnell provide a general discussion of welfare measurement in the household production framework, emphasizing the distinction between a commodity such as infant health and the market goods that are used as inputs to produce the commodity. They show how the welfare effect of a change in the level of a public good can be measured either in the hypothetical ‘market’ for the commodity (output) or in an actual market for a good (input). The welfare measure in the goods market is empirically implementable, and corresponds to the change in the area behind a compensated demand curve for an input that is caused by a change in the level of a public good. Dickie and Gerking (1991) use this approach to infer willingness to pay for ozone control from the demand for medical care.

Some empirical studies estimate the impact of a policy on both the commodity infant health and its impact on the use of a health input like prenatal care. This raises the hope that the results are informative about the change in the area behind the demand curve for prenatal that results from the policy change. As in the similar example of Dickie and Gerking (1991), it is probably reasonable to assume that prenatal care satisfies the assumptions needed for the Bockstael and McConnell (1983) approach to be valid. And although privately and publicly insured consumers may pay little or no out–of-pocket monetary costs for prenatal care, a demand curve can be still derived with respect to travel and time costs incurred. With estimates of the demand curve and how the policy changes the demand curve, in principle it should be possible to implement the welfare measurement derived by Bockstael and McConnell (1983). However, the problem of recovering structural parameters from reduced-form equations re-appears. In this case, the problem is to recover a demand function from a reduced-form equation showing the impact of a policy change on input usage. For example, it may not be clear if the estimated effect of the policy is on the demand side through changes in consumers incentives or the supply side through changes in providers’ incentives. It may again require extra information or assumptions to identify the parameters of the demand function needed to implement the Bockstael and McConnell (1983) welfare measure.

Empirical Estimates of the Impact of Public Policies on Infant Health

Table 4 lists 10 studies of the impact of public policies on infant health. In all but one study, the focus is on public policies such as Medicaid that are targeted at low-income and disadvantaged populations. All of the studies examine the impact of a policy on some measure of infant birthweight, with the focus often being on low birthweight and very low birthweight as the most serious adverse outcomes. At least four of the studies also estimate the impact of the policy under study on the use of prenatal care. At least some of the remaining studies measure prenatal care, but it may not be used as an outcome variable. For example, Currie and Cole (1993) include prenatal care use as an explanatory variable to estimate the impact of AFDC participation on infant birthweight, controlling for differences in prenatal care use. Currie and Cole (1993) do not provide a structural interpretation of the estimated impact of AFDC participation, but note that it may combine an income effect with an additional effect due to improved access to a range of other services from the welfare system.

Illustrative Calculations of Willingness to Pay for Infant Health

Existing research on the impact of natural policy experiments on infant health inputs and outcomes does not support calculations of willingness to pay for infant health. As discussed above, such calculations require additional information or assumptions to: (a) recover structural parameters from the estimation results; and (b) implement the appropriate welfare measure for a marginal or non-marginal change. Alternatively, an avenue for future work might be to re-analyze these data sets to estimate the value of infant health.

VII. Discussion

The review of empirical health economics research suggests a potential vein to be mined for information on the value of fetal and infant health. As discussed in section III, it is probably most straight-forward to derive estimates of maternal marginal willingness to pay for infant birthweight. Because birthweight is associated with infant mortality and a range of subsequent outcomes, it is a useful summary of infant health. Similarly, estimates of the value of birthweight are potentially useful for the benefit-cost analysis of a variety of environmental and public health policies. For example, food safety regulations to prevent exposure to *Toxoplasma gondii* reduce risks for infants (Roberts and Frenkel 1990). Previous analyses that value reduced infant mortality risks based on the discounted present value of lifetime earnings may substantially underestimate willingness to pay.

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Prenatal Investment-Exercise

	Full Sample	Live Birth Sample	Fetal Death Sample	Infant Death Sample
	N=18,594	N=9,953	N=3,309	N=5,332
exercise 3+ times a week before found out pregnancy	47%	47%	42%	43%
exercise 3+ times a week after found out pregnancy	42%	42%	36%	34%
start to do exercise 3+ times after found out pregnancy	7%	8%	6%	6%
quit doing exercise after found out pregnancy	13%	13%	13%	15%
months of doing exercise during pregnancy	2.76	2.77	2.07	1.87

Prenatal Investment-Prenatal Care

	Full Sample	Live Birth Sample	Fetal Death Sample	Infant Death Sample
	N=18,594	N=9,953	N=3,309	N=5,332
prenatal childbirth class	38%	38%	27%	19%
prenatal care	98%	98%	97%	94%
number of prenatal visits	12.87	12.90	11.32	10.27

Prenatal Investment-Vitamins Intake (at least 3 days a week during the three 3 months before found out pregnancy)

	Full Sample	Live Birth Sample	Fetal Death Sample	Infant Death Sample
	N=18,594	N=9,953	N=3,309	N=5,332
multivitamins and/or minerals	26%	26%	25%	25%
Vitamin A	2%	2%	2%	2%
Vitamin C	4%	4%	5%	4%
Folic Acid	1%	1%	1%	1%
Calcium	4%	4%	4%	4%
Iron	9%	9%	10%	11%
Zinc	1%	1%	1%	1%

Prenatal Investment-Vitamins Intake (at least 3 days a week during the three 3 months after found out pregnancy)

	Full Sample	Live Birth Sample	Fetal Death Sample	Infant Death Sample
	N=18,594	N=9,953	N=3,309	N=5,332
multivitamins and/or minerals	81%	81%	79%	76%
Vitamin A	3%	3%	3%	3%
Vitamin C	4%	4%	4%	4%
Folic Acid	3%	3%	3%	2%
Calcium	8%	8%	8%	8%
Iron	33%	33%	33%	35%
Zinc	2%	2%	1%	2%

Prenatal Investment-start to take vitamins at least 3 days a week after found out pregnancy

	Full Sample	Live Birth Sample	Fetal Death Sample	Infant Death Sample
	N=18,594	N=9,953	N=3,309	N=5,332
multivitamins and/or minerals	57%	57%	56%	52%
Vitamin A	2%	2%	2%	2%
Vitamin C	2%	2%	2%	2%
Folic Acid	2%	2%	2%	2%
Calcium	6%	6%	6%	6%
Iron	27%	27%	26%	27%
Zinc	1%	1%	1%	1%

Prenatal Investment-Cigarette Consumption

	Full Sample	Live Birth Sample	Fetal Death Sample	Infant Death Sample
	N=18,594	N=9,953	N=3,309	N=5,332
smoking participation before the 12 months of delivery	30%	30%	33%	37%
smoking participation after found out pregnancy	22%	22%	25%	30%
number of cigarettes per day before found out pregnancy	4.84	4.83	5.28	5.84
number of cigarettes per day after found out pregnancy	2.69	2.68	3.01	3.43
quit smoking after found out pregnancy	8%	8%	8%	7%

Prenatal Investment-Conditional Cigarette Consumption

	Full Sample	Live Birth Sample	Fetal Death Sample	Infant Death Sample
number of cigarettes per day before found out pregnancy	16.15 (N=5,973)	16.15 (N=2,986)	16.24 (N=1,083)	15.92 (N=1,908)
number of cigarettes per day after found out pregnancy	12.06 (N=4,720)	12.07 (N=2,326)	12.15 (N=838)	11.60 (N=1,556)

Prenatal Investment-Alcohol Consumption

	Full Sample	Live Birth Sample	Fetal Death Sample	Infant Death Sample
	N=18,594	N=9,953	N=3,309	N=5,332
drinking participation before the 12 months of delivery	45%	45%	42%	43%
drinking participation after found out pregnancy	21%	21%	16%	18%
number of drinks monthly before found out pregnancy	4.07	4.06	3.92	4.39
number of drinks monthly after found out pregnancy	0.72	0.72	0.78	1.09
quit drinking after found out pregnancy	25%	25%	26%	25%

Prenatal Investment-Conditional Alcohol Consumption

	Full Sample	Live Birth Sample	Fetal Death Sample	Infant Death Sample
number of drinks monthly before found out pregnancy	9.03 (N=7,185)	9.02 (N=3,781)	9.37 (N=1,318)	10.24 (N=2,086)
number of drinks monthly after found out pregnancy	3.50 (N=3,145)	3.47 (N=1,738)	5.03 (N=522)	6.17 (N=885)

Table 2: Infant Health Production Function Estimates

Study	Health output	Data
Rosenzweig & Schultz (1983)	Birthweight in grams	1967-69 U.S. National Natality Followback Surveys
Corman, Joyce and Grossman (1987)	Neonatal mortality; Low birthweight (below 2500 grams)	county-level data
Rosenzweig and Schultz (1988)	Birthweight (grams)	1980 National Natality Survey
Joyce, Grossman and Goldman (1989)	Neonatal mortality	1977 county-level data
Grossman and Joyce (1990)	Birthweight (grams)	1984 New York City Vital Statistics
Jones (1990)	Low birth weight (below 2500 grams)	1984 state-level data
Frank, et al. (1992)	Low birthweight (below 2500 grams)	1975 - 1984 county-level data from natality files
Joyce (1994)	Birthweight (grams)	1984 New York City Vital Statistics
Warner (1995)	Birthweight (grams)	1980 - 1990 New York City Vital Statistics
Warner (1998)	Birthweight (grams)	1988 NMIHS
Liu (1998)	Birthweight (grams)	1984 Virginia birth and abortion certificates

Table 3: Maternal Cigarette and Alcohol Demand during Pregnancy

Study	**Demand measure**	**Data**
Evans and Ringel (1989)	Smoking participation	1989 - 1992 national natality files
Ringel and Evans (2001)	Smoking participation	1989 - 1995 national natality files
Gruber and Kosegi (2001)	Smoking participation	1989 - 1996 national natality files
Bradford (2002)	Smoking participation; conditional quantity demanded	1988 National Maternal and Infant Health Survey, and 1991 Followup
Colman, Grossman and Joyce (2003)	Smoking participation	1993 - 1999 Pregnancy Risk Assessment Monitoring System
Kenkel and Lin (2003)	Drinking participation;. Conditional quantity demanded	1988 National Maternal and Infant Health Survey, and 1991 Followup

Table 4: Empirical Estimates of Public Policies on Infant Health

Study	**Policy**	**Outcome**
Devaney, Bilheimer and Schore (1992)	WIC participation; prenatal care	birthweight; Medicaid costs
Currie and Cole (1993)	AFDC participation	birthweight
Reichman and Florio (1996)	New Jersey Health Start Program	birthweight; hospital costs
Currie, Nixon and Cole (1996)	restrictions on Medicaid funding of abortion	birthweight; pregnancy outcomes
Currie and Gruber (1996)	Medicaid expansions	birthweight; infant mortality
Levinson and Ulman (1998)	Medicaid managed care	prenatal care; birthweight
Joyce (1999)	New York State's Prenatal Care Assistance Program	birthweight
Dubay, Kaestner and Waidmann (2001)	malpractice insurance reform	prenatal care; birthweight
Gray (2001)	Medicaid physician fees	prenatal care; birthweight
Currie and Grogger (2002)	Medicaid expansions; Welfare reform	Use of prenatal care; fetal deaths

Valuing Fetal and Infant Heath Effects

Trish Hall
US EPA

Overview

- Introduction
- Why valuation is important
- Discussion of the papers from a policy perspective
- Summary

Why is it important to value fetal and infant health effects?

- The ability to monetize benefits is critical to the regulatory development process
  - Benefit transfer using adult values is controversial
- Improved information regarding fetal and infant health effects
  - Birth defects
  - Fetal loss
  - Endocrine disrupters

Why is it important to value fetal and infant health effects?

- Magnitude of the problem: Fetal Loss Example
  - Approximately one million fetal losses per year in the US
    - small change in risk = large reduction in cases = large benefits

Comparison in brief

- Mother's decisions regarding her own health reveals how she values the health of her unborn child
- Specific values of unborn child or infant are not considered
- Same data set: 1988 National Maternal and Infant Health Survey
- A good first step

Policy Implications:
Nastis & Crocker

- Conclusion: A mother values the health of her fetal child about six times more than she values her own health
- Interpretation?
  - Fetal child can be valued at six times the adult value (either VSL or WTP)?

Points to Consider

Nastis & Crocker

- Impact of elimination criteria
  - did not include gestations less than 20 weeks
  - only considered singleton births to mothers 35 or younger excluding adolescents
- Specific findings may not have an impact on national-level analysis
  - A mother's first-borne child is valued more than her subsequent children
  - Nonsmoking mother value their children more highly than smokers do

Policy Implications

Kenkel

- Conclusion: Varies depending on which approach is used
  - prenatal care and birthweight
  - cessation of smoking or drinking
- Interpretation:
  - Designed to explore existing health data but illustrative calculations could be beneficial to policy analysis

Policy Implications

Kenkel

- Conclusion from Prenatal care and Birthweight:
  - Marginal WTP $6 per extra gram of birth weight
- Interpretation?
  - Could be useful if we can determine a relationship between exposure and birthweight

Policy Implications

Kenkel

- Conclusion: VSL for an infant can be calculated using the two methodologies
  - Prenatal care = $43,000 to $1.5 million
  - Smoking cessation = $1.4 million
- Interpretation-
  - Provides estimate of magnitude of loss from mother's perspective
  - Application may be limited

Points to Consider

Kenkel

- Voluntary vs. Involuntary Risks
  - smoking/drinking vs. exposure to environmental contaminants
- Consider using elimination criteria outlined in Nastis & Cocker

Note about Terminology

- Both papers use terms such as child, fetal child, neonate, and infant interchangeably
  - consistency needed
  - clarify what specific valuation refers too

Summary

- Fetal and infant valuation is an extremely complex issue but also extremely important to public policy

- Quantitative applications limited
  - but improves are ability to discuss the magnitude of impacts

Summary of Q&A Discussion Following Session III

Glenn Harrison (University of Central Florida) opened by saying, "I guess only Kerry Smith could with a straight face say that he did a study of fertility amongst couples and concluded that there is an important interaction between the male and female," to which Dr. Smith retorted, "This came as a big surprise to me!"

Directing his next comment to Tom Crocker and Don Kenkel, Harrison continued by stating what he felt was a very important issue for the purpose of this workshop: the fact that "the extent to which the mother or the parent cares about the kid's health relative to her own, or we try to draw the similar source of conclusions about the ratio of willingness to pay" may depend on other motives in addition to the commonly assumed motive of health concerns. He noted that Dr. Smith and Dr. Crocker were careful to talk about *contemporaneous* sets of choices, and he suggested, "But let's have a minimal–*minimal*–two-period contemporal choice by the mother, where the mother–forgive me if there are any pregnant women in the house, because they'll kill me–where the mother *only* cares about the consumption value of the child, from her own perspective, in the future period. In other words, if the kid is born unhealthy, it's a *pain* for the mother–it reduces her consumption in the following period, and that at least deserves some weight–we'll let the data put what actual weight is on it." Harrison went on to explore the situation in which the mother cares about the child's health *exactly* to the extent of her own, claiming that "it could be contemporaneous because it could cause pregnancy complications for the mother herself if she doesn't look after the kid, so that they're highly correlated, but very physically." He closed by reiterating that "it could be that everything you two [i.e., Crocker and Kenkel] label as the ratio of caring about the infant's health to the mother's health is simply the mother caring about her future consumption, and it's got nothing to do with the children." This is a fundamental idea, he said, that "everyone at this workshop has to address somehow rather than just *impose* their politically correct view on the observed behavior."

Tom Crocker responded that he absolutely agreed that "introducing an additional period, or a sequence of periods, after the birth into the mother's expected utility" makes sense. He stated that it was mentioned but not made explicit in the model "in that the mother has to worry about how much effort she will have to put forth and the extent to which she can care for the child." He acknowledged that this was a good point, though a very complex issue.

Don Kenkel said that he agreed also and explained that in the interest of constructing a simple model, he had assumed that the only reason women were interested in good health was through the preference function. For clarification, he asked Dr. Harrison whether he was saying that health decisions also enter the budget constraint with regard to future consumption. When Harrison confirmed this, Kenkel responded that he had "assumed that away" and acknowledged Dr. Smith's point that these assumptions are important to the willingness to pay expression and interpretations.

Harrison then followed up with a related observation regarding the smoking data that had been cited. He emphasized that the data revealed *dramatic* reductions in expectant mothers' smoking *during* the pregnancy (and he acknowledged that the timing—after the first trimester or before—is an important issue) followed by a resumption of smoking or of higher levels of smoking after the pregnancy is over. To make his point, he further stated that if the data show that the mothers tend to resume the same level of smoking that they engaged in before the pregnancy, then there would be some basis for assuming that the smoking modification was motivated by concerns for the fetuses' health. Reiterating Dr. Smith's point, he closed by saying, "You've gotta have some more handles in order to draw that and tease those motives."

Don Kenkel responded by saying, "Empirically, you're exactly right–a lot of women quit smoking, but *just* during pregnancy, and there's this *incredible* recidivism effect where after the pregnancy is over they start back up smoking."

Dr. Crocker added, "From a structural perspective, what you're saying also implies that to explain the consumption of drinking or smoking post-natal requires that one go back and look at the mother's decisions while she was pregnant, simply because her decisions while she was pregnant may very well affect her demand for inputs–smoking, drinking–after the child is born."

Dr. Smith commented that one of the reasons why he and his colleagues were interested in looking at the restrictions of the negative preferences anew is that "weak complementarity and weak substitution are actually examples of discontinuities in preferences, where there is a change–and that's really what's important about them–and we lose track of that when we focus exclusively on the zero consumption level." He went on to agree with Glenn Harrison that there are lots of other points of discontinuity where there are abrupt changes in behavior, and he stated that these situations provide *really important* information for answering some of these questions. He concluded by adding that "oftentimes, in the health data sets and these kinds of other behaviors there are real opportunities to get at those discontinuities, and we're just failing to use them."

Dr. Crocker commented that he doesn't understand the appeal to weak complementarity when dealing with health considerations. He stated that it makes sense when dealing with recreation—for example, if your pond is polluted and you don't fish, then you'll have no demand for fishing rods. He concluded by saying, "But if you're in poor health, why it is that you have no demand for health inputs is a bit beyond me. I would think you'd have *more* of a demand for health inputs, for cleaner air, if in fact you're in poor health."

Glenn Harrison replied that there are certain segments of the population for whom the non-pecuniary costs of availing themselves of health inputs are massive. He cited the "huge differences in black/white fetal death rate and infant death rate" that most studies attribute largely to the real costs of getting off work, traveling to a healthcare setting, arranging baby care, and so forth. In closing he said that "there are some stories there" for anyone who takes the time to tease the racial differences apart.

Partly in response to Dr. Crocker's comment, Dr. Smith offered this clarification: "If a person is not sick chronically with asthma or something else, you don't have a demand for care-giving activities. That would be an example of weak complementarity. If on the other hand, you live in an area where there is a high level of ozone or something and you have a child . . . in a highly polluted area with ozone or something, you might take some mitigating behavior, which would be more like weak substitution–you would not allow the child to play outside, let's say, on an ozone-alert day or something like that. So, the point is the discontinuity arises as a consequence of the child's condition and what state the child is in in relationship to the environmental conditions, and it could be either weak complementarity or it could be weak substitution."

Scott Grosse (Centers for Disease Control and Prevention) responded to Dr. Crocker's paper by saying that he thought the meaning of "health" needs to be made clearer. He stated that weight gain during pregnancy is only one dimension of an expectant mother's health and that there are many other dimensions of the mother's health that possibly relate differently to the infant's health. He also suggested that it would be useful to have a comparable measure, such as healthy days–healthy days of the child, healthy days of the mother–by which one could actually make a comparison. Dr. Grosse went on to point out that gestational diabetes actually leads to higher birth weight and that anemia might present a different relationship for every dimension of maternal health. Factors such as these make it very difficult to generalize about the relative value of weight gain during pregnancy.

In agreement, Don Kenkel replied, "And to make Kerry's point: We have multiple attribute health production–health outputs, as they say. Just think of the extra structure we have to impose to estimate all the different marginal products."

Valuing Environmental Health Risk Reductions to Children

PROCEEDINGS OF

SESSION IV-AM: AGE-SPECIFIC VALUE OF STATISTICAL LIFE ESTIMATES

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE), NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER), AND OFFICE OF CHILDREN'S HEALTH PROTECTION; AND THE UNIVERSITY OF CENTRAL FLORIDA

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Session IV-AM: Age-Specific Value of Statistical Life Estimates

Valuation of Cancer Risk in Children and Adults in Minnesota

Nathalie Simon and Chris Dockins, US EPA[1]

presented by Chris Dockins

In Minnesota, there is some expectation among health policy professionals that "negligible risk" may soon be defined more stringently for cancer risks that affect children, resulting in standards for cancer risk setting of 1 in a million rather than the current level of 1 in 100,000. How exactly such standards could be effected in practice is a difficult question, and it is possible that the de facto outcome of this type of policy change would be a 1 in a million negligible risk standard for virtually all contaminants in an effort to protect children.

Faced with the possible need to assess the merits of this approach the Minnesota Department of Health (MDH) asked EPA for information on recent or ongoing work that could answer questions about the extent of risk avoidance, especially cancer risk, that the public believes is appropriate for adults and children. The economics literature is quite sparse in the areas of children's health valuation and cancer risk valuation generally and as such currently contains little guidance on this question. To fully address this issue requires assessment of at least two largely unaddressed sources of heterogeneity in risk valuation: age (or, more specifically, adult/child status) and cancer.

Surprisingly, given the current crises faced by state governments across the country, the MDH secured state funding to investigate these questions with an eye toward developing a survey of state residents. After learning that EPA's National Center for Environmental Economics (NCEE) and Office of Children's Health Protection (OCHP) had an ongoing interest in promoting work in this field, MDH approached EPA for technical consultation regarding survey development on these issues. After a series of meeting in which we each presented our existing work on valuation and children's health and identified mutual research interests, we resolved to develop a survey instrument that would address the following questions:

- How do public preferences compare with private preferences for risk reduction
- How do Minnesota residents perceive and value lifetime or long-term cancer risks
- What generally are the public and private preferences in Minnesota for reduced risks of dying from cancer as an adult from (1) child exposure and (2) adult exposure?
- How does the length of the latency period affect valuation estimates for cancer risk reductions? Does this vary between adult exposures and child exposures?

[1] The opinions expressed in this paper are those of the authors and do not necessarily represent the US EPA. Also, this work is being developed in consultation with a consortium of government analysts and academicians in Minnesota, including: Pamela Shubat, Chuck Stroebel, and Amy Lockheart at the Minnesota Department of Health (MDH); Pat Welle at Bemidji State University; Andy Klemer at the University of Minnesota-Duluth; and Becky Judge, St. Olaf College.

We began by holding a series of focus groups in order to understand some fundamental perceptions and concerns about environmental cancer risks in Minnesota. These focus groups included parents and non-parents, and sought to represent a general cross-section of the adult population in the state. Because about half of the state population live in the greater Minneapolis-St. Paul metropolitan area, we held four of the eight focus groups we conducted in that area with the remaining four groups held in the cities of Mankato, Rochester, Duluth, and Bemidji. The locations outside of the twin-cities area were chosen to capture regional variation in risk attitudes and perceptions. In particular, Mankato was chosen because of the heavy agriculture industry in the area, while Duluth was chosen because of its size and role as a shipping port and industrial center. Bemidji was chosen as representative of the northern portion of the state which is dominated by lakes and recreational opportunities. The area around Bemidji also has a relatively large Native American population. Finally, Rochester is one of the three largest cities in Minnesota and was chosen to be representative of the state to the southeast of the twin cities.

Distinct materials were developed to guide the discussion in each focus group and these materials evolved over time.[2] In general, we developed scenarios to address both public and private "goods" that would reduce carcinogenic exposure to adults and children. These exposures would cause cancer with a latency period. We began by testing scenarios for risk reductions that were based on specific contaminants (e.g., benzene) and specific types of cancer (e.g, brain cancer and kidney cancer). Further, in an attempt to separate risk reduction possibilities for adults and children we initially focused on scenarios with separate exposures and policies for adults and children. For example, some hypothetical situations considered policies targeted narrowly at reducing exposure to carcinogens in schools, which would primarily, but not exclusively, affect children.

Because MDH and NCEE wanted to focus on long-term cancer risks, we initially presented focus groups with a presentation of lifetime cancer risks including detailed information on the when risks were reduced. In their most complex form this information was presented as distributions of risk over a lifetime based on data from the National Cancer Institutes SEER database. We also presented separate displays of magnitude of lifetime risk reduction accompanied by stylized displays of the distribution of the reduction over time.

What did the focus groups tell us? First, any scenario that involved public risk reduction paid for through a tax mechanism was rejected. The size and distribution of state taxes is simply too sensitive a topic to be included in the hypothetical scenario. Interestingly, however, when public interventions are portrayed as a rise in prices for associated commodities, food prices, for example, there was little rejection of the policies based on payment mechanism.

Local issues played a key role in the perceptions of environmental policies to reduce cancer risk. In Duluth, for example, residents were keenly aware of surface water quality and

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[2]In keeping with Paper Work Reduction Act requirements, no more than 9 people participated in each of our focus group discussions. Topics and materials developed to guide discussions varied across focus groups.

could even recall specific state recommendations on fish consumption. The presence of a Superfund site near Bemidji seemed to increase the respondents sensitivity to environmental cancer risks in that area, while Mankato's concern for programs that might target pesticides reflected the region's economic reliance on agriculture.

We also found that respondents demanded more information on background mortality risks before responding to choice questions about cancer risk reductions. In fact, we modified the draft questions to explicitly account for non-cancer mortality risk to satisfy these concerns. Respondents also had difficulty linking specific exposure scenarios with specific cancers and other illnesses. Further, when the proposed risk reduction scenario required modification to existing systems in their home (e.g., installation of air filters), respondents required additional information on current risk levels before proceeding.

Finally, very initial responses suggest that there is little sensitivity to the timing of risk reductions associated with children's exposures to environmental carcinogens. This is perhaps not surprising considering there is a minimum of 30 years before childhood exposures become manifest in cancer outcomes. If choices for children's risk reduction reflect standard discounting assumptions then the difference in a risk reduction 40 years hence from one 50 years hence is small in present value terms. On the other hand, insensitivity to timing could simply reflect that parents are considering only whether the child will receive a risk reduction at any time, regardless of the time or magnitude. Additional interviews are necessary to determine how adults are considering long term risks to children.

So, where are we now? We have found that respondents accept our framing the scenario in terms of persistent environmental carcinogens in food as the source of environmental cancer risk and risk reduction. Also, respondents seem to accept distinguishing public and private programs by whether a testing program is optional (labeled foods at a premium price) or mandatory (all foods at an increased price). Risk reductions to adults vs. children are distinguished by whether the testing programs focus on contaminants primarily associated with (1) long-term cancer risks from child exposure, or (2) cancer risks from adult exposure. We have loosely correlated these with cancer initiators and cancer promoters, respectively.

Our risk communication devices are based on the grids recently developed and used by others in the literature (Alberini, et al.; Krupnick, et al.; Corso, et al.; Cameron and DeShazo). These grids include cancer and non-cancer mortality risks typically over a 20-year time period in order to respond to MDH's interest in views of lifetime cancer risks. We plan to experiment with animation to convey the timing and magnitude of risk reductions in additional cognitive interviews.

We anticipate continuing with survey development in the coming months. If all continues to go well, MDH will have the option of implementing their survey as early as summer 2004.

THE EFFECTS OF AGE AND FAMILY STATUS ON THE VALUE OF STATISTICAL LIFE: EVIDENCE FROM THE AUTOMOBILE MARKET AND A NATIONAL SURVEY OF AUTOMOBILE USE

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Research Strategy

We develop a theoretical model in which automobile safety is shown to be a family public good where the marginal cost of purchasing and operating a safer automobile is set equal to the usage-weighted sum of the values of statistical life (VSL) of family members.

Using this theoretical result we can estimate the VSL for different family members (children, adults and seniors) by collecting primary data on automobile usage by family members that is combined with secondary data from both the automobile market and the FARS data set on automobile accidents.

An important issue that has clouded the potential reliability of the VSL obtained from estimated hedonic price functions for automobiles (that include risk of death) is that prior studies have shown what appears to be a positive correlation between fuel consumption and the price of automobiles rather than the expected negative correlation since people should be willing to pay less for cars with poor fuel economy (See Atkinson and Halvorsen, 1990, and Dreyfus and Viscusi, 1995). Our theoretical work provides a possible explanation that also suggests a revised estimation procedure.

Theory: Fuel Consumption

To begin, we address the problem of fuel consumption by considering the case of a single individual (buyer) with no family who may, or may not, survive for a single period. We then consider the choice of fuel consumption by makers.

The Buyer's Decision:

Let

c = consumption,
w = wage income,
r = risk of a fatal automobile accident per mile driven,
Π = probability of survival without automobile fatality risk,
Π-r = probability of survival with automobile fatality risk,
m = total miles driven
a = level of some other automobile attribute
P(r,a) = automobile price per mile driven (decreasing in r)
F*(r,a)) = fuel consumption per mile (increasing in r and a)
G = price of fuel
U(c,a,m) = strictly concave utility function.
Note: subscripts or primes denote derivatives where appropriate.

Note that we propose that the individual realizes that the fuel consumption of the car is itself a function of the attributes of the automobile. We will justify this proposal when we consider the manufacturer's decision below.

To abstract from the life cycle issues of owning and financing an automobile, we analyze the problem in terms of the annualized price per mile of owning the vehicle, P, without loss.

The buyer is assumed to maximize expected utility,

$$(\Pi\text{-}rm)U(c, a, m), \tag{1}$$

where it is assumed that the death state provides no utility because the individual has no family, subject to the budget constraint,

$$(\Pi\text{-}rm)(w\text{-}c) - P(r,a)m - GF^*(r,a)m = 0. \tag{2}$$

The optimal choice for r, risk per mile, is determined by

$$VSL = -(P_r + GF_r^*), \tag{3}$$

where

$$VSL \equiv (U/U_c) + w - c. \tag{4}$$

The optimal choice of the attribute, a, is determined by

$$U_a/U_c = m(P_a + GF_a^*) \qquad (5)$$

The total miles driven, m, is determined by

$$U_m/U_c - rVSL - GF^* = P \qquad (6)$$

<u>The Maker's Decision</u>

Competitive automobile manufactures will be forced to minimize the cost per mile of driving their automobiles including both the capital and fuel cost per mile of automobile life given the choice of other characteristics (r and a).

Consider the design problem of a particular manufacturer with a cost of production per mile of life for the cars that they offer of C(r,a,F). Given a particular choice of r and a by buyers, the maker is forced by competitive pressure to minimize the total cost per mile to buyers,

$$C(r,a,F) + GF. \qquad (7)$$

The condition for optimal fuel consumption in the engineering design of the vehicle is then

$$-C_F = G. \qquad (8)$$

This implies that there is an optimum fuel consumption F*(r,a) for any choice by consumers of r and a and the cost function relevant for the hedonic price solution for profit maximization over r and a by the maker is C*(r,a,F*(r,a)).

The maker faces a hedonic price function only defined in r and a, P(r,a), not fuel consumption which is optimized in the engineering design of the vehicle, and maximizes profits

$$P(r,a) - C^*(r,a,F^*(r,a))$$

with respect to a, implying

$$P_a = C_a^*, \qquad (9)$$

and with respect to r, implying

$$P_r = C_r^*. \qquad (10)$$

In summary, given G, the price of fuel, the choice of F will be made by the automobile maker since fuel usage will be optimized by makers for any combination of attributes chosen by consumers. Consumers and makers are faced with a hedonic price function P(r,a) which is the envelope curve of the cost tradeoffs for makers and value tradeoffs for consumers between attributes. Buyers face a pre-optimized choice of fuel consumption, F*(r,a), for each level of attributes that they choose in their purchase decision.

If these arguments are correct, the appropriate procedure is to estimate F*(r,a) and P(r,a) and use (3) above to estimate the VSL for the individual from these relationships and the price of gasoline, G.

The VSL for Family Members

The model developed above can be extended to a family setting by using the Nash cooperative bargaining between parents approach employed by McElroy and Horney (1981).

Let

- i = 1, 2,….,n denotes individual family members,
- i = 1 denotes the mother,
- i = 2 denotes the father,
- i = k = 3, …..,n denotes children,
- c_i = consumption of the ith family member,
- w_i = wage of family member i,
- r= automobile fatality risk per family member per mile,
- Π_i = probability of survival, excluding automobile fatality risk, of i,
- m = total vehicle miles driven
- m_i = total miles of driving for family member i
- P(r,a) = automobile price per mile driven,
- F*(r, a) = fuel consumption per mile driven,
- $U^k(c_k,a,m_k)$ = child's utility function,
- $U^i(c_i;\ldots, m_i,a,(\Pi_k\text{-}r)U^k(c_k,m_k),\ldots)$ = parent's utility function, and
- E^i = individual expected utility in separation (i = 1, 2).

In the Nash cooperative bargaining solution,

$$[(\Pi_1\text{-}rm_1)U^1 - E^1]\ [(\Pi_2\text{-}rm_2)U^2 - E^2], \qquad (11)$$

is maximized with respect to c_i, r, a, m, and m_i,
subject to the budget constraint,

$$\sum_{i=1}^{n} (\Pi_i\text{-}rm_i)\ (w_i - c_i) - (P - GF^*)m = 0, \qquad (12)$$

and constraints on the use of the car such as,

$$m - m_i \geq 0 \qquad i = 1,\ldots, n$$

so that no individual family member can ride more miles than the car itself travels, and

$$m_1 + m_2 - m_{12} - m_k \geq 0 \qquad k = 3,\ldots, n$$

so that no child can ride more miles than the parents can collectively drive the child. Note that, to avoid pointless complication of the model, m_{12} is taken to be a constant.

The resulting conditions for choosing the level of automobile risk and miles driven imply that the individual VSLs of family members all take the form:

$$VSL_i \equiv U^i/U^i_c + w_i - c_i \qquad i = 1,\ldots,n. \qquad (13)$$

The choice of automobile risk, r, is determined by

$$\sum_{i=1}^{n} k_i VSL_i = -(P_r + GF_r^*) \qquad (14)$$

where usage weights for the vehicle for each family member are defined as $k_i = m_i/m$.

Estimation Strategy

Since available measures of vehicle safety are affected by selection bias (more dangerous drivers are attracted to Corvettes and safer drivers to minivans) the FARS data set was used to estimate vehicle risk for vehicles in the sample for a standard driver. This corrected risk is used in estimating the hedonic vehicle price function.

Hedonic vehicle price and separate fuel consumption equations were estimated to calculate the per mile cost of reducing risk for vehicles purely as a function of vehicle (not driver) attributes. This allows estimation of the rhs of equation (14).

Since data were not available on m_i and m, we conducted a national survey to obtain the necessary information to allow estimation of the VSL for children, adults, and seniors using equation (14).

Because m_i and m are endogenous variables in a system of simultaneous first order conditions, a two-stage procedure is required to obtain consistent estimates using equation (14). In the first stage, reduced-form equations for m_i and m are estimated using appropriate exogenous variables. The predicted m_i and m that are uncorrelated with the residuals in equation (14) are then used as instrumental variables for m_i and m to obtain consistent estimates of the VSL for children, adults and seniors.

Survey Design and Implementation

The survey consisted of two parts, a telephone screening survey used to develop an appropriate sample and collect information on usage, followed by a mail survey used to collect subjective probability measures.

Both the telephone and mail surveys were extensively pre-tested and revised prior to implementing a pilot aimed at 80 households to formally test the telephone/mail survey methodology.

The purpose of the telephone survey was to identify appropriate households and to obtain data on automobile usage that was judged too difficult for respondents to fill out themselves in a mail survey.

Both the telephone and the mail survey were developed following Donald Dillman's Tailored Design Method (1999).

The telephone survey:

- Determined if a household met the requirements for the sampling.

- Asked for detailed information on automobiles owned or leased by the household and elicits information on the residents' ages and relationships.

- Elicited the total mileage driven and percentage of miles that each member of the household rides in each of the three most driven cars. Needless to say, these are difficult questions and necessitated a personal telephone interview with trained interviewers.

- Employed a random digit-dialing sample of 8519 telephone numbers from Sample Survey Inc. (Note that random digit dialing produces a large number of non-household, disconnected, or ineligible numbers for household surveys.)

- Was implemented between July 1 and August 5, 2001 and employed a minimum of 13 attempts to reach each telephone number.

The overall response rate was 40%. This produced 1,235 completed interviews. Of these, 926 or 75% agreed to participate in the mail survey.

The follow-up mail survey:

- Was titled "WHAT ARE YOUR VIEWS ON AUTO SAFETY," and shows a picture of a family next to a Ford Windstar (thanks to Ford for granting permission to use the photo).

- Thanks the respondent and repeats the information on the most, second most and third most driven automobiles.

- Asks about insurance and repair costs and features of each of the vehicles.

- Collects subjective risk information from respondents that requires use of risk ladders and asks for a subjective risk assessment of having a fatal accident (compared to the average driver in the same type of automobile) for the respondent, for a child's risk of dying relative to an adult's risk in a serious automobile accident and for their perceived risk of the safety of the vehicles that they drive.

The mail survey was sent in waves from July 6, 2001 to August 6, 2001. The survey packet included a letter, a $5 cash incentive, the 12-page survey booklet, and a post-paid return envelope. The overall response rate after multiple contacts including reminder phone calls for the mail survey was 74% with 625 completed surveys, exceeding the initial target of 600.

Estimating the Components of the VSL Model

Vehicle Risk (Step 1):

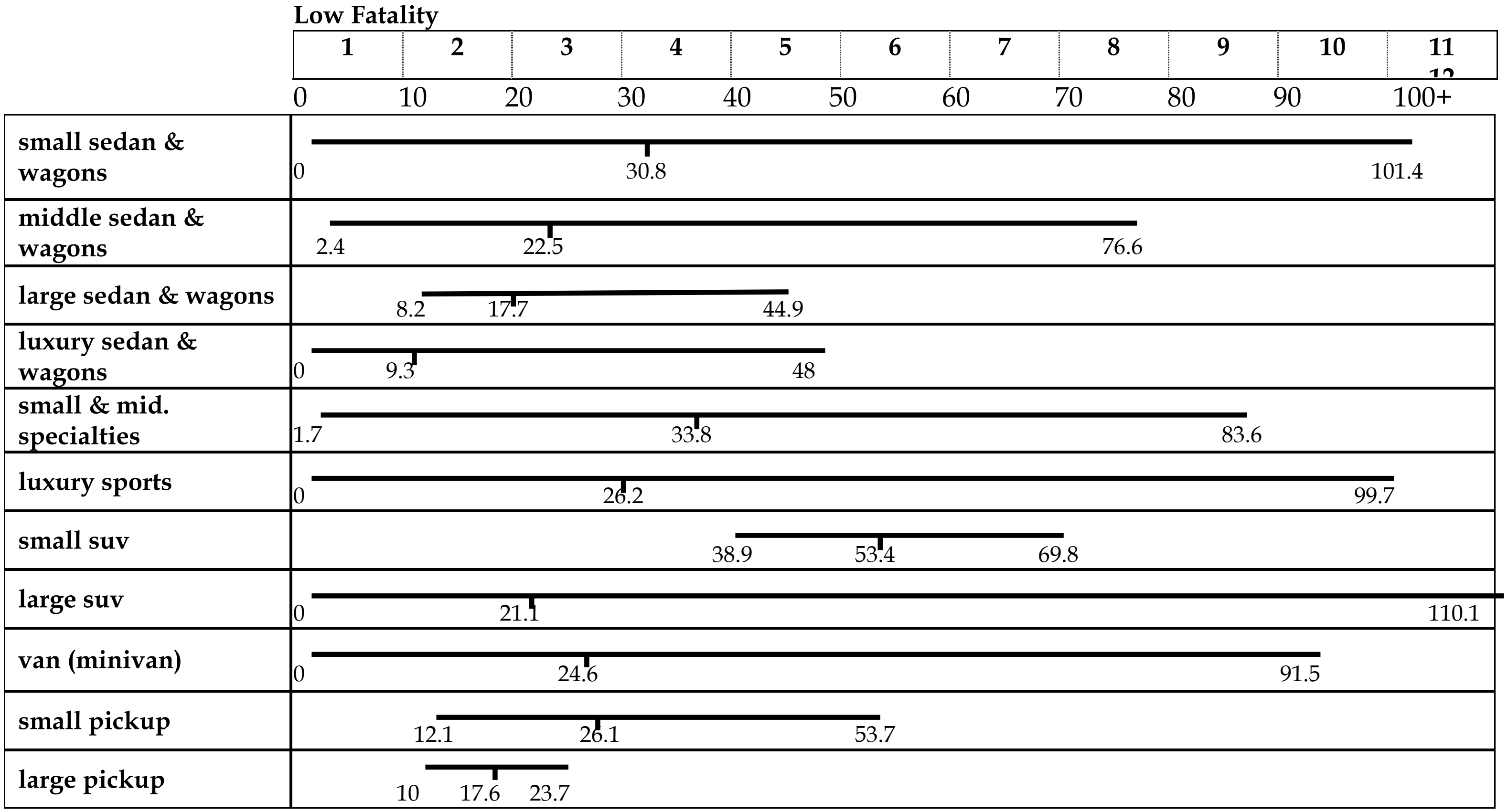
Data from the Fatal Accident Reporting Service (FARS) and National Personal Transportation Survey (NPTS) were used to estimate the driver independent risk of vehicles. This analysis has been presented in full in a report to the EPA (Environmental Protection Agency) and a research paper.

This risk was determined by the probabilities of having different types of accidents (one-vehicle, two-vehicle and multi-vehicle), and the probabilities that the occupants will survive in these accidents. All of these probabilities are functions of the vehicle's characteristics and the characteristics of the driver and the occupants.

The safety rating of each type of vehicle is computed using the same set of characteristics for the driver and the occupants.

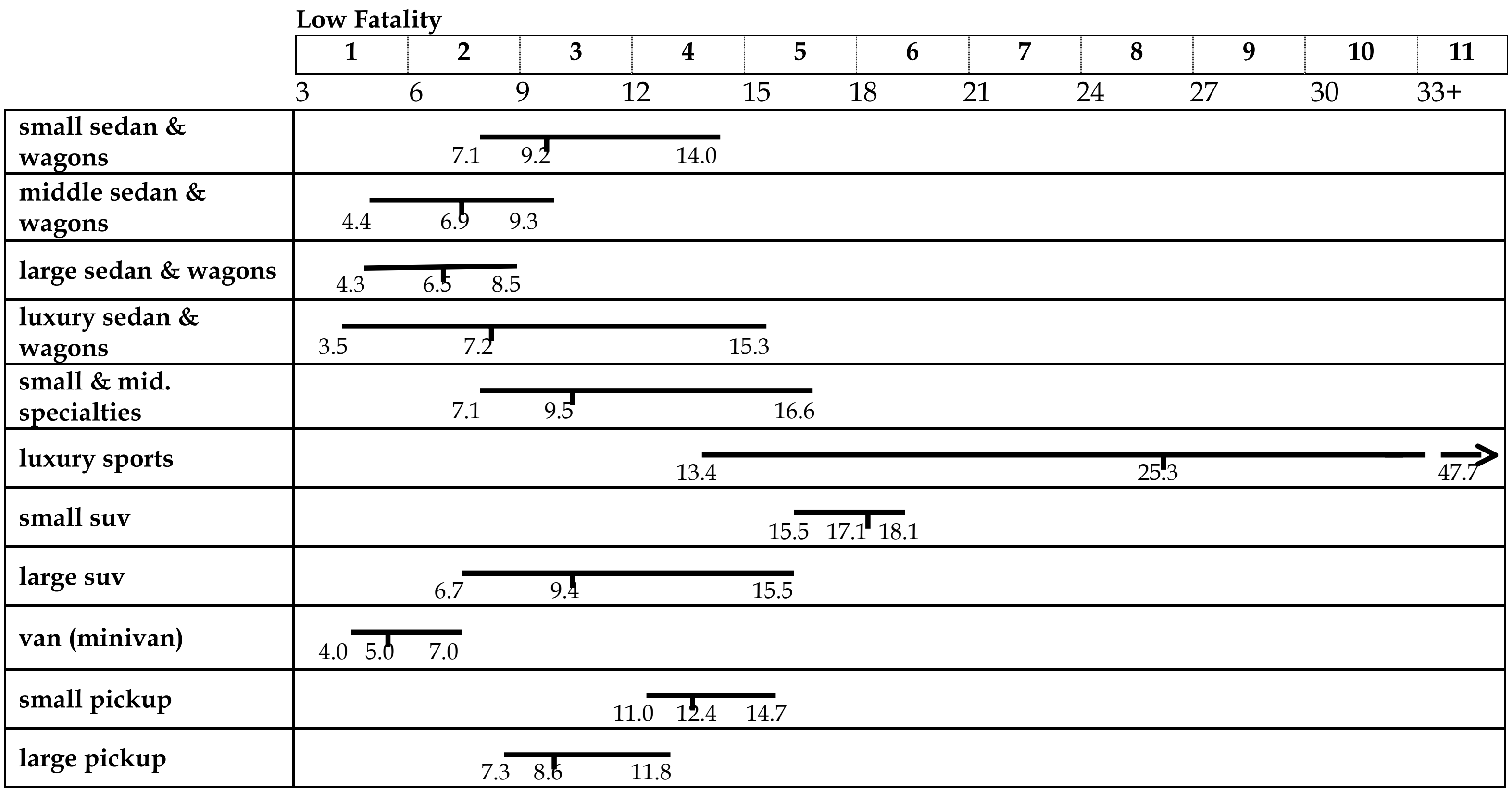
The safety rating used in the hedonic models for each type of vehicle was computed under the assumption that there are two adults in each vehicle who drive 14,000 miles in a year. The effect of making this assumption (as shown in the standardized risk scales) is that some vehicles, which have high-observed rates of fatalities, such as pickup trucks, have lower predicted rates of fatalities. The reason is that the specified occupants are more safety conscious (e.g. by wearing seat belts) than the typical behavior of the actual occupants in the fatality data.

Unadjusted Scales for the Risk of Mortality



Note: The scale is based on the observed total fatalities in year 1996-1997 per 100,000 vehicles (1995 model year) on road per 10,000 miles driven (average annual miles driven is 13989 miles).

Standardized Scales for the Risk of Mortality



Note: The scale is based on predicted total fatalities per 100,000 vehicles (1995 model year) per 10,000 miles driven with 2 occupants.

Hedonic Models (Step 2):

Parameter Estimates for the Hedonic Equations

Variable	Model A Estimated Coefficient	t ratio	Model B Estimated Coefficient	t ratio
Dependent	Fe_city		P_{auto}	
Constant	2.5689	14.13	7.7174	25.45
Value Retained	0.0549	3.35	0.4594	11.10
Mortality Rate	0.0258	1.99	-0.0690	-3.53
Injury Rate	0.0330	4.01	-0.0161	-1.31
Reliability Rating	0.0170	5.05	0.0617	5.23
Acceleration	-0.2290	-8.04	0.6014	13.99
Traditional Styling	-0.2786	-5.21	0.6035	7.56
Class2	-0.1873	-16.56	0.2426	14.34
Class3	-0.2751	-14.69	0.3734	13.28
Class4	-0.2852	-19.29	0.6752	29.76
Class5	-0.6397	-37.47	0.8127	31.94
Class6	-0.4846	-24.84	0.6558	22.67
Class7	-0.4352	-27.49	0.3398	14.31
Year91			0.1137	6.31
Year92			0.2100	10.53
Year93			0.2977	13.16
Year94			0.3880	15.30
Year95			0.4474	16.14
Ford	0.0347	1.90	-0.0972	-3.58
GM	0.0334	1.94	-0.0879	-3.44
Chrysler	0.0196	1.12	-0.1148	-4.43
Germany	-0.0562	-2.84	0.1489	5.05
Japan	0.0470	2.73	-0.0430	-1.71
MB	-0.0078	-0.33	0.5237	14.89
R^2	0.7626		0.8996	

Estimating VSL by Age Group and Household Type (Step 3):

Note that the simple one car model can be easily extended to multiple vehicles if the last car purchased is the most-driven, newest vehicle and is chosen subject to the constraint of prior vehicle purchases.

In the case of multiple vehicles, the allocation of driving miles across family members and vehicles is endogenous and reduced form equations must be used to predict this allocation and miles ridden and driven.

Thus, our estimates of the VSL for family members uses the optimizing condition for the risk level choice for the most-driven vehicle since other, now non-optimal, vehicles may be retained in a family fleet because of transactions costs.

Three typical family groups own most of the total 783 vehicles used in the analysis:

1) PA: pure adults family (424 vehicles);
2) AK: family with both kids and adults (267 vehicles);
3) PS: pure senior family (57 vehicles).

To address possible income effects on the VSL, we divide families into three types:

1) Low income family: Per Capita Income<=$15000;
2) Middle income family: $15000<Per Capita Income<=$37500;
3) High income family: Per Capita Income>$37500.

Three no intercept OLS regressions were run, one for each of three family groups. (If we run regressions with intercepts, the intercepts are insignificant).

The average ages for adults, seniors and kids in our data set are 39.8, 74.2 and 7.8 respectively, so the value for each group can be interpreted as the average VSL for that age.

The estimated results are inconsistent with the simple discounted present value of life-year model.

The estimated results without intercepts are shown in the following table:

Estimated VSL for Families

Family Type	Income Type	Sample Size	Person Type*	VSL (million)	t value
PA	Low	67	Adult low	6.81	9.37
	Middle	188	Adult middle	6.07	13.63
	High	169	Adult high	7.27	14.88
AK	Low	133	Adult low	3.36	8.36
			Kid low	2.54	3.64
	Middle	120	Adult middle	3.79	8.96
			Kid middle	5.12	6.46
	High	14	Adult high	-	-
			Kid high	-	-
PS	Low	9	Senior low	7.67	4.60
	Middle	31	Senior middle	8.42	6.85
	High	17	Senior high	8.25	3.35

Note:
1. *Person Type is Defined as:
   Adult low: adults from low-income families;
   Adult middle: adults from middle-income families;
   Adult high: adults from high-income families;
   Kid low: kids from low-income families;
   Kid middle: kids from middle-income families;
   Kid high: kids from high-income families;
   Senior low: seniors from low-income families;
   Senior middle: seniors from middle-income families;
   Senior high: seniors from high-income families.
2. –means insufficient sample size to obtain reliable estimates.

Fragility

It should be noted that the analysis so far has omitted an important effect that has not previously been considered, fragility. Seniors are, on average, more fragile than adults and kids are, on average, less fragile than adults. From the mail survey data, people's perception of the likelihood of a 70-year-old person dying compared to an average adult when involved in a serious accident is about 39% higher. For children, the survey data shows that the perception of the likelihood of a 8-year-old child dying compared to an average adult when involved in a serious accident is about 12% lower.

Pooling the data for the different income groups and adjusting for fragility does imply that, with the exception of parents facing the financial stress of raising children, that the VSL for kids, adults without kids, and seniors follows the humped shaped pattern predicted by theory.

Fragility Adjusted VSL ($million) by Family Group

Age Group	Fragility Unadjusted VSL	Fragility Adjusted VSL
Kids(AK)	3.63	4.13
Adults(AK)	3.72	3.72
Adults(PA)	6.62	6.62
Seniors(PS)	8.44	6.07

Income Elasticity Measurements

Income elasticities can be obtained by assuming that

VSL=a+b(Y-averageY), and estimating:

$$MC_{risk} = (a_{kids} + b_{kids}\,(Y\text{-}averageY))(M_{kid}/TVM) + (a_{adults} + b_{adults}\,(Y\text{-}averageY))(M_{adult}/TVM + (a_{senior} + b_{senior}\,(Y\text{-}averageY))(M_{senior}/(TVM)$$

Note that the estimated coefficients for the constant term, a, are estimates of the VSL for average per-capita income by person by family type and the income elasticity at this point is: b(averageY)/a.

The very low income elasticities (0-.33) obtained in this study suggest that utility may depend on many things other than money income. Recent research on the psychology of happiness suggests that income plays a relatively minor role compared to family, friends, and work satisfaction.

Income Elasticity Estimates

Family Type	Sample Size	Per Capita Income	Person	a (million)	t value	b	t value	elasticity
PA	424	40776	Adult	6.67	22.28	18.19	2.05	0.111
AK	267	18709	Adult	3.59	12.25	0.62	-0.02	-0.003
AK	267	18709	Kid	3.64	6.80	65.08	1.14	0.335
PS	57	26462	Senior	8.18	8.97	7.97	0.14	0.026

Income elasticities are obtained by assuming that VSL=a+b(Y-averageY), and estimating:

MC_{risk} =(a_{kids} + b_{kids} (Y-averageY))(M_{kid}/TVM)
+(a_{adults} + b_{adults} (Y-averageY))(M_{adult}/TVM
+ (a_{senior} + b_{senior} (Y-averageY))(M_{senior}/(TVM)

Note that the estimated coefficients for the constant term, a, are estimates of the VSL for average per-capita income by person by family type and the income elasticity at this point is: b(averageY)/a.

Draft - Do Not Quote or Cite

Willingness to Pay for Reduced Accident Risk for Children: Inferences from the Demand for Bicycle Safety Helmets

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November 6, 2003

Abstract: This paper develops a household production model in which parents produce bicycling safety for their children. Using data from the National Survey on Recreation and the Environment, via a random utility model, we estimate conditional indirect utility as a function of bike safety and infer WTP for reduced risk of fatal and non-fatal head injury. We estimate parental values for reducing biking risks faced by their children. We obtain estimates of parental values for children that include a VSL of $9.5 million and a VSI of $7.0 million.

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1. Introduction

Improving children's health is a relatively new federal priority. The Clinton Administration's Executive Order (E.O.) 13045 directs policy makers to examine and reduce health and safety risks to children. This directive has led to a new need for more accurate measures of the benefits of policies that improve children's health; more specifically, for better estimates of the economic value of reducing childhood risks. To date, the economics literature contains only a handful (albeit a growing handful) of such estimates, whereas it contains a multitude of estimated values of reducing risks to adults. Thus for policy applications, at present, analysts must choose between two practical but conceptually lacking alternatives for child health values. The first is to rely on estimates of the medical costs associated with an illness. The second is to transfer estimates of willingness-to-pay (WTP) for risk reductions estimated for adults to child populations.

The first approach has been labeled "cost-of-illness" and usually involves estimates of direct medical expenditures and of the more indirect cost due to lost work time (or for children, future lost work time). Conceptually, the cost-of-illness approach simply measures ex post costs and does not attempt to measure the loss in utility due to pain and suffering or the costs of any averting behaviors that individuals have taken to prevent an illness. Some consider a cost-of-illness estimate to be a lower bound estimate of WTP because it fails to account for many effects of disease, such as lost leisure time or pain and suffering (Harrington and Portney 1987; Berger et al. 1987). Others suggest that cost-of-illness might exaggerate risk values since in some cases the cost of averting behaviors that prevent a medical condition can be far less than the ex post costs of treatment (insert cite). Economists widely recognize that the preferred measure to assess the benefits of federal policy is to estimate WTP for ex ante risk reduction rather than using cost-of-illness estimates (U.S. EPA 2000).

Due to a lack of WTP estimates for children, at present analysts routinely transfer WTP estimates for adult risk reductions to child populations. The appropriateness of these transfers is questionable (Dockins et al. 2002; Agee and Crocker 2003). Researchers are currently asking whether a risk reduction of the same character and size should be valued differently when experienced by children as compared to adults. This paper is a first step in shedding light on this issue by estimating parental values for reducing the risk of a bicycle injury to their children. In a future paper, the authors will estimate adult values for reducing the same risk to themselves and compare the values.

Many of the estimates of adult health and safety values have been derived via hedonic wage analyses. For obvious reasons, this methodology is not viable for analysts focused on children or for analysts seeking insight regarding the differences between adults and children. A valuation alternative that does hold promise, however, is analysis of safety product markets.

Of particular promise is the bicycle helmet market. A bike helmet is a personal safety product whose ownership is generally assigned to a single individual, not to a family or some other group which would render it impossible to assign the benefits of the safety product to one person. In addition, bike helmets are owned by young and old alike leaving open the possibility of discerning a relationship between age and willingness-to-pay for safety. This paper and future work will take advantage of these desirable attributes of the bicycle helmet market by examining households' purchase decisions regarding helmets for adults and children. We develop a household production model in which adults produce bicycling safety for themselves or parents produce it for their children. Via a random utility model, we estimate conditional indirect utility as a function of bike safety and infer WTP for reduced risk of fatal and non-fatal head injury. We estimate parental values for reducing biking risks faced by their children and, in the future, we will estimate adult values for reducing their own risks.

Data were obtained from a telephone survey that was part of the most recent National Survey on Recreation and the Environment. Respondents can be separated into two groups: parents who report having a child age 5 to 14 who had bicycled within the previous 12 months, and adults age 20 to 59 who report having bicycled themselves within that same time frame. In addition to socioeconomic information, we have information on the amount of bike-riding, the perception of helmet laws, the importance of helmet features and the price paid for the helmet. Data on the risk of bicycling is obtained from the Centers for Disease Control (CDC) and varies according to age, gender and race.

Previously in the economics literature, analyses of safety product markets have estimated the value of risk reduction by assuming that the marginal benefit of risk reducing activities equates with their marginal cost. These papers have lacked price information and have based estimates of the value of risk reduction solely on estimates of implicit values (and amounts) of time and/or on estimates of monetized dis-utility (Blomquist 1979 and 1991; Blomquist, Miller and Levy 1996; Carlin and Sandy 1991). Other product market analyses estimate lower bound values of risk reduction based directly on highly aggregated product prices (Dardis 1980; Garbacz 1989; Jenkins, Owens and Wiggins 2001). The current paper adopts a different approach, one developed outside the safety product literature. Dickie and Gerking (1991) and Agee and Crocker (1996) develop household production models in which utility depends upon health or risk of family members. The household makes many unobserved choices regarding the production of health or risk but there is one observable discrete choice, such as whether or not to purchase medical care. The probability of the discrete choice is estimated via a random utility model with which welfare effects can be computed (Small and Rosen 1981). For the current paper, the discrete choice is whether or not to purchase a helmet.

To estimate how consumer WTP for risk reduction varies with the age of the beneficiary requires an ability to discern the age of the beneficiary. Previous analyses have examined spending on safety products that benefit an entire household -- smoke detectors (Dardis 1980, Garbacz 1989) and automobile size (Mount et al. 2000) -- or that benefit only children or only adults -- car safety seats and motorcycle helmets (Carlin and Sandy 1991; Blomquist 1991; Blomquist, Miller and Levy 1996). Our analysis is unique in that bicycle safety helmets are used by all age groups but are purchased for specific individuals. This allows us to estimate separately the WTP for bicycle safety for children and adults.

The choice of whose preferences to rely upon to determine the value of childhood risk reductions is an important one. Dockins et al (2002) suggests that the parental perspective is advantageous for multiple reasons.[1] The current paper examines parental decisions regarding bicycle safety, specifically regarding the purchase of a child bicycle helmet. Also reported by parents are other variables in the demand function for helmets, such as the perception of helmet laws and the amount of time a child spends riding. Thus, for children's safety, we estimate a parent-determined WTP.

The following sections of the paper develop a model of household production and then translate propositions from the model into empirically testable form. We describe the data that we analyze and the tentative results that we obtain via a logit model of the purchase decision.

2. Household Production Model

This section presents a household production model of utility from which we derive the compensated demand for bicycle safety helmets. The household perspective is chosen in order to represent helmet purchase decisions made by parents for their children. However, the model can be easily adjusted to represent adults making decisions only for themselves, without explicit consideration of children. The model will illuminate the important underlying variables in the discrete choice decision of whether or not to purchase a helmet. The model also provides structure for the estimation of risk valuation. We derive from the model an equation to represent adult willingness to pay for own risk reduction as well as parental willingness to pay for child risk reduction. This section draws heavily from household production and random utility models developed by Dickie and Gerking (1991), Agee and Crocker (1996) and Agee, Crocker and Shogren (2001), which in turn drew from Small and Rosen (1981).

Parents derive utility, U_p, from consumption of commodities and activities, Z_p, produced for themselves, and from the risk they perceive themselves as facing by riding a bicycle, R_p. Parents also derive utility from commodities and activities, Z_c, produced for each of their $i = 1, ..., n$ children and from the risk they perceive their children face, R_c, from bicycling. If we represent a single-period, two-generation family in which children's utility is additive to parents' utility but separable, then:

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[1]Four possible perspectives for valuing children's risk reductions are suggested by Dockins et al. (2002): that of society, the child, adult-as-child, and parent.

$$U_p = u_p(Z_p, R_p) + \sum_{i=1}^{n} \alpha_{pi}(\gamma) u_{ci}(Z_{ci}, R_{ci}), \qquad (1)$$

where $U'_z \geq 0$ and $U'_R < 0$. $U_p(.)$ is quasi-concave and increasing in at least some of the Z's, and is finite whenever some of the Z's are zero (Small and Rosen 1981). Parents combine their time, effort and market good purchases to produce child-related commodities, Z_c. The u_p and u_c functions differ because children and their parents experience their environments differently. The multiplier $\alpha_{pi}(.)$ converts child i's utility into his parents' utility and depends on γ which represents family characteristics that affect the conversion of childhood utility into parental utility.

Parents also combine their time, effort and market purchases to affect the level of risk, R, faced by themselves and their children from riding bicycles:

$$R_j\left(D_j, H_j, b_j, \gamma\right)_{j=p,c} \qquad (2)$$

where D represents the amount of time spent riding a bicycle, H represents the use of a bicycle safety helmet, b is the level of risk per unit of riding time, assuming no helmet-wearing, that is expected for the rider and varies according to the risk taking behavior of the individual, and γ represents any family characteristics, such as parents' educations, which may influence risk perception. As mentioned already, helmets are unique in their ability to reduce by significant proportions the risks of injury and death from bicycling. Spending on helmets produces nothing of value other than reductions in R.

Let q denote a vector of market prices for commodities and activities; t denote a vector of parental time inputs, and t_s denote time spent away from paid work. Then the parental income constraint can be written as a sum of expenditures on own and children's consumption,

$$Y_p = r_p Z_p + r_{hp} H_p + \sum_i \left(r_{ci} Z_{ci} + r_{hci} H_{ci}\right) \qquad (3)$$

where $r_j = (q_j + wt_j)$; $j = p, c, hp, hc$; and $w = Y_p/(T-t_s)$ so that parents' income, Y_p, determines their opportunity cost of time, w. Parents choose t_j, R_p, Z_p, R_c and Z_c to maximize total utility in (1) subject to (2) and (3).

Assume that parental WTP is the largest income that parents must forego after a reduction in expected risk, to maintain ex ante expected utility. Parental WTP estimates the value to the household of a reduction in the level of risk, b, that the rider is expected to face. Let $V_p(.)$ denote the parents' indirect utility function from the above utility maximization problem.

Given the properties of expression (1), $V_p(.)$ is continuous and strictly increasing in household income, Y_p, and thus can be inverted to find the expenditure function, $e[.]$, satisfying

$$U_P = V_p\left(r, D, b, \gamma; e\left[r, D, b, \gamma\right]\right). \qquad (4)$$

Differentiating (4) with respect to b yields adults' or parents' marginal willingness to pay for a reduction in the expected riskiness in either their own or their child's bike riding activity.

$$MWTP_b \equiv \partial e / \partial b = -(1/\lambda)\partial V_p / \partial b, \qquad (5)$$

where $\lambda \equiv \partial V_p / \partial Y_p$ is the marginal utility of income.

Expression (5) portrays parents' marginal disutility of the expected risk of bicycling converted to monetary units via the marginal utility of income. In general, this measure is empirically intractable because actual utility levels are not observed. However, an empirical representation is available via a discrete choice model of the decision to purchase a bicycle helmet.

The household production model portrayed in (1) through (5) can be adjusted to represent adults making decisions for themselves without explicit consideration of children by assuming $Z_{ci} = 0$ and $R_{ci} = 0$ for all i.

3. Empirical Model

A parent's decision to purchase a helmet or not is a discrete choice based upon information about the risk reduction provided by helmets. Let $\bar{v}_H$ denote the maximum attainable expected utility if a helmet is purchased and let $\bar{v}_O$ denote the maximum attainable expected utility if a helmet is not purchased. For households characterized by b and γ, the choice to purchase a helmet or not is made by comparing these two expected utility levels, given income, Y_p, and a wage-price vector, $r = (w, q)$:

$$H = 1 \text{ if } \bar{v}_H - \bar{v}_O > 0$$
$$H = 0 \text{ otherwise.} \qquad (6)$$

The utility difference is specified econometrically as

$$\bar{v}_H(.) - \bar{v}_o(.) = X'\beta + \varepsilon \qquad (7)$$

where X is a vector whose first element is unity and whose remaining elements measure arguments of the conditional utility function in (4), β is a parameter vector and ε is a random error component. The probability of purchasing a safety helmet, conditional on ε, is

$$\Pr(H = 1) = F(X'\beta + \varepsilon), \qquad (8)$$

where $H = 1$ if a helmet is purchased and 0 otherwise, and $F(.)$ is the symmetric distribution of V conditional on ε.

Let $\overline{X}'\hat{\beta}$ be the inner product of explanatory variables and estimated coefficients, with each explanatory variable except risk set equal to its sample mean. Assume that ε is distributed standard logistic and note that bicycle expenditures are a small part of the family budget. Then, following Small and Rosen (1981) if the compensated demand for a bicycle helmet is approximated by its Marshallian counterpart, parents' $MWTP_b$ in expression (5) is approximated by

$$MWTP_b = -(\hat{\beta}_b / \hat{\lambda})F(\overline{X}'\hat{\beta}), \qquad (9)$$

where $\hat{\beta}_b$ is the estimated coefficient for risk, $\hat{\lambda}$ is the estimated marginal utility of income, $F(.)$ is the standard logistic cumulative distribution function and $F(\overline{X}'\hat{\beta})$ is the estimated probability of purchasing a helmet.

Helmets seem essential to reducing the risk of head injury from bicycle riding thus the concern shown by Bockstael and McConnell (1983) that (9) will yield an incomplete measure of the true $MWTP_b$ in (5) is lessened.

4. Data Description

The primary data source for this work is the 2000 National Survey on Recreation and the Environment (NSRE), conducted by the U.S. Department of Agriculture's Forest Service. Other data we relied upon includes income and population data from the U.S. Census Bureau, weather data from the National Climatic Data Center, and pedal cycle injury and death statistics from the Centers for Disease Control and Prevention (CDC).

The NSRE is a random-digit-dialed phone survey of U.S. residents over age 16. The survey collected information from the American public on demographics, participation in a multitude of outdoor activities, and opinions concerning environmental and natural resource issues. Between July 2000 and July 2001, the NSRE asked respondents questions related to bicycling, especially regarding bicycle helmet purchases and use. Respondents were either asked a series of questions related to their own bicycle helmet purchasing decisions (adult module) or, if the respondent had a bike riding child between the ages of 5 and 14, questions related to purchasing decisions for that child's bicycle helmet (child module). Respondents were asked about the amount of bike riding they (or their child) did, their beliefs regarding the existence of helmet laws, the price they or another family member paid for their (or their child's) helmet, the factors influencing their choice of helmet, their (or their child's) expected helmet use patterns at the time of purchase and a question to determine if the respondent would have changed their helmet purchase decision after being given accurate information on the risk reduction provided by helmets.

In order to maximize the number of responses to the bicycle helmet modules subject to a constraint on the length of each interview and because of the anticipated difficulty contacting respondents with bike riding children of an appropriate age, most of the respondents were asked the child module first. The first question in the child module asked if the respondent has a bike riding child between the ages of 5 and 14. An affirmative answer to that question led to the remaining questions in the children's bike helmet module. If the respondent did not have any bike riding children of an appropriate age, the questions in the adult bike helmet module were asked. A concern that we were not getting responses to the adult questions from any parents who had bike riding children led to approximately 100 interviews in which respondents with bike riding children were also asked the adult questions.

The initial data set included 15,010 observations.[2] After eliminating observations for respondents who did not ride a bicycle in the past year or have a bike riding child between the ages of 5 and 14[3], the samples contained 2,463 respondents with a bike riding child between the ages of 5 and 14, and 1,493 adult respondents who rode bikes themselves. Observations with missing data values for variables included in our regression analysis were eliminated, as were observations where the respondent (or her child) had a helmet, but the helmet was not purchased by herself or an immediate family member.[4] In order not to lose those observations where

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[2]The data set comes from versions 5, 7, and 9 of the NSRE which contain the adult and child bicycle helmet modules.

[3]Observations were eliminated from the data set if income was greater than $4 million (this eliminated the few income observations that were greater than 3 standard deviations from the mean); if the respondent answered that his or her helmet would last over 50 years; if the respondent was less than 19 years old; and for the child questions, if the parent age minus the child's age was less than 15.

[4]In this situation, respondents were not asked further helmet questions because it is unlikely they would have known the helmet purchase price or other factors that went into the

household income was the only relevant variable that was missing, we used data from the 2000 Census[5] to create a proxy income variable. Proxy income is equal to the median family income by race for the zip code in which the respondent lives. If the respondent lived alone or in a house with roommates, proxy income is equal to the mean individual income by race for his or her zip code. The final data set used for our analysis includes 1,984 child observations and 941 adult observations. Means and standard deviations of the data for children are summarized in Table 1.

Of the 1,984 child observations, 89.5% were helmet purchasers. These numbers are similar to a 1999 U.S. Consumer Product Safety Commission (U.S. CPSC 1999) survey that found 84% of bike riding children under 16 own a helmet.

About 12% of the U.S. population is covered by state or local helmet laws (BHSI 2001). All 20 of the state laws are specific only to children and 30 of the 83 local laws apply to all ages, with the others being specific only to children. Interestingly, 52% of the respondents in our child sample said that there was a law in their community or state requiring children to wear bicycle helmets and 17% said they did not know whether there was a law applicable to children. People may believe that a helmet law exists in their community when they are exposed to a helmet education campaign. For example, McDonald's Corporation ran a national campaign encouraging helmet use for children and adults. Whether the respondents are correct in their knowledge of helmet laws in their community or not, it is their perception of the law that will drive their helmet purchasing decisions.

The federal safety standard for bicycle helmets (U.S. CPSC 1998) ensures that all bicycle helmets manufactured after March 10, 1999 must meet a minimum level of safety. It is unlikely that manufacturers would create helmets that go too far beyond this standard. To make a helmet safer than the federal standard would require additional cost to the manufacturer, but also more weight and size to the helmet making it less likely to be bought or worn (U.S. CPSC 1998). Even though helmets themselves do not differ significantly in their levels of protection, different levels of risk-taking behavior or exposure to risk during riding will cause individuals to face different risk reductions provided by their helmets. The CDC reports annual pedal cycle deaths and injuries by age, race, and gender. We combine this data with information on population and the percent of population that rides a bicycle in order to assign a fatal and non-fatal risk measure to each individual in our sample that is equal to the average for that individual's age-gender-race

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purchase decision.

[5]Data was obtained from Census 2000 Summary File 1 and Census 2000 Summary File 3 (http://www.census.gov/main/www/cen2000.html - accessed May - June 2003).

group.[6]

5. Empirical Implementation

We estimate a purchase equations representing parents' purchases of helmets for children. The indirect utility function in (4) suggests that the purchase decision depends on a variety of variables including the wages of the family and the price of the helmet. We combine these two variables and include in the equation one variable measuring household income less the helmet price. To measure the amount of time spent riding, *D*, we include a variable indicating the number of days ridden by the bicycler during the previous 30 days. Since the prevailing weather during the month in which the survey was administered would influence the number of days a bicyclist might ride, we also include the average temperature during that month and a term that interacts avidity with temperature. We include separately both the rate of death and the rate of injury to measure the risk of bicycling. To represent the attributes of families, γ, that either affect the conversion of childhood utility into adult utility or affect risk perception we include a variety of socioeconomic information: age, gender, race and education of the bicycler and/or his parents. (For the child equation we substitute parent's education for rider's education and we include an indicator variable for whether the parent respondent rode. For age, we include both the parent's age and the child's.) Finally, we include two indicator variables that indicate whether the respondent believed that there was a helmet law requiring use or whether the respondent was unsure.

Table 2 presents the results of four logit models of the decision to purchase a helmet for children and adults. The first column gives the primary results. The sign of the coefficient on the child's age is positive, in agreement with the burgeoning consensus among studies targeted at children that parent's valuation of risk reduction varies inversely with child age (Agee and Crocker 2003). The suggestion is that as a child ages through middle childhood, the probability that a bike helmet will be purchased for him declines. Similarly, parents of male children are less likely to purchase a helmet. This could indicate a greater parental acceptance of risky behaviors undertaken by boys compared to girls or undertaken by older children compared to younger ones. Alternatively, parents of boys and older children might have lower expectations regarding their children's compliance with parental wishes for the child to wear a helmet. Parents would naturally be reluctant to purchase a helmet that they believe it will not be worn.

The probability that a helmet will be purchased for a child increases if the respondent believed there was a law requiring helmet usage or if the respondent was unsure about the presence of a helmet law. This finding bodes well for the recent dramatic increase in popularity of helmet laws for youngsters. Parents really are responding to such laws. However, parents

[6]For the child observations, we assume that the race of the child is the same as the race of the respondent.

also respond positively to uncertainty about the existence of a law.

As expected, greater household income positively affects the probability that a parent will purchase a helmet for her child as does greater education level. The indicator variables for black and white race are significant and negative. Relative to households of other races (Asian, Pacific Islander, American Indian and others) these households are less likely to purchase a helmet for their child. The indicator variable for whether or not the parent rides a bike is significant and positive suggesting a greater awareness of bike safety issues by parents who themselves bike.

A parent's age is not correlated with the probability of purchasing a helmet. The indicator variable for whether or not the parent rides a bike is significant and positive suggesting a greater awareness of bike safety issues by parents who themselves bike. As expected, the rate of death and injury faced by the child as a consequence of bicycling is positively and significantly associated with the probability of purchasing a child's helmet.

In addition to the primary model described above, we estimate three additional logit models. To check the sensitivity of the results to the rather rough measure of avidity represented by the number of days ridden and the temperature variables, we re-run the logit and omit those three variables in specification (2), and omit just the two temperature variables in specification (3). The results are robust. Finally, we wished to include measures of the importance to the respondent of the helmet's appearance and comfort level. We include two variables indicating whether the respondent believed these features of the helmet were important in specification (4) and find that neither is significant, nor does their inclusion alter substantially the coefficients estimated for the remaining variables.[7]

Our principal purpose is to approximate parental WTP for child risk reduction. To do this we estimate for each respondent the percentage change in income necessary to keep utility constant when bicycling risk is reduced by one percent. This is achieved by evaluating equation (9) and converting to percentage terms. For specification (1) the resulting values of statistical life and injury for children are \$9.5 million and \$7 million, respectively. These estimates vary between \$8.9 and \$9.9 million for VSL and \$7 and 8.4 million for VSI among the four specifications.

6. Discussion

These estimates of VSL for children are higher than most VSL estimates reported in the

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[7]The appearance and comfort variables are constructed with responses to questions in the survey regarding the importance of comfort and appearance and with the days ridden variable thus we omit direct measures of days ridden and temperature from specification (4).

literature for adults. A good summary estimate of a set of high quality, policy relevant adult VSL studies is provided by the EPA. To analyse proposed regulations, EPA relies on a VSL estimate of approximately $6 million (in 2000 dollars). This estimate was derived by fitting a Weibull distribution to 26 adult VSL studies (21 that use the hedonic wage method and five that examine stated preferences). The suggestion is that parents value reductions in risk to their children by more than adults value reductions in risk to themselves. However, this suggestion is made with caution since there are important differences between the nature of the risk being examined and the valuation estimation methodology in the current study compared to the adult studies. In the future, we plan to estimate adult willingness to pay for reductions in bicycle risk and will more confidently make direct comparisons to our estimates for children.

Our VSL estimates for children are quite high relative to the two values for children found in the published literature: between $0.75 million (Carlin and Sandy 1991) and $4.0 million (Jenkins, Owens and Wiggins 2001)[8] However, these two studies were examinations of direct time and/or money expenditures on safety products. So, again the methodology is different enough to suggest caution in making comparisons.

To get an idea of the relative magnitude of the VSI estimates, we gathered information about the medical costs of non-fatal bicycle injuries in the U.S. A review of hospital discharge data in Washington state (1989-1991) found that treatment for nonfatal bicycle injuries among children ages 14 and under costs an average of $218,000 per injured child (Bicycle Helmet Safety Institute 2003). A cost of illness (COI) estimate would add to these direct costs, such indirect costs as the value of the parent's lost work time from caring for the sick child and the value of future lost wages due to any brain injury or long term debilitating injury to the child. Even after accounting for these indirect costs, the COI of non-fatal bicycle injury would be far less than our VSI estimates. Dickie and Gerking (1991) also obtain estimates of WTP that are higher than corresponding medical costs. Using a similar model and empirical method as in the current paper, the estimates of WTP for ozone control turn out to be about double the medical expenses associated with treating respiratory illness that is associated with ozone pollution. While the magnitude of the difference is much smaller, these findings and ours give examples when estimates of WTP are substantially higher than comparable COI estimates. The unmonetized costs such as pain-and-suffering might be the explanation.

On the other hand, the opposite is suggested by the WTP estimates inferred from demand functions for chelation therapy to reduce child lead burdens. Agee and Crocker (1996) estimate parental WTP for a 1 percent reduction in child lead burden as falling between $11 and $104. Lutter (1994) converts these WTP estimates into estimates of the value of a lost IQ point and obtains values that range from $1,100 to $1,900. Lutter compares these parental WTP estimates

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[8]These estimates are in 1997 dollars. The estimate for Jenkins, Owens and Wiggins (2001) is the upper limit of a range beginning at $1.1 million.

to government COI estimates of lost income due to lowered IQ and finds the latter to be much higher, approximately $8,800 per lost IQ point.

Dockins et al. (2002) attribute this difference to the fact that the WTP estimates represent the parental viewpoint while the COI estimates represent a lower bound of what a child should be WTP him or herself (if lending constraints were relaxed). Our own paper suggests that parental WTP for children is actually much higher than COI. The nature of the risks being valued by the two studies is quite different. Children with high body burdens of lead exhibit long-term cognitive and adaptive behavior deficits. In the short term, effects include hyperactivity, poor attention and learning problems. Risks of bicycling include catastrophic brain injury, concussion and contusion. A second important difference between the two studies is the education and income levels of parents in the study sample. Parents in the Agee and Crocker (1996) study had an average education level of 11 years and an average income of only $17,000 (1985 dollars). Almost 70 percent of our sample went to college and they earn an average of $60,000 (2000 dollars). Thus the Agee and Crocker paper examined a risk that imposes intangible effects, the most devastating of which are in the distant future, and estimated the WTP to reduce this risk among relatively low income parents. The current paper examines a risk that poses a dramatic immediate physical threat and estimates WTP among relatively high income parents. In light of these difference, the larger gap between WTP and COI for non-fatal bicycle injury is easier to understand.

In a future version of this paper, we will estimate a logit equation representing adult's helmet purchase decision for self. This will enable us to compare values of risk of the same nature and similar magnitude for children and adults.

Table 1 **Means of Variables for Child Bicyclists** (Standard deviations are in parentheses)	
	children (n=1984)
Own	0.895 (0.307)
Age	9.513 (2.871)
Parent's Age	38.855 (7.650)
Male	0.534 (0.499)
Helmet Law - Yes	0.519 (0.500)
Helmet Law - Don't Know	0.171 (0.377)
Household Income Minus Price($1000)	58.247 (39.635)
Black	0.088 (0.284)
White	0.887 (0.316)
Parent Rides	0.583 (0.493)
Highschool	0.284 (0.451)
College	0.671 (0.470)
Days Ridden	11.008 (10.937)

Fatal Head Injury Risk	5.300 E-6 (3.669 E-6)
Non-Fatal Head Injury Risk	3.083 E-3 (1.488 E-3)
Monthly Mean High Temperature (degrees)	62.413 (20.974)

Table 2 Econometrics Results for Logit Model of Purchase Decision for Child				
Variable	**(1)**	**(2)**	**(3)**	**(4)**
Constant	1.225 (1.030)	0.573 (0.913)	0.898 (0.958)	0.338 (0.924)
Age	-0.122** (0.048)	-0.093** (0.045)	-0.120** (0.046)	-0.082* (0.046)
Parent's Age	0.014 (0.012)	0.021* (0.011)	0.020* (0.011)	0.019* (0.011)
Male	-1.848** (0.735)	-1.858*** (0.694)	-1.942*** (0.715)	-1.900*** (0.699)
Helmet Law - Yes	1.905*** (0.195)	1.877*** (0.183)	1.866*** (0.188)	1.887*** (0.184)
Helmet Law - Don't Know	1.012*** (0.224)	0.946*** (0.208)	0.896*** (0.212)	0.956*** (0.209)
Household Income Minus Price ($1000)	0.01*** (0.003)	0.01*** (0.003)	0.01*** (0.003)	0.01*** (0.003)
Black	-2.578** (1.035)	-2.882*** (0.976)	-3.00*** (1.002)	-2.802*** (0.972)
White	-1.528* (0.882)	-1.903** (0.828)	-1.912** (0.853)	-1.823** (0.828)
Parent Rides	0.631*** (0.164)	0.551*** (0.154)	0.570*** (0.158)	0.540*** (0.155)
Highschool	0.764** (0.319)	0.673** (0.297)	0.815*** (0.304)	0.712** (0.302)
College	1.303*** (0.323)	1.247*** (0.298)	1.298*** (0.305)	1.301*** (0.304)
Fatal Head Injury Risk	199886** (82924)	195097** (78693)	210878*** (80635)	189992** (79207)
Non-Fatal Head Injury Risk	254.2** (129.4)	286** (122.4)	276.3** (125.2)	305.9** (123.1)

Table 2 Econometrics Results for Logit Model of Purchase Decision for Child				
Variable	**(1)**	**(2)**	**(3)**	**(4)**
Days Ridden	-0.016 (0.027)		-0.001 (0.007)	
Temp	-0.009* (0.005)			
Days Ridden * Temp	0.0003 (0.0004)			
Appearance Factor				9.810 (863.3)
Comfort Factor				13.398 (825.1)
Number of observations	1984	2159	2103	2114
Likelihood Ratio	232.724	238.397	233.163	247.622

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Valuing Environmental Health Risk Reductions to Children Workshop
Session IV Discussant Comments: Age-Specific Value of Statistical Life Estimates

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US EPA, National Center for Environmental Economics

October 21, 2003

The two papers presented in this session provide empirical evidence using revealed preference methods to estimate to values associated with risk reductions to children. Thus far, we have heard presentations regarding theory and conceptual models that may be used to determine how children's health risk reductions can be valued and whose preferences should be used to elicit such values. Today, we are turning our attention to empirical applications.

In terms of policy, while EPA does not currently use age adjustments in our formal benefit-cost analyses, the research in this area can help inform policy decisions by providing information on how children's risks are valued relative to risks to adults. Such information can be used to prioritize decisions and highlight areas where new decisions might be needed regarding risk reductions.

Both the automobile and bicycle helmet studies presented in this session rely on revealed preference methods in which the analyst examines trade-offs between price and risk, or risk reduction, for a market good to infer how people might value the risk reduction. As we know, our traditional tools for valuation are often difficult to apply to children who do not control a budget and may or may not behave in a rational manner. In addition, there may be issues associated with asking a parent their willingness to pay for their own child in a stated preference study because of the emotions associated with that question. Product market studies, such as those presented in this session, hold promise because we can explore what parents spend on safety for their children, thus using real market transactions by the decision-maker to infer values.

In Bill Schulze's paper the "good" is an automobile, or more specifically, automobile safety. The idea is that children ride in cars that have various safety ratings. By looking at the choices parents make with regards to car purchases and time spent in the car the authors infer values of a statistical life for a child, as well as other family members.

They use a Nash cooperative bargaining model to motivate the decision-making, where investments in safety are a function of parent and child utility. They then conduct a telephone/mail survey where they ask people about the kinds of cars they drive and how many miles each member of the household spends in each car. This information is combined with safety ratings for the various cars to infer VSLs for adults, children, and various types of households.

The good in this study is well-defined and there is very accurate and detailed information regarding the safety of automobiles. Unfortunately, people likely value their cars for more than just safety. When deciding what car to purchase safety is likely to be a factor, along with comfort, fuel economy, and type. If these features of the car purchase decision are not carefully controlled then the authors may be over-estimating the VSL by attributing all of the spending to safety.

In the bike helmet study, the "good" is a bicycle helmet, which is used to protect against fatal risks and non-fatal injuries. The authors use a household production model to motivate the decision-making and a telephone survey where people are asked how much money they spent on a helmet and other information regarding its use. They combine this information with death and injury data to estimate a value of a statistical life and injury to a child.

The good in this study is also well-defined. In fact, the primary purpose of the good is safety for a specific member of the household. For these reasons it is not necessary to tease out the usage by various family members, as in the automobile study or with other goods that are jointly consumed. In addition, because the primary purpose of the good is safety it is plausible to attribute most, if not all, of the spending to risk reduction. While some of the spending may be for comfort and style, it is probably difficult, if not impossible to tease out these individual effects.

Turning now to the results. In the automobile study the authors estimate a variety of VSLs. I focus on the adult-child comparisons because these are most relevant for policy and comparable to the bicycle helmet study. The authors find comparable results for both the adult and child VSLs when they aggregate across income groups - both estimates are around $5 million. In terms of policy analysis, the results at the aggregate level, which is what we would be most likely to use in a benefit-cost analysis, may be somewhat comforting in that applying one value to all individuals comports with their results.

In the bicycle helmet study the authors estimate a VSL and a VSI - or value of a statistical injury - for children. They plan to add similar results for adults in the future. Their VSL for a child in about $9.5 million, or double the results found in the automobile study. This creates a problem for the policy analyst who must decide how to use this information. Here we have two results, both for fatal, immediate risks, both involving decisions made from the parental perspective, and one result is double the other. While we do not know if these differences are statistically significant, there may be reasons why we would expect them to differ in magnitude.

In the automobile study the parent may feel a certain amount of control over the risk reduction. That is, the parent probably drives more safely when the child is in the car - or believes that he or she is a better driver than others on the road, in general. The parent may avoid particularly dangerous traveling situations, such as avoiding the roads when there is heavy traffic or rain. By taking these precautionary measures the parent may feel a certain amount of control over the risk and is not using the car, exclusively, to mitigate the risk associated with driving. These alternative behaviors are not reflected in the analysis and therefore may result in a lower VSL estimate than if they were included.

On the other hand, the parent may feel little or no control over the child on his or her bicycle. This is likely to vary somewhat with age. For smaller children the parent may accompany the child on the bike, maintaining control over the types of trails used and how fast or reckless the child rides. However, as the child gets older and becomes more independent with bike-riding, the parent loses some control - or transfers some of it to the child - and the bicycle helmet is the only safety feature that remains from the parent's perspective. Hence, the bicycle helmet might represent all of the mitigating behavior that is used, in which case the VSL estimated might be higher than in situations where the parent has other options.

Turning to the value of a statistical injury estimated in the bicycle helmet study. The authors estimate a value of approximately $7.0 million, which is almost as high as the VSL estimated and much higher than expected. It is likely the case that the parent is buying protection from serious injuries associated with a cycling accident, as opposed to cuts and scrapes - injuries that could potentially be very debilitating and painful. These serious injuries could be devastating and therefore may in fact carry a value that nears that associated with death.

In terms of contribution to the literature, both of theses studies provide much needed estimates of risk reductions to children. Currently, only a few estimates exist and it is useful to add to this literature as we build our understanding of these values. In the automobile study, it would be useful to have estimates for morbidity, which can be calculated given the data used in the paper.

In terms of applications to policy, analysts are very often interested in how results can be applied in a benefit transfer context. OMB has stated that estimates should only be transferred when the context in the study parallels the policy question. Many of the environmental policies at EPA deal with risks that have a long latency period, which may or may not ultimately end in death. In these cases it may not be appropriate to use estimates for fatal, immediate deaths in policies where there is a long latency period. The authors should address how their results may be used in a policy context given that the nature of the risks in these studies may differ from those used in environmental policy.

In summary, both studies provide much needed estimates for how people value risks to children. Even if the context does not mimic that found in many environmental policies, these studies are a step in furthering our understanding of how we might value risks to children, in general.

Summary of Q&A Discussion Following Session IV-AM

Anna Alberini (University of Maryland) opened by asking for "Just a clarification from Nicole Owens and Lanelle Wiggins–How did you calculate the baseline risks that you used in your regressions?"

Nicole Owens (EPA NCEE) responded that "the CDC has data on the number of people that were either killed or injured as a result of biking. We adjust that to take into account the fact that people are wearing helmets, so for kids and adults the percentage is different, but eighty percent of kids out there are wearing helmets and we know how many of them died or were injured taking into account that helmet use. So we back out either the number that would be injured or would have died in the absence of helmet use and call that baseline risk."

Albernini followed up with, "But how does it vary across the respondents?–which is my original question."

Owens clarified by stating that the data is tabulated by age, race, and gender and, therefore, is not really a personal measure of risk.

Albernini closed by asking, "So, potentially there is correlation with age, which is also one of the regressors?" and Dr. Owens responded, "Yes."

Don Kenkel (Cornell University), addressing the researchers of the bicycle helmet study, observed that "your risk variable is just some kind of non-linear combination of other variables on your right hand side, so in some sense, you could question are you picking up the effect of risk versus the effect of quadratic interaction terms of those other variables . . ."

Nicole Owens (EPA NCEE) responded that they have "tried *really* hard to get a more individual measure of risk and so far it's been kind of unsuccessful." She said they had thought of implementing people's zip codes to help make some assumptions, but even that wouldn't provide information about "*where* they ride, whether it's urban or rural," so they still are left with the problem that the number they get from the CDC is categorized.

Lanelle Wiggins added that they also tried to include some notion of exposure by using the "days ridden" variable within the risk variable, but that had created some troubles also.

Al McGartland (EPA) said that the automobile market and bicycle helmet study presentations brought his thoughts back to yesterday's lunchtime talk and the issue of how kids deal with low-probability events or high-probability events. He asked if either of the research groups had "thought at all about *perceived* risk versus your measured objective risk and whether that might influence or put your results in perspective."

William Schulze (Cornell University) said that they "actually collected in the mail survey perceived risk information, and I used that for the fragility, so we've got at least the engineering risk, is what I call it, or the non-person-specific risk that we calculated from the FARS data set–we also have subjective risk from our survey that we haven't had a chance yet to utilize and compare the results both ways."

Lanelle Wiggins said they also had thought about that and in their survey had included a question designed to get at risk perception, something to the effect of, "If you knew that the helmet you purchased provided this much risk reduction, would you still have purchased it?" She concluded by saying that they are still trying to figure out an effective way to get at and use that information.

Robin Jenkins added, "I think Lanelle mentioned the NSRE was done over the phone, so we struggled a lot with the original questions we had for trying to ask people about their perceived risks, and you just can't explain that over the phone. It wasn't going very well, and then we also had no control over when the survey was implemented, so we came to give up that endeavor." She said she believes the NSRE is scheduled to be redone in 2005, which will present a new opportunity to try to gather that kind of information.

Barbara Kanninen asked Dr. Schulze whether he had explicitly accounted for family size in the automobile study model. In explaining why this would matter, she stated that current laws regarding air bags and child safety seats coupled with space issues eliminate the option of purchasing a safe Volvo stationwagon once you have three kids–they simply won't fit into what might be your vehicle of choice. She personally knows several families who, as soon as they had three kids, traded in their Volvo wagons for Ford minivans. She continued, "So, I was thinking, especially when you get to the multinomial choice models, that might be a place where you can really account for that, because basically, choice hasn't changed. They, of course, I think are very much thinking of safety, but they also don't have some of the safe cars available to them anymore."

Picking up on a related issue, Dr. Kanninen said, "I'm not a family economist, so maybe I'm out on a limb here, but–depending on the size of your family, if you have one kid versus five kids, at some point when you've got a lot of kids you have to sort of mentally think of them as a pack. They're sort of not individuals any more–it's like mentally, financially, emotionally, everything–you're dealing with *the kids*. And so I was kind of wondering if when it comes to decision-making, especially when it comes to the pocketbook, do families with single children actually value that one child a lot more than if you divided that five-kid family into five? . . . So, to use an inappropriate term, there might be sort of like almost "diminishing marginal returns" to a family who has more kids, and I wondered if that might come out of this model as well."

Dr. Schulze replied that although he fully agrees with Dr. Kanninen's first comment, he is reluctant to say much about what's going on with the kids and the parents. He added that the VSL switching that goes on between kids and adults in the lower income and middle income groups (with kids worth less than adults in the lower income group, and adults worth less than kids in the middle income group) is something he doesn't fully understand. He also commented regarding "the fact that parents' values are so low relative to families which you don't have children in, so something strange is going on here, and I don't want to claim that I understand it." He agreed that a multinomial model would probably be a productive way to move forward "along with adding some additional explanatory variables that we have collected . . . we know there are broken homes and things like that." In closing, he reiterated that "there's a lot more work that needs to be done with the data that we collected, and anything I would say would be very speculative. I already speculated a little, but *I* don't understand it at this point."

Ted Bergstrom had this to say: "I don't do econometrics very often, but I'm used to seeing numbers with confidence intervals around them. Kelly Maguire remarked that she thought the differences between the bicycle helmet study and the car study values of child life were *big*. I didn't think they seemed so big, and I especially thought that neither of them seemed terribly reliable. I would guess that a responsible policy analysis would suggest that you should provide some confidence intervals."

After a long pause, Dr. Schulze drew laughter by responding simply "Yes." He was quick to add that one shouldn't be misled by a "t" of 14 on an estimate of VSL because an enormous amount of statistical machinery is behind that calculation, and he conceded, "You need someone smarter in statistics than I to construct a confidence interval." He went on to say, "You know, there are many questions about the functional forms we used to predict the allocation of miles, so I fully agree with that. What we know about the VSL is that it falls in a certain range, and that range is not unreasonable compared to the physical science estimates we get in the environment, where an order of magnitude is *great*. Well, we certainly know the order of magnitude, and there's not a lot of evidence that old people are worth a lot less than adults, and there's not any reliable evidence that we should value kids less, and EPA uses one number for everybody, and I don't see any support for changing that until we know a lot more. So, I think you're exactly right because of that confidence interval."

Ted Bergstrom then directed a similar question to the bicycle helmet researchers: "How about the bike study–have you got any notion about how confident you are in your numbers? Would you be surprised if you were off by a factor of 10 or even 5?"

Nicole Owens answered that early in the study they were actually getting estimates that were much, much higher and since they haven't calculated confidence intervals, they would not be surprised at all if they off by a factor of that much.

Robin Jenkins quickly added, "But we *can.* We *can* estimate them, so we will.

Charles Griffiths (U.S. EPA NCEE) directed his comments to Dr. Schultze, first stating that he would view thirteen telephone calls to a home with no response as a refusal. He cited the fact that many people use their caller ID function to screen calls and simply won't pick up if they don't recognize the caller.

Dr. Griffiths then made his main point by stating, "I was curious what the theoretical justification was for *miles* in the utility function. It seemed like an intermediate product– you would sort of *go* somewhere in the miles required to get something that's useful for the utility function. I noticed it was in the kid's utility function, too, and there I'd have trouble citing it–I mean you'd think it would be negative, but, you know, I gave my son a Gameboy and now he loves to ride in the car . . ."

He closed with this final question regarding econometrics: "I noticed in your model the omitted category was the high-income kids and child VSL. I assume that was done for econometric purposes, but my question is just: Does that force then the equation to implicitly assume the same VSL for the high-income because . . .?"

Dr. Schulze responded, "No, there were actually different coefficients–there wasn't a subscript working on them, so no–they could be different for each group."

He addressed the phone call comment by saying, "The thirteen calls–sure, who knows? It's just that you call a number thirteen times and it never gets a pick-up–you're right, it could be caller ID, but then they'd have to have been there . . . I don't know–who knows? My recommendation is forget telephone surveys, forget mail surveys, go to the web-based and you need to get some approval on a better approach. I certainly would not do this again–it's a very expensive, very inefficient way of collecting data. You know, it was the only thing available to us at the time. So, that's my position on that."

Dr. Schulze continued by asking, Dr. Griffiths: "In terms of your point about *miles* in the utility function, how many miles did you drive last year?" to which Dr. Griffiths answered, "10,000." Dr. Schulze concluded, "You must like driving–you spend a lot of money doing it. That's my answer. I mean, people do it–they like doing it. . . . We spend a major part of our life doing it, and I just didn't want to make the model more complicated." He acknowledged the point that "it actually is an intermediate good" but said that for simplicity's sake he "just dumped it in there." He closed by saying he didn't give it more attention because he didn't think that was where the theoretically interesting stuff was.

Ronnie Levin (U.S. EPA) opened by commenting that in her experience the utility of telephone surveys depends on what you're doing. She said, "We do a lot of targeted randoms and not random *digit* dialing, so when we're surveying sectors, we do a lot of surveys using the telephone, and it works very well."

Regarding the bicycle helmet study, Ms. Levin then asked, “In the CDC injury data, do they record whether the injuree was wearing a hemet?”

Nicole Owens answered that although that information was included in some “smaller surveys that observed hospital emergency room visits,” the CDC doesn’t collect those data.

Levin continued, saying that “injuries in most sports don’t occur equally distributed across the population of participants, and so that may be something to further investigate. Now, the purchasing is happening by the *parent*, who is *not* the person who’s actually exhibiting the risky behavior. But, again, going back to Al McGartland's comment that perceptions of what is risky behavior vary by age and sex–and so that’s something else for us on the finessing of loose ends. But, I think it doesn’t negate in any way the fact that I find the numbers remarkably similar, also.”

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Mary Evans (University of Tennessee) stated her interest in the issue of how decisions about *multiple* mortality risks are made. Addressing Dr. Schulze, she said, “You have this kind of inherent in your structure, where you have a baseline survival probability and you *assume* sort of an additive framework, so that risks just add on top of each other. I wonder if you could comment on how an alternative framework in which you have individuals confronting risks in a sequence–in other words, I have to *survive* some baseline risk in order to then be confronted with and ultimately deal with fatality risk–how that might change the way that you think about estimating VSL.”

Dr. Schulze responded that he would need a blackboard to work through that explanation, and he borrowed a quote from his doctoral microeconomics professor, who claimed not to be “*smart* enough to do economic theory except using mathematics as a crutch.” He said the question required “*real* thought” and a lot of figuring.

Evans commented that she and Kerry Smith “have done a little bit of work looking at that” and offered to speak with Dr. Schulze afterwards, to which he responded, “I would *love* that–it’s even better if *I* don’t have to do it.”

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Bryan Hubbell (U.S. EPA) addressed Lanelle Wiggins and Nicole Owens regarding his concern “about this issue of jointness in production: You’re using the cost of the bicycle helmet somewhere in there–I couldn’t figure exactly whether they have individual prices or not, but if you do have individual prices, there is this issue that you’re producing this utility for your child by buying him a bicycle helmet that looks ugly. And they’re also less likely to wear it. So, there are two things they’re buying when they pay additional price for a helmet beyond what the minimum price might be to get an effective helmet. And if there’s a systematic willingness to pay either to improve the child’s utility because of the ugliness factor or to get them to increase their compliance behavior, that could affect your VSL in an upward fashion. Now, the compliance behavior–you may want that to be part of it, but you certainly don’t want to include the child’s willingness to pay or the parent's willingness to pay to reduce the child's disutility for appearance's sake into that VSL." Dr. Hubbell suggested finding some way to adjust the price of the bicycle helmet "to get rid of, or *net out*, this co-production of this other utility." As a related example, he cited the purchase of bottled water, where you're not just buying the safety–you're buying the taste and other things. He added that figuring out a way to pull that factor out might make the numbers more in line with some of the adult values.

Nicole Owens responded that the idea made sense but it was not something they had thought of.

Cristina McLaughlin (U.S. FDA) commented that she thought the use of temperature data in the bicycle helmet study was very creative and she asked whether they had also used that data to examine if temperature actually played a role in the decision to use the helmet.

Nicole Owens responded that the original intention was to predict days ridden as a function of temperature and precipitation. She said that they found that temperature was a significant factor: i.e., when it was warmer, kids rode more. The data also indicated that precipitation had no effect, but she stated that it was difficult to draw any really strong conclusions regarding this because the associated equation "was dismal."

T.J. Wyatt (U.S. EPA/OPP/Division of Biological and Economic Analysis) asked the presenters to comment on how they think the *absolute* cost of the risk mitigating decision plays into the estimate of VSL. He pointed out that "a helmet that costs 25 or 30 bucks seems like a fairly small expenditure to avoid risk, whereas an auto purchase would be a major commitment of resources, particularly for low-income families." He questioned to what extent they thought that might have something to do with the difference in magnitude of their estimates.

Lanelle Wiggins responded that they had thought about getting at that issue by trying to figure out how to measure the time it takes to use a helmet and somehow incorporate that into the price. She added that because of the way the model is currently structured, with the helmet price simply subtracted from income to reduce the amount available to spend on all other goods, it probably wouldn't change the results that much. She acknowledged, however, that it is an important point.

Dr. Schulze affirmed that "a single mom, newly divorced, and with a kid, might very well have a hard time getting auto financing, and that could be affecting our values, so that's a very good point."

Nicole Owens added that helmets, especially for kids, are very cheap and effective. People were asked how long they thought the helmets would last and their answers along with the prices of the helmets yielded an annualized price of the helmet somewhere around $6. She continued to say that combining this information with the risk data, it brings back Al McGartland's point about what is the risk that parents perceive. She closed by stating that it also might be that for $6 "you're almost buying yourself out of the uncertainty associated with what the specific to your kid might be" or you might feel better about the cost per use of a rarely used helmet.

Ted Bergstrom asked, "What is the reduction in the probability of the child dying as a function of having that [helmet]?"

Nicole Owens responded with the figure "2 million,"–the annualized price divided by the risk reduction for kids, yielding the estimated VSL.

Bergstrom continued, "So we're saying that all the parents who do *not* buy helmets, by your methodology, think their kids are worth *less* than $2 million. . . . How do you get to the $10 million statistic?" He asked whether that comes from all the extra paid for fancy helmets.

Robin Jenkins said that the paper they had written previously in fact did make it that simple–just looking at the price divided by the risk reduction. She clarified that the current study involves a household production model, in which the household is producing safety and the decision to purchase a helmet is really representing the indirect utility function of the household. So, the valuation is on risk–the model is designed to represent something *beyond* what you would get from such a simple calculation. She closed by saying, "So, I guess it's all embedded in the modeling–the fact that we've got this random utility model that's representing the conditional utility function."

Bergstrom said, "But somehow that seems to me it's producing something from nothing." He added that the data shows that there are a lot of people willing to pay at least $2 million for a statistical child's life, and he reiterated, "That's all you've got. And so now you've got a complicated model that produces $9 million. How can this be? I love magic, but . . . where's it coming from?"

Jenkins responded that "It's not really magic–it's just a representation of the household's decision that is trying to build into the equation other considerations about the valuation of safety . . ." When one of the participants clarified, "You're dividing by the marginal utility of money–you're not dividing by the price," she added, "Exactly–marginal utility of income."

Someone commented, "And if it's true that 90 percent of them are buying helmets, then the lower bound is $2 million but the mean is going to be up there . . ."

Jenkins added that the 2 million figure was just "off the top of their heads" and may not be right. She acknowledged that the "other paper" dealt with a higher value, closer to 4 million.

Owens clarified that the other figure was "the adult valuation . . ."

Scott Grosse (Centers for Disease Control and Prevention) asked whether any of the researchers had tried to calculate VSLs by parents' education levels and added that "There is a large literature suggesting that parental education leads to different valuations of children's health and investments in children's health, so it would be plausible that the VSL would differ by the education level."

William Schulze responded that their study represented "sort of a first look" at these data, and he affirmed that they did have information on that. Furthermore, he said that the parent education level is "exactly one of the variables that I hope to use to try to figure out what's going on with kids' and adults' relative values switching between income classes." He conjectured that the hypothesis that "lower-income families have lower education" levels might help explain the situation.
Nicole Owens explained that parent education was not factored into their equation, although it was significant, so the relationship remains to be explored.

Glenn Harrison (University of Central Florida) commented that listening to these study reports every couple of years always brings to mind the fact that "there are other sources of data that are extraordinarily rich that might be worth accessing, and it's the sort of thing an agency could do if they approach the right people." As one such source, he mentioned HMOs, "particularly Health Partners, based in Minnesota" as groups that engage in the collection of a lot of health-related data about cars, bike helmets, smoking, alcohol, etc. He continued by saying that "basically, they're collecting information from their target population about all sorts of risk factors" because they're interested in educating the people on the risks of obesity and all sorts of things and the interactions between them. The bottom line is they want to lower their own costs. Dr. Harrison explained that although these organizations are generally extremely reluctant to let others access their data, agencies can talk to them "and get cooperative agreements with some of these places." As an example, he said the CDC has negotiated such arrangements with some HMOs. He closed by testifying to the "incredible" quality and value of the data available from these groups because "they track everything else about these people as well."

Valuing Environmental Health Risk Reductions to Children

PROCEEDINGS OF

SESSION IV-PM: AGE-SPECIFIC VALUE OF STATISTICAL LIFE ESTIMATES (CONT'D)

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE), NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER), AND OFFICE OF CHILDREN'S HEALTH PROTECTION; AND THE UNIVERSITY OF CENTRAL FLORIDA

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DRAFT-Preliminary and Incomplete

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An Empirical Life-cycle Model of Demand for Mortality and Morbidity Risk Reduction

J.R. DeShazo and Trudy Ann Cameron[1,2]

Abstract

This paper explores empirically the way that demand for health-enhancing and life-extending programs varies over the life-cycle for individuals. We test the hypothesis that, at any given current age, an individual's schedule of marginal utility for future risk reductions rises on average with the age at which the future adverse health status would be experienced. However, as individuals age, we also hypothesize that there is a systematic downward shift in these schedules of marginal utility for risk reductions at future ages. Using data from a representative national sample of US households, we estimate the net effect of these two offsetting age effects for various risk-reducing policies. We identify the systematic age-varying determinants that explain why demand for some programs varies significantly with age, while demand for other programs does not.

[1]Senior authorship is not assigned. Nominal lead authorship will rotate though the series of papers associated with this project.

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1 Introduction

Empirically, scholars know little about how demand varies, over individuals' life-cycles, for programs that reduce the risk of morbidity and mortality. These programs include publicly provided environmental, safety and health programs as well as privately available preventative care and medical therapies. Understanding how demands for these programs vary with age has become increasingly important to several fields in economics.

Environmental and regulatory economists measure the social benefits of publicly mandated environmental, health and safety regulations. At the prompting of policymakers, they are now seeking to determine whether the sizes of the social benefits from these programs vary by age group (Smith and Evans, 2003; Alberini, et al., 2003).

Health economists have a longstanding focus on how individuals' investments in their health vary throughout their lifecycle. While this literature has made considerable theoretical advances in understanding the life-cycle determinants of demand for health (Grossman, 1972, Chuma and Erhlich, 1990, Johannsson, 1997; Erhlich, 2002) there has been a shortage of empirical analyses that test the hypotheses implied by these theories.

Finally, we are in the midst of a number of major demographic shifts, including a general aging of the population. Public economists have become interested in how changes in health and longevity affect individuals' consumption of government programs such as Social Security, Medicare, Medicaid (Hamermesh, 1995; Hurd et al., 1995, 1995, Gan et al., 2003).

The central contribution of this paper is an empirical exploration of the way individual demand for health-enhancing and life-extending programs varies with age. We test two hypotheses about how individuals will value risk-reductions over their life cycle. We motivate these hypotheses though a [stochastic dynamic optimization] model in which the individual chooses a quantity of a risk-reducing program in each period throughout her life cycle (Ehrlich, 2000). Our first hypothesis is that, at any age, individuals will derive increasing marginal utility from reducing risks that come to bear later in life. This comports with the intuition that marginal value of health investments rises with age and concurrently that life-saving programs will grow more valuable with age.

Our second hypothesis is that as individuals age, there is systematic downward shift in their schedule of marginal utility for risk reductions at future ages. Our second hypothesis is based in the assumption that there are strong complementarities between health and other commodities. Individuals only learn about the extent of these complementarities as they age. With greater age, the declining quality of health begins to have appreciable affect on the marginal utility of consumption. Such age-induced learning causes individuals to decrease their expected value of future consumption. In response, individuals intertemporally adjust by shifting their consumption forward in time. As the value of future consumption declines, so does the shadow value of investment in life-extension. The effect of this process is to diminish the value of investment in current and future life-saving programs.

While this model illustrates these two countervailing dynamics, the net effect on age-varying demand for risk reductions is ultimately an empirical question. To evaluate these two hypotheses and to assess this empirical question, we develop an estimating specification that enables individuals to express their demands for risk-reduction programs that will alter the time-pattern of risk faced during their remaining life cycle. This empirical model makes several contributions to the existing empirical literature (Krupnick et al., 2002; Alberini et al., 2003; Evans and Smith, 2003).

First, we cast the demand for risk reducing programs in an option price framework (Graham, 1982). This approach is appropriate for the vast majority of public and private life-saving programs, since they involve a stream of certain costs and uncertain future benefits. Second, this model recovers the individual's marginal utility of avoiding a year spent in a morbid condition, the marginal utility of a year spent in a recovered state, if the condition is not fatal, and the marginal value of avoiding a lost life-year. Our specification allows these marginal values to shift with both the individual's current age and the future age at which the risk of each particular health state is reduced. For each age cohort, we are able to estimate the schedule of marginal values associated with reducing risks over all future ages.

We estimate this model using data from an innovative national survey of over 1,300 U.S. citizens. In the survey, individuals were asked to choose between programs that reduced the probability of experiencing a future time profile of undesirable health states. The time profiles for these health states were described in the context of the individual's current age and nominal life expectancy. Each profile described the future age of onset of an illness, the level and duration of pain and disability that could be expected to follow, including surgery and hospitalization, and the number of life-years lost relative to nominal life expectancy. The risk-reducing programs consisted of an ongoing annual diagnostic test for a specific illness. If the individual is found to be at risk for the illness, they would be given drug therapies, and prescribed lifestyle changes, that would reduce their risk of experiencing the illness profile. These data enable us to evaluate how individual demand for avoiding a future year of morbidity and premature mortality varies with each individual's current age and with their age during each future period of reduced health (or they age that they would have been, had they not experienced premature mortality).

Controlling for the individual's current age, we find that the marginal utility of avoiding a future lost life-year rises with age. Controlling for the age at which the undesirable future health states would potentially be experienced, we find that as individuals grow older, their marginal value of current and future risk reductions declines. Together, these effects produce distinct schedules of marginal utility for each age cohort. To evaluate the present value of these future risk reductions, these marginal values must be discounted, and the risk reduction normalized to 1.00, to obtain the present value benefits of avoiding a "statistical" case of a particular morbidity/mortality health profile.

We conclude our analysis by exploring how a number of selected types of risk-reducing programs will be valued by different age groups. Most previous empirical studies (notably wage-risk studies) have focused on the risk of sudden death, so we emphasize these health profiles here. Through simulations, we evaluate the social benefits of a program that reduces the risk of sudden death for five age groups: 25-, 35-, 45-, 55-, and 65-year-olds. Because the individuals enjoy the risk reduction immediately, any differences that are observed are determined exclusively by the age-specific declines in the marginal value of risk reductions. We find in models with no explicit age effects, and in models with linear age effects, that our inferred values of statistical lives (VSLs) decline by age cohort. In more general models with quadratic age effects, the pattern is non-monotonic. First one effect dominates, then the other.

Our second policy simulation, a latency period of five years is hypothesized before the risk of sudden death would materialize so that benefits would begin to accrue. In this context, discounting becomes important when calculating the VSL, but the discounted latency period (five years) is constant across age groups. As should be expected, we find differences in age-specific VSLs that are roughly comparable to the first simulation.

Our third policy simulation considers how all age cohorts would value a reduction in the risk of death at the common age of 70. A model with no explicit age effects suggest strongly that the VSL increases as the respondent's age gets closer to 70. In models with age effects, however, the pattern of VSLs is non-monotonic due to the competing influences of the two types of age variables in our models. For models with age effects, we find no clear differences in the VSL for this policy which is consistent with the findings of Krupnick et al., (2002) and Alberini et al., (2003). Our results suggest that the reason for no apparent age effect may be the existence of offsetting effects of discounting and downward shifts in the marginal utility of risk reduction with age. Younger cohorts have a higher marginal utility for the risk reduction but this value is discounted over a longer time period. Older cohorts express a lower marginal utility for the risk reduction but discount it over a shorter period.

In our final policy simulation, we hold the age group constant (focusing only on 25 year olds) in order to evaluate the implied VSLs for policies with latency periods that vary by 5, 15, 25, 35 and 45 years. In this simulation, we utilize only the upward sloping schedule of marginal utility for future risk reduction associated with 25 year olds. Therefore, any difference in VSLs results from differences in (1.) the slope of the marginal utility schedule for future risk reduction, (2.) the discount rate, and (3.) the latency period over which discounting occurs. In a specification that ignores age effects, there in an apparent strong decline in the VSL as the latency period for the mortality risk increases. In a model with linear age effects, this pattern persists but is somewhat attenuated. In a model with quadratic age effects, however, the pattern becomes again non-monotonic.

2 Theoretical Model of Life-Cycle Demand

This model follows Ehrlich (2002) who develops a life-cycle model of demand for risk reduction programs.[3] To maximize lifetime utility, individuals choose quantities of a risk-reducing program, $I(t)$, and a composite consumption activitiy, $Z(t)$, in each period, t.[4] Demand for risk reduction arises because individuals face a conditional per-period arrival frequency, $f(t)$, of life-threatening events (such as major illnesses) that lead to mortality.

Individuals control the flow of $f(t)$ though the purchase of risk reducing programs in the following way:

$$\begin{aligned} f(t) &= j(t) - I(t) \qquad (1) \\ \text{where } I(t) &= I(m(t),\, M(t);\, e(t),\, t), \end{aligned}$$

and where $j(t) > 0$ is the exogenous conditional probability of a major illness, which is determined by heredity in conjunction with biological and environmental risks. $I(t)$ defines the difference between the exogenous risk and the individual's actual risk, $j(t) - f(t)$.[5] These risk-reducing programs are produced using inputs of time,

[3] This model generalizes similar life-cycle models by Conley (1976), Shepard and Zeckhauser (1984), Rosen (1988), and Johansson (2001).

[4] For simplicity, we assume that individuals habor no bequest motives. Nor do individuals participate in insurance markets that are designed to protect against "living too long" (by purchasing guaranteed annuities) or "living too short" (by purchasing life insurance).

[5] This formulation simplifies the derivation of the time path for $I^*(t)$.However, it abstracts from the possibility that current period expenditures on risk reduction could affect the the conditional risks in future periods.

$m(t)$, and market goods $M(t)$. Production of these programs is also determined by efficiency parameters, $e(t)$ (reflecting the individual's human capital or education level), and their current age, t. In keeping with theories of aging (Kirkwood, 1977; Kirkwood and Rose, 1997; Sozou and Seymour, 2003), health risks are assumed to rise at an increasing rate throughout the remaining lifespan $(\dot{j}(t)) \equiv dj(t)/dt > 0$.

The cost function for $I(t)$ is given by

$$C(I(t)) = c(t)\ I(t)^{\alpha} \text{ where } \alpha > 1 \text{ and } c(t) = c(w(t), P(t), e(t), t), \tag{2}$$

where w is the wage rate per unit of human capital. The wage rate also represents the opportunity cost of time, where $w \equiv \dot{w}(e)/e$. All prices, $P(t)$, and efficiency parameters, $e(t)$, are held constant across the life cycle. For simplicity, assume that $\alpha = 2$ so that the cost function for the risk-reducing program is $C(I(t)) = c\,I(t)^2$. The production function for risk reductions is subject to diminishing returns to scale because of the fixed scale of the human body.

In each period the individual will consume a flow of health-state denominated time, $h(t)$, and a flow from a composite consumption activity, $Z(t)$. We treat the risks of morbidity and mortality as independent risks in our empirical analysis. However, we assume here, for simplicity, that they are monotonically related to one another.[6] Health-state denominated time is assumed to be a decreasing and concave function of $f(t)$ to capture the positive correlation between the risk of a life-threatening illness and associated morbidity. Health denominated time, $h(\cdot)$, may range from perfect health to acute morbidity as function of :

$$h(t) = (h\,f(t), \beta) \text{ with } h'(\cdot) < 0 \text{ and } h''(\cdot) < 0. \tag{3}$$

The argument β represent shifts in medical technologies that reduce the levels of morbidity associated with

[6] As a practical matter this assumption limits us only in that we cannot theoretically explore the determinants of individuals' marginal rate of substitution between morbidity and mortality as health states. Such tradeoffs are not the focus of this paper; see Cameron and DeShazo (2004) for an exploration of these issues.

$h(f(t))$. We assume that this measure of health-state denominated time perfectly exhausts each individual's time constraint.

The consumption activity $Z(t)$ is produced by combining purchased market goods, $M(t)$, at constant unit prices (P) and the individual's time, $m(t)$. The individual purchases these market goods subject to an instantaneous wealth constraint:

$$\dot{A}(t) = r\,A(t) + w\,h(f(t)) - cI^2(t) - Z(t)\,, \tag{4}$$

where $\dot{A}(t) \equiv dA(t)/dt$ is the rate of change in savings in period t.[7] Parameters r and w denote the market interest rate and the wage rate, $h(t)$ represents healthy labor time, and the full price of consumption, $P_z = 1$, is the numeraire. The individual knows her terminal condition (age of death) only stochastically, which represents an innovation on Ehrlich and Chuma (1990). In the following equation, E represents the expectation operator which applies to the stochastic length of life, D, while ρ denotes the individual's subjective discount rate.

Individuals choose optimal time paths for Z and I to maximize[8]:

$$J(A(t), t; \alpha) = \underset{Z,I}{Max}\; E\left[\int_t^D \exp\left[-\rho(s-t)\right] U\left(Z(s),\, h(s),\, h(f(s))\right) ds\right]. \tag{5}$$

The individual maximizes (5) subject to equations (1) and (3), $A(t) > 0$, as well as a vector of exogenous parameters: $\alpha = w, e, P, \rho, j$. The terminal conditions, $A(D) > 0$ and $J(A(D), D; \alpha) = 0$ must hold. The optimal time paths for $\{Z^*(t), I^*(t)\}$ are found by applying the stochastic dynamic programming approach

[7] To avoid any discontinuity, which occurs whenever $A(t)$ assumes its boundary value, the individual optimizes subject to $A(t) > 0$. Furthermore, without an insurance market, it is impossible for the individual to die with negative wealth.

[8] The instantaneous utility function (.) is to be concave and possess other standard properties (Judd, 1998).

(Judd, 1998) as determined by the Hamilton-Bellman-Jacobi condition:

$$-J_t = -(\rho + f^*)J + U(Z^*, h(f^*)) + J_A \left[rA + wh(f^*) - cI^{*2} - Z^* \right] \tag{6}$$

where $J_t \equiv \partial J(A(t), t; \alpha)/\partial t$ and where Z* and I* satisfy the optimality conditions:

$$\begin{aligned} U_z(Z^*, h(f^*)) &= J_A & (7) \\ 2cI^* &= J/J_A + [w + (1/J_A)U_h(Z^*, h(f^*))][-h'(f^*)] \equiv v_0^* & (8) \end{aligned}$$

Equation (8) describes the conditions that shape the optimal time path of investment in risk reductions over individuals' life cycles. On the left hand side is the marginal cost of the risk-reducing program. On the right-hand side is the *complete* value of the risk reduction which consists of two terms. The first term, (J/J_A), describes the value of the individual's remaining life span. The second term, $[w + (1/J_A)U_h(Z^*, h(f^*))][-h'(f^*)]$, characterizes the change in utility derived from this remaining life span as a result of reducing morbidity.

2.1 Marginal Value of Future Risk Reduction

This model predicts that the time path of investment in risk reduction will rise with the conditional probability of risk. To see this explicitly, assume (for the sake of expositional ease only) that the individual's utility function is separable in healthy time and consumption. From equation (8) we can show the path of risk reduction investment depends upon two countervailing influences:

$$\begin{aligned} \dot{I}^*(t) &= \left(\frac{1}{\Delta}\right) \left\{ \begin{array}{c} [d(J/J_A)/dt + (U_h/J_A)(-h')(r - \rho - f(t^*))] \\ - \left[(w + (U_h/J_A))h'' + (U_{hh}/J_A)(h')^2 \right] \dot{j}(t) \end{array} \right\} & (9) \\ &\equiv \dot{v}^*(t), \end{aligned}$$

where $\Delta \equiv 2c - [w + (U_h/J_A)h'' - (U_{hh}/J_A)(h')^2 > 0$ and $\dot{X} \equiv dX/dt$. Examining the first term, the time path of investment in risk reduction depends upon the rate of increase in exogenous risks, $\dot{j}(t)$, associated with aging. Concurrently, the marginal value of improving health-denominated time rises with $j(t)$ and t. The aging process raises the marginal benefits of investment in risk reductions. Concurrently, the marginal value of improving health-denominated time rises with $j(t)$ and t. Therefore, we hypothesize that individuals will express a higher marginal value for risk reductions that occur at later ages. This should be true even though there are diminishing returns to increasing investments in risk reduction. The first two terms inside the braces (9) illustrate how the value of protective investments rises with the value of reducing the risk of mortality, $d(J/J_A)/dt$, plus morbidity, $(U_h/J_A)(-h')(r - \rho - f(t^*))$. We discuss the time path of these two terms in more detail below.

2.2 Health and Consumption Complementarities

Traditional theoretical expositions of this class of models leave open the question of whether utility from the consumption activity $Z(t)$ and health $h(t)$ are separable, i.e., whether $U_{zh}(t) = 0$ (see Grossman, 1972; Chuma and Ehrlich, 1990; Ehrlich, 2000). While the modeling exercise is less complicated if the separability assumption is invoked, such an a priori assumption seems unwarranted. To begin with, the production function for $Z(t)$ is assumed to require the individual's non-market time, $m(t)$ (Ehlrich, p. 345, 2000). The health quality of this input should affect the level of utility that the individual derives from the consumption activity. It is much more likely that the individual's time, $m(t)$, and market goods, $M(t)$, are complements in consumption, rather than perfect substitutes. As the level of morbidity $h(f(t))$ rises, the quality of the individual's time input, $m(t)$, should fall. So should the utility derived from the consumption activity, $Z(t)$. These theoretical relationships are supported by a large body of literature on the physiological and cognitive effects of aging (Kenney, 1989; Gfellner, 1989; Posner, 1995). As individuals age, their ability to derive utility from market goods declines. With increasing age, individuals begin to have trouble driving a car, for example, or enjoying the same recreational activities as they did in their youth or middle age. With age, the level of utility they derive from basic market goods declines. They may eventually experience difficulty in feeding themselves, dressing, and moving about freely.

To see the theoretical importance of this separability assumption, consider the individual's optimal consumption path:

$$\begin{aligned} \dot{Z}(t) &= -\left[U_Z(t)/U_{zz}\right](r - \rho - f^*(t)) \\ &\quad -[(U_{Zh}(t)/U_{zz}(t)]h'(f^*(t))\dot{f}^*(t) \end{aligned} \tag{10}$$

If $U_{Zh}(t) = 0$, the second term in (10) drops out. Examining the first term, we get the well-known result due to Yaari (1965) that lifetime consumption rises only if the market discount rate exceeds the subjective discount rate and the conditional rate of mortality. Both theoretically (Sozou and Seymour, 2003) and empirically (DeShazo and Cameron, 2003), scholars have shown that subjective discount rates rise with age. Therefore, even with the assumption of separability, the quantity of consumption is likely to fall with age. However, once the assumption of complementarities between health-denominated time and commodities is made (i.e. that $U_{Zh}(t) > 0$), the rate of decline with age will be even greater. As shown by equation (8) this decline in the value of future consumption will, in turn, lower the marginal value of current and future risk reduction.

2.3 Learning with age and shifts in the marginal value of future risk reductions

This model assumes that individuals have perfect information on all parameters over the course of their life cycle. But what would be the implications if, instead, individuals learned about the aging process as they aged? Current-period expectations about the future values of parameters are likely to be biased towards their current-period value. Through learning, however, individuals might update their future expectations by assessing trends in key parameters over their recent life histories. Candidate parameters for updating might include the individual's conditional risk of a life-threatening illness, $j(t)$, the individual's subjective discount rate, her future wealth constraint or the extent of complementarities between health and consumption (i.e. if $U_{Zh}(t) > 0$). While the effect of learning about any of these parameters is likely to cause individuals to revise their future time path of consumption downward, we argue that the possibility of learning about complementarities between health and consumption is the most plausible, since such knowledge is most likely to be acquired though the personal experience of aging.[9]

If individuals do progressively learn, as they age, that health and consumption commodities are strong complements, the exogenous rise in $j(t)$ with age will cause the value of consumption in future periods to fall. Intertemporally, individuals will respond to this knowledge by reallocating consumption to earlier time periods where it will yield more utility. This action, in turn, reduces the value of investment in risk reduction in future periods; from equation (8) the remaining value of reducing mortality risk (J/J_A) and morbidity, $[w + (1/J_A)U_h(Z^*, h(f^*))][-h'(f^*)]$ will decline. Based on our conjecture of age-driven learning, we hypothesize that as individuals age, their schedule of marginal utility for future risk reduction will decline with their current age. A related (and empirically testable) consequence of this conjecture is that individuals' projected schedules of future marginal utility of consumption should vary systematically with their current age. Specifically these schedules of future marginal utilities of consumption should be steeper and turn down later in life for younger age groups relative to those of older age groups.

3 Data and Survey Methods

Our data were collected in a national random survey of U.S. adults in 2002. The innovative feature of our survey consisted of a conjoint choice exercise wherein individuals could purchase a program that reduced their risk of experiencing specific illnesses over future periods of their life. These programs were described

[9] Ehrlich (2003) provides comparative static analysis for all of these parameters except for changes in the complementarity between health and consumption.

as involving annual diagnostic testing and, if needed, associated drug therapies and recommended life-style changes. Each program required a constant annual payment in return for reducing the risk of an illness profile. Each illness profile is a description of a time sequence of health states associated with a major illness that the individual is described as facing with some probability over the course of his or her lifetime. We briefly describe the development, design and administration of this survey instrument below. A fuller description is available in Appendix A.

3.1 Survey Development and Design

In order to effectively describe the illness profiles, the associated risk, and the programs that reduced these risks, we conducted extensive one-on-one interviews (i.e., cognitive interviews) and pre-testing. We conducted 36 cognitive interviews over the nine-month development period. During this period the survey went through four significant revisions. We pretested the last three versions. These three pretests involved a total of 1,500 respondents over a three-month period. We also benefited greatly from a peer review panel that evaluated the second of the four versions of the instrument.

The final conjoint survey is structured around four modules: 1) the introductory module, 2) a tutorial for the illness profile and the risk-reducing program, 3) the presentation of the choice sets, and 4) a debriefing and follow-up module. For the sake of brevity, we focus below on only the risk-reducing program and the design of the illness profiles in the context of the conjoint choice set.

For the risk reduction programs in our survey, we specified combinations of diagnostic testing and drug therapies because respondents viewed these as technically feasible and potentially effective. Respondents were familiar with comparable and pre-existing diagnostic tests such as mammograms, pap smears and prostrate exams, or the new C-reactive protein tests for heart disease. Important from our perspective was the fact that this class of interventions could plausibly be applied to all of the illnesses upon which we focused. The effectiveness of these programs was described using a risk grid (Krupnick, et al., 2002).

The payment vehicle for each program was presented as a co-payment that would have to be paid by the respondent for as long as the diagnostic testing and medication was needed. For the sake of concreteness we asked the respondents to assume the payments would be needed for the remainder of his or her lifespan unless they actually experienced that illness. Costs were expressed in both monthly and annual terms. To ensure that respondents carefully considered their budget constraint, we included a "cheap talk" reminder as well as language to discourage overstating their willingness to pay.

3.2 Illness Profiles in Choice Sets

Each conjoint choice set presents the respondent with the attributes of two illness profiles: the illness name, the age of onset, medical treatments, duration and level of pain and disability and a description of the outcome of the illness. This is followed by a description of the cost and effectiveness of the risk-reducing program. Subject to several plausibility constraints, we randomly varied these attributes across each illness profile. Both the age of onset and the final stage of each illness are determined by the respondent's current age. Gender specific illnesses (e.g., breast and prostate cancer) are chosen to comport with the respondent's gender.

We summarize the results of the choice set design process in Table 2. The first row in this table presents the frequency with which each of the twelve illnesses appeared in the choice sets. The remainder of the table presents the mean levels of each of the risk, morbidity, and mortality attributes associated with that illness. While the mean levels of the costs, baseline risk, and risk change are very comparable across all of the illnesses, the average levels of the other attributes vary greatly across illnesses. For example, heart attacks are associated with much shorter periods of pain, hospitalization, and death than is lung cancer.

3.3 Sample and Survey Administration

Our conjoint choice survey and a separate health-profile survey were administered by Knowledge Networks to approximately 1,800 panelists. Each survey required about 30 minutes to complete. Respondents were paid an incentive for completing the conjoint choice survey. Respondents' ages ranged from 25 to over 90 years of age. Our response rate for those panelists contacted was 79 percent. Attrition response bias may be present between the point when Knowledge Networks made their initial contact to join their panel and the point when we initially contacted each panelist. To address potential sample selection bias, we are preparing to implement sample selection correction procedures using the Knowledge Networks database of initial telephone contacts and other attrition data.

4 An Empirical Option Price Model of Life Cycle Risk Reductions

We now turn to develop an empirical model in which individuals can express their option price for a program that intertemporally redistributes their investment in risk reductions over their remaining life span.(See Cameron and DeShazo (2003) for a more general discussion of this model.)

4.1 Indirect utility from health states

We develop a simple model of the individual's future undiscounted indirect utility as a function of their health state in that future period. We expand upon most earlier empirical treatments by considering four distinct health states: 1) a pre-illness healthy state, 2) illness state, 3) a post-illness recovered state and 4) a dead state.[10] We define each of these states as a time segment. Within each segment, the individual's health status is assumed (for now) to be relatively homogeneous.

To capture an illness profile, we use sets of dummy variables that collectively exhaust the period of time

[10] Within our empirical model, the illness states are further differentiated into one of twelve specific illnesses, each of which can exhibit a wide variety of different symptom-treatment profiles that may last from zero to six years. In appropriate cases, the illness may also be chronic, lasting for more than six years.

between the individual's present age and the end of his nominal life expectancy. In Figures 1 and 2, we depict examples of these four discrete health states. Let i index individuals and let t index time periods[11]. The dummy variable $\mathsf{Pre\text{-}illness\_year}_{it}$ take a value of 1 in years when the individual enjoys a healthy state. When the health state ends, the value of $\mathsf{Pre\text{-}illness\_year}_{it}$ changes to 0 and remains there for the rest of the individual's expected lifespan. At the end of the healthy period the individual may die suddenly or become sick. Let the dummy variable $\mathsf{Illness\_year}_{it}$ take on a value of 1 at this point and remain equal to 1 for the years during which the individual is ill. When he is not sick, it takes a value of zero. The dummy variable labeled $\mathsf{Recover\_year}_{it}$ takes on value of 1 in the years between the conclusion of the illness and the individual's expected time of death. Finally, we define $\mathsf{Lifeyear\_lost}_{it}$ to distinguish the extent to which death is premature (that is, the time between death and what would otherwise have been the individual's nominal life expectancy).

Next we define the future undiscounted indirect utilities per unit of time in each health state. Let these marginal utilities be denoted as δ_s for an episode of type s, where s in our model can be illness, recovered status, or a life-year lost to premature death. Let the undiscounted utility from each future year in a particular health state be defined relative to no new illness. In other words, we normalize utility on the level of utility being experienced by the individual in their current health state. We abbreviate $\mathsf{Pre\text{-}illness\_year}_{it}$ to pre_{it}, $\mathsf{Illness\_year}_{it}$ to ill_{it}, $\mathsf{Recover\_year}_{it}$ to rcv_{it} and $\mathsf{Lifeyear\_lost}_{it}$ to lyl_{it} to allow more-compact notation.

$$V_{it} = \beta f(Y_{it}) + \delta_0 pre_{it} + \delta_1 ill_{it} + \delta_2 rcv_{it} + \delta_3 lyl_{it} + \eta_{it} \tag{11}$$

Let the undiscounted marginal utility of some function of current income, $f(Y_{it})$, be the parameter β. Let the undiscounted (dis)utility from each future year of illness be defined as δ_1, from each year of the post-illness recovered state be δ_2, and from each year of being prematurely dead be δ_3.

[11] Time may be measured in years, months, or even a smaller units of time, depending on the degree of resolution needed.

Our basic specification assumes that the undiscounted (dis)utility of a year of illness or injury is a constant (in the homogeneous specification). Let age_{i0} denote the current age of respondent i. This is distinct from the age of respondent i in future period t, which we will denote age_{it}. The individual's current age is just another personal characteristic that we can allow to shift the marginal (dis)utility of a sick-year and the marginal (dis)utility of a lost life-year.

We allow the indirect utility in each future period to depend upon the age of the individual while they are experiencing the health state corresponding to that period. Age in period t may shift the marginal utility of transformed income and of each health status:

$$\begin{aligned} V_{it} &= \left[\beta_0 + \beta_1 age_{it} + \beta_2 age_{it}^2 + \beta_3 Y_{it}\right] f(Y_{it}) \qquad (12) \\ &+ \left[\delta_{10} + \delta_{11} age_{it} + \delta_{12} age_{it}^2\right] ill_{it} \\ &+ \left[\delta_{20} + \delta_{21} age_{it} + \delta_{22} age_{it}^2\right] rcv_{it} \\ &+ \left[\delta_{30} + \delta_{31} age_{it} + \delta_{32} age_{it}^2\right] lyl_{it} + \eta_{it}. \end{aligned}$$

Or,

$$\begin{aligned} V_{it} &= \beta_0 f(Y_{it}) + \beta_1 age_{it} f(Y_{it}) + \beta_2 age_{it}^2 f(Y_{it}) + \beta_3 Y_{it} f(Y_{it}) \\ &+ \delta_{10} ill_{it} + \delta_{11} age_{it} ill_{it} + \delta_{12} age_{it}^2 ill_{it} \\ &+ \delta_{20} rcv_{it} + \delta_{21} age_{it} rcv_{it} + \delta_{22} age_{it}^2 rcv_{it} \\ &+ \delta_{30} lyl_{it} + \delta_{31} age_{it} lyl_{it} + \delta_{32} age_{it}^2 lyl_{it} + \eta_{it} \end{aligned}$$

The disutility of each of these states will be interpreted as being the same as the utility associated with avoiding them. The dummy variables, ill_{it} , rcv_{it}, and lyl_{it} adjust the limits of the summations used for the present value of future continued good health, future intervals of illness, recovered time, and life-years lost. In this paper we assume that the individual uses the same discount rate, r, to discount both future money costs and health states. [12]

With this set-up, we can develop a structural model of the ex ante option price that an individual will be willing to pay for a program that reduces his/her risk of a morbidity/mortality profile over the future. Define the present discounted value of indirect utility V_i^{jk} for the ith individual when $j = A$ if the program is chosen and $j = N$ if the program is not chosen. The superscript k will be S if the individual suffers the illness (or injury) and H if the individual does not suffer the illness.

The pattern of income and program costs under the four different health states will be relevant to the individual's indirect utility in each state. We define γ_1 as the fraction of the individual's income that will be earned while the individual is sick, should he suffer the illness in question. With adequate disability insurance or sick leave, this fraction might be assumed to be 1.00. Let γ_2 be the fraction of income received if the individual is no longer living, but would have been, had they not suffered the illness. This parameter will be assumed to be zero in our empirical models, but a non-zero value could be invoked to activate a bequest motive. The parameter γ_3 is the fraction of the cost of the program that must be paid while the individual is suffering from the illness in question. Logically, the program would be unnecessary in this health state, so we will assume that γ_3 is typically zero. Likewise, the individual would not participate in the program if dead, so we will be assuming that $\gamma_4 = 0$.

4.2 Present Discounted Values of Indirect Utility

The present value of indirect utility if the individual does choose the program and does suffer the illness takes the following form. All summations below will run from 0 to T_i, the remaining number of years in the

[12] Empirically estimated discount rates for future money as opposed to future health states are suspected to differ to some extent. Discount rates also differ across individuals and across choice contexts, time horizons and sizes and types of outcomes at stake. No comprehensive empirical work has been undertaken that conclusively demonstrates the relationships between money and health discount rates.

If we were to choose hyperbolic discounting for our specification, all of the discount factors in the expressions for present discounted value, below, would need to be changed from $1/(1 + r)^t$ to $1/(1 + t)^\lambda$. Other than this, the formulas will be the same.

individual's nominal life expectancy:

$$\begin{aligned} PDV(V_i^{AS}) &= \beta_0 \sum \frac{f(Y_{it}^* - c_{it}^{A*})}{(1+r)^t} + \beta_1 \sum \frac{age_{it} f(Y_{it}^* - c_{it}^{A*})}{(1+r)^t} \\ &+ \beta_2 \sum \frac{age_{it}^2 f(Y_{it}^* - c_{it}^{A*})}{(1+r)^t} + \beta_3 \sum \frac{(Y_{it}^* - c_{it}^{A*}) f(Y_{it}^* - c_{it}^{A*})}{(1+r)^t} \\ &+ \delta_{10} \sum \frac{ill_{it}^A}{(1+r)^t} + \delta_{11} \sum \frac{age_{it} ill_{it}^A}{(1+r)^t} + \delta_{12} \sum \frac{age_{it}^2 ill_{it}^A}{(1+r)^t} \\ &+ \delta_{20} \sum \frac{rcv_{it}^A}{(1+r)^t} + \delta_{21} \sum \frac{age_{it} rcv_{it}^A}{(1+r)^t} + \delta_{22} \sum \frac{age_{it}^2 rcv_{it}^A}{(1+r)^t} \\ &+ \delta_{30} \sum \frac{lyl_{it}^A}{(1+r)^t} + \delta_{31} \sum \frac{age_{it} lyl_{it}^A}{(1+r)^t} + \delta_{32} \sum \frac{age_{it}^2 lyl_{it}^A}{(1+r)^t} + \varepsilon_i^{AS} \end{aligned} \tag{13}$$

where $Y_{it}^* = Y_i \left(pre_{it}^A + \gamma_1 ill_{it}^A + rcv_{it}^A + \gamma_2 lyl_{it}^A\right)$ and $c_{it}^{A*} = c_i^A \left(pre_{it}^A + \gamma_3 ill_{it}^A + rcv_{it}^A + \gamma_4 lyl_{it}^A\right)$. Y_{it}^* and c_{it}^{A*} are sufficiently general to allow for a number of different assumptions about how individuals view their potential income and how they view their cost obligations under each program in different health states.

What individuals assume about their future income and program costs, if they choose the program, has implications for the formulas we develop in later sections. For their future income, our default assumption will be that individuals expect constant real annual income Y_i in each future year until the expected time of death if the individual gets the illness. When $\gamma_1 = 1$ and $\gamma_2 = 0$, the term $pre_{it}^A + \gamma_1 ill_{it}^A + rcv_{it}^A + \gamma_2 lyl_{it}^A = \left(1 - lyl_{it}^A\right)$ in equation (13) will be nonzero in those periods when the individual is still alive. While earned income is likely to suffer if the individual gets the illness, we assume that their annual income can be sustained through insurance coverage. For program costs, we assume that the annual costs of the risk-management program in question are incurred in the years leading up to the onset of the illness or injury, but are not paid while the individual is sick or injured.[13] If the individual recovers from the illness or injury, rather than dying from it, they will again participate in the risk-management program until their death. When $\gamma_3 = \gamma_4 = 0$, the term $pre_{it}^A + \gamma_3 ill_{it}^A + rcv_{it}^A + \gamma_4 lyl_{it}^A = pre_{it}^A + rcv_{it}^A$ in equation (13) will be non-zero only prior to the onset

[13] While the individual is sick, the health testing program would provide no further information, and we assume that the major traffic accident is likely to result in the vehicle being "totaled" so that a new vehicle, with its safety features, would not be acquired until the individual has recovered from his or her injuries.

of the illness or during the recovered state.

The present value indirect utility, if the individual does choose the program but does not suffer the illness, involves no illness, recovery, or reduced lifespan. Thus, the expression for indirect utility takes the following form:

$$\begin{aligned} PDV(V_i^{AH}) &= \beta_0 f(Y_i - c_i^A) \sum \frac{1}{(1+r)^t} \\ &+ \beta_1 f(Y_i - c_i^A) \sum \frac{age_{it}}{(1+r)^t} \\ &+ \beta_2 f(Y_i - c_i^A) \sum \frac{age_{it}^2}{(1+r)^t} \\ &+ \beta_3 (Y_i - c_i^A) f(Y_i - c_i^A) \sum \frac{1}{(1+r)^t} + \varepsilon_i^{AH} \end{aligned} \tag{14}$$

In this case, both income and the annual costs of program will continue until the end of the individual's nominal life expectancy. However, there are no benefits in the form of illness-years or lost life-years avoided.

Present value indirect utility, if the individual does not choose the program but does suffer the illness, is given by:

$$\begin{aligned} PDV(V_i^{NS}) &= \beta_0 \sum \frac{f(Y_{it}^*)}{(1+r)^t} + \beta_1 \sum \frac{age_{it} f(Y_{it}^*)}{(1+r)^t} \\ &+ \beta_2 \sum \frac{age_{it}^2 f(Y_{it}^*)}{(1+r)^t} + \beta_3 \sum \frac{(Y_{it}^*) f(Y_{it}^*)}{(1+r)^t} \\ &+ \delta_{10} \sum \frac{ill_{it}^A}{(1+r)^t} + \delta_{11} \sum \frac{age_{it} ill_{it}^A}{(1+r)^t} + \delta_{12} \sum \frac{age_{it}^2 ill_{it}^A}{(1+r)^t} \\ &+ \delta_{20} \sum \frac{rcv_{it}^A}{(1+r)^t} + \delta_{21} \sum \frac{age_{it} rcv_{it}^A}{(1+r)^t} + \delta_{22} \sum \frac{age_{it}^2 rcv_{it}^A}{(1+r)^t} \\ &+ \delta_{30} \sum \frac{lyl_{it}^A}{(1+r)^t} + \delta_{31} \sum \frac{age_{it} lyl_{it}^A}{(1+r)^t} + \delta_{32} \sum \frac{age_{it}^2 lyl_{it}^A}{(1+r)^t} + \varepsilon_i^{NS} \end{aligned} \tag{15}$$

The individual's lifespan is potentially reduced, so future income continues only until the time of death, and the disutility of the illness, any recovery period, and any life-years lost will be relevant.

Present value indirect utility, if the individual does not choose the program and does not suffer the illness, is:

$$
\begin{aligned}
PDV(V_i^{NH}) \quad = \quad & \beta_0 f\left(Y_i\right) \sum \frac{1}{\left(1+r\right)^t} + \beta_1 f\left(Y_i\right) \sum \frac{age_{it}}{\left(1+r\right)^t} \\
& + \beta_2 f\left(Y_i\right) \sum \frac{age_{it}^2}{\left(1+r\right)^t} \\
& + \beta_3 \left(Y_i\right) f\left(Y_i\right) \sum \frac{1}{\left(1+r\right)^t} + \varepsilon_i^{NH}
\end{aligned} \tag{16}
$$

Recall, the individual assumes that his current income level will be sustained until the end of his lifespan in the absence of premature mortality.

4.3 Expected indirect utility

In deriving the individual's option price for the program, given the ex ante uncertainty about future health states, we need to calculate expected utilities. In this case, the expectation is taken across the binary uncertain outcome of getting sick, S, or remaining healthy, H. The probability of illness or injury differs according to whether the respondent participates in the risk-reducing intervention program. Let the baseline probability of illness be Π_i^{NS} if the individual opts out of the program, and let the reduced probability be Π_i^{AS} if the individual opts in. The risk change due to program participation, $\Delta\Pi_i^{AS}$, is presumed to be negative.

Expected utility if the individual buys program A is:

$$E\left[V_i^A\right]_{S,H} = \Pi_i^{AS} \times PDV(V_i^{AS}) + \left(1-\Pi_i^{AS}\right) \times PDV(V_i^{AH}) \tag{17}$$

$$= \quad \Pi_i^{AS} \left[\begin{array}{c} \beta_0 \sum \frac{f(Y_{it}^*-c_{it}^{A*})}{(1+r)^t} + \beta_1 \sum \frac{age_{it} f(Y_{it}^*-c_{it}^{A*})}{(1+r)^t} \\ +\beta_2 \sum \frac{age_{it}^2 f(Y_{it}^*-c_{it}^{A*})}{(1+r)^t} + \beta_3 \sum \frac{(Y_{it}^*-c_{it}^{A*}) f(Y_{it}^*-c_{it}^{A*})}{(1+r)^t} \\ +\delta_{10} \sum \frac{ill_{it}^A}{(1+r)^t} + \delta_{11} \sum \frac{age_{it} ill_{it}^A}{(1+r)^t} + \delta_{12} \sum \frac{age_{it}^2 ill_{it}^A}{(1+r)^t} \\ +\delta_{20} \sum \frac{rcv_{it}^A}{(1+r)^t} + \delta_{21} \sum \frac{age_{it} rcv_{it}^A}{(1+r)^t} + \delta_{22} \sum \frac{age_{it}^2 rcv_{it}^A}{(1+r)^t} \\ +\delta_{30} \sum \frac{lyl_{it}^A}{(1+r)^t} + \delta_{31} \sum \frac{age_{it} lyl_{it}^A}{(1+r)^t} + \delta_{32} \sum \frac{age_{it}^2 lyl_{it}^A}{(1+r)^t} + \varepsilon_i^{AS} \end{array} \right]$$

$$+ \left(1-\Pi_i^{AS}\right) \left[\begin{array}{c} \beta_0 f(Y_i - c_i^A) \sum \frac{1}{(1+r)^t} + \beta_1 f(Y_i - c_i^A) \sum \frac{age_{it}}{(1+r)^t} \\ +\beta_2 f(Y_i - c_i^A) \sum \frac{age_{it}^2}{(1+r)^t} + \varepsilon_i^{AH} \end{array} \right]$$

Expected utility if the program is not purchased (i.e. "no program", N), with the expectation taken over uncertainty about whether the individual will suffer the illness, is:

$$E\left[V_i^N\right]_{S,H} = \Pi_i^{NS} \times PDV(V_i^{NS}) + \left(1 - \Pi_i^{NS}\right) \times PDV(V_i^{NH}) \tag{18}$$

$$= \Pi_i^{NS} \left[\begin{array}{c} \beta_0 \sum \frac{f(Y_{it}^*)}{(1+r)^t} + \beta_1 \sum \frac{age_{it} f(Y_{it}^*)}{(1+r)^t} \\ \\ +\beta_2 \sum \frac{age_{it}^2 f(Y_{it}^*)}{(1+r)^t} + \beta_3 \sum \frac{(Y_{it}^*) f(Y_{it}^*)}{(1+r)^t} \\ \\ +\delta_{10} \sum \frac{ill_{it}^A}{(1+r)^t} + \delta_{11} \sum \frac{age_{it} ill_{it}^A}{(1+r)^t} + \delta_{12} \sum \frac{age_{it}^2 ill_{it}^A}{(1+r)^t} \\ \\ +\delta_{20} \sum \frac{rcv_{it}^A}{(1+r)^t} + \delta_{21} \sum \frac{age_{it} rcv_{it}^A}{(1+r)^t} + \delta_{22} \sum \frac{age_{it}^2 rcv_{it}^A}{(1+r)^t} \\ \\ +\delta_{30} \sum \frac{lyl_{it}^A}{(1+r)^t} + \delta_{31} \sum \frac{age_{it} lyl_{it}^A}{(1+r)^t} + \delta_{32} \sum \frac{age_{it}^2 lyl_{it}^A}{(1+r)^t} + \varepsilon_i^{NS} \end{array} \right]$$

$$+ \left(1 - \Pi_i^{NS}\right) \left[\begin{array}{c} \beta_0 f(Y_i) \sum \frac{1}{(1+r)^t} + \beta_1 f(Y_i) \sum \frac{age_{it}}{(1+r)^t} \\ +\beta_2 f(Y_i) \sum \frac{age_{it}^2}{(1+r)^t} \\ +\beta_3 (Y_i) f(Y_i) \sum \frac{1}{(1+r)^t} + \varepsilon_i^{NH} \end{array} \right]$$

Details concerning the simplification of the expected utility difference $E\left[V_i^A\right]_{S,H} - E\left[V_i^N\right]_{S,H}$ are provided in an Appendix. Concerning the time paths of future income and program costs, we will maintain the hypothesis that $(\gamma_1, \gamma_2, \gamma_3, \gamma_4) = (1, 0, 0, 0)$. In words, usual income is sustained through illness by insurance, but not after death (there are no bequests), and program costs are only paid while alive and healthy.

We make use of a number of notational abbreviations in getting to the expected utility difference formula. First, let $\Delta\Pi_i^{AS} = \left(\Pi_i^{AS} - \Pi_i^{NS}\right)$. Then, there are many distinct present discounted value terms. We abbreviate each of these as follows:

$$\begin{aligned}
pdvc_i^A &= \sum \frac{1}{(1+r)^t} & agepdvc_i^A &= \sum \frac{age_{it}}{(1+r)^t} & age2pdvc_i^A &= \sum \frac{age_{it}^2}{(1+r)^t} \\
pdve_i^A &= \sum \frac{pre_{it}^A}{(1+r)^t} & agepdve_i^A &= \sum \frac{age_{it}pre_{it}^A}{(1+r)^t} & age2pdve_i^A &= \sum \frac{age_{it}^2 pre_{it}^A}{(1+r)^t} \\
pdvi_i^A &= \sum \frac{ill_{it}^A}{(1+r)^t} & agepdvi_i^A &= \sum \frac{age_{it}ill_{it}^A}{(1+r)^t} & age2pdvi_i^A &= \sum \frac{age_{it}^2 ill_{it}^A}{(1+r)^t} \\
pdvr_i^A &= \sum \frac{rcv_{it}^A}{(1+r)^t} & agepdvr_i^A &= \sum \frac{age_{it}rcv_{it}^A}{(1+r)^t} & age2pdvr_i^A &= \sum \frac{age_{it}^2 rcv_{it}^A}{(1+r)^t} \\
pdvl_i^A &= \sum \frac{lyl_{it}^A}{(1+r)^t} & agepdvl_i^A &= \sum \frac{age_{it}lyl_{it}^A}{(1+r)^t} & age2pdvl_i^A &= \sum \frac{age_{it}^2 lyl_{it}^A}{(1+r)^t}
\end{aligned}$$

Notice that the following two relationships hold, since the indicator variables for each health status are mutually exclusive and exhaustive:

$$\begin{aligned}
pdvc_i^A &= pdve_i^A + pdvi_i^A + pdvr_i^A + pdvl_i^A \\
agepdvc_i^A &= agepdve_i^A + agepdvi_i^A + agepdvr_i^A + agepdvl_i^A \\
age2pdvc_i^A &= age2pdve_i^A + age2pdvi_i^A + age2pdvr_i^A + age2pdvl_i^A
\end{aligned}$$

To accommodate the different time profiles of income and program costs over the individual's remaining lifespan, we must also define two additional terms

$$
\begin{aligned}
pdvy_i^A &= \sum \frac{\left(pre_{it}^A + \gamma_1 ill_{it}^A + rcv_{it}^A + \gamma_2 lyl_{it}^A\right)}{(1+r)^t} = pdve_i^A + \gamma_1 pdvi_i^A + pdvr_i^A + \gamma_2 pdvl_i^A \\
pdvp_i^A &= \sum \frac{\left(pre_{it}^A + \gamma_3 ill_{it}^A + rcv_{it}^A + \gamma_4 lyl_{it}^A\right)}{(1+r)^t} = pdve_i^A + \gamma_3 pdvi_i^A + pdvr_i^A + \gamma_4 pdvl_i^A \\
pdvyy_i &= \sum \frac{\left(pre_{it}^A + \gamma_1 ill_{it}^A + rcv_{it}^A + \gamma_2 lyl_{it}^A\right)^2}{(1+r)^t} = pdve_i + \gamma_1^2 pdvi_i + pdvr_i + \gamma_2^2 pdvl_i \\
pdvpp_i &= \sum \frac{\left(pre_{it}^A + \gamma_3 ill_{it}^A + rcv_{it}^A + \gamma_4 lyl_{it}^A\right)^2}{(1+r)^t} = pdve_i + \gamma_3^2 pdvi_i + pdvr_i + \gamma_4^2 pdvl_i \\
pdvyp_i &= \sum \frac{\left(pre_{it}^A + \gamma_1 ill_{it}^A + rcv_{it}^A + \gamma_2 lyl_{it}^A\right)\left(pre_{it}^A + \gamma_3 ill_{it}^A + rcv_{it}^A + \gamma_4 lyl_{it}^A\right)}{(1+r)^t} \\
&= pdve_i + \gamma_1\gamma_3 pdvi_i + pdvr_i + \gamma_2\gamma_4 pdvl_i
\end{aligned}
$$

The Appendix shows that the expected utility difference driving the individual's choice between Program A and the Neither Program aternative can then be written as follows (there will be an analogous utility-difference for the B program versus the Neither Program alternative).

$$
\begin{aligned}
E\left[V_i^A\right]-E\left[V_i^N\right] = & \left[c_i^A\right](-1)\beta_0\left[\left(1-\Pi_i^{AS}\right)pdvc_i+\Pi_i^{AS}pdvp_i\right] \\
& +\left[c_i^A\right](-1)\beta_1\left[\left(1-\Pi_i^{AS}\right)agepdvc_i+\Pi_i^{AS}agepdvp_i\right] \\
& +\left[c_i^A\right](-1)\beta_2\left[\left(1-\Pi_i^{AS}\right)age2pdvc_i+\Pi_i^{AS}age2pdvp_i\right] \\
& +[c_i^A](-1)\beta_3 2Y_i\left[\left(1-\Pi_i^{AS}\right)pdvc_i+\Pi_i^{AS}pdvyp_i\right] \\
& +[c_i^A]^2\beta_3\left[\left(1-\Pi_i^{AS}\right)pdvc_i+\Pi_i^{AS}pdvpp_i\right] \\
& +\beta_0 Y_i\Delta\Pi_i^{AS}\left(pdvy_i-pdvc_i\right) \\
& +\beta_1 Y_i\Delta\Pi_i^{AS}\left(agepdvy_i-agepdvc_i\right) \\
& +\beta_2 Y_i\Delta\Pi_i^{AS}\left(age2pdvy_i-age2pdvc_i\right) \\
& +\beta_3 Y_i^2\Delta\Pi_i^{AS}\left(pdvyy_i-pdvc_i\right) \\
& +\delta_{10}\Delta\Pi_i^{AS}pdvi_i+\delta_{11}\Delta\Pi_i^{AS}agepdvi_i+\delta_{12}\Delta\Pi_i^{AS}age2pdvi_i \\
& +\delta_{20}\Delta\Pi_i^{AS}pdvr_i+\delta_{21}\Delta\Pi_i^{AS}agepdvr_i+\delta_{22}\Delta\Pi_i^{AS}age2pdvr_i \\
& +\delta_{30}\Delta\Pi_i^{AS}pdvl_i+\delta_{31}\Delta\Pi_i^{AS}agepdvl_i+\delta_{32}\Delta\Pi_i^{AS}age2pdvl_i+\varepsilon_i
\end{aligned}
\tag{19}
$$

4.4 Ex ante option prices

The respondent's implied ex ante option price for program A can be determined by setting the expected utility difference equal to zero and solving for the vale of c_i^A that makes the equality hold. First however, the unknown utility parameters must be estimated. For parameter estimation, all terms involving the same β parameter must be combined. These constructed variables, listed according to their corresponding parameters, are:

$$
\begin{aligned}
\beta_0 \quad &: \quad \left[c_i^A\right](-1)\left[\left(1-\Pi_i^{AS}\right) pdvc_i + \Pi_i^{AS} pdvp_i\right] \\
& \quad + Y_i \Delta\Pi_i^{AS}\left(pdvy_i - pdvc_i\right) \\
\beta_1 \quad &: \quad \left[c_i^A\right](-1)\left[\left(1-\Pi_i^{AS}\right) agepdvc_i + \Pi_i^{AS} agepdvp_i\right] \\
& \quad + Y_i \Delta\Pi_i^{AS}\left(agepdvy_i - agepdvc_i\right) \\
\beta_2 \quad &: \quad \left[c_i^A\right](-1)\left[\left(1-\Pi_i^{AS}\right) age2pdvc_i + \Pi_i^{AS} age2pdvp_i\right] \\
& \quad + Y_i \Delta\Pi_i^{AS}\left(age2pdvy_i - age2pdvc_i\right) \\
\beta_3 \quad &: \quad [c_i^A](-1)\, 2Y_i\left[\left(1-\Pi_i^{AS}\right) pdvc_i + \Pi_i^{AS} pdvyp_i\right] \\
& \quad + [c_i^A]^2\left[\left(1-\Pi_i^{AS}\right) pdvc_i + \Pi_i^{AS} pdvpp_i\right] \\
& \quad + Y_i^2 \Delta\Pi_i^{AS}\left(pdvyy_i - pdvc_i\right)
\end{aligned}
$$

4.5 Solving for option prices from estimated models

Once the parameters have been estimated, we can solve for the payment c_i^A that would make the utility-difference exactly zero. This yields a quadratic form of the type $0 = Ax^2 + Bx + C$, where $x = c_i^A$. The squared term in c_i^A will be activated only if $\beta_3 \neq 0$, and will bear the coefficient:

$$
A = \beta_3\left[\left(1-\Pi_i^{AS}\right) pdvc_i + \Pi_i^{AS} pdvpp_i\right]
$$

The linear coefficient on c_i^A will be.

$$B = \begin{bmatrix} \beta_0 (-1) \left[\left(1 - \Pi_i^{AS}\right) pdvc_i + \Pi_i^{AS} pdvp_i \right] \\ +\beta_1 (-1) \left[\left(1 - \Pi_i^{AS}\right) agepdvc_i + \Pi_i^{AS} agepdvp_i \right] \\ +\beta_2 (-1) \left[\left(1 - \Pi_i^{AS}\right) age2pdvc_i + \Pi_i^{AS} age2pdvp_i \right] \\ +\beta_3 (-1)\, 2Y_i \left[\left(1 - \Pi_i^{AS}\right) pdvc_i + \Pi_i^{AS} pdvyp_i \right] \end{bmatrix}, \text{ or}$$

$$-B = \begin{bmatrix} \beta_0 \ \left[\left(1 - \Pi_i^{AS}\right) pdvc_i + \Pi_i^{AS} pdvp_i \right] \\ +\beta_1 \ \left[\left(1 - \Pi_i^{AS}\right) agepdvc_i + \Pi_i^{AS} agepdvp_i \right] \\ +\beta_2 \ \left[\left(1 - \Pi_i^{AS}\right) age2pdvc_i + \Pi_i^{AS} age2pdvp_i \right] \\ +\beta_3 \ 2Y_i \left[\left(1 - \Pi_i^{AS}\right) pdvc_i + \Pi_i^{AS} pdvyp_i \right] \end{bmatrix}$$

Finally, the terms not involving c_i^A can be collected as:

$$\begin{aligned} C = \ & \beta_0 \ Y_i \Delta\Pi_i^{AS} \left(pdvy_i - pdvc_i\right) \\ & +\beta_1 \ Y_i \Delta\Pi_i^{AS} \left(agepdvy_i - agepdvc_i\right) \\ & +\beta_2 \ Y_i \Delta\Pi_i^{AS} \left(age2pdvy_i - age2pdvc_i\right) \\ & +\beta_3 \ Y_i^2 \Delta\Pi_i^{AS} \left(pdvyy_i - pdvc_i\right) \\ & +\delta_{10} \ \Delta\Pi_i^{AS} pdvi_i + \delta_{11} \ \Delta\Pi_i^{AS} agepdvi_i + \delta_{12} \ \Delta\Pi_i^{AS} age2pdvi_i \\ & +\delta_{20} \ \Delta\Pi_i^{AS} pdvr_i + \delta_{21} \ \Delta\Pi_i^{AS} agepdvr_i + \delta_{22} \ \Delta\Pi_i^{AS} age2pdvr_i \\ & +\delta_{30} \ \Delta\Pi_i^{AS} pdvl_i + \delta_{31} \ \Delta\Pi_i^{AS} agepdvl_i + \delta_{32} \ \Delta\Pi_i^{AS} age2pdvl_i + \varepsilon_i \end{aligned}$$

where $\Delta\Pi_i^{AS} = \Pi_i^{AS} - \Pi_i^{NS}$ is a negative number for each of our risk reduction scenarios. If the error term can be considered to be zero, the systematic portion of the difference in expected utilities can be solved to yield point estimates of the option price.

Many practitioners currently use samples drawn from the joint distribution of the maximum likelihood parameter estimates to generated simulated 90% confidence intervals for the option price predictions. In this exercise, it is possible either to ignore the error term, or to replace it with a random draw from a unit logistic distribution before computing the value of the C term for each replication. As usual for a quadratic formula, fitted values of option price for each simulation will be given by:

$$c_i^A = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

If $B^2 - 4AC > 0$, the equation has two distinct real roots. In cases where only one of these roots is positive, the correct solution will be obvious. In models where $\beta_3 = 0$, the formula for c_i^A is simply linear, rather than a quadratic form. The A term is zero, and the B term loses its component in β_3 so that $c_i^A = -C/B$

4.6 Fully quadratic marginal utilities

The discrete choice among program alternatives can thus be modeled as depending upon the marginal utility of income and the marginal (dis)utilities of time in each health state. The marginal utility of income may involve up to four parameters, β_0, β_1, β_2, and β_3, depending upon whether it is allowed to depend on both the linear and squared values of the respondent's age in the future period when the income is to be enjoyed, and on the level of income itself. Further generality will also be explored in this paper. In particular, the age of the respondent at the time he or she is being asked to make these tradeoffs will be allowed to influence the indirect utility function. The baseline marginal utility parameters $\beta_0, \delta_{10}, \delta_{20}$, and δ_{30} will be allowed to shift with age_{i0} and with age_{i0}^2, making indirect utility potentially fully quadratic in the respondent's current age. Also, β_1, δ_{11}, δ_{21}, and δ_{31} can be allowed to shift with age_{i0}, which will allow for an interaction between current age and the age at which income or a particular health status is to be experienced. While we do not expect, a priori, that each undiscounted marginal utility in our model will be fully quadratic in both age now and age-at-event, we wish to allow the data to reveal nonlinearities, including maxima or minima over the range of current ages or ages when income or health status is to be experienced.

From the simple undiscounted indirect utility function in equation ( ), it is necessary to go through several steps to achieve the estimating form that can be used to explain respondent's choices among risk-reduction programs. We see from equation ( ) that the difference in expected present value indirect utilities associated with choosing a risk-reduction program is a function of the illness profile as captured by the $pdvi_i^A$, $pdvr_i^A$,and $pdvl_i^A$ terms, as well as a function of the individual discount rate r_i assumed for each respondent. In this analysis, we assume $r_i = r$, the same for each respondent, and we conduct sensitivity analyses with respect to the magnitude of this discount rate.

In our empirical application, equation (19) is the basis for estimation of the random utility choice model that explains individuals' choices among the three alternatives presented in each choice scenario: Program A, Program B, or Neither Program. There is an analogous difference in expected utilities between Program B and the Neither Program choice. All choices posed to respondents were three-way choices, so the models will be estimated using McFadden's conditional logit estimator (or appropriate modifications of this model).

4.7 From maximum annual payment to PDV of payment stream

The option price for the program that accomplishes this decrease in illness probabilities is the common certain payment, regardless of which way the uncertainty about contracting the illness is resolved, that makes the individual just indifferent between paying for the program and enjoying the risk reduction, or not paying for the program and not enjoying the risk reduction. This payment, c_i^{A*}, will make $E\left[V_i^A\right] - E[V_i^N\right] = 0$. The amount of money c_i^{A*} is the maximum constant annual payment that the individual will be willing to make, regardless of whether he suffers the illness, in order to purchase the program that reduces his probability of suffering the illness from Π_i^{NS} to Π_i^{AS}.

While the payment $\widehat{c_i^A}$ is the maximum annual payment the individual is willing to make, these payments are necessary for the rest of the individual's life, so the present value of these payments must be calculated. In this context, however, there is some uncertainty over just what will constitute "the rest of the individual's life," since this may differ according to whether the individual suffers the illness or not. We will use the expected present value of this time profile of costs, with the expectation taken over whether or not the individual suffers the illness when they are participating in the program.

$$
\begin{aligned}
& E\left[PV(\widehat{c_i^A})\right] \qquad (20) \\
= & \left(1-\Pi_i^{AS}\right)(\widehat{c_i^A}) pdvc_i^A + \left(\Pi_i^{AS}\right)(\widehat{c_i^A}) pdvp_i^A \\
= & (\widehat{c_i^A})\left[\left(1-\Pi_i^{AS}\right) pdvc_i^A + \Pi_i^{AS}\left(pdvp_i^A\right)\right]
\end{aligned}
$$

In the case where the marginal utility of income is constant, so that $\beta_1 = \beta_2 = \beta_3 = 0$, the denominator of the option price formula is just $\beta_0\left[\left(1-\Pi_i^{AS}\right) pdvc_i^A + \Pi_i^{AS}\left(pdvp_i^A\right)\right]$, so that capitalizing this payment over the rest of the individual's life allows the terms in square brackets to cancel. The formula for the present value of the streams of annual maximum payments willingly made to avoid a specified health profile reduces to:

$$E\left[PV(\widehat{c_i^A})\right] = \beta_0^{-1}\left[\begin{array}{c} \beta_0 Y_i \Delta\Pi_i^{AS}\left(pdvy_i - pdvc_i\right) \\ +\delta_{10}\Delta\Pi_i^{AS} pdvi_i + \delta_{11}\Delta\Pi_i^{AS} agepdvi_i + \delta_{12}\Delta\Pi_i^{AS} age2pdvi_i \\ +\delta_{20}\Delta\Pi_i^{AS} pdvr_i + \delta_{21}\Delta\Pi_i^{AS} agepdvr_i + \delta_{22}\Delta\Pi_i^{AS} age2pdvr_i \\ +\delta_{30}\Delta\Pi_i^{AS} pdvl_i + \delta_{31}\Delta\Pi_i^{AS} agepdvl_i + \delta_{32}\Delta\Pi_i^{AS} age2pdvl_i + \varepsilon_i \end{array}\right]$$

$$= \Delta\Pi_i^{AS}\beta_0^{-1}\left[\begin{array}{c} \beta_0 Y_i \left(pdvy_i - pdvc_i\right) \\ +\delta_{10} pdvi_i + \delta_{11} agepdvi_i + \delta_{12} age2pdvi_i \\ +\delta_{20} pdvr_i + \delta_{21} agepdvr_i + \delta_{22} age2pdvr_i \\ +\delta_{30} pdvl_i + \delta_{31} agepdvl_i + \delta_{32} age2pdvl_i + \varepsilon_i \end{array}\right]$$

From this result, it is clear that if the marginal utility of income is constant across the population, the expected present value of the lifetime stream of maximum annual payments is merely proportional to the size of the risk reduction, given individual preferences, income and the illness profile in question.

4.8 Proportionality to risk differences

This proportionality is a common assumption in much empirical work on WTP to avoid health risks and this proportionality has been used to justify the normalization across different risk reductions inherent in the concept of the valuation of a "statistical" life. Indeed, if the risk reduction involved and the cost of the program pertained only to a single year (as is the case in a number of existing VSL studies) there would be no difference between $pdvy_i$ and $pdvc_i$, so that the first term in the square brackets would disappear. Furthermore, if all illness profiles were to be treated as identical and no dependency on age was being assumed, all of the terms involving δ parameters would collapse into a single constant parameter, δ, multiplying a dummy variable, say D_i^A, that indicates whether the health state occurs in alternative A. This new parameter would describe the marginal utility of the generic health outcome to be avoided. This health outcome is "sudden death this year" in many existing empirical studies. In this case, we would have:

$$
\begin{aligned}
E\left[PV(\widehat{c_i^A})\right] &= \Delta\Pi_i^{AS}\beta_0^{-1}\left[\delta D_i^A\right] \\
&= (\delta/\beta_0)\Delta\Pi_i^{AS} \qquad \text{to avoid death } (D_i^A = 1) \\
&= 0 \qquad \text{for "no program," where } (D_i^A = 0)
\end{aligned}
$$

When the marginal utility of income is heterogeneous across individuals, these simplifications are not possible. The process of calculating the expected present value of program costs does not produce a term that cancels with everything but β_0. The expected present value can still be calculated, but the formulas will remain functions of both $\left(1 - \Pi_i^{AS}\right)$ and Π_i^{AS} and the other arguments of the B term above.

4.9 Value of a statistical illness (VSI)

The expected present discounted value in equation (20) pertains to the maximum annual willingness to pay for a small risk reduction, $\Delta\Pi_i^{AS}$. There is a tradition in the mortality valuation literature of ignoring the size of the risk difference involved, $\Delta\Pi_i^{AS}$, and scaling each expected present value option price to the amount that would correspond to a 100% risk difference. To convert our expected present value option price to something that might be termed the "value of a statistical illness" (VSI), we could divide by the absolute size of the risk reduction. In our study, all probability changes $\Delta\Pi_i^{AS}$ are negative, while the absolute magnitude of these changes will be positive. Multiplication by $\Delta\Pi_i^{AS}/\left|\Delta\Pi_i^{AS}\right|$ will amount to multiplying by -1, which will change the effective sign on each of the terms involving this ratio. Using the same abbreviations B and C for the detailed expressions defined above, if the researcher desires measures of a quantity that is comparable to traditional VSL estimates, the effective formula for the value of a statistical illness, in the case where $\delta_3 = 0$, will be:

$$VSI = \frac{E\left[PV(\widehat{c_i^A})\right]}{\left|\Delta\Pi_i^{AS}\right|} = \frac{C\ \left[\left(1-\Pi_i^{AS}\right) pdvc_i^A + \Pi_i^{AS}\left(pdvp_i^A\right)\right]}{B\ \left|\Delta\Pi_i^{AS}\right|}$$

In the special case where the marginal utility of income is simply a constant, this formula simplifies to:

$$\frac{E\left[PV(\widehat{c_i^A})\right]}{\left|\Delta\Pi_i^{AS}\right|} = \beta_0^{-1}\left[\begin{array}{c} \beta_0 Y_i pdvl_i \\ -\delta_{10}pdvi_i - \delta_{11}agepdvi_i - \delta_{12}age2pdvi_i \\ -\delta_{20}pdvr_i - \delta_{21}agepdvr_i - \delta_{22}age2pdvr_i \\ -\delta_{30}pdvl_i - \delta_{31}agepdvl_i - \delta_{32}age2pdvl_i + \frac{\varepsilon_i}{\left|\Delta\Pi_i^{AS}\right|} \end{array}\right] \tag{21}$$

where we take advantage of the fact that $pdvy_i + pdvl_i = pdvc_i$ so that $(pdvy_i - pdvc_i) = -pdvl_i$.

Across the distribution of the logistic error term, ε_i, the expectation is zero, so the expected value of a statistical illness depends only on the systematic portion of equation (21). The VSI in this case will depend upon the different marginal utilities of avoided periods of illness, recovered status, and premature death and on the way these marginal utilities vary with age at the time each health status is experienced. It will also depend upon the time profiles for each of these states as embedded in the terms $pdvi_i^A$, $pdvr_i^A$, and $pdvl_i^A$, as well as $agepdvi_i^A$, $agepdvr_i^A$, $agepdvl_i^A$ and potentially $age2pdvi_i^A$, $age2pdvr_i^A$, $age2pdvl_i^A$, and (implicit in this model) upon the individual's own discount rate.[14]

In this simple model with a constant marginal utility of income, increases in income Y_i will increase the predicted point estimate of the VSI. The effect of income on VSI_i^A is given by $\partial VSI_i^A/\partial Y_i = pdvl_i^A$ which is non-negative. Thus the effect of an increase in income on the predicted VSI will be larger (i.) as more

[14] Subsequent work will preserve individual discount rates as systematically varying parameters, to be estimated with reference to the individual's responses to a hypothetical "how to take your lottery winnings" question. Here, discount rates are presumed to be exogenous and constant across individuals. Our empirical work explores the consequences of using different discount rate assumptions.

life-years are lost, (ii.) as the individual is older, so that life-years lost come sooner in time. The effect of income on VSI can be estimated more generally if the marginal utility of income is not constant.[15]

The error term ε in equation (**??**) is assumed to be identically distributed across observations in a manner appropriate for conditional logit estimation. Given the transformation needed to solve for the VSI, however, the error term in the VSI formula will be heteroscedastic, with smaller error variances corresponding to cases with larger absolute risk reductions, $\left|\Delta\Pi_i^{AS}\right|$.

In expectation, the fitted value of a statistical illness can potentially vary systematically across types of illnesses according to the labels assigned to the illnesses, the symptoms and treatment associated with them, the individual's characteristics besides just age now and age-at-event, perceptions of risks associated with the type of illness, and prior experience with that illness. This heterogeneity can be accommodated by making the indirect utility parameters δ_1, δ_2, and δ_3 depend upon other individual characteristics. In future empirical models, the addition of illness labels and a symptom-treatment profile (within the illness state) will convey to the respondent some information about what health consequences might ensue from each illness we describe. These illness characteristics can be expected to shift the value of δ_1, the marginal (dis)utility of a sick-year. The marginal utility of each period of recovered health status, δ_2, could be allowed also to vary by type of illness as well, since the illness labels may connote the degree of "health" that nominal recovery from that illness actually implies. Finally, the marginal utility of a lost life-year may depend upon the health state prior to death. In the meantime, readers should keep in mind that the essentially randomized design of the illness profiles, conditional only on the individual's age and gender (and excluding nonsensical combinations), ensures that omitted variables bias concerning attributes of each illness profile

[15] Nothing in this specification precludes negative point estimates of the VSI. A positive VSI estimate will result if the estimated value of the marginal utility of income, β, is positive and there are negative values for the marginal utilities of illness-years, recovered-years, and lost life-years (the δs).

The key undiscounted marginal utility parameters are not presently constrained to be strictly positive (for income) and strictly negative (for episodes of undesirable health profiles). This is especially a concern when these marginal utilities are permitted to vary systematically with of the attributes of the illness profile and/or the characteristics of the individual in question. The marginal utility of income, the scalar parameter β in our simplest models, bears a point estimate that is robustly positive, but positive values for one or both of the systematically varying parameters capturing the marginal utility of an illness-year (δ_1) or a lost life-year (δ_3) can push an individual fitted value of the VSI for a particular morbidity/mortality profile into the negative range.

will be minimized in this analysis.

4.10 VSIs versus Conventional VSLs

The existing literature, especially the hedonic wage-risk literature, focuses on society's willingness to pay for incremental reductions in the chance of a sudden accidental death in the current period. In general, there are no age effects, and age_{i0} is the same thing as "age-at-event" (age_{it}). In the framework of our illness profiles, such an event would be captured by zero years of morbidity and death in the current year, with the remainder of the individual's nominal life expectancy experienced as lost life-years. Since the terms in $pdvi_i^A$ and $pdvr_i^A$ will be zero, our analog to the conventional VSL formula will be simply:

$$\begin{aligned} E[VSL] &= \frac{E\left[PV(\widehat{c_i^A})\right]}{\left|\Delta\Pi_i^{AS}\right|} = \left(\frac{-\delta_{30}}{\beta} + Y_i\right) pdvl_i^A \\ \text{where} \quad pdvl_i^A &= \sum \frac{lyl_{it}^A}{(1+r)^t} \end{aligned} \tag{22}$$

The summation in the formula for $pdvl_i^A$ is from the present until the individual's nominal life expectancy. This interval depends upon the individual's current age, so even in a model with homogeneous preferences, the VSI will vary with age. The VSI also depends upon the individual's income, and of course, the individual's discount rate will also matter. See Cameron and DeShazo (2003) for discussion of calculating policy-relevant VSLs with this model.

5 Results and Discussion

For this paper, we examine the model in equation (19) and a number of its special cases. Our estimating sample consists of stated preferences for 5 sets of three-way program choices provided by roughly 1320 respondents from an originally representative sample of roughly 2000 from the US population. [16]

[16] For this analysis we have dropped the choices of individuals who appear to have spent too little total time on the five choice tasks to have allowed fully-considered selections. An Appendix details the consequences for parameter estimates in our

Table 1 compiles estimation results for three different specifications estimated for three different assumptions about individual discount rates: 3%, 5%, and 7%. These rates were chosen based on the official range of values recommended for benefit-cost analysis by the Science Advisory Board of the US EPA. For each discount rate, we calculate the various present discounted value terms (capturing the time profiles of morbidity and mortality) employed in the construction of variables for use in the estimating specification.[17]

5.1 Estimating Specifications

Our baseline model allows for the level of income to affect the marginal utility of additional income, but excludes any age effects on the marginal (dis)utilities of health states. Our "No Age Effects" specification is

$$\begin{aligned} E\left[V_i^A\right] - E\left[V_i^N\right] &= \beta_0 \left\{ \begin{array}{c} \left[c_i^A\right](-1)\left[\left(1-\Pi_i^{AS}\right)pdvc_i + \Pi_i^{AS} pdvp_i\right] \\ +Y_i \Delta\Pi_i^{AS}\left(pdvy_i - pdvc_i\right) \end{array} \right\} \\ &+\beta_3 \left\{ \begin{array}{c} \left[c_i^A\right](-1)\,2Y_i\left[\left(1-\Pi_i^{AS}\right)pdvc_i + \Pi_i^{AS} pdvyp_i\right] \\ +[c_i^A]^2\left[\left(1-\Pi_i^{AS}\right)pdvc_i + \Pi_i^{AS} pdvpp_i\right] \\ +Y_i^2 \Delta\Pi_i^{AS}\left(pdvyy_i - pdvc_i\right) \end{array} \right\} \\ &+\delta_{10}\Delta\Pi_i^{AS} pdvi_i + \delta_{20}\Delta\Pi_i^{AS} pdvr_i + \delta_{30}\Delta\Pi_i^{AS} pdvl_i + \varepsilon_i \end{aligned} \tag{23}$$

Our "Linear Age Effects" model allows the marginal utility of income to be shifted by the respondent's current age (age_{i0}), and allows the marginal (dis)utility of a sick-year, a recovered-year and a lost life-year to shift with both the respondent's current age (age_{i0}) and the respondent's age at the time that health state

preferred specification as our criteria for rejecting observations are successively weakened, leaving more and more respondents in the estimating sample. We focus on a subset of people we will characterize as "careful choosers who do not explicitly reject the choice scenarios." Selectivity correction exercises are pending.

[17] In current models, we lean heavily on linearities that allow us to estimate our parameters using packaged software algorithms for McFadden's conditional logit models.

is being experienced (i.e. the "age-at-event," age_{it}):

$$
\begin{aligned}
E\left[V_i^A\right] - E\left[V_i^N\right] \quad = \quad & (\beta_{00} + \beta_{01} age_{i0}) \left\{ \begin{array}{c} \left[c_i^A\right](-1)\left[\left(1-\Pi_i^{AS}\right) pdvc_i + \Pi_i^{AS} pdvp_i\right] \\ +Y_i \Delta\Pi_i^{AS}\left(pdvy_i - pdvc_i\right) \end{array} \right\} \qquad (24) \\
& +\beta_3 \left\{ \begin{array}{c} \left[c_i^A\right](-1)\, 2Y_i \left[\left(1-\Pi_i^{AS}\right) pdvc_i + \Pi_i^{AS} pdvyp_i\right] \\ +[c_i^A]^2 \left[\left(1-\Pi_i^{AS}\right) pdvc_i + \Pi_i^{AS} pdvpp_i\right] \\ +Y_i^2 \Delta\Pi_i^{AS}\left(pdvyy_i - pdvc_i\right) \end{array} \right\} \\
& +(\delta_{100} + \delta_{101} age_{i0}) \Delta\Pi_i^{AS} pdvi_i + \delta_{11} \Delta\Pi_i^{AS} agepdvi_i \\
& +(\delta_{200} + \delta_{201} age_{i0}) \Delta\Pi_i^{AS} pdvr_i + \delta_{21} \Delta\Pi_i^{AS} agepdvr_i \\
& +(\delta_{300} + \delta_{301} age_{i0}) \Delta\Pi_i^{AS} pdvl_i + \delta_{31} \Delta\Pi_i^{AS} agepdvl_i + \varepsilon_i
\end{aligned}
$$

The most general model described in Table 1 is our "Quadratic Age Effects" model. This model retains the same formulation for the marginal utility of income, but allows for each of the (dis)utilities of the three different health states to be fully quadratic in the respondent's age now (age_{i0}) and age-at-event (age_{it}).

$$
\begin{aligned}
E\left[V_i^A\right]-E\left[V_i^N\right] \quad = \quad & (\beta_{00}+\beta_{01}age_{i0})\left\{\begin{array}{c} \left[c_i^A\right](-1)\left[\left(1-\Pi_i^{AS}\right)pdvc_i+\Pi_i^{AS}pdvp_i\right] \\ +Y_i\Delta\Pi_i^{AS}\left(pdvy_i-pdvc_i\right) \end{array}\right\} \qquad (25) \\
& +\beta_3\left\{\begin{array}{c} [c_i^A](-1)\,2Y_i\left[\left(1-\Pi_i^{AS}\right)pdvc_i+\Pi_i^{AS}pdvyp_i\right] \\ +[c_i^A]^2\left[\left(1-\Pi_i^{AS}\right)pdvc_i+\Pi_i^{AS}pdvpp_i\right] \\ +Y_i^2\Delta\Pi_i^{AS}\left(pdvyy_i-pdvc_i\right) \end{array}\right\} \\
& +(\delta_{100}+\delta_{101}age_{i0}+\delta_{102}age_{i0}^2)\Delta\Pi_i^{AS}pdvi_i \\
& +\delta_{110}\Delta\Pi_i^{AS}agepdvi_i+\delta_{111}\Delta\Pi_i^{AS}agepdvi_iage_{i0}+\delta_{12}\Delta\Pi_i^{AS}age2pdvi_i \\
& +(\delta_{200}+\delta_{201}age_{i0}+\delta_{202}age_{i0}^2)\Delta\Pi_i^{AS}pdvr_i \\
& +\delta_{210}\Delta\Pi_i^{AS}agepdvr_i+\delta_{211}\Delta\Pi_i^{AS}agepdvr_iage_{i0}+\delta_{22}\Delta\Pi_i^{AS}age2pdvr_i \\
& +(\delta_{300}+\delta_{301}age_{i0}+\delta_{302}age_{i0}^2)\Delta\Pi_i^{AS}pdvl_i \\
& +\delta_{310}\Delta\Pi_i^{AS}agepdvl_i+\delta_{311}\Delta\Pi_i^{AS}agepdvl_iage_{i0}+\delta_{32}\Delta\Pi_i^{AS}age2pdvl_i+\varepsilon_i
\end{aligned}
$$

The marginal utility of income should be positive, but is not constrained to be so. Our competing specifications also involve several parameters that describe the marginal (dis)utility of a sick year, a recovered year, and a lost life-year. Intuitively, the marginal utility of a sick-year should be negative, but we do not enforce this restriction. The estimated marginal utility of a lost life-year may also depend on several parameters, and these parameters are also estimated freely from the observed choices, without sign restrictions. In general, one would expect that the marginal utility of a lost-life-year would be negative.[18] For our two models with age effects, we will provide figures that show the systematic variation in these two marginal utilities as a function of age-at-event, for each of a 25, 35, 45, 55, and 65-year-olds.

[18] A positive marginal utility associated with a lost life-year might be expected only when the illness is question constitutes a "fate worse than death." For certain illnesses, such as severe Alzheimers' disease, we might expect that death would "come as a blessing." In any situation where the pre-death state was less onerous, however, we would expect death to be unwelcome, and hence that the marginal utility of a lost life-year would be negative.

5.2 Parameter Estimates

In Table 4 which present our parameter estimates, we will emphasize the middle set of three models, for the 5% discount rate assumption. Our "No Age Effects" specification shows robust significance and the expected signs on all five core parameters. The marginal utility of income is positive, but declines with the level of income. The marginal utilities of sick-years, recovered years, and lost life-years are all negative, and (somewhat surprisingly) each has a similar point value. The surprising result is that recovered years are not interpreted by respondents to be equivalent to health pre-illness years. Despite our having intended respondents to view these years as equivalent to health years, they do not. They seem to be imputing reduced health or reduced function to these recovered years. The similarity in the magnitude of the marginal utility of a sick-year and a recovered-year, however, may be due to the fact that the illnesses are described as major life-threatening illnesses, including cancers, respiratory disease, and stroke, for example.

The "Linear Age Effects" model makes the main empirical point in this paper. In this model, the respondent's current age is permitted to shift his or her marginal utility of income (see Figure 3A), and the marginal utility of each health status is allowed to depend on the respondent's current age and on the age at which they would experience each year of each health status. The marginal utility of income declines with the current age of the respondent.[19] The marginal utilities of sick-years and lost life-years are less negative, the greater the current age of the respondent, but more negative with the age at which these health states would be experienced, controlling for current age. These findings are fully consistent with the two main hypotheses discussed in the theoretical section of this paper. For recovered years, the results are somewhat less precise. Age-at-event makes the marginal utility of a recovered year significantly more negative, but the respondent's age now has no statistically discernible effect upon the marginal utility of a recovered year. The anticipated marginal utility of a recovered-year appears to be independent of the current age of the

[19] We have explored the consequences of allowing the marginal utility of income to depend upon age-at-event. However, a noticeable proportion of fitted MU(Y) estimates are then negative. Negative MU(Y) produces nonsensical results for the implied WTP for an avoided sick-year, recovered-year, or lost life-year, since the marginal utility of income acts as the denominator of the WTP formula.

respondent in these data.

One troubling feature of the Linear Age Effects models is the persistence of positive values for the marginal utilities of all three health states for some future ages. These positive marginal utilities lead to negative WTP estimates in those early future years and will tend to bias downward the present value employed as an estimate of the Value of a Statistical Illness (VSI). Figures 3B, 3C, and 3D show that, for example, WTP to avoid a statistical sick-year, recovered-year, and lost life-year for a currently 25-year-old respondent (the line tagged with "25") appear to be negative for the first few years into the future. We suspect that many respondents, feeling currently rather healthy, doubt that the health risk we describe will actually affect them in the next 5-10 years, although the possibility of becoming ill in the years beyond that is more credible. It is not clear whether this should be interpreted as a form of scenario rejection in response to our stated preference choice scenarios, or whether this is a legitimate property of people's preferences.

Recall that there is no opportunity for any respondent to express a negative willingness to pay explicitly. At a minimum, respondents can imply that the value they place on a program is zero (i.e. no greater than the cost of the Neither Program alternative, available at zero net cost). To determine whether these negative fitted WTP estimates in the linear models are merely an artifact of a too-restrictive functional form, we estimate a specification that allows the marginal utilities associated with all three health states to be fully quadratic in both age now and age-at-event.

It would be desirable, in our quadratic model, also to allow the marginal utility of income to be a fully quadratic function of both age now and age-at-event. However, as Figure 4A reveals, generalizing the marginal utility of income in this way leads to occasional negative fitted values for the marginal utility of income. Since this marginal utility serves as the denominator in WTP calculations, negative and zero values are particularly problematic. Pending further exploration of models that restrict the marginal utility of income to be strictly positive, we revert to the simpler specification where the marginal utility of income depends only upon current age.

For the 5% discount rate, the "Quadratic Age Effects" model reveals individually statistically significant point estimates on the quadratic and interaction terms in age-at-event for sick-years. It also reveals statistically significant point estimates on the age-now term and the interaction term for lost life-years. None of the additional parameters for recovered-years is individually statistically significant, but the maximized log-likelihood increases by almost seven.

Figures 4B, 4C, and 4D reveal the consequences of allowing a more general functional form. For each current age, the only relevant portions of these curves lie to the right of that current age. These diagrams strongly suggest that most respondents place zero value on avoiding a sick-year that will occur prior to their 50s. They may tend to believe, on average, that they will remain healthy until their 50s. Respondents who are currently younger place higher value on avoiding future sick-years at specified ages than do currently older respondents (for those same specified ages). Similar patterns, to a greater or lesser degree, are apparent for recovered-years and lost life-years.

5.3 Potential Extension

The Quadratic Age Effects specification creates a strong impression that it will be desirable to break away from linear-in-parameters models, in spite of their extremely attractive properties for ease of estimation. In particular, our next task is to specify a non-linear model wherein we estimate the logarithms of the marginal utilities of income and years in each health state, rather than their absolute levels. The logarithmic transformation will prevent the fitted marginal utility of income from going negative and will prevent the marginal utility of a sick-year, a recovered-year, and a lost life-year from being positive. In the simple case with no age effects, it seems appropriate to specify a model of undiscounted utility of the form:

$$\begin{aligned} V_{it} &= \exp\left[\beta_0 + \beta_3 Y_{it}\right]\ f(Y_{it}) \qquad (26) \\ &\quad - \exp\left[\delta_{10}\right]\ ill_{it} - \exp\left[\delta_{10}\right]\ rcv_{it} - \exp\left[\delta_{30}\right]\ lyl_{it} + \eta_{it}. \end{aligned}$$

This form constrains the marginal utility of income to be positive, equal to $\exp[\beta_0 + \beta_3 Y_{it}]$. It also constrains to be negative the marginal utility from each health state $[ill_{it}, rcv_{it}, lyl_{it}]$ in each year. In the more general case where all marginal utilities are fully quadratic in the respondent's current age, age_{i0}, and the respondent's future age-at-event, age_{it},the undiscounted utility will be of the form:

$$\begin{aligned} V_{it} &= \exp\left[\beta_{00} + \beta_{01} age_{i0} + \beta_{02} age_{i0}^2 + \beta_{10} age_{it} + \beta_{11} age_{it} age_{i0} + \beta_2 age_{it}^2 + \beta_3 Y_{it}\right] f(Y_{it}) \quad (27) \\ &- \exp\left[\delta_{100} + \delta_{100} age_{i0} + \delta_{100} age_{i0}^2 + \delta_{110} age_{it} + \delta_{111} age_{it} age_{i0} + \delta_{12} age_{it}^2\right] ill_{it} \\ &- \exp\left[\delta_{200} + \delta_{200} age_{i0} + \delta_{200} age_{i0}^2 + \delta_{210} age_{it} + \delta_{211} age_{it} age_{i0} + \delta_{22} age_{it}^2\right] rcv_{it} \\ &- \exp\left[\delta_{300} + \delta_{300} age_{i0} + \delta_{300} age_{i0}^2 + \delta_{310} age_{it} + \delta_{311} age_{it} age_{i0} + \delta_{32} age_{it}^2\right] lyl_{it} \\ &+ \eta_{it}. \end{aligned}$$

This specification precludes the eventuality of "fates worse than death" (positive marginal utility of a lost life-year following a particularly unpleasant illness). However, prior to differentiating by the types of illnesses addressed in our survey, it may be plausible to assume that the average marginal utility of a prematurely lost life-year is negative.

5.4 Fitted VSIs

Table 5 gives summary statistics concerning the marginal distribution of fitted VSIs in the estimating sample. However, these VSI estimates reflect the artificial range of illness profiles generated for use in eliciting individual choices. They do not reflect the true joint distribution, in the real world, of illnesses, symptoms and treatments, and prognoses. In particular, there are may short-term and non-fatal illnesses among the programs we presented to respondents. Thus, we do not expect to see the usual $6.1 million VSL estimate in these distributions. For the 5% discounting assumption, for the Linear Age Effects model and the Quadratic Age Effects model, median VSI is around $2.0-$2.1 million. It is slightly higher for the 3% discount rate assumption ($2.6-$2.8 million). For the 7% discount rate model, it is lower ($1.6-$1.65 million).

How do the WTP results from our model compare to those of earlier VSL results? Many hedonic wage estimates of "the" VSL estimate wage-risk tradeoffs for middle-aged white males in blue collar jobs. For comparison with earlier results, we should consider just the VSI for an illness profile consisting of sudden death at age 45 for a 45-year-old. However, in order to highlight the generality of our WTP models, compared to earlier VSL models, we will consider four classes of simulations:

Simulation 1. How would a 25-, 35-, 45-, 55-, and 65-year-old value a reduction in the chance of sudden death starting now?

Simulation 2. How would a 25-, 35-, 45-, 55-, and 65-year-old value a reduction in the chance of sudden death starting 5 years from now?

Simulation 3: How would a 25-, 35-, 45-, 55-, and 65-year-old value a reduction in the chance of sudden death starting at age 70?

Simulation 4. How would a 25-year-old value a reduction in the chance of sudden death starting 5, 15, 25, 35 and 45 years from now?

Table 6 summarizes the results of these four classes of simulations for the No Age Effects model, the Linear Age Effects model and the Quadratic Age Effects model. For each simulation, we make 1000 random draws from the joint distribution of the maximum likelihood conditional logit parameters. For each set of parameter values, we calculate the desired VSI. We report the median of this distribution, as well as the 5th and 95th percentiles.

The No Age Effects model in Table 6 is our model that conforms as closely as possible to most previous studies. This model does not differentiate the marginal utility of a lost life-year according to the age of the respondent now or the age the respondent would have been during each life-year lost. The median VSI can be expected to differ with the respondents current age, however, because our model emphasizes life-years and involves discounting. Remarkably, despite these differences from previous models, our median VSI for sudden death for a 45-year-old is $6.82 million, with simulated 90% confidence bounds of ($5.34 million to $8.83 million). This range of estimates compares very closely to the $6.1 million estimate used routinely by the US EPA in their major benefit-cost analysis. Evidence for any sort of a "senior death discount" is sparse in simulations 1 and 2. The medians decline monotonically with the current age of the respondent, but the differences are small. In Simulations 3 and 4, there are larger effects. In Simulation 3, we see substantial increases in the VSI for sudden death at age 70 as the respondent is closer to 70 in age. In Simulation 4, where 25-year-olds are asked to consider risks of sudden death at increasingly distant future times, the VSI falls substantially and significantly.

However, our data emphatically reject the No Age Effects model in favor of a model that acknowledges the systematic variation of WTP for risk reductions with respect to the respondent's age now and the age at which they would experience future lost life-years. The second column of VSI results in Table 6 reveals, for the Linear Age Effects model, a considerably lower median VSI of $2.08 million for sudden death this year for a 45-year-old. The bootstrapped confidence interval is wide, and admits for values as low as $50,000 and as high as $4.42 million. However, one must keep in mind that fitted WTP for avoided adverse health states is negative during the "early future" for the inflexible Linear Age Effects models. These spurious negative values will tend to bias downward our estimates of VSI for each age group.[20]

In Table 6, for simulation 1 under the Linear Age Effects model, the decline in WTP with the respondent's current age is evidenced in the lesser VSI associated with increasing current age. These calculations suggest the presence of a "senior discount" in WTP to avoid sudden death.[21] This same decline with current age is exhibited in simulation 2 (sudden death in 5 years). In simulation 4, because of discounting, WTP to avoid sudden death in more remote future years also falls. The progression in WTP is non-monotonic, however, for simulation 3 which pertains to sudden death at age 70 for people of different ages now.

[20] Less biased estimates await constrained estimation of a model featuring a positive marginal utility of income and negative marginal utilities of adverse health states.

[21] Perhaps, however, sudden death is viewed as less likely for older respondents. It is possible that respondents substitute lower risks than the survey instrument suggests, interpreting their own risk to be lower than the "average" that they assume is being quoted in the survey.

For the Quadratic Age Effects model in Table 6, however, the situation is rather different. First of all, the bootstrapped confidence intervals are even wider because of the greater number of statistically insignificant parameter estimates in this specification. The quadratic models also allow WTP for avoided sick-years, recovered-years, and lost life-years to increase much more quickly with age-at-event than they do in the Linear Age Effects models. This can lead the positive effect of age-at-event to dominate the negative effect of age-now on VSIs over some parts of the range of simulations. However, one must keep in mind that the estimated VSIs may be biased (ambiguously) because the quadratic forms can fit slighted negative or slightly positive values for the undiscounted WTP for avoided sick-years, recovered-years, and lost life-years when the true value probably ought to be positive but very close to zero.

In Table 6, none of the simulated VSI progressions based on the Quadratic Age Effects model are monotonic. This is a consequence of the countervailing positive effect of age-at-event, and the negative effect of age now, on undiscounted WTP for future years in each health state. These processes are further confounded by the discounting process.

6 Conclusions

Policy analysis with respect to risk-management programs requires detailed information about consumer demand for these programs. We begin with a concise theoretical model, adapted from Ehrlich (2001) that produces two key insights. First, individuals will derive increasing marginal utility from reducing risks that they will face later in life, which implies that individuals will be willing to pay more to reduce risks that will afflict them when they are older (and correspondingly less to reduce risks that will afflict them when they are younger). The second insight is that health and other consumption goods are likely to be complements. As individuals age, they learn more about the extent of complementarity between health and other goods–in particular, they learn that future consumption will provide less utility because of declining physical well-being. Hence they are inclined to shift more consumption forward in time and their willingness to pay for health risk reductions will fall as they are older.

Which of these two countervailing effects will dominate is an empirical question, so we have set out to build a formal utility-theoretic model that captures the relevant considerations in private ex ante consumer choices about incurring ongoing expenditures to reduce risks to life and health. Most past studies have focused on current-period costs and current-period benefits. In contrast, our model recognizes the future time profiles of illnesses and injuries for which individuals may choose to act to reduce their risks. Intertemporal consumer optimization requires explicit treatment of the interaction between disease latencies and individual discount rates. Our model permits us to derive option prices for programs that reduce well-defined types of risks. Option prices are the appropriate theoretical construct for decision-making under uncertainty, where the uncertainty in this case concerns whether the individual will actually suffer the illness or injury that the proposed risk reduction measure addresses.

While we believe that it is important to preserve information about the nature of the risk reduction involved (its size, and perhaps the baseline risk), we show that our option price WTP formulas lead naturally to what we have labeled as the "value of a statistical illness" (VSI). The VSI is the present discounted value of the stream of maximum annual payments that the individual would be willing to pay for the specified (typically small) risk reduction, scaled up proportionately to correspond to a risk reduction of 100%. This construct is analogous to the more familiar, but more-limited, concept of the value of a statistical life (VSL). A VSL is typically constructed by looking simply at the static single-period willingness to pay for a specified risk reduction, and scaling this willingness to pay up to a 100% risk reduction. However, static VSL estimates do not typically vary with important morbidity/mortality attributes such as latency, time profiles of illness, symptoms and treatments, outcomes, or life-years lost.

In the empirical analysis presented in this paper, we first consider a model wherein preferences are considered to be homogenous across all types of individuals and where the marginal (dis)utility of a sick-year or a lost life-year is independent of the respondent's age now and his or her age at the time he or she would be experiencing that health state (or the age that they would have been, had they not died prematurely). Even these very simple models can be used to display the sensitivity of option prices to the timing of events in an illness profile. The pattern of future health states in question matters for willingness to pay to avoid different types of risks to life and health..

Our empirical analysis also demonstrates conclusively that the current age of the respondent, as well as the prospective age at which they will experience illness or premature death, will have a systematic effect on willingness to pay for programs that reduce health risks. These findings are relevant to the current debate about whether there should be a "senior death discount" in assessing the health benefits of costly risk reductions. The choices made by the individuals in our sample strongly suggest that, ceteris paribus, the older an individual is when asked to begin paying for a particular health risk reduction, the less he or she will be willing to pay. However, this tendency can be confounded by the fact that for individuals of a given age, willingness to pay for health risk reductions increases with the age at which these health risks would be experienced. Any given individual, looking forward, may feel that they would be willing to pay more to reduce risks to their health that materialize when they are older. This tendency may feed the intuition that the benefits of risk reductions should be, if anything, higher for older persons. However, across individuals of different ages, individuals who are older seem willing to pay less to reduce risks to their health.

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Appendices A and B are available from the authors upon request.

Table 1

Descriptive statistics for Risk Reduction Programs

Variable	Mean	Std. Dev.	Min	Max
Risk Reduction Programs				
Present discounted sick-years	2.236	2.525	0	16.277
Present discounted recovered-years	0.4746	1.356	0	14.589
Present discounted lost life-years	2.596	2.938	0	17.803
Monthly cost	$ 31.03	29.46	2	140
Risk change	-.0034124	.0016695	-0.006	-0.001
Respondents				
income	$ 50,606	33,533	5,000	150,000
age	51.60	15.11	25	93

Table 2

Distribution of Program Characteristics within Illness Types

Variable	Breast Cancer	Prostate Cancer	Lung Cancer	Colon Cancer	Skin Cancer	Heart Attack	Heart Disease	Stroke	Respiratory Disease	Diabetes	Alzheimer's Disease
N=	599	548	1111	1107	1122	1144	1150	1154	1108	1097	1103
Cost	**31.649**	**29.095**	**31.611**	**30.866**	**31.162**	**30.677**	**30.148**	**30.724**	**30.888**	**30.290**	**30.480**
baseline_risk	0.0167	0.0155	0.0166	0.0159	0.0169	0.0166	0.0167	0.0165	0.0162	0.0156	0.0161
risk_change	-0.0033	-0.0035	-0.0034	-0.0035	-0.0035	-0.0035	-0.0034	-0.0034	-0.0034	-0.0033	-0.0034
mod_pain_duration	41.68	38.79	64.55	69.78	75.35	29.62	84.81	31.61	56.76	54.76	55.53
sev_pain_duration	18.32	18.84	34.15	30.35	13.89	10.70	37.19	10.76	31.73	23.59	25.09
hospital_duration	2.190	2.287	2.184	2.167	2.054	1.012	2.129	0.839	1.950	2.157	27.177
hosp_open_end	0.000	0.000	0.026	0.034	0.031	0.014	0.047	0.095	0.037	0.013	0.073
minor_surgery	0.329	0.336	0.320	0.476	0.543	0.441	0.344	0.432	0.337	0.000	0.000
major_surgery	0.331	0.314	0.357	0.524	0.457	0.159	0.312	0.167	0.292	0.000	0.000
latency	16.66	18.13	18.69	18.19	17.33	20.15	18.97	21.25	20.95	17.83	21.96
life-years lost	**11.072**	**11.535**	**10.175**	**8.388**	**9.725**	**13.191**	**7.070**	**11.920**	**7.492**	**13.235**	**8.840**
die_suddenly	0.000	0.000	0.000	0.000	0.000	0.523	0.000	0.510	0.000	0.000	0.000
die_sick	0.404	0.339	0.354	0.224	0.291	0.073	0.106	0.063	0.204	0.861	0.842
die_after_chronic	0.000	0.000	0.395	0.380	0.298	0.210	0.624	0.231	0.410	0.139	0.158
recover	0.596	0.661	0.251	0.396	0.412	0.194	0.270	0.196	0.386	0.000	0.000

Table 4

Sensitivity of Parameter Estimates to Alternative Discount Rate Assumptions

Parameter and description of variable(s)	3% discount rate: No Age Effects	3%: Linear Age Effects	3%: Quadratic Age Effects	**5% discount rate: No Age Effects**	**5%: Linear Age Effects**	**5%: Quadratic Age Effects**	7% discount rate: No Age Effects	7%: Linear Age Effects	7%: Quadratic Age Effects
β_{00} (linear net income term)	3.83E-05 (8.60)***	6.11E-05 (4.20)***	0.0000726 (4.54)***	**4.62E-05 (8.31)*** **	**8.29E-05 (4.37)*** **	**0.0001009 (4.81)*** **	5.336E-05 (7.97)***	9.658E-05 (4.14)***	0.0001293 (4.94)***
β_{01} (age_{i0} interaction)		-3.65E-07 (-1.64)	-5.44E-07 (2.15)**		**-5.61E-07 (1.98)** **	**-8.34E-07 (2.58)*** **		-6.296E-07 (1.84)*	-1.119E-06 (2.83)***
β_3 *E-9 (DMU(Y) term)	-0.1350 (4.40)***	-0.1514 (4.08)***	-0.1468 (3.95)***	**-0.2130 (4.62)*** **	**-0.195 (4.17)*** **	**-0.1917 (4.09)*** **	-0.2670 (4.78)***	-0.2398 (4.22)***	-0.2378 (4.17)***
Sick years									
$\delta_{100}\Delta\Pi_i^{AS} pdvi_i$	-7.4602 (6.01)***	0.0323 (0.00)	-69.0238 (-1.40)	**-9.6248 (5.41)*** **	**2.0959 (-0.17)**	**-85.1591 (-1.35)**	-11.582 (4.79)***	3.6529 (-0.23)	-105.5609 (-1.33)
$\delta_{101}\Delta\Pi_i^{AS} pdvi_i \times age_{i0}$		0.6526 (4.22)***	-2.1009 (-1.52)		**1.3143 (5.04)*** **	**-3.6357 (1.68)* **		2.2562 (5.43)***	-6.0954 (1.86)*
$\delta_{102}\Delta\Pi_i^{AS} pdvi_i \times age_{i0}^2$			0.0018 (-0.13)			**-0.0243 (-1.01)**			-0.0931 (2.22)**
$\delta_{110}\Delta\Pi_i^{AS} agepdvi_i$		-0.5568 (2.76)***	3.5999 (1.72)*		**-1.1362 (3.55)*** **	**5.3522 (1.77)* **		-1.9604 (4.04)***	8.0433 (1.88)*
$\delta_{111}\Delta\Pi_i^{AS} agepdvi_i \times age_{i0}$			0.0352 (-1.13)			**0.1025 (1.86)* **			0.2536 (2.66)***
$\delta_{12}\Delta\Pi_i^{AS} age2\,pdvi_i$			-0.0428 (1.86)*			**-0.0842 (2.23)** **			-0.167 (2.73)***

Recovered years									
$\delta_{200}\Delta\Pi_i^{AS}\,pdvr_i$	-6.4233	47.7764	-41.111	-9.3288	65.9143	-82.4354	-12.691	86.569	-143.7686
	(2.86)***	(2.59)***	(-0.47)	(2.70)***	(2.49)**	(-0.69)	(2.51)**	(2.37)**	-0.92
$\delta_{201}\Delta\Pi_i^{AS}\,pdvr_i \times age_{i0}$		0.2011	-3.5696		0.5672	-7.3201		1.1393	-13.751
		(-0.67)	(-1.16)		(-1.11)	(-1.47)		(-1.36)	(1.76)*
$\delta_{202}\Delta\Pi_i^{AS}\,pdvr_i \times age_{i0}^2$			-0.0048			-0.0238			-0.0807
			(-0.16)			(-0.45)			(-0.87)
$\delta_{210}\Delta\Pi_i^{AS}\,agepdvr_i$		-0.9283	4.6351		-1.5232	9.1315		-2.3448	16.5341
		(2.31)**	(-1.12)		(2.34)**	(-1.43)		(2.32)**	(1.74)*
$\delta_{211}\Delta\Pi_i^{AS}\,agepdvr_i \times age_{i0}$			0.0592			0.1453			0.3319
			(-0.85)			(-1.17)			(-1.55)
$\delta_{22}\Delta\Pi_i^{AS}\,age2\,pdvr_i$			-0.062			-0.1318			-0.2643
			(-1.28)			(-1.59)			(1.92)*
Lost life-years									
$\delta_{300}\Delta\Pi_i^{AS}\,pdvl_i$	-6.9292	11.0571	16.3833	-9.4543	17.6609	44.1991	-11.9302	24.7046	81.9856
	(7.70)***	(-1.29)	(-0.34)	(6.70)***	(-1.45)	(-0.68)	(5.75)***	(-1.5)	(-0.97)
$\delta_{301}\Delta\Pi_i^{AS}\,pdvl_i \times age_{i0}$		0.6312	-1.7962		1.2888	-2.3208		2.2547	-2.6087
		(5.13)***	(-1.25)		(5.80)***	(-1.02)		(5.96)***	(-0.75)
$\delta_{302}\Delta\Pi_i^{AS}\,pdvl_i \times age_{i0}^2$			-0.0177			-0.0525			-0.1224
			(-1.49)			(2.41)**			(3.13)***
$\delta_{310}\Delta\Pi_i^{AS}\,agepdvl_i$		-0.6921	1.0102		-1.3365	0.7263		-2.2651	0.0092
		(3.88)***	(-0.47)		(4.56)***	(-0.22)		(4.89)***	0
$\delta_{311}\Delta\Pi_i^{AS}\,agepdvl_i \times age_{i0}$			0.0563			0.1225			0.2461
			(1.87)*			(2.31)**			(2.68)***
$\delta_{32}\Delta\Pi_i^{AS}\,age2\,pdvl_i$			-0.0315			-0.0579			-0.1064
			(-1.35)			(-1.51)			(1.71)*
Alternatives	19788	19788	19788	19788	19788	19788	19788	19788	19788
Log L	-7175.195	-7146.39	-7141.535	-7186.375	-7149.029	-7142.45	-7196.076	-7154.093	-7143.988

Table 5

Sensitivity of Fitted VSIs in Estimating Sample to Alternative Discount Rate Assumptions

Descriptive Statistic	3% discount rate			**5% discount rate**			7% discount rate		
	No Age Effects	Linear Age Effects	Quadratic Age Effects	**No Age Effects**	**Linear Age Effects**	**Quadratic Age Effects**	No Age Effects	Linear Age Effects	Quadratic Age Effects
Sample mean VSI ($ million)	4.17	4.09	4.65	**2.2**	**3.65**	**8.92**	1.96	2.69	2.11
Sample 5th %	0.13	0.03	0	**0**	**0**	**0**	0	0	0
Sample 25th %	1.21	1.26	1.45	**0.61**	**0.96**	**1.09**	0.36	0.71	0.82
Sample 50th %	2.4	2.62	2.78	**1.54**	**2.01**	**2.11**	1.07	1.59	1.65
Sample 75th %	4.16	4.28	4.13	**2.88**	**3.29**	**3.11**	2.29	2.68	2.46
Sample 95th %	11.74	8.51	8.25	**6.76**	**6.65**	**6.16**	6.4	5.46	4.72

In the choice scenarios presented to respondents, there was no opportunity for any individual to express a negative willingness to pay for a program. At most, they could choose the other alternative, or "Neither Program." As a consequence, for these descriptive statistics, we interpret negative fitted point values of the VSI for a particular program as zero values, both in computing the marginal mean and in describing the percentiles of the marginal distribution.

Table 6

VSI for Four Classes of Sudden Death Scenarios (US $ million)

	Age Now	Age at Death	Latency	No Age Effects 50% (5%,95%)	Linear Age Effects 50% (5%,95%)	Quadratic Age Effects 50% (5%,95%)
1. Simulation:	25	25	0	7.40 (5.79,9.58)	2.94 (0.08,6.34)	1.32 (-4.03,7.55)
Sudden death	35	35	0	7.19 (5.62,9.31)	2.74 (0.35,5.53)	2.90 (-0.87,7.20)
this year	**45**	**45**	**0**	**6.82 (5.34,8.83)**	**2.08 (0.05,4.42)**	**3.59 (0.69,6.89)**
	55	55	0	6.36 (4.97,8.24)	1.35 (-0.58,3.34)	3.98 (1.19,7.33)
	65	65	0	5.68 (4.44,7.36)	0.15 (-2.24,2.42)	3.70 (0.12,7.50)
2. Simulation:	25	30	5	5.71 (4.47,7.40)	4.00 (2.21,6.57)	2.11 (-0.39,5.42)
Sudden death	35	40	5	5.50 (4.31,7.13)	3.86 (2.41,5.86)	3.07 (1.63,5.03)
in 5 years	45	50	5	5.13 (4.02,6.65)	3.34 (2.25,4.77)	3.27 (2.17,4.65)
	55	60	5	5.67 (3.66,6.06)	2.72 (1.70,3.86)	3.19 (1.99,4.65)
	65	70	5	4.00 (3.12,5.18)	1.75 (0.41,3.04)	2.49 (0.96,4.10)
3. Simulation:	25	70	45	0.49 (0.38,0.63)	1.36 (1.00,1.96)	2.08 (1.45,3.01)
Sudden death	35	70	35	0.82 (0.64,1.06)	1.99 (1.53,2.64)	2.51 (1.90,3.36)
@ fixed age (70)	45	70	25	1.34 (1.04,1.73)	2.53 (2.02,3.22)	2.57 (2.05,3.19)
	55	70	15	2.32 (1.81,3.01)	2.98 (2.46,3.66)	2.54 (1.84,3.28)
	65	70	5	4.00 (3.12,5.18)	1.75 (0.41,3.04)	2.49 (0.96,4.10)
4. Simulation:	25	30	5	5.71 (4.47,7.40)	4.00 (2.21,6.57)	2.11 (-0.39,5.41)
Sudden death	25	40	15	3.36 (2.63,4.36)	4.32 (3.22,6.07)	3.32 (2.09,5.19)
varying latency	25	50	25	1.92 (1.50,2.48)	3.52 (2.65,4.90)	3.63 (2.61,5.26)
	25	60	35	1.03 (0.80,1.33)	2.41 (1.81,3.34)	3.11 (2.25,4.46)
	25	70	45	0.49 (0.38,0.63)	1.36 (1.00,1.92)	2.08 (1.45,3.01)

NOTE: Based on 1000 random draws from joint distribution of estimated parameters. Models do not restrict the signs of parameters and do not restrict the sign of fitted VSI to be non-negative; no negative or zero values drawn for marginal utility of income

Examples of Illness Profiles

Figure 1: A nonfatal illness (with recovery) that reduces life expectancy

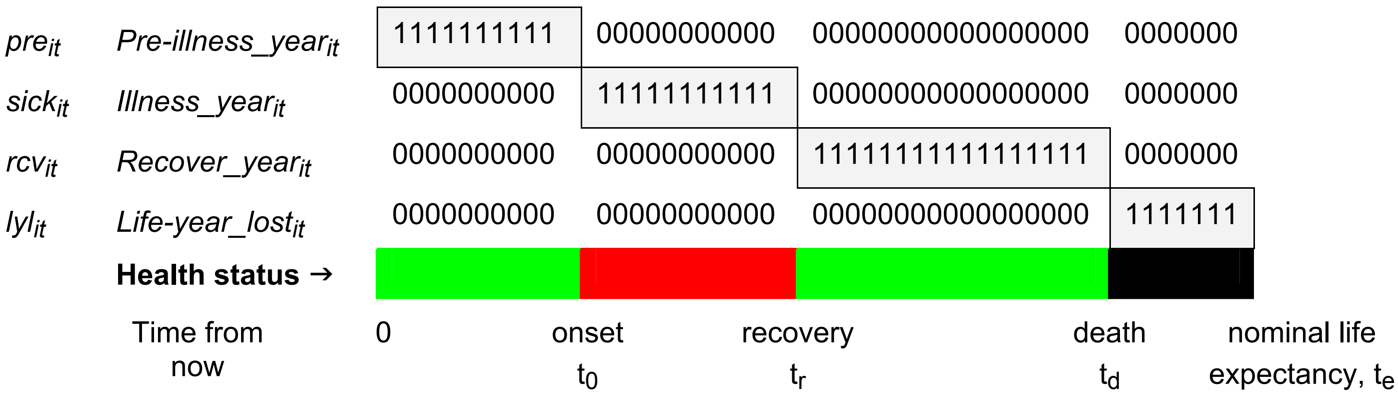
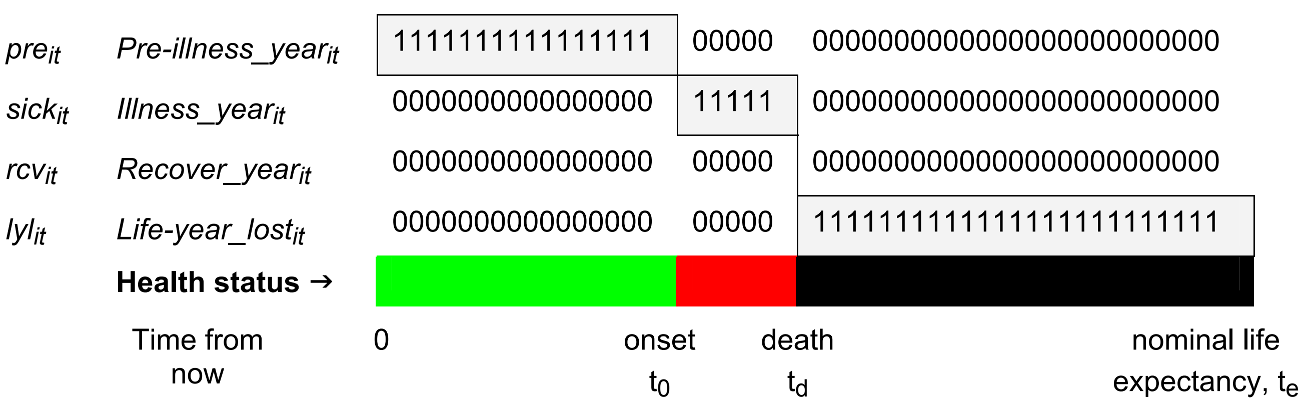


Figure 2: A fatal illness



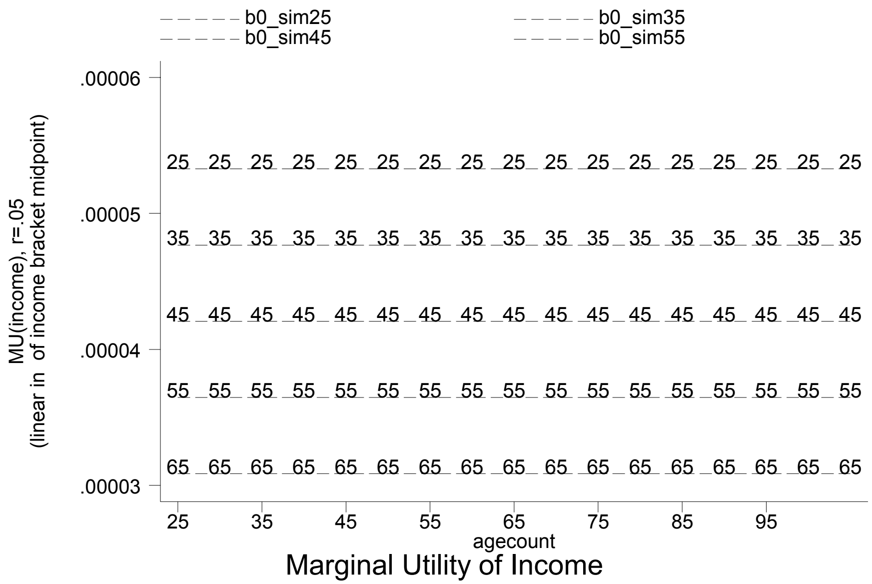


Figure 3A

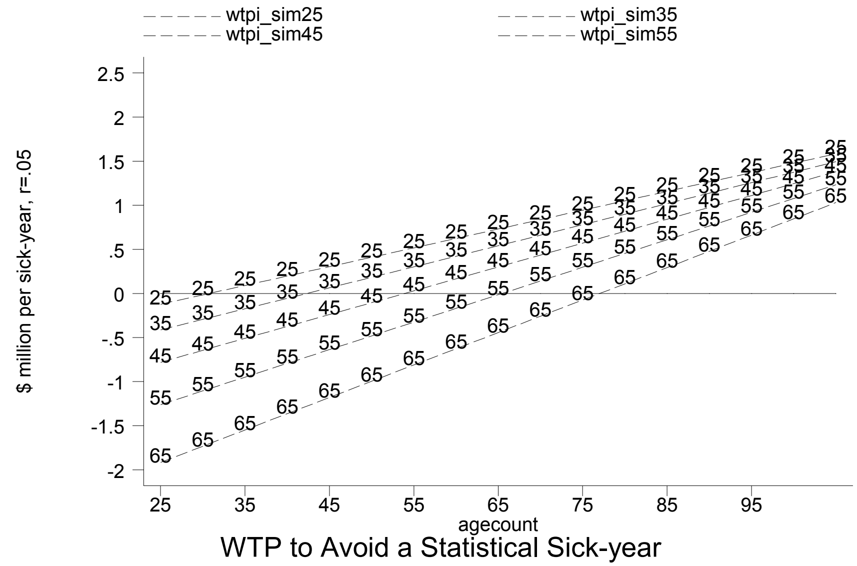


Figure 3B

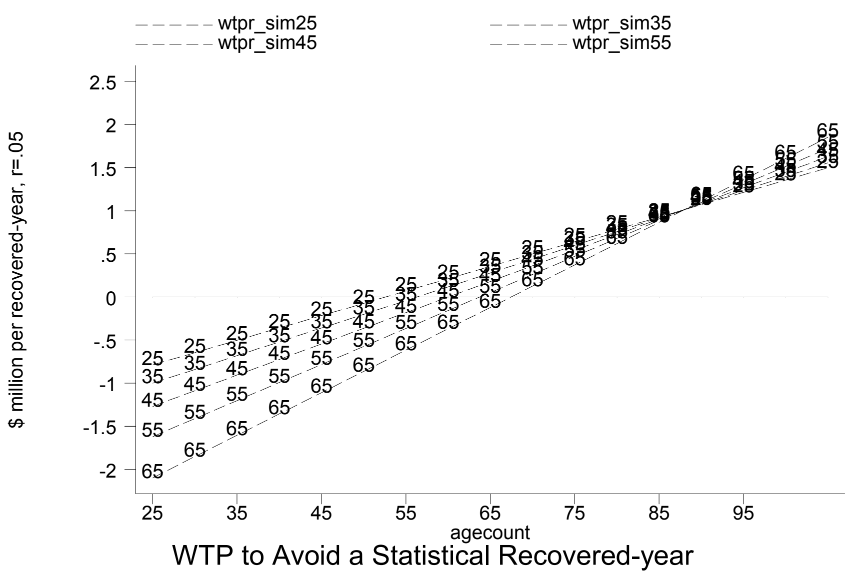


Figure 3C

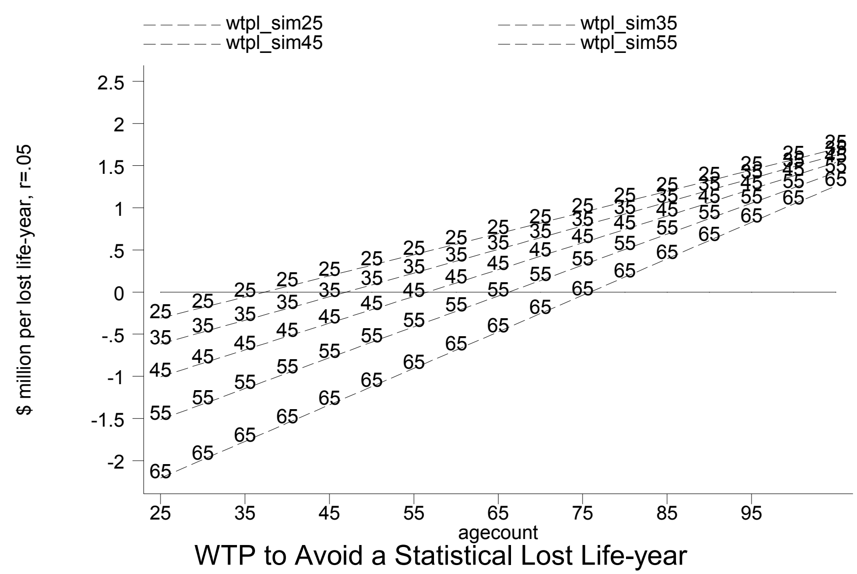


Figure 3D

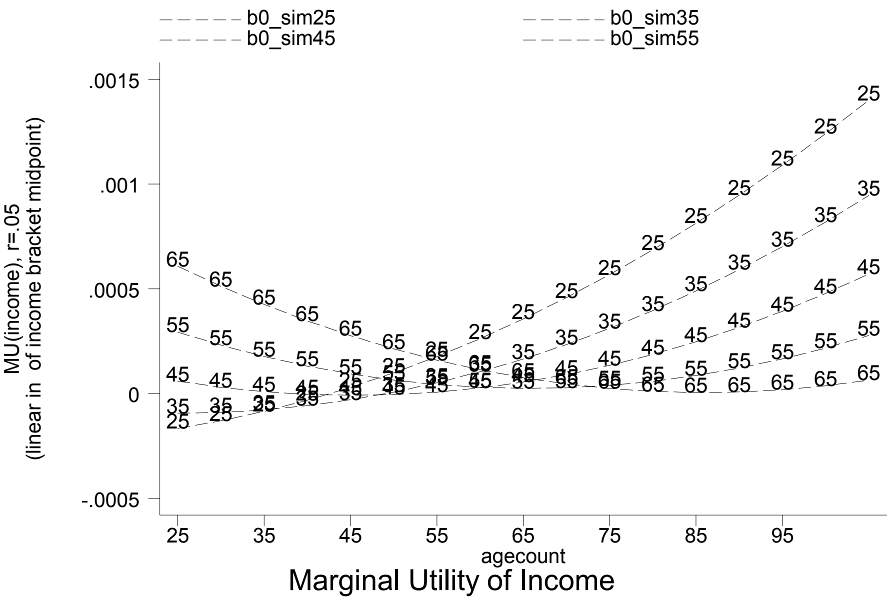


Figure 4A

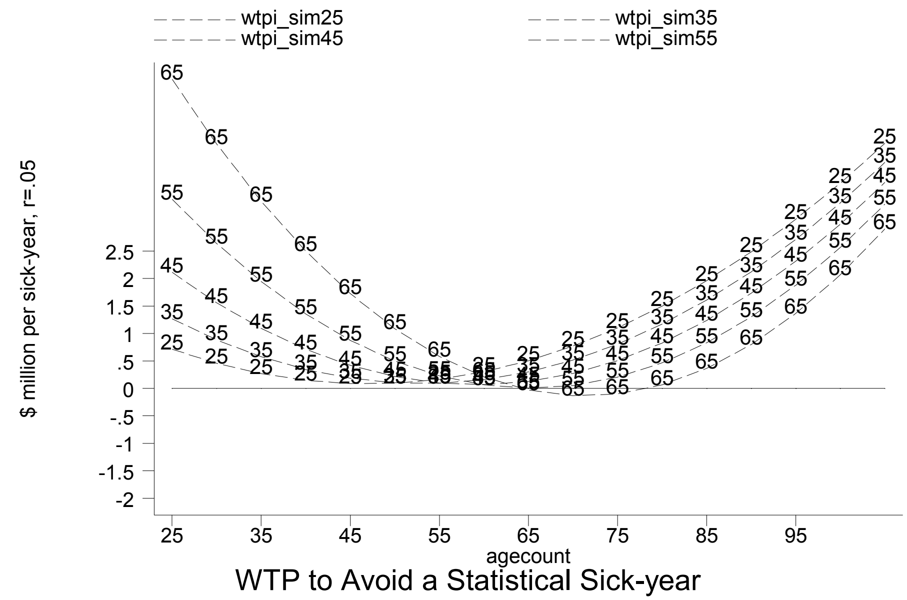


Figure 4B

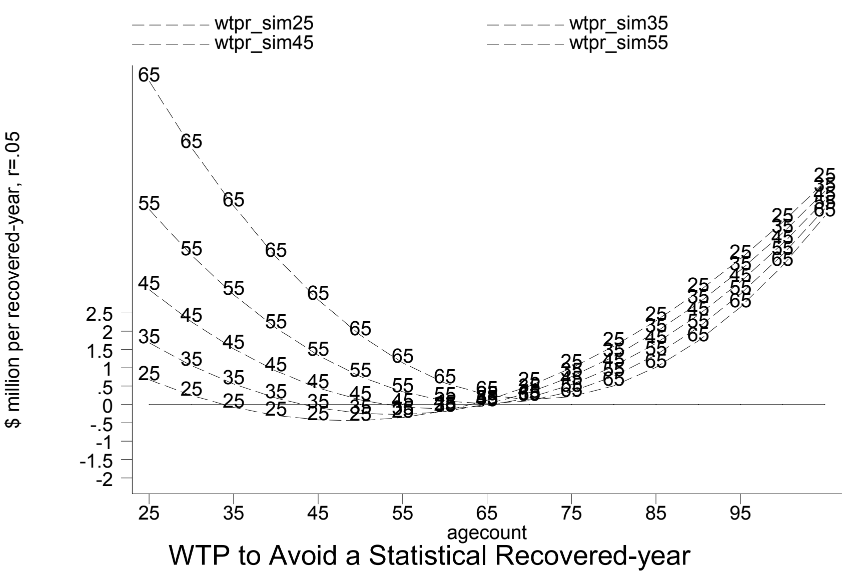


Figure 4C

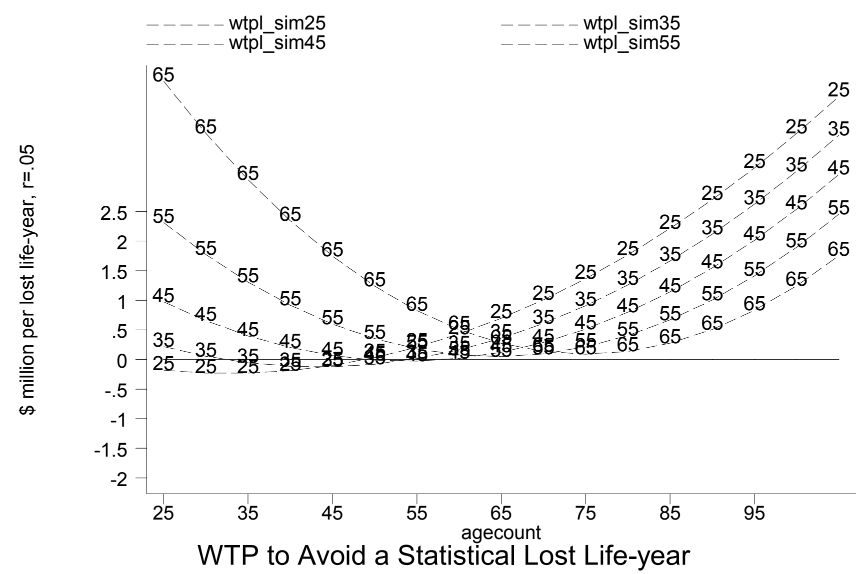


Figure 4D

Valuation of Environmental Risks to Children's Health[*]

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1. Introduction

Do parents value improvements in their children's health more than improvements in their own health? This question bears directly on central issues in research on family behavior including resource allocation between family members and the extent of parental altruism toward their children. It also has important implications for public policy in light of the growing worldwide emphasis on protecting children's health from environmental hazards (Scapecchi 2003). Nevertheless, little is known about how parents allocate health-related resources between themselves and their children despite the fact that public policy measures for protecting children operate at least partly through parents or other adult caregivers. Also, the few studies that do examine how parents value their own health relative to their children's health focus more heavily on morbidity (Liu *et al.* 2000 and Dickie and Messman 2003), base estimates on crude health measures (Agee and Crocker 2001), and reach widely differing conclusions. For example, Jenkins, Owens, and Wiggins (2001) find that the value of a statistical life (VSL) of a child (about $3 million year 2000 dollars) is about two-thirds of that for a parent, while Mount *et al.* (2001) find that the VSL for parent and child are about equal ($7.3 million in year 2000 dollars). Additionally, Liu *et al.* (2000), Dickie and Messman (2003), and Agee and Crocker (2001) find that parents are willing to pay about twice as much to reduce morbidity risk for their children than for themselves.

This paper uses unique field data on skin cancer to estimate parents' marginal rates of substitution between morbidity and mortality risks to themselves and to their children. Skin cancer risk, previously considered in related context by Dickie and Gerking (1996, 1997), is a common affliction that can but usually does not result in death. Also, solar radiation exposure during childhood is an important determinant of lifetime skin cancer risk (e.g., Reynolds, et al.

1996, Robinson, Rigel and Amonette 1997, American Academy of Dermatology 1997 and Creech and Mayer 1998) and people accumulate as much as 80% of lifetime exposure before the age of 18.

From a conceptual standpoint, a key advantage of this study is that morbidity and mortality risks are treated together in a consistent theoretical framework. Prior studies of health risks treat either morbidity or mortality, but not both, yet these two health outcomes are obviously related (i.e., death is a possible outcome of illness). Also, the expected utility model developed shows how to make econometric estimates of the desired marginal rates of substitution as risk-risk tradeoffs from an indifference map. Whereas Viscusi, Magat and Huber (1991) used risk-risk tradeoffs to see how people evaluate different sources of risk, this study looks at how parents make interpersonal risk trade offs between themselves and their children, as well as how they make trade offs between morbidity and mortality risks from the same disease.

An important methodological advantage of the study is that data are collected using an experimental design that randomizes health risk changes presented to parents. This feature sidesteps a number of econometric problems because risk changes are exogenous treatments that are orthogonal to individual characteristics. Additionally, although marginal rates of substitution are obtained from parents' stated preference bids, the desired estimates are ratios of bids. Thus, the problem identified by Diamond and Hausman (1994) and Cummings et al. (1997) that stated preference bids overestimate what people actually would pay may be at least partially ameliorated. Additionally, use of stated preference bids may in any case be more appropriate than revealed preference value estimates because tastes do not have to be disentangled from a household production technology (Hanemann 2003).

The paper is divided into four additional sections. Section 2 develops an expected utility model with compound probabilities for a parent-child “family” in which either person might get skin cancer and then might die from this disease. Section 3 describes field data on perceived risk of skin cancer and willingness to pay to avoid the disease collected from 610 parents in Hattiesburg, MS during the summer of 2002. Section 4 presents results indicating that for the full sample, parents’ estimated marginal rate of substitution between health risk reductions for their children and health risk reductions for themselves is about 2. This estimate, however, exhibits considerable variation across sub-samples of parents. It is larger for white parents than for black parents, larger for sons than daughters, and larger for younger children than older children. Section 5 concludes.

2. Model

This section presents a one-period expected utility model with state dependent utility functions to guide the experimental design, data collection and empirical analysis. The model consistently treats both morbidity and mortality risk from skin cancer in a “family” composed of one parent and one child. This approach abstracts from several issues considered elsewhere to make application tractable in the field study. For example, the model does not consider divergent interests between family members (see Mount et al. 1991 and Smith and van Houtven 2002) because expenditures to reduce risks of skin cancer represent a small fraction of family budgets. The child is assigned no role in household decision-making; in consequence, the parent is assumed to allocate family resources to maximize his or her own expected utility. Only one child is included in the model to focus on how parents make tradeoffs between their own health and the health of their children, rather than on how parents allocate resources among different children. A one-period model is presented so as to emphasize parent-child tradeoffs and consistent treatment of morbidity and mortality while abstracting from latency periods and time preferences. Extensions of the model to introduce latency periods and two or more children are briefly described at the end of this section.

The parent's expected utility is a probability-weighted sum of utilities in $3^2=9$ possible states of the world that depend on whether the parent and child are healthy, sick, or dead. Four probabilities determine which of the nine states of the world actually emerges: (1) the probability that the parent will get skin cancer (S_p), (2) the conditional probability that the parent will die from skin cancer given that the disease is contracted (D_p), (3) the probability that the child will get skin cancer (S_c), and (4) the conditional probability that the child will die from skin cancer given that the disease is contracted (D_c). This approach has at least broad similarities to models previously applied in the literature on environmental risks to health. In their model of health consequences of exposure to hazardous wastes, Smith and Desvousges (1986, 1987) split the unconditional risk of death from exposure into the probability of exposure and the conditional probability of premature death given exposure. Eeckhoudt and Hammitt (2001) examine how a specific risk to an individual's health should be valued when the individual faces independent life-threatening background risks. Both of these models, however, envision only two health states (alive and dead) and thus do not explicitly treat morbidity, and neither model considers the allocation of health resources in a family.

In the model applied in this paper, the four probabilities are determined as shown in equation (1).

$$S_j = S_j(Z_j, \Omega_j, l_j) \qquad D_j = D_j(Z_j, \Omega_j, d_j), \qquad j = p, c, \tag{1}$$

In this equation, probabilities of getting skin cancer and of dying from the disease if it is contracted are influenced by predetermined factors ($\Omega_j, \;\; j = p, c$) such as genetic characteristics like complexion and sensitivity of skin to sunlight. Still, the probabilities are endogenously determined because parents may purchase goods (e.g., hats, sun lotions, medical care) for themselves and their children ($Z_j, \;\; j = p, c$) to reduce the chances of getting skin cancer and to reduce conditional death risk if the disease is contracted. Because the experimental design applied in the field study manipulates the four probabilities, S_j and D_j also are specified as functions of treatments l_j and d_j.

As described in Section 3, the treatments are hypothetical sun lotions that resemble currently marketed products but offer greater skin cancer protection. If purchased, the hypothetical sun lotion would replace any currently used sunscreens, resulting in a savings in expenditure on existing products but no attenuation of the risk reduction offered by the hypothetical sun lotion. Any changes in other protective actions Z_j (e.g., seeking less evaluation of skin damage during medical checkups) are assumed to be negligible. (See Dickie and Gerking 1996 for a model incorporating adjustments in protective behavior.) Also, for ease of exposition, treatment parameters have the property $\partial S_j / \partial l_j = \partial D_j / \partial d_j = -1$.

Perceived skin cancer risks are incorporated into the expected utility model as shown in equation (2).

$$\begin{aligned} E(U) &= (1-S_p)(1-S_c)U_0(Y) \\ &+ (1-S_c)S_p[(1-D_p)U_p(Y) + D_pV_p(Y)] + (1-S_p)S_c[(1-D_c)U_c(Y) + D_cV_c(Y)] \\ &+ S_pS_c[(1-D_p)(1-D_c)U_{pc}(Y) + (1-D_c)D_pW_p(Y) + (1-D_p)D_cW_c(Y) + D_pD_cW_{pc}(Y)], \end{aligned} \tag{2}$$

where U_0 denotes utility in the state where both parent and child are healthy, U_j denotes utility in a state in which either the parent or child ($j = p, c$) contracts skin cancer but the other does not and neither dies, V_j denotes utility in a state in which either the parent or child ($j = p, c$) dies from skin cancer but the other does not get it, U_{pc} denotes utility in the state where both parent and child get skin cancer but neither dies, W_j denotes utility in the state in which both parent and child contract skin cancer and one of the two dies ($j = p, c$) but the other does not, and W_{pc} denotes utility in the state in which both parent and child die from skin cancer. In states in which the parent and/or child die, parental utility is not restricted to zero; for example, if the child dies, the parent's life may still go on and if the parent dies utility may be obtained from a bequest. Also, Y denotes the parent's wealth net of: (1) expenditures for self- and child-protection goods (Z_j) and (2) bids for treatments presented in the experimental design (l_j and d_j). The parent's gross wealth is denoted as y and for simplicity here is assumed to be the same in all health states. (See Shogren and Crocker (1991) for a model incorporating differences in wealth between health states.)

The model can be manipulated to obtain parents' willingness to pay for reduced morbidity and mortality risks to themselves and their children. Ratios of marginal willingness to pay values provide measures of parents' marginal rates of substitution between: (1) morbidity risk to themselves and to their children, (2) mortality risk to themselves and to their children, (3) morbidity and mortality risk themselves, and (4) morbidity and mortality risk to their children. Assume that the parent already has chosen expected utility maximizing values of self- and child-protection expenditures in each health state, and l_j and d_j are initially zero. Then, willingness to pay for reduced risk of skin cancer to the child is obtained by setting $dE(U) = 0$ $= d\,l_p = dd_p = dd_c$ and computing

$$
\begin{aligned}
-\partial y / \partial l_c = \{ & (1-S_p)[(U_0 - U_c) + D_c(U_c - V_c)] \\
& + S_p(1-D_p)[(U_p - U_{pc}) + D_c(U_{pc} - W_c)] + S_p D_p[(V_p - W_p) + D_c(W_p - W_{pc})]\} / \Delta.
\end{aligned} \tag{3}
$$

In equation (3), Δ denotes the expected marginal utility of wealth and is positive if the marginal utility of wealth is positive in each state. Also, the numerator of the right hand side of equation (3) is positive if the utility difference in each term of the sum is positive (i.e., healthy is preferred to sick, sick is preferred to dead, one person sick is preferred to two people sick, etc.). Then, $\partial y / \partial l_c < 0$ and gross wealth must fall to hold expected utility constant if the child's morbidity risk is reduced.

Similarly, willingness to pay for a small reduction in perceived conditional death risk faced by the child, holding all other perceived health risks constant, is

$$
-\partial y / \partial d_c = S_c \{(1-S_p)(U_c - V_c) + S_p[(1-D_p)(U_{pc} - W_c) + D_p(W_p - W_{pc})]\} \big/ \Delta. \tag{4}
$$

Thus $\partial y / \partial d_c < 0$ if $\partial y / \partial l_c < 0.$ Because perceived unconditional risk of death from skin cancer is $R_c = S_c D_c$, equations (3) and (4) can be combined to obtain the parent's willingness to pay to reduce the child's unconditional death risk:

$$
-\partial y / \partial R_c = \left(\frac{1-S_c}{1-R_c} \right) \left(-\partial y / \partial l_c \right) + \left(\frac{1-D_c}{1-R_c} \right) (1/S_c) \left(-\partial y / \partial d_c \right). \tag{5}
$$

Thus $\partial y / \partial R_c < 0$ if $\partial y / \partial l_c < 0.$ The parent's marginal rate of substitution, or risk-risk tradeoff, between the child's unconditional risk getting skin cancer and unconditional risk of dying from the disease equals $(\partial y / \partial R_c) \big/ (\partial y / \partial S_c).$ This ratio measures the parent's relative valuation of reducing mortality and morbidity risks for the child. However, if skin cancer is an event that may occur in the future, the absolute magnitudes of $\partial y / \partial R_c$ and $\partial y / \partial S_c$ cannot be used to estimate the value of a statistical life or of a statistical case of skin cancer (i.e., the willingness to pay today to save a life or to avoid a case today).

Key comparative static properties of willingness to pay expressions in equations (3) – (5) are similar those found in the more familiar setting of one individual facing mortality risk only (Jones-Lee 1974). For example, parental willingness to pay to reduce the child's morbidity or mortality risk increases with gross wealth and with the initial levels of risk faced by the child, if the expected marginal utility of wealth is decreasing in wealth and in initial risk levels. Also, for marginal reductions in small risks of morbidity or mortality, willingness to pay is approximately proportional to the size of the risk change.

Similar properties apply to parents' willingness to pay for reduced risks to themselves. These values, which can be obtained by parallel calculations corresponding to equations (3) – (5), are useful in their own right and as benchmarks for assessing the magnitudes of parents' valuations of their children's risks. It will be of interest to test whether parents' marginal rates of substitution between unconditional risks to their children and unconditional risks to themselves equal unity, i.e., whether $(\partial y / \partial l_c) / (\partial y / \partial l_p) = 1$ and whether $(\partial y / \partial R_c) / (\partial y / \partial R_p) = 1$.

The model may be extended to a temporal setting incorporating a latency period before the possible onset of skin cancer and including an arbitrary number of children in the family. The specific extension envisioned features identical children who face a longer latency period than do their parents. In this broader model, willingness to pay for reduced risk for the parent or a child falls as the number of children rises, if the marginal utility of aggregate family consumption is higher when more children are present. Willingness-to-pay values and parent-child marginal rates of substitution depend on weighted sums of utility differences similar to those appearing in the one-period setting, as well as on discount factors determined by latency periods and parents' subjective discount rates. Like the individual utility differences appearing in equations (3)-(5), the discount factors are components of parents' valuations that need not be separately identified to estimate willingness to pay or marginal rates of substitution. While measures of parents' discount factors for latent health risks would be of interest, these measures might be better estimated in a study that focused on latency of one risk to one person, rather than on morbidity and mortality risk for two people.

3. Data Collection

Data on risk beliefs about skin cancer and willingness to pay to avoid this disease were collected during summer of 2002 using a self-paced, interactive, computerized instrument. All respondents were residents of the Hattiesburg, MS metropolitan statistical area. Hattiesburg is located in the southern part of Mississippi, has a mean annual high temperature reading of 77.5 degrees Fahrenheit, a subtropical climate, and a large number of sunshine days each year. Thus, residents have experience with consequences of exposure to ultraviolet radiation from sunlight. The sample was drawn by random digit dialing after removing business, government, and cellular telephone numbers. When the calls reached adults, interviewers described the general purpose of the survey (federally funded research on health risks to parents and their children), asked whether they had at least one biological child between the ages of 3-12 living at home, and asked whether they were willing come to the University of Southern Mississippi to participate in the survey. Biological children were singled out for inclusion in the study because skin cancer risk is partly determined by genetic characteristics inherited from parents (e.g., fairness of skin and sensitivity of skin to sunlight). The age range was chosen to have children old enough to regularly spend time outdoors, but young enough for parents to exert substantial control over their activities. Respondents were paid $25 for completing the 30-minute questionnaire.

The final sample consisted of 610 parents; children did not participate in the survey. The survey obtained information about the parent/respondent and one sample child (chosen at random from among biological children living at home if more than one in the 3-12 year age range was present. Information was obtained about the number of children in the household, but other questions about children pertained only to the sample child in order to limit the length of the interview, to avoid repetitive questioning, and because the model presented in Section 3 assumes that parents treat each child equally. Of sample parents, 75.4% were white, 20.0% were African-American, 4.6% were members of other races, 23.4% were male, 76.9% were under the age of 40, mean household income was $53,000 per year, 75.9% were married, and 59.0% worked full time. Because of random selection, about half (50.5%) of the sample children were male. The average age of sample children was 7.07 years. Also, parents were generally familiar with skin cancer: (1) 95.4% had heard of skin cancer, (2) 83.8% knew of someone (public figures, friends, or relatives) who had been diagnosed with this disease, (3) 22.1% knew of someone who had died from skin cancer, (4) 80.3% had thought about the possibility of getting skin cancer, (5) 3.4% had been diagnosed with this disease themselves, and (6) 71.1% had considered the possibility that one of their children might get skin cancer.

Chances of getting skin cancer were assessed using an interactive risk scale that closely resembled the grid squares used by Krupnick et al. (2002). This approach was used because risk information appears to be better understood using this type of visual aid (Corso, Hammitt, and Graham 2001). As shown in Figure 1, the scale depicted a large square divided into 20 rows and 20 columns showing 400 equal-sized smaller squares. Initially, all 400 of these squares were green. Parents changed green squares to red ones to represent the amounts of risk. By pressing a button at the bottom of each column of squares, they could recolor a column of 20 squares from green to red (or from red back to green) and the color of any individual square could be changed by clicking on it with a mouse. A box beneath the scale showed the percentage of red squares out of 400. This calculation was updated each time one or more squares was re-colored. Before using the scale to estimate skin cancer risk, parents practiced using the risk scale for an unrelated event (a possible auto accident) and were told about the meaning of "chances in 400". Also, they were told to consider only the chances of getting this disease (or of getting it again if they had already had it), rather than how serious the case might be. Parents then used the risk scale to estimate lifetime chances of getting skin cancer, first for themselves and then for their sample children. In making these estimates, they could take as much time as they desired and could make as many changes in the risk scale as desired. Table 1, discussed momentarily, presents the frequency distribution of these risk estimates.

After providing lifetime skin cancer risk estimates for themselves and their children, parents were: (1) provided with information about skin cancer, (2) asked a series of questions about skin cancer risk factors, and (3) given an opportunity to revise these estimates. The idea behind asking respondents to estimate lifetime skin cancer risk a second time was to help them pin down their estimate as well as they could before moving on to the remaining portions of the survey. In particular, they were told that according to the National Cancer Institute, the average person in the United States has a lifetime risk of getting skin cancer of 18% and were questioned about skin color and sensitivity to sunlight, family history of skin cancer, time spent outdoors in direct sunlight, past sunburns, and use of sun protection products and protective clothing. Brief narratives provided information about how these aspects have been related to skin cancer risks in epidemiological studies. To elicit the revised lifetime skin cancer risk perception estimates, parents again were shown the previously described risk scales for themselves and their sample child as they originally were marked, and were given an opportunity to make changes.

After this task was completed, parents were asked about their perceived severity of skin cancer: "Suppose that a doctor tells you that you have skin cancer and you begin treatment. What do you think is the chance that you would die within five years of this diagnosis?" Parents answered for themselves and their sample child using a risk scale like the one shown in Figure 1. Responses are interpreted as estimates of the conditional risk of death from skin cancer given that the disease is contracted.

Table 1 presents frequency distributions of parents' perceived lifetime risk of skin cancer and conditional risk of death from skin cancer both for themselves and for their children. For perceived lifetime risk, the frequency distribution shown pertains to the initial risk estimates. As it turned out, parents made only small revisions in their initial lifetime risk estimates for themselves (the two estimates of mean risk are virtually the same, 23.9%), but revised risk estimates for children were on average about 1.5 percentage points lower than initial risk estimates (19.0 vs. 20.5), a significant difference at the 1% level. Table 1 indicates considerable variation in perceptions about lifetime skin cancer risk, with some parents believing that skin cancer is highly unlikely and a smaller number of other parents believing that skin cancer is virtually inevitable. Regarding the possibility of death from skin cancer, about two-thirds of parents believed that their conditional risk of death given a diagnosis of skin cancer is 10% or less and about three-fourths of parents believed that if similarly diagnosed, their sample child's conditional risk of death is 10% or less. This outcome suggests that parents were aware that skin cancer is seldom fatal.

Table 2 shows estimates of mean lifetime of getting skin cancer and mean conditional risk of dying from this disease for various sub-samples of parents. These sub-samples are further analyzed in Section 4. As shown, white parents estimated that their own lifetime risk of getting skin cancer exceeded that of their sample child (27.6% vs. 22.8%, a statistically significant difference at the 1% level), whereas among blacks, the corresponding difference was not significant at conventional levels (11.8% vs. 12.9%). Parents in both racial groups appear to have overestimated this risk. Ries et al. (1999) found that whites have a lifetime chance of 21% of getting either melanoma or non-melanoma skin cancer and African-Americans have a corresponding risk of less than a 1%. The fact that the survey introduced the possibility of getting skin cancer again if the parent had already had it does not appear to be an important complicating factor in this regard. Sample members are relatively young and few reported having been previously diagnosed with this disease.

Table 2 also shows that parents reported higher mean conditional death risk estimates for themselves (12.2%) than for their sample children (9.4%), a statistically significant difference at 1%. Differences in these estimates between white and black parents are quite small. Thus, it appears that parents generally believe that skin cancer risks for their children are lower than their own. This outcome may reflect parents' beliefs that they take greater precautions to protect their children from skin cancer risk with their own children than their parents did in an earlier period when less was known about the hazards of solar radiation exposure. Also, it may reflect a belief that skin cancer will take longer to develop in children than in parents together with the idea that delayed risks are perceived as smaller. Finally, Table 2 indicates that among whites, who comprise 67% of the sample: (1) mothers believed that their own risks of skin cancer exceeded those for fathers, (2) parents thought that their sons' and daughters' risk was about the same, (3) parents believed that risks faced by younger children exceeded those for older children.

The final section of the survey assessed willingness to pay for a hypothetical sun protection product that would reduce skin cancer risk for both the parent and the child when used as directed. The approach of using a single product to get willingness to pay means that parents do not make separate bids to protect themselves and their children as in Liu *et al.* (2000) and Dickie and Messman (2003). This procedure is aimed at reducing the potential problem that parents might feel that they "should" bid more for child protection than for protection for themselves. Parents became familiar with this product by reading a label that was designed to look like those used on bottles of over-the-counter sun lotions (see Figure 2). The label indicated that the hypothetical sunscreen would be similar in most respects to currently marketed products (available in a variety of SPFs, offer protection against premature aging of skin, non-comedogenic, oil-free, and unscented), but that it would offer greater levels of skin cancer protection.

Eight labels were used in the study. Except for differences in the amount of skin cancer reduction offered, labels were identical in every respect to control for other possible motivations driving the purchase decision such as to prevent or get a suntan and guard against aging or wrinkling of skin (see Dickie and Gerking 1996 who more fully discuss these possibilities). Four labels varied reductions in risk of getting skin cancer, while four other labels varied reductions in conditional death risk of this disease. Table 3 shows the reductions in risk stated on each of label. Labels A, D, E, and H offered equal percentage reductions in skin cancer risk (either 10% or 50%) for both adults and children. Labels B and F offered relatively greater skin cancer protection for children, while Labels C and G offered protection for adults. Each respondent was shown two randomly assigned labels. One of these offered reduced risk of getting skin cancer and the other offered reduced conditional death risk from skin cancer. The order in which these labels were presented was randomized.

After respondents were given time to read the label as if buying a product for the first time, the risk scale was used to show the amount by which the hypothetical sunscreen would reduce skin cancer risks for themselves and their children. Then, parents were asked, "Now please think about whether you would buy the new sun protection lotion for yourself or your child. Please do not consider buying it for anyone else. Suppose that buying enough of the lotion to last you and your child for one year would cost $X. Of course, if you did buy it, you would have less money for all of the other things that your family needs. Would you be willing to pay $X for enough of the sunscreen to last you and your child for one year?" The value of X was varied between $20 and $125. When responses were affirmative, parents were asked if they would pay a higher price; when responses were negative, they were asked whether a lower price would be paid. This procedure was repeated for the second label assigned to the parent.

4. Empirical Estimates

Data described in Section 3 are used to obtain estimates of the marginal rates of substitution described in Section 2. Marginal rates of substitution are inferred from estimates of an equation describing parents' willingness to pay for the hypothetical sunscreen. This equation was obtained from the model presented in Section 2 by totally differentiating equation (2), setting $dE(U) = 0,$ and interpreting the bid for the sunscreen as the change in wealth, $dy.$ The equation estimated is

$$\ln(w_{it}) = d_{it}'b + x_i'g + u_i + v_{it}, \tag{6}$$

where i indexes parents and $t = 1, 2$ indexes the two experimental treatments (labels) assigned to parent i. In equation (6), w_{it} denotes willingness to pay for one year's supply of the sun lotion, d_{it} denotes a vector of attributes of the sun lotion including the risk changes for the parent and child as described on the label, and b represents the corresponding vector of coefficients. The b coefficients measure effects of risk changes on (the log of) willingness-to-pay and must be estimated to infer marginal rates of substitution. Also, x_i represents a vector of measured characteristics of the parent, child or family, g represents the corresponding vector of coefficients, and u_i and v_{it} are uncorrelated mean zero normal random variables with variances s_u and s_v, respectively. Thus, v_{it} reflects uncontrolled factors varying over parents and over treatments, while u_i captures the impact of uncontrolled factors specific to the parent (or her child or family) and constant over treatments. Among the many factors that might be reflected in the individual-specific error component are unobserved genetic endowments, current spending on sunscreen lotion, concern for skin cancer risks to herself and her child, and propensity to misstate willingness to pay in response to hypothetical questions. Willingness-to-pay is assumed log-normally distributed in view of its non-negativity and the positive skewness typically characterizing its distribution.

Random assignment of labels to parents implies that risk changes are exogenous experimental treatments that are independent of all measured and unmeasured individual and family characteristics. As a consequence, randomization avoids two potential problems that would otherwise complicate estimation of willingness to pay for reduced risks and marginal rates of substitution. First, variables measuring risk change are orthogonal to characteristics such as initial perceived risks, income, number of children in the household, and race and gender of parent and child, so that the d_{it} is orthogonal to x_i. Thus, the specification of the variables in x_i has no effect on the estimate of b.

Second, random assignment implies that d_{it} is uncorrelated with u_i, so that b may be estimated consistently in a random-effects framework. Without random assignment (e.g., with non-experimental data), the risk changes to be valued are likely to be correlated with unobserved individual characteristics. Previous research indicates that inferences about intra-family allocations may be seriously misleading when heterogeneity of this sort is uncontrolled (Pitt and Rosenzweig 1990, Pitt, Rosenzweig, and Hassan 1990). Fixed-effects methods would remove family-specific heterogeneity but are less efficient that random-effects when heterogeneity is absent, as it is under randomization of experimental treatments. Instrumental-variable methods represent an alternative approach to the heterogeneity problem that are frequently used when repeated observations on individuals are not available. But randomization allows consistent and efficient estimation of b without resorting to use of instrumental variables.

Estimates of equation (6) are obtained by maximum likelihood. Respondents did not directly report their bids for the sunscreen, but the interval in which willingness-to-pay lies may be inferred from responses to the initial and follow-up questions asked about each sun lotion (Hanemann, Loomis and Kanninen 1991). Let w_{it}^u and w_{it}^l respectively denote the natural logarithms of the upper and lower bounds of willingness-to-pay for parent i, label t. Thus w_{it}^u equals the log of the lowest price at which the respondent declined to purchase the sunscreen (or $+\infty$ if she responded "yes" to both initial and follow-up questions), while w_{it}^l equals the log of the highest price at which the respondent agreed to purchase the sunscreen (or $-\infty$ if she responded "no" to both initial and follow-up questions). Then the probability that the natural logarithm of willingness-to-pay lies between the upper and lower bounds, conditional on u_i, equals

$$L_{it} = \Phi\left(\frac{w_{it}^{u} - d_{it}'b - x_i'g - u_i}{s_v}\right) - \Phi\left(\frac{w_{it}^{l} - d_{it}'b - x_i'g - u_i}{s_v}\right), \tag{7}$$

where Φ denotes the standard normal cumulative distribution function. The sample log-likelihood function is

$$\sum_{i=1}^{N} \ln\left[\int_{-\infty}^{+\infty} \prod_{t=1}^{2} L_{it} f(u)du\right], \tag{8}$$

where N equals the number of parents in the sample and f denotes the normal density function. The automated routine included in the econometric package LIMDEP and used to maximize the log-likelihood function computes the integral in equation (8) using Monte Carlo simulation.

Estimates of equation (6) are presented in Table 4. Covariate definitions are in column 1, their sample means are presented in column 2, and results from two regressions using the full sample of 610 parents are in columns 3 and 4. Five covariates are dummy variables that reflect the reductions in skin cancer risk shown on the eight labels (see Table 3). *GET* shows whether the label presented a reduction in the chance of getting skin cancer or a reduction in the conditional risk of dying from it. Thus, *GET=1* for Labels A-D and *GET=0* for Labels E-H. Also, *PARENTCHG=1* if the label offered parents a 50% reduction in risk for themselves and *KIDCHG=1* if the label offered a 50% risk reduction for their children. Interactions of *GET* and (*1-GET)* with *PARENTCHG* and *KIDCHG* show whether the risk reduction pertained to getting skin cancer or the conditional risk of dying from it. Label E, offering a 10% reduction in the conditional risk of dying from skin cancer for both parents and children, is represented by setting all five dummies equal to zero.

The column 3 regression uses only the five label dummies as covariates and column 4 shows the outcome when covariates measuring household income and number of children in the family are added. In both of these regressions, likelihood ratio tests at the 1% level reject the null hypotheses that: (1) the variance of the parent-specific error is zero and (2) all slope parameters are jointly zero. Asymptotic t-statistics, presented in Table 4, show that each coefficient estimated differs significantly from zero at the 5% level or lower under a two-tail test. As expected, coefficients of the label dummies change little when controls for family characteristics are added.

In columns 3 and 4, the positive coefficients of *GET*PARENTCHG, GET*KIDCHG, (1-GET)*PARENTCHG,* and *(1-GET)*KIDCHG* indicate that parents are willing to pay more for larger risk reductions than for smaller risk reductions. Although this outcome is broadly consistent with the conceptual model presented in Section 2, larger risk reductions bring about less than proportional increases in willingness to pay (see Hammitt and Graham 1999 for further discussion of this issue). For example, as shown by the coefficient of *GET*KIDCHG*, a five-fold reduction in risk to children of getting skin cancer (from 10% to 50%) increases willingness to pay by a little more than 40%. Also, likelihood ratio tests at the 1% level reject the null hypothesis that coefficients of *GET*PARENTCHG* and *GET*KIDCHG* are equal as well as the null hypothesis that coefficients of *(1-GET)*PARENTCHG*, and *(1-GET)*KIDCHG* are equal. In fact, the numerically larger coefficients of the risk change treatments for children suggest that parents are willing to pay more for skin cancer risk reduction for their children than they are for risk reduction for themselves. This point is developed more fully below in the context of estimating parents' marginal rates of substitution between skin cancer risk to their children and skin cancer risk to themselves.

In column 4, the positive coefficient of household income indicates that, all else constant, an increase in income by $10,000 increases willingness to pay for the hypothetical sunscreen by 3%. At sample mean household income of $53,000, the estimated income elasticity of willingness to pay for the hypothetical sunscreen is about 0.16. Also, the negative coefficient of the number of children in the household suggests that an additional child (of any age) in the household reduces willingness to pay for the hypothetical sunscreen by about 8%. This outcome is consistent with the discussion in Section 2 that fewer resources are invested in risk reduction per child when more children are present.

Estimates of marginal rates of substitution are computed as ratios of marginal willingness to pay from the column 4 regression. For example, the marginal rate of substitution between unconditional morbidity risk for the parent and child is estimated as the ratio of the coefficient of (*GET*KIDCHG)* to the coefficient of (*GET*PARENTCHG)*, multiplied by the ratio of the sample mean change in the level of unconditional morbidity risk for parents to the sample mean change in the level of unconditional morbidity risk for children. A parallel procedure is used to estimate the marginal rate of substitution between conditional death risks for the parent and child. The marginal rate of substitution between *unconditional* death risks for the parent and child then is estimated by combining the marginal valuations of morbidity and conditional mortality risk using equation (5), and taking the ratio of the resulting child valuation to the parent valuation.

The outcomes of these calculations, based on the column 3 in Table 4, are shown in column 2 of Table 5. These results indicate parents are willing to pay about twice as much to reduce the risk of getting skin cancer for their children as they are to reduce it for themselves. Similarly, the child vs. parent unconditional mortality marginal rate of substitution estimate is

2.33 (again see column 2 of Table 5). Standard errors of these estimates, reported in Table 5, indicate rejection of the null hypotheses that these marginal rates of substitution are equal to unity. That parents are willing to pay more to reduce risks to their children's health than they are willing to pay to reduce risks to their own health is of particular interest because age at onset of skin cancer is in the more distant future for children than for parents. Based on the discussion of latency in Section 2, if the time to onset of illness were the same both for parents and children, the marginal rate of substitution values may well be larger.

Column 2 of Table 5 also reports calculations of parents' marginal rates of substitution between the unconditional risk of dying from skin cancer and the unconditional risk of getting skin cancer for themselves and for their children. Whereas the marginal rates of substitution discussed above reflect tradeoffs between the same risk faced by different people, these calculations reflect tradeoffs between different types of risk faced by the same person. As shown in Table 5, parents' marginal rate of substitution between unconditional death risk and unconditional morbidity risk for themselves is 19.16 and the corresponding value for their children is 21.78. These estimates indicate that parents are willing to pay approximately 20 times more to reduce unconditional death risk by one unit than to reduce unconditional morbidity by one unit. Although, this outcome supports the idea that public policies aimed at reducing death risk are much more important to people than policies aimed at reducing morbidity, it may not generalize to related situations. Skin cancer is frequently not life threatening and while treatment may be disfiguring, patients generally expect to resume normal activities. Other illnesses and injuries may exact a greater toll on health if death does not occur and in these cases the marginal rate of substitution between mortality and morbidity may well be lower.

In addition to obtaining point estimates of marginal rates of substitution for a representative parent, it is of interest to examine how health risk tradeoffs may vary with the characteristics of parents or children. To obtain this information, the Table 4, column 4 regression was re-estimated for sub-samples defined by (exogenous) genetic characteristics that may be associated with differences in perceived risks and other initial endowments. A useful starting point in this regard is to compare marginal rates of substitution for whites and blacks. As discussed in Section 3, average perceived risks of skin cancer by white parents are roughly twice as large as those for black parents. Estimates shown in Table 5 indicate that the four marginal rates of substitution for whites are roughly similar to those obtained for the full sample (notice that the 460 white parents represent 67% of 610 parents in the full sample). These estimates, however, differ substantially from those for blacks; in fact, a likelihood ratio test at 1% rejects the null hypothesis that marginal rates of substitution for the two groups are equal. For blacks, two of the marginal rates of substitution could not be computed because the coefficient of *GET*PARENTCHG* was negative and did not differ significantly from zero at conventional levels. Also, the marginal rate of substitution for child vs. parent unconditional mortality is significantly less than unity at the 1% level, suggesting that black parents may be less altruistic toward their children than are white parents. This interpretation, however, should be treated quite cautiously because of the relatively small number of black parents in the sample.

The significant racial differences in valuation estimates suggest that pooling sub-samples of black and white parents to estimate marginal rates of substitution is inappropriate. Thus, in light of the relatively small sample size for blacks, outcomes from additional demographic breakdowns shown in Table 5 are computed only for parents in the white sub-sample. The first of these compares marginal rate of substitution estimates for 351 white mothers and 109 white fathers. Whereas both mothers and fathers similarly evaluate the child vs. parent unconditional mortality tradeoff, the child vs. parent unconditional morbidity tradeoff for fathers is about unity and about half the magnitude of that found for mothers. Thus, in comparison to mothers, fathers appear to be relatively less concerned with morbidity than mortality. This outcome leads fathers' marginal rate of substitution between mortality and morbidity for their child to be larger than that for mothers (50.05 vs. 19.06).

Also, parents appear to place significantly greater weight on reducing both morbidity and mortality risk for sons than for daughters. Estimates of child vs. parent marginal rate of substitution for unconditional morbidity is 2.60 for sons and 1.14 (not significantly different from unity) for daughters. Corresponding estimates of the marginal rate of substitution for unconditional mortality are 5.40 for sons and 2.01 for daughters. The null hypothesis that marginal rates of substitution for sons and daughters are equal is rejected at 1% level. Thus, relative to their own health, parents appear to be willing to invest more in health risk protection for sons than daughters.

Finally, parents are more protective of younger children than older children. The child vs. parent marginal rate of substitution estimates for unconditional morbidity are 1.42 for children aged 3-7 years and 2.22 for children aged 8-12 years; however, these estimates do not differ significantly from zero at the 1% level. On the other hand, corresponding estimates of the marginal rate of substitution for unconditional mortality are significantly larger for young children than for older children (4.38 for children aged 3-7 years vs. 1.73 for children aged 8-12 years). This finding is consistent with recent evidence that health risk protection for young children is valued more highly than that for older children. Nastis and Crocker (2003), find that mothers-to-be value the expected postnatal health of their unborn child as much as six times more than the expected post-partum state of their own health.

5. Conclusions

This paper has presented new empirical estimates aimed at valuing environmental risks affecting parents and children. The application focused on skin cancer, the most common form of cancer in the U.S. Links between environmental exposure to ultraviolet radiation and skin cancer are well established, and chances of getting skin cancer, for a given amount of exposure to solar radiation, depend partly on observable genetic characteristics such as skin type and complexion. The theoretical model is developed from the viewpoint of parents and supports empirical valuation of morbidity and mortality risks faced by both parents and children in a consistent framework. Risk is treated as endogenous and is measured as the risk perceived by survey respondents. The method for estimating willingness to pay rests on directly estimating an indifference relation showing utility-constant trade-offs between morbidity risks, mortality risks, and consumption goods.

The model provides a basis for computing parents' marginal rates of substitution between risk of death from skin cancer faced by both themselves and their children. This calculation shows how parents value children's health relative to their own and may be useful benefits transfer in situations where willingness to pay for reduced risk to adults have been established but corresponding values for children are not available. The model is estimated using data collected by an interactive computerized questionnaire administered on the University of Southern Mississippi campus during summer of 2002. Key aspects of the experimental design were to: (1) determine parents' perceptions of skin cancer risk to themselves and their children, and (2) obtain willingness to pay for skin cancer risk reductions. Risk reductions were presented to parents using randomly assigned labels of a hypothetical sun lotion that offered different amounts of protection to adults and children. Random assignments of risk reductions facilitate estimation of marginal rates of substitution between parent's health and children's health. For example, parents' marginal rate of substitution between their children's unconditional lifetime risk of dying from skin cancer and the corresponding risk for themselves is 2.33. Thus, parents view their children's health as more than twice as valuable than their own. Also, parents see the reductions in mortality risk to be about 20 times more valuable than reductions in morbidity risk both for themselves and their children. This outcome suggests that the morbidity component of benefits for environmental risk reduction may be quite small.

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Table 1. Frequency Distribution of Parents' Perceived Risks.
N=610.

	Risk of Getting Skin Cancer[a]		Conditional Risk of Dying from Skin Cancer	
Risk Range (%)	**Parents**	**Children**	**Parents**	**Children**
0 - 4.75	85	75	103	142
5 - 9.75	57	79	163	194
10 - 14.75	70	94	122	111
15 - 19.75	65	69	67	44
20 - 24.75	65	74	42	31
25 - 29.75	66	73	26	23
30 - 34.75	45	35	13	8
35 - 39.75	23	19	8	8
40 - 44.75	36	25	7	7
45 - 49.75	6	5	5	2
50 - 54.75	53	32	19	11
55 - 59.75	4	2	2	1
60 - 64.75	5	7	3	0
65 - 69.75	0	1	0	0
70 - 74.75	5	2	2	0
75 - 79.75	6	5	0	0
80 - 84.75	2	3	0	0
85 - 89.75	3	2	0	0
90 - 94.75	8	5	0	0
95 – 100	6	3	0	0

[a]Initial risk assessment.

Table 2. Parents' Mean Risk Perceptions (%).

Sample	Risk of Getting Skin Cancer[a]	Conditional Risk of Dying from Skin Cancer	Sample Size
All Parents	23.90	12.24	610
All Children	20.54	9.44	610
Black Parents	11.79	12.98	122
Black Children	12.88	9.77	122
Whites:			
All Parents	27.61	12.15	460
All Children	22.76	9.44	460
Mothers	29.79	12.54	351
Fathers	20.59	10.90	109
Daughters	22.76	9.39	230
Sons	22.76	9.49	230
Children aged 3 to 7 years	24.47	10.35	258
Children aged 8 to 12 years	20.57	8.28	202

[a]Initial risk assessment.

Table 3

Hypothetical Sun Protection Product Labels

Label	Percent Change in Morbidity Risk		Percent Change in Mortality Risk	
	Parent	Child	Parent	Child
A	10	10	0	0
B	10	50	0	0
C	50	10	0	0
D	50	50	0	0
E	0	0	10	10
F	0	0	10	50
G	0	0	50	10
H	0	0	50	50

Table 4
Willingness to Pay for Reduced Risk of Skin Cancer

Variable	Full Sample Mean	Estimate (t-ratio)	Estimate (t-ratio)
Constant	---	4.028 (130.32)	4.023 (86.63)
GET=1 if label changes risk of getting skin cancer; *=0* if label changes conditional risk of dying from skin cancer	0.500	-0.089 (-1.992)	-0.093 (-2.079)
PARENTCHG=1 if parent risk change = 50%; *=0* if risk change = 10%	0.498	---[a]	---[a]
KIDCHG=1 if child risk change = 50%; *=0* if parent risk change = 10%.	0.496	---[a]	---[a]
*GET*PARENTCHG*	0.249	0.251 (6.82)	0.252 (6.86)
*GET*KIDCHG*	0.251	0.436 (11.84)	0.437 (11.85)
*(1-GET)*PARENTCHG*	0.248	0.309 (8.38)	0.306 (8.30)
*(1-GET)*KIDCHG*	0.245	0.340 (9.23)	0.339 (9.22)
FAMILY INCOME ($10,000 per year)	5.325	---	0.031 (7.66)
NUMBER OF CHILDREN IN HOUSEHOLD	2.075	---	-0.076 (-5.23)
s_u	---	1.029 (53.79)	1.023 (53.65)
s_v	---	0.548 (57.78)	0.548 (57.80)
Number of Parents	610	610	610

[a] Denotes omitted dummy variable.

Table 5

Estimated Marginal Rates of Substitution
(Asymptotic Standard Errors in Parentheses)

			White Parents						
Marginal Rate of Substitution	**Full Sample**	**Black Parents**	**All**	**Mothers**	**Fathers**	**Child is Daughter**	**Child is Son**	**Child Age 3-7 yrs**	**Child Age 8-12 yrs**
Child vs. Parent Unconditional Morbidity	2.05 (0.35)	---[a]	1.61 (0.27)	1.83 (0.35)	0.96 (0.38)	1.14 (0.24)	2.60 (0.88)	1.42 (0.29)	2.22 (0.74)
Child vs. Parent Unconditional Mortality	2.33 (0.32)	0.52 (0.20)	3.28 (0.51)	3.24 (0.58)	3.35 (1.02)	2.01 (0.40)	5.40 (1.46)	4.38 (0.90)	1.73 (0.46)
Unconditional Mortality vs. Unconditional Morbidity (Parent)	19.16 (3.15)	---[a]	11.35 (1.83)	10.76 (2.08)	14.36 (4.09)	10.42 (1.78)	14.17 (4.93)	7.86 (1.55)	24.60 (7.73)
Unconditional Mortality vs. Unconditional Morbidity (Child)	21.78 (2.59)	22.48 (8.98)	23.19 (2.84)	19.06 (2.57)	50.05 (15.74)	18.42 (3.55)	29.38 (4.84)	24.25 (3.58)	19.18 (4.71)
Number of Parents	610	122	460	351	109	230	230	258	202

[a] Estimate is negative but not significantly different from zero at the ten percent level.

Figure 1. Risk Scale.

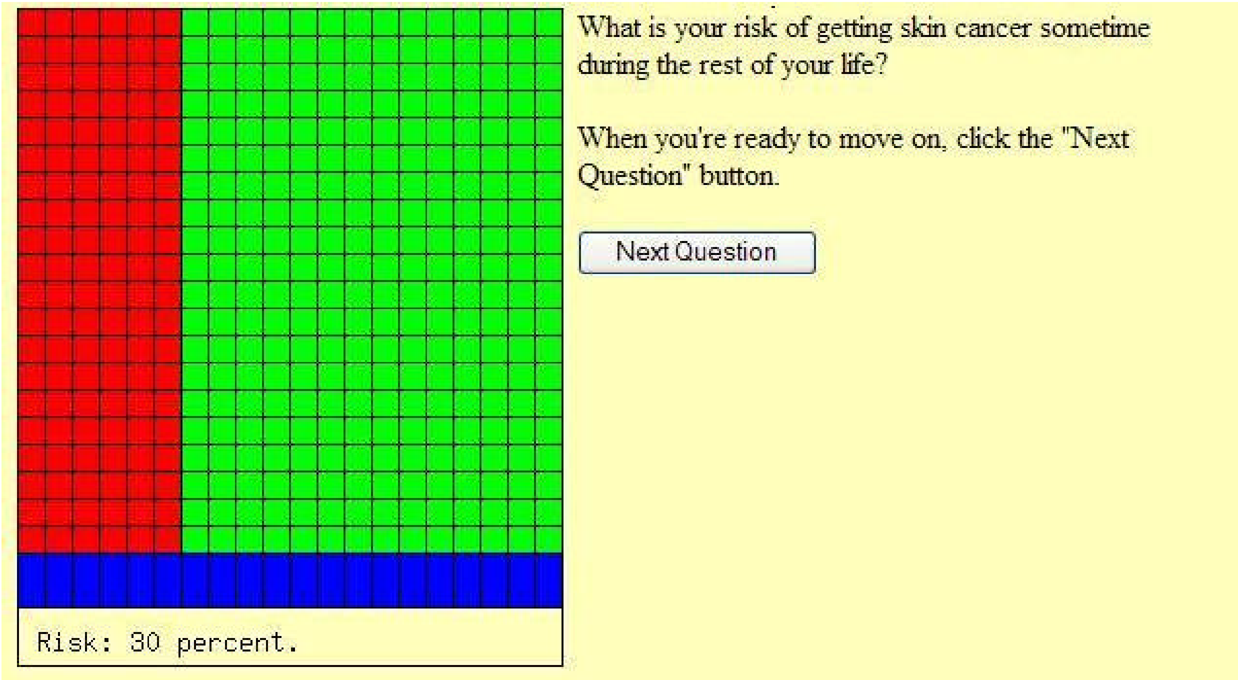
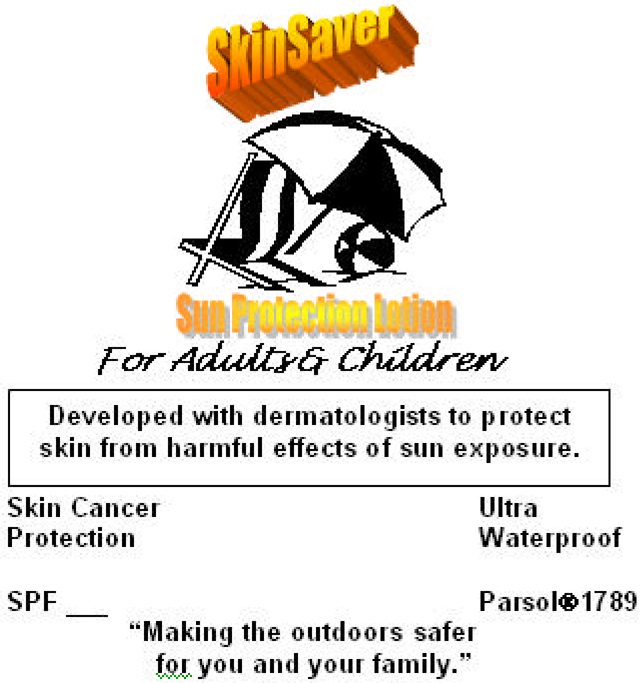


Figure 2. One of Eight Sun Lotion Labels.



(Back of bottle)

New SkinSaver® sun protection lotion.

Skin Cancer Protection

✓ **Used as directed in clinical trials, SkinSaver reduced risk of skin cancer by:**

10% for Adults	**10% for Children**

✓ **Used as directed in clinical trials, SkinSaver had no effect on the risk of dying if skin cancer occurred.**

More Skin Protection

Parsol®1789		SPF_____
Protects against premature skin aging		Protects against sunburn

More Added Features

* Ultra long-lasting waterproof formula – One application lasts all day *

* Non-comedogenic–Won't block pores * Oil-free–Won't feel greasy *

* Hypoallergenic * PABA-free * Unscented *

DIRECTIONS: Apply generously and evenly to all exposed areas of skin at least 15 minutes before sun or water exposure.

ACTIVE INGREDIENTS: Oxybenzone, octocrylene, 2-ethylhexyl salicate, homosalate, avobenzone.

Comments on "Not All Deaths Are Created Equally"

Glenn W. Harrison

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November 2003

Cameron and DeShazo undertake an ambitious survey to elicit valuations of health episodes that respect the timing of the episode. They incorporate latency of onset, as well as latency of the experience, for a wide range of possible health episodes. Mortality and morbidity are treated in the same conceptual framework, which is a major attraction. In short, their attempt to undertake valuation of the "health life cycle" is novel and important. The strengths of the study are well presented by the authors.

They claim that one novelty of their work is that they calculate the value of a statistical illness (VSI) rather than the value of a statistical life (VSL). Since many of the hedonic wage-risk regressions also included non-fatal risks, this would seem to be a trivial innovation. Important to do, but nothing to claim as novel.

Similarly, they claim to show that individual differences matter for the VSI and VSL. Again, this is worth saying as loudly as possible, but isn't this already in older data, even if has tended to be ignored in analysis? That is, many of the earlier studies included a rich array of individual characteristics that could have been used to predict VSL estimates that would have varied over those characteristics. So I am not sure what is conceptually novel here.

With respect to heterogeneity of VSI or VSL estimates, I worry a lot about the treatment of negative predicted values. These appear to have been set to $0, but that causes obvious biases in the aggregate estimates. One of the grubby secrets of VSL analysis, particularly in some recent meta-analyses, is that negative or statistically insignificant estimates are dropped or set to zero. One understands the desire of the Environmental Protection Agency to "see big VSL numbers," but such mis-handling of the data is not acceptable. I am not sure that such things are going on here, but the results appear to be very sensitive to how certain observations are dropped, and this deserves more careful discussion.

Related to this, the practice of deleting "outliers" should be completely reconsidered. If my data set includes a Bill Gates, who is an outlier in terms of income and wealth, and he responds in a numerically extreme manner, then in what sense is that an outlier? There are answers to this question that make sense, but they should not be enshrined in mechanical rules for dropping subjects. The present analysis has some questionable bases for dropping observations, and that needs further exploration.

The massive cognitive burden on respondents is an obvious concern, but we need to start somewhere if we are to examine health life-cycles. My concern here is tempered by the desire to see someone spell out a complete framework for valuation, such as one has here. But one cannot take the responses too seriously for policy work, given the uncontrolled context in which subjects were responding and the unfamiliarity of the task.

Related to this concern, I believe it was a major error to start such a complex survey with elaborate field survey procedures. While the *Knowledge Networks* technology is fascinating, it makes much more sense to pilot surveys of this kind in a less constrained and more controlled setting. My understanding is that such data points cost roughly $50 per subject, which seems a lot for such a pilot study. I appreciate that the authors undertook a large number of focus groups, and consulted some smart people in the field about design issues, but that is no substitute for controlled comparisons of different ways of presenting tasks and evaluation of cognitive burden.

The authors implicitly take the view that there is only one way to generate a social VSL – to estimate the individual VSL for different segments of the population and then take some appropriately weighted average. Of course, there are other ways to arrive at the same concept. One could elicit a household VSL rather than an individual VSL, and then weight those. Or one could directly elicit a social VSL from individuals or households. There is no *a priori* reason for the directly elicited social VSL to equal the weighted averages of individual or household VSLs. Indeed, it would be interesting to see how they are related. In the same vein, estimates of individual VSLs could be used in various social welfare functions to arrive at a social VSL. So there are many paths to the social VSL, not just the one implicit here.

The statistical analysis is heavy on math that could be relegated to appendices, and light on some of the nuts and bolts that likely drive the results. I should add that some of the "present value math" is really very interesting, and notationally delicate, so I would not want to see that lost; but it detracts from the general comprehension since it is better read off-line. My concern is more with the way the data is handled. I have already discussed the handling of negative valuations and outliers. But I missed the use of control for characteristics other than income, own-age and age-of-onset of the disease. Since this is, after all, a conference on children's health valuation, one is entitled to a "where is the beef?" question: why no controls for whether the respondent has children, or how many? I suspect that there may be some dark computational reason why more covariates are not thrown in, akin to why one sees so few covariates in the "stated choice" literature. But this needs a simple explanation and evidence, rather than assertions that it would not change results.

There are some hidden assumptions about risk aversion and individual discount rates that need to be made explicit. These are not minor matters. Once we recognize individual heterogeneity with respect to the valuation of uncertain future heath states, we have to confront the fact that these estimated values will necessarily confound the certainty-equivalent valuation of the health state, individual risk attitudes, individual discount rates, and possibly preferences individuals might have over the temporal resolution of uncertainty. Is it possible that the first component is constant with respect to the things it is claimed to vary over, but that the others vary? We simply do not know, and teasing these apart is a formidable enterprise. We do now have relatively good estimates of risk attitudes and discount rates for individuals from controlled laboratory experiments, in some cases conducted in the field with samples representative of larger populations than college students, and one would hope that one could marry such estimates to the valuations of health life-cycles to see what is really driving the VSI estimates. The evidence so far suggests considerable heterogeneity of risk attitudes and individual discount rates with respect to the standard observables, so we cannot ignore the issue by assuming homogeneity (as is done here).

The authors loudly trumpet the claim that a "senior VSL discount exists!" This claim is far too premature. The issue is an important one, but I am sensitive to a rush to judgment on such an important issue from such a pilot study. My enthusiasm for the scope of this pilot study would be nearly unbounded if I were not concerned that such claims would be ripped out of their academic context. In terms of the old Latin motto, *festine lente* (hasten slowly).

Comments on "Valuation of Environmental Risks to Children's Health"

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November 2003

Dickie and Gerking get at risks to children through parental decisions. This is a sensible way to get at children's valuation, and deserves to be explored further. Their elicitation scope is also modest, which makes for a well-focused study. The study looks at morbidity and mortality in the same framework, which is attractive. Related to this, one again sees the nice idea of a "health life-cycle" as the conceptual setting for valuation.

Asking parents for valuation of risks to the health of children makes obvious sense, but raises some questions. Which parent? The one that makes the decisions, or the one that was picked at random? How would this differ from the situation in which both parents made the decision, allowing them to endogenously resolve their internal household decision-making as they do naturally?

One major concern, however, was whether subjects would or could keep morbidity and mortality separate. It seems incoherent *a priori* that some product could reduce the risk of contracting skin cancer but not reduce the risk of dying from it. At the very least, one would surmise that they are highly, positively correlated. Given this, how do we know that the responses that subjects make to the morbidity question are in fact just that, and do not include concerns with mortality?

The data for blacks should e discarded. Given the low propensity of blacks to get skin cancer, and the wide understanding of this by blacks, why should they ever rationally invest in knowledge about the risks? At the very least, these data should be analyzed separately.

Related to this concern, why compare an individual's own perception of risk to the population risk? It is quite possible that individuals know more about their own circumstances than they do about the population as a whole. In particular, occupation may influence the amount of time spent outside, which could be an important factor influencing individual risk.

Why rely solely on hypothetical responses? This is a setting in which it would have been easy to use real incentives for risk elicitation, and possibly even elicit a real willingness to pay (WTP) for sunscreen. Hypothetical bias is not obviously avoided by taking ratios for a marginal rate of substitution, although that is an intriguing speculation worth investigation. We simply have too much data on the unreliability and higher variance of hypothetical responses to ignore when we are able to elicit responses for which subjects have real consequences.

What effect might the existence of field substitutes for sunscreen have on responses? Such field substitutes might be expected to play an important role, by censoring the WTP for a new product. Simple statistical methods exist for handling this.

The elicitation format was double-bounded dichotomous-choice. That method is not incentive compatible when responses are real, since the subjects have an incentive to reduce their payment for the good by misrepresenting. Hence the assumption under which it generates more information, that the underlying population of valuations is invariant to the repeated sampling sequence, is invalid. One could conjure up heavily-parametric ways to correct for this, but that seems like a costly thing to do when one could avoid the problem by design. In a hypothetical setting, subjects have no incentives for any response, but one hardly wants to rely on that premiss to defend the double-bounded procedure! In the future this procedure should be dropped. For now, at the very least the analysis should just use the first response, and then see if there are large differences when the second response is included.

The authors note that the WTP for risk reduction of a child exceeds the WTP for risk reduction for the parent. This need not be a puzzle, since these are not the same good. If 80% of exposure causing skin cancer occurs up to age of 18, which is apparently the case, then one is simply buying more health benefit for children. There should be a simple way to normalize these estimates to account for this.

Summary of Q&A Discussion Following Session IV-PM

Bryan Hubbell (U.S. EPA) addressed J.R. DeShazo and Trudy Cameron saying that he, too, finds it interesting that they "rushed to the conclusion that we have this big age difference," and adding that he "tried to look quickly at the confidence intervals and . . . as far as I could tell, *all* of them overlap, so there's no statistical difference between any of those numbers." He also suggested that it might be worthwhile to look at the possibility of controlling the variance with respect to age, because "it certainly looked like there might have been higher variance in the responses from the older individuals."

Trudy Cameron responded that "the first and last confidence intervals, for the youngest group and the oldest group, don't overlap. . . . Linking together, all the intervening ones do have some overlap, but, fortunately, the first and last ones don't.

Addressing the other comment, Dr. Cameron stated, "We have been estimating models that employ systematic differences in the errors, and one thing that does show up, not surprisingly, is education level. If we include, specifically, a dummy for less than high school education—those folks are way noisier in the information they're giving us—but as I recall, there wasn't a lot of other action on the dimension."

Laurie Chestnut (Stratus Consulting, Inc.) addressed what she termed a "primarily empirical question" to Trudy Cameron and J.R. DeShazo. She said that in the survey she and her colleagues conducted, they asked about *physical* health, which declined with age, although a simple question regarding enjoyment of life showed no decline with *current* age. On the other hand, she said, peoples' expectations regarding quality of life 10 to 20 years in the future *did* show a decline. In considering the list of all the terrible things that happen as we get older, she urges "some qualification of, maybe while some things deteriorate, some heart-felt appreciation for what we have left might be moving in the other direction." She clarified that this possibility interests her partly because she is facing a "big birthday" soon.

She went on to ask another question regarding what appears to her to be some "counter-intuitive results" (admittedly preliminary) from the study. This concern regards the finding that the value of a current risk reduction was found to be less for someone who is 65 than for someone who is 70, going from half a million to two million over this 5-year span. Reiterating that this seems counter-intuitive, she questioned whether this might be an artifact of the way the researchers "chopped the things up."

Trudy Cameron responded, "There's this one little anomaly in those sloping graphs of the portion that hangs down below zero: People, in considering risk profiles that involved something dreadful happening to them in the near term, the next five years, weren't interested in that program, quite typically. So, there's this sort of bias against near-term risks. So, the near-term negative willingness to pay is there for all the age groups."

Glenn Harrison interjected, ". . . you didn't want to tell people that "your life expectancy is one year," –you've jacked it up by 8 years."

J.R. DeShazo answered that peoples' "nominal assessment of their life expectancy and what we told them that the doctor would assess their life expectancy at were both inflated compared to what their actual life expectancy was." He then explained a couple of issues relevant to Laurie Chestnut's question, saying, "One is that people's information set contains a focus on their immediate perceived risk, and then people seem to have confidence intervals around that as they look further into the future—they're more willing to accept that 5 or 10 years from now they may face a threat of a heart attack or a stroke, whereas they really feel healthy today and so anything in the next 2 or 3 years they disbelieve."

Speaking to Ms. Chestnut's initial point, Dr. DeShazo clarified that nothing in their analysis suggests that older people value a year of their life less. However, he said, the evidence does suggest that people begin to look at the gains from avoiding illness differently as they get older. He cited the fact that after the age of sixty-five 50 to 60 percent of people have some chronic condition—"they're in some state of morbidity, and their assessment of avoiding other kinds of morbidity in the future changes. Their information set upon which they base their willingness to avoid a worsening of the health state changes." He clarified that what he and his colleagues have found is that "how much you're willing to pay to avoid a loss in the future changes because that loss looks smaller the more morbid your current health state becomes."

Alan Krupnick (Resources for the Future) said that he also was interested in the question about the latency result. He said that he and his colleagues had found a strong latency effect in their study, which looked at the whole population aged 40 to 60 and their willingness to pay for a reduction in the risk of death beginning at age 70 and going up to 80. They found a "strong lower willingness to pay for that contemporaneous risk reduction." He asked the researchers to consider the question: "If you looked at it *that* way, would you find that same effect?"

He then addressed two questions to Shelby Gerking: Stating that he and his colleagues found that blacks are willing to pay more than whites for an equivalent risk reduction, he asked whether Dr. Gerking and his colleagues had found that to be true also. In addition, he commented that a lot of researchers have struggled with trying to get people to understand conditional probability, and this seems so implausible to him. He asked for their views on, for example, a person saying "When I apply this sunscreen, it doesn't reduce my risk of getting cancer, but it reduces my risk of dying from cancer," which he related to their latter cases.

In regard to Dr. Krupnick's first question, Trudy Cameron replied that she didn't know off the top of her head but they could surely run a simulation that captures the same type of information he had gathered and find an answer.

Shelby Gerking conjectured that blacks aren't willing to pay a lot for sunscreen probably because their risk of getting skin cancer is much lower than it is for whites "so the result here is specific to the context in which it's estimated." He continued by saying, "Regarding the plausibility of dying from skin cancer," it's an issue that he and Mark Dickie "worried about quite a lot and then went ahead with on the basis of the results they got initially." He closed by saying that it didn't seem to be as big a problem as he initially thought it might have been and he was pleasantly surprised.

J.R. DeShazo stated, "We found that when you look at individuals' subjective assessment of their risks for specific illnesses and then their ability to mitigate and defend against or control those risks that there was a lot of variability in socio-economic and ethnic characteristics."

Don Kenkel (Cornell University) said he was struck by the fact that "there is an active market to *get* skin cancer—in the tanning booths—where people spend time and money to do this." He commented that he wondered about the implications of the fact that there is "a very real sense that skin cancer prevention is jointly produced with being pale." Are there whites who aren't going to pay for sunscreen because of this? Furthermore, Dr. Kenkel posited that some people's attitude that "I'm willing to make my kids have disutility to keep *them* safe, but *I* want to look good" might explain some of the differences observed.

Shelby Gerking responded that these questions and the ones brought by Alan Krupnick are really important. He said that he was involved in a prior skin cancer study that looked at the issue of the joint products associated with tanning beds and being out in the sun—"some people want *some* tanning; others don't want premature aging and wrinkling—and we tried to sort all of that out in an earlier paper and discovered that the joint production effects . . . really weren't that important to consider. So, even though we do consider them a little bit in this study, it's not to the same extent as in the earlier study, and I didn't talk about that at all."

Valuing Environmental Health Risk Reductions to Children

PROCEEDINGS OF

SESSION V: AIR POLLUTION AND ASTHMA IN CHILDREN

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE), NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER), AND OFFICE OF CHILDREN'S HEALTH PROTECTION; AND THE UNIVERSITY OF CENTRAL FLORIDA

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DISCLAIMER

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Valuing Reduced Asthma Morbidity in Children*

Presented at
EPA Workshop of Valuation of Children's Health
October 20-21, 2003

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Abstract
This economic study models household willingness-to-pay to minimize a specific health endpoint: morbidity effects on children with asthma (defined as asthma symptoms including coughing, wheezing and/or shortness of breath). The project addresses three main questions: 1) what determines households' perceptions of risks to an asthmatic child, 2) what averting and/or mitigating actions do households take, and 3) what are households' stated willingness-to-pay for a reduction in their children's asthma morbidity.

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* *This is a report on research in progress. Please do not quote without authors' permission. Please contact the authors for the most recent report.*

I. Introduction

While both our medical understanding of the mechanisms involved in asthmatic episodes and the resources devoted to its treatment have increased, the rise in asthma is a well-documented international phenomenon. The CDC estimates that 14 million Americans have asthma, including 5 million children. Despite dramatic improvements in the understandings of the mechanisms of asthma and asthma therapies, from 1980-1994, the prevalence of the disease has increased 75% and the mortality rate for children under 19 has increased 79%. Asthma is the 2nd leading cause for pediatric emergency room visits (behind accidents) and is the most common reason for school absenteeism.

The economic burden of asthma and asthma therapy in the United States is large and growing. The majority of economic analyses of asthma use a cost of illness method (for reviews see Jönsson (2000) and Weiss and Sullivan (2001)). These studies categorize costs into direct costs (cost of medical treatment) and indirect costs (loss of production). The total direct and indirect cost of asthma in the U.S. was estimated to be $6.2 billion in 1990 (Weiss, Gergen and Hodgen, 1992) and $12.7 billion in 1998 (Weiss and Sullivan, 2001)[1]. Lozano et al. (1999) estimate that children, ages 1 to 17 years, with asthma incurred an average cost of $1129 per child per year in total health care expenditures compared to $468 for children without asthma[2]. The intangible cost of asthma, the loss of utility due to the disease, is omitted from this body of literature. A second component missing from cost of illness studies is the cost of risk avoiding or risk mitigating behavior. Cost of illness studies therefore should be taken as a lower bound of the true cost of asthma.

While these direct costs of asthma are large enough to justify substantial policy interest, asthma is also of great interest because it is a disease whose burdens have significant distributional ramifications. The health burdens associated with asthma fall disproportionately on the young and the poor in the United States. The increase in asthma has been largest in children (under age 18), and the rate of hospitalization for the disease is greatest for those from poor neighborhoods. (See Koren, 1995, and Claudio et al., 1999.) A comparison of asthma hospitalization rates in New York neighborhoods found that while children in lower Manhattan and Queens neighborhoods with average household incomes greater than $57,000 had zero hospitalizations from asthma, children in East Harlem, where the average household income is $19,000, had hospitalization rates of 222 per 10,000 youths. (Claudio et al. 1999)

The valuation of reduction in asthma morbidity is of significant relevance for public policy decisions targeted at children and susceptible populations. Asthmatics have physiologic differences, such as more narrow airways, and, therefore may be more susceptible to the health effects of air pollution. Relative to adults, children also may be more susceptible because they are more physically active, spend more time outdoors and therefore breathe more pollutant per

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[1] The direct costs include cost of medical treatments: inpatient hospitalization, inpatient physician services, emergency room care, outpatient care, outpatients physician services, medications). The indirect costs include: lost workdays of caregiver, lost workdays of asthmatics, loss of lifetime earnings from asthma mortality.

[2] Total expenditures included prescriptions, ambulatory provider visits, emergency room visits, and hospitalizations.

pound of body weight than do adults (American Academy of Pediatrics, 1993). Therefore, asthmatic children represent a susceptible population of particular policy interest. This project consists of a first survey to analyze households' risk perception, their risk reduction behavior and the costs of averting and mitigating behavior and a second survey on stated willingness to pay for reduced asthma morbidity in children.

II. Theoretical Models

A. Modeling Willingness to Pay: A Household Production Approach

Households' behavior will be modeled using a health production approach as introduced by Grossman (1972). Unlike Cropper (1981), this study will follow the approach of Gerking and Stanley (1986) in which ambient air quality will enter as a factor in the production of health.

This study models household behavior to minimize a specific health endpoint: morbidity effects of pollution on children with asthma (defined as asthma symptoms including coughing, wheezing and/or shortness of breath). We are interested in the incidence of asthma symptoms among children clinically diagnosed with asthma, not with the prevention of the disease. The surveys will ask what choices the household makes to minimize the risk of asthma exacerbation in that survey period; therefore, the household model will not be dynamic.

Following the standard household model (Freeman, 1993), the health outcome is a function of pollution exposure and the mitigating and averting behavior of the household. The standard approach assumes that individuals know their health production function, choose their level of output optimally and choose inputs to minimize costs. An important contribution of this study is that our surveys on households will provide information on households' risk perceptions, their averting and mitigating behavior, the costs of such behavior, and the households' evaluation of effectiveness of their actions. Our estimation therefore does not rely on proxies for perceived risks and does not assume households perfectly predict risk.

The health outcome, S, is a measure of asthma morbidity (e.g. cough, wheezing, or shortness of breath). This outcome will depend on pollution exposure, D; mitigating behavior, B; and other socio-demographic variables, Z. Mitigating behavior includes preventative medication and other investments that *reduce the effect* of pollution exposure. For example, control medications, an entire class of drugs for mitigation, are prescribed to reduce the hyper-responsiveness and inflammation of asthmatics' airways[3]. In addition to mitigating behavior, the household can also engage in averting behavior, A, which includes actions to *minimize the exposure* to pollution; an example of averting behavior is the purchase of home air filters. As a result, pollution exposure, D, is a function of both pollution level, C, and averting behavior, A.

To summarize, the measure of asthma morbidity is written as a function of exposure, mitigation, and other covariates that affect health outcome:

[3] Control medications for severe asthmatics include inhaled corticosteroids. For moderate asthmatics, cromolyn sodium can be prescribed to reduce airway hyper-responsiveness.

(1) $S = S(D, B, Z)$

where the exposure to pollution is a function of the levels of pollutants and the household averting behavior:

(2) $D = D(C, A)$

where
S = measure of asthma morbidity
D = realized exposure to environmental pollution
C = levels of pollutants
B = mitigating behavior of household
A = averting behavior of household
Z = covariates that affect health outcome

The utility of the household is a function of consumption goods (X), leisure (L), and morbidity of the asthmatic child (S). As in Dickie (1999), the household maximizes a single utility function where children are "passive" in that they comply with parents'/guardians' decisions.

(3) $U = U(X, L, S)$.

The implication of this utility function is that pollutants affect household well-being only through their impact on health and they have no other associated disutility.

The household has a budget constraint that total income equals total expenditures on consumption goods and on averting and mitigating behavior. The household loses days at work when the severity of the asthmatic symptoms warrants the child's absence from school. The budget constraint is written:

(4) $I + W(T - L - \alpha S) = X + P_a A + P_b B$

where
I = non-wage income
W = wage rate
T = total available time to work
X = consumption goods
L = leisure time
P_a = price of averting behavior
P_b = price of mitigating behavior
αS = lost days of work due to attending to child with asthma symptoms
$P_x = 1$, the price of bundle of consumption goods is normalized to one

The household maximizes its utility function (3) subject to its budget constraint (4) with respect to the choice variables, X, L, A and B. Using (1) and (2) in the utility function, the household's maximization problem is:

$$(5) \quad \max_{X,L,A,B} \quad U(X, L, S(D(C,A), B, Z))$$

$$\text{subject to} \quad X + P_a A + P_b B = I + W(T - L) - W \alpha\, S(D(C,A), B, Z)$$

The resulting first order conditions for an interior solution are:

$$(6a) \quad \partial U/\partial X = \lambda$$

$$(6b) \quad \partial U/\partial L = \lambda W$$

$$(6c) \quad (\partial U/\partial S)(\partial S/\partial D)(\partial D/\partial A) = \lambda [P_a + W\alpha (\partial S/\partial D)(\partial D/\partial A)]$$

$$(6d) \quad (\partial U/\partial S)(\partial S/\partial B) = \lambda [P_b + W\alpha (\partial S/\partial B)]$$

where λ is the Lagrangean multiplier. Some manipulation yields:

$$(7a) \quad \frac{(\partial U/\partial S)}{(\partial U/\partial X)} = W\alpha + \frac{P_a}{(\partial S/\partial D)(\partial D/\partial A)}$$

$$(7b) \quad \frac{(\partial U/\partial S)}{(\partial U/\partial X)} = W\alpha + \frac{P_b}{(\partial S/\partial B)}$$

The solution to the first order conditions is a set of household demand functions for leisure, for consumption goods, for averting behavior, and for mitigating behavior:

$$(8) \quad X = X(P_a, P_b, W, I + WT, C, Z)$$
$$(9) \quad L = L(P_a, P_b, W, I + WT, C, Z)$$
$$(10) \quad A = A(P_a, P_b, W, I + WT, C, Z)$$
$$(11) \quad B = B(P_a, P_b, W, I + WT, C, Z)$$

Our collaboration with Fresno Asthmatic Children's Environment Study [FACES] makes it possible for us to use parametric methods to estimate the functions for realized exposure to environmental pollution, $D = D(C,A)$, and for asthma morbidity given exposure to pollutants, $S = S(D, B, Z)$. The data from our economic surveys of risk mitigating and averting behavior will enable us to estimate the demand functions for A and B in (10) and (11). Combining these pieces of information and choosing appropriate functional forms for these expressions will make it possible for us to identify the underlying household utility function, U(X,L,S) (see Hanemann, 1991 and Hanemann & Kanninen, 1999).

This information can be utilized to estimate the household's willingness to pay for either a marginal or non-marginal reduction in pollution levels. If the demand functions (8) – (11) are substituted into the original utility function, one obtains the indirect utility function

$$(12) \quad U = V(P_a, P_b, W, I + WT, C, Z).$$

Given a change in pollution levels from C^0 to C^1, the household's utility changes from $U^0 = V(P_a, P_b, W, I + WT, C^0, Z)$ to $U^1 = V(P_a, P_b, W, I + WT, C^1, Z)$. Suppose this change is an improvement. The household's willingness to pay for the change is given by the quantity WTP_c where:

(13) $V(P_a, P_b, W, I + WT - WTP_c, C^1, Z) = V(P_a, P_b, W, I + WT, C^0, Z)$

The household's marginal willingness to pay for a small increment in pollution, $\Delta WTP_c / \Delta C$, can be shown to be measured in terms of mitigating behavior by

(14) $\Delta WTP_c / \Delta C = -P_b [(\partial S/\partial C) / (\partial S/\partial B)]$.

and in terms of averting behavior by

(15) $\Delta WTP_c / \Delta C = -P_a [(\partial S/\partial C) / (\partial S/\partial A)]$.

The implication of this household health production model is that the marginal WTP for a reduction in pollution can be estimated using observable costs of household behavior, and the non-marginal WTP can be estimated using the utility function that is recovered when one combines the observed demand functions for mitigating and averting behavior together with the health production functions D(C,A) and S(D, B, Z).

B. Stated Willingness to Pay: Contingent Valuation

Our model assumes that a child's well being is a part of a household utility function which determines parent's behavior. We propose a utility maximization model which follows previous models in that area (Rosenweig and Shultz, 1983; Gerking and Stanley, 1996; and Dickie and Gerking, 1986). Household's utility is a function of a vector of market goods not related to health, X, a vector of health related goods, Z, income, I and health, H. The utility function is a random utility model linear in income and covariates, and has the general form:

(1) $U_0 = U_0 (X, Z, H, I) + \varepsilon_0$

A simple model of health production defines health as a function of health capital (K) and averting/mitigating behavior (A) which is determined by a set of health beliefs (B). This set of beliefs, includes risk perceptions, self-efficacy regarding desired outcomes, etc.

(2) $H = H (A, K,)$

The theoretical marginal willingness to pay (WTP) is the maximum amount that households are willing to pay to mitigate their asthma by forgoing some of the market goods and hold the utility at a constant level. Individuals are asked to pay a dollar amount, W for reduction in asthma morbidity, and with some positive probability they agree to this amount. Then their utility function is:

(3) $U_1 = U_1(X, Z, H, I-W) + \varepsilon_1$

The probability that they will say yes to this amount is

(4) $Pr[Yes] = Pr [U_1(X, Z, H_1, I\text{-}W) + \varepsilon_1 > U_0(X, Z, H_0, I) + \varepsilon_0$

which can be rewritten as

(5) $Pr [\varepsilon_0 - \varepsilon_1] < U_1(X, Z, H_1, I\text{-}W) – U_0(X, Z, H_0, I) = \Delta U = WTP$

i.e. at the point of indifference, where

(6) $U_1(X, Z,H_1, I\text{-}W) – U_0(X, Z,H_0, I) = 0$

the marginal value of reduction in morbidity equals to the marginal disutility of paying for this reduction. The utility function is assumed to have the following functional form
$u = u (\alpha + \beta *I)$ and the difference in utility, ΔU is assumed to have a logistic cumulative density function.

(7) $\Delta U = (1 + e^{-\Delta U})^{-1}$

Then,

(8) $\Delta U = (\alpha_1 - \alpha_0) – \beta *W$

The median WTP is calculated by

(9) $Pr [U_1(X, H_1, I\text{-}W) > U_0(X, H_0, I)] = 0.5$

Modeling directly the WTP function (which is assumed to be a linear random function), an approximation of compensating surplus, using the formula derived by Hanemann (1984) has the form:

(10) $Pr[Yes] = (1 + e^{-\alpha-\beta W})^{-1}$

where α is the grand intercept evaluated at the mean values of the covariates and β is the estimated coefficient for W.
Median WTP is calculated by solving the above expression for Pr[Yes] = 0.5 which yields

(11) $\text{Median WTP} = e^{-(\alpha /\beta)}$

Median WTP is calculated for the positive part of the probability function, by integrating within the interval

(12) $\text{Mean WTP} = \int_0^T [1-Gwtp]dW$,

where G_{wtp} is the distribution function of the true willingness to pay. T is infinite for the true willingness to pay and is truncated at some value for the purpose of estimation.

C. Socio-economic Indicators and Risk Reducing Behavior

Significant research has documented the disparities across ethnicities in hospitalization rates for asthma; however, the empirical quandary is disentangling which of the correlated social economic status indicators are the factors that create the disparity in morbidity. Recent research indicates that minority children were more likely to underuse preventative medications that could reduce asthma severity (Fiscella et al., 2000; Halterman et al., 2000; Eggleston et al., 1998). This underuse of preventative medication in minority populations is consistent even when there are not disparities in financial access and insurance coverage (Lieu, et al, 2002). Thus we are complementing standard economic instruments with elements used in the public health literature and psychological literature, specifically the Health Belief Model and Theory of Planned Behavior.

The Health Belief Model [HBM] predicts health behavior as a function of four groups of determinants, each of which leads to specific beliefs and incentives that are then motivators for preventative action. Commonly used to predict preventative behavior, HBM is particularly appropriate to our study of households' actions to minimize asthma triggers and comply with asthma control medication regime. The four major components of the HBM are: perceived susceptibility/vulnerability, perceived severity of the disease, perceived benefits from taking action, perceived barriers from undertaking action.

The Theory of Planned Behavior [TPB] explains behaviors as functions of behavioral *intentions*, which are explained by the individual's attitude and subjective norms toward performing the specific behavior (Fishbein and Ajzen, 1975). Attitudes are based on beliefs about the likelihood of an event and evaluation of the consequences of a particular action (Smith and Stasson, 2000). Social norms are determined by what is socially acceptable and by personal motivation to comply with family expectations. An additional element of interest is that of self-efficacy, the individual's perceived ability to perform specific actions under specific conditions (Bandura, 1977). We believe that the elements of these models will contribute to understanding of risk reducing behavior, particularly with respect to compliance with asthma management protocol.

D. Prior expectations

Self-efficacy will be quantified through a standard five-point psychometric scale measuring self-reported efficacy in managing asthma. Applied to asthma mitigating behavior, parents with high level of self-efficacy would be expected to be more effective in their interventions in their child's asthma. In the context of the major domains affecting asthma care, self efficacy affects averting behavior on three levels: (1) the amount of attention that the child receives from the medical care providers[4]; (2) school acceptance and attention on the part of teachers and nurses, and (3) compliance to medications, in cases where the long term beneficial effect of asthma medications is not known to parents.

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[4] Due to subtlety in asthma symptoms, some parents could not get admission by the emergency room registration unless they were very assertive, and others reported to have avoided emergency rooms because they couldn't persuade the registration that their child needed to be examined

Perceptions about risk are expected to have a positive effect on WTP, however this effect would be uneven. Risk factors which have a 'salient' effect, (i.e. perceived to be riskier to asthma outcomes as compared to what the scientific risk is) is expected to inflate WTP. Factors that are perceived less risky than they should be will have a deflating effect on WTP.

<u>E. Statistical Analysis of Survey Data</u>
Three types of statistical analysis will be performed, dealing with household choice of averting and mitigating behavior in the context of a health outcomes production function, the determinants of household risk perceptions, and estimation of responses to stated preference questions.

Household Choice of Averting and Mitigating Behavior, and Health Production Function
This involves estimating the behavioral equations for averting and mitigating behavior (10) and (11), together with the reduced form health production function S = S(D(C,A),B,Z). Both of these involve some issues arising from how the variables are measured.

Because both mitigating and averting behavior consist of discrete actions, an index of behavior will be constructed. For mitigating behavior that is repeated daily, the components of the index will be the frequency of each type of behavior over the previous three months. Likewise, for averting behavior that is repeated, the index will be a function of the frequency of each type of averting behavior. In the case of averting behavior, however, there is a class of actions that are essentially one-time investments. Therefore, there will be a second component of the averting index for fixed averting investments. Because the behaviors are discrete and the indices are inherently ordered, the demand system will be estimated using ordered probit. Maximum likelihood estimation will be used.

The dependent variable in the health production function is asthma morbidity. Because households are observed over multiple periods, we can improve upon existing valuations of asthma by disaggregating morbidity into presence of asthma symptoms and the severity of symptoms if present. The presence of symptoms is an indicator variable.

S = 1, if symptoms are present
S = 0, otherwise.

If symptoms are present, then the severity of symptoms (M) is rated on a scale from one to ten.

M = 1 ,…, 10 where 1 indicates mild symptoms and 10 indicates extreme symptoms.

Therefore, a two-stage estimation will be used. The first stage is a binomial logit where the outcome is the presence of symptoms (S=1,0). If symptoms are present, then in the second stage the severity of symptoms (M) is estimated as a Poisson process.

Risk Perception
A goal of the study is to analyze the determinants of household's perceptions of the risk that different risk factors pose to their child and to investigate how their risk perceptions compare

with objective assessments by medical and scientific experts. By asking households to evaluate the impact of typical asthma triggers on their child's asthma symptoms, we can create discrete dependent variable that is an index of the household's risk perception. An example is to ask, "If your child is exposed to tree pollen are his/her asthma symptoms: greatly affected, slightly affected, not affected at all?" The epidemiological data provides an index of the degree of that child's asthma response to fluctuations in pollen. Using these data we can construct a contingency table of the households' subject indexes and the objective risk indexes.

The risk perceptions variable takes the form of a ranking by the respondent of the seriousness of each risk factor for that household. Because of the form of this dependent variable, we will use a model for an ordered categorical response variable, such as ordinal probit or logit, when analyzing the rankings to investigate what are the significant socio-demographic factors that influence the household's perceptions of risk and whether factors such as the age of the child or recent onset of symptoms affect risk perceptions. The other major issue is the correlation between subjective household perceptions of risk factors and objective assessments of these factors by scientific experts. To test this relationship, we can use a limited dependent variable model where the dependent variable is the subjective risk index, and independent variables include the objective risk index, household characteristics and relevant interaction terms

III. Empirical Study

A. Collaborative Economic and Epidemiological Study

One criticism of studies of households' behavior is estimation bias due to omitted variables (see Atkinson and Crocker, 1992 and Harrington and Portney, 1987). By collaborating with an extensive epidemiological study of the effects of air pollution on asthmatic children [Fresno Asthmatic Children's Environment Study, FACES] we minimize the potential for omitted variable bias. The FACES study includes a large sample, follows households over multiple years and will incorporate the most detailed socio-demographic, indoor air quality and pollution monitoring data collection effort to date (California Air Resources Board). This project complements the work of Rowe and Chestnut (1986) and O'Conor and Blomquist (1997) by focusing on children's health and generating detailed data on children's clinical health status and household behavior.

The FACES cohort includes children with clinically diagnosed asthma, residing in a section of Fresno County, California[5]. Children are 6-10 years of age at intake and will be followed for approximately 4 years. The study population will include children who have a physician's diagnosis of asthma and at least one of the following: 1) reported utilization of or valid prescription for asthma medication in the previous 12 months; or 2) symptoms consistent with asthma in the past 12 months; or 3) an emergent asthma visit or hospitalization in the past 12 months. The requirements for asthma medication use, symptoms, or health care utilization are to minimize the chance of enrolling subjects whose asthma is quiescent (remission). Children who meet these criteria may be enrolled regardless of the severity of asthma.

B. The Study Area

[5] FACES has been recruiting households for the survey since 2000.

Located in the Central Valley of California, Fresno County has a population of 815,734 which has increased by 19.8% since 1990. Forty-four percent of the population is of Hispanic or Latin origin, followed by forty percent of white origin, eight percent Asian and five percent African-American. The Fresno population has lower medium income, less education, poorer living conditions and a greater percent of residents below the poverty line as compared to the rest of CA. For example, median household income for 2001 was $34,725 as compared to $47,493 for California. The proportion of residents with a high school degree was 67.5% as compared to 76.8% for the rest of the state, and the proportion of residents below the poverty line was 22.9 % while that in CA was 14.2% (US Census data, 2000). The asthma hospitalization rate in Fresno is among the highest in California at 28.8 per 10,000 (California Facts, 2003).

A study of pediatric asthma-related hospital discharges in California shows that the very young children (0-4 years of age), African-American children and males were over represented in the discharge population (see Table 1).

Table 1: Pediatric Asthma-Related Discharges in California

Variable	Frequency	Percentage of discharges
Age		
0-4	64,260	57
5-11	33,485	29
12-17	16,229	14
Race		
White	46,696	57
Latino/a	30,986	27
African-American	28,802	25
Asian	7,490	7
Gender		
Male	71,935	63
Female	42,039	37

Source: Calmes, Leake and Carlisle, "Adverse asthma outcomes among children hospitalized with asthma in CA", Pediatrics, 1998; 101(5), 845-50. This study includes 114,000 records from hospital discharge records.

C. The FACES Cohort

The FACES study has complete screening interviews for 473 households, baseline interviews for 241 households, and currently has 205 participating households. The major reasons households who inquired about the study were ineligible to participate include: other chronic disease, lived in house for less than three months, sleep at home less than five nights/week, and planned to move within two years (Mann, 2003).

The ethnicity of the children in the FACES study is representative of the Fresno general population. Forty-three percent of the sampled parents were Hispanic, followed by 16.7% black and 37.5% white. The unemployment among the FACES cohort is more similar to that of the population hospitalized for asthma, than the general Fresno population.

Table 2: Number of Asthma-Related Hospitalizations of FACES Cohort by Race

Race	% of FACES Sample	Zero Hospitalizations	One or more Hospitalizations
Hispanic	43.0%	19 (61%)	12 (39%)
Black	16.9%	5 (42%)	7 (58%)
White	33.8%	19 (76%)	6 (24%)

Source: Authors' analysis of FACES survey data.

The majority of the interviewed households were covered by health insurance (90.3%). Almost 70% households had at least one parent who was affected by asthma. Table 3 presents a general description of the households participating in FACES.

Table 3. Characteristics of Households Participating in FACES

Household Characteristics	Selected Variables	Relative Frequencies	
Employment	Mother employed	61.1% Yes	38.9% No
	Father employed	69.4% Yes	27.8% No
Health Insurance	Is child currently covered by health insurance?	90.3% Yes	9.7% No
Health History	Mother diagnosed with asthma?	48.6% Yes	51.4% No
	Father diagnosed with asthma*?	31.9% Yes	61.3% No

Source: Authors' analysis of FACES baseline survey data.
* 2.8% missing

FACES data on asthma hospitalization, ER visits and intensive care unit visits showed that 34.7% of the children had been hospitalized at least once in their life, 36.1% had received unscheduled asthma care (such as emergency room) and 12.5% had been placed in intensive care units because of asthma. As expected, number of hospitalizations was lower among Hispanic and white (Table 2), which is consistent with state level hospital discharge data. For the state of California, African-Americans were hospitalized 3 times more for asthma than any other ethnic group. In our sample we get consistent results: the percentage of blacks enrolled in the FACES program (16.7%) is much greater than the percentage of blacks for the Fresno population (5.3%). The average age of children in the FACES cohort is between eight and nine years.

Table 4. Characteristics of Children Participating in FACES

Child Characteristics	Selected Variables	
Ages of children	Mean age (standard deviation) Median age	8.6 years (1.8) 9 years
	Frequency by current grade in school	5.6% in kindergarten 1st grade = 20.9% 2nd grade=13.4%

		3rd grade= 16.4% 4th grade= 17.9% 5th grade = 23.9% 6th grade = 7.5%
Health History	age of mother when child was born	Mean = 26.7(5.5) Median = 27.5 years
	Gestation length	26.4% Early 29.2% Late 44.4% On time
	Child seen by doctor or other health care provider for a chest illness before the age of 2 years	44.4% Yes 54.2% No
	Was child ever hospitalized because of asthma?	34.7% Yes 65.3% No
	Presence of hayfever or allergic rhinitis	29.1% Yes 65.3% No 5.6% missing

Source: Authors' analysis of FACES baseline survey data.

D. Initial Findings of EPA-STAR Project

Survey One

We have conducted five focus groups in Fresno, California and nine personal interviews in Springfield, Massachusetts. The focus groups and interviews were conducted over an eleven month period, from July 2002 to May 2003. In the summer of 2003 the survey instrument was reviewed by asthma specialists including Drs. Kathleen Mortimer, University of California-Berkeley School of Public Health, and Matthew Sadof, Associate Director of Ambulatory Pediatrics at Baystate Children's Hospital. During the fall of 2003, the team wrote the protocol for contacting families and tracking all surveys and correspondence. By late October 2003, the survey will be mailed to all households participating in the Fresno Asthmatic Children's Environment Study and households with an asthmatic child who were either ineligible or declined to participate in longitudinal environment study. We extended the sample group to include families outside of FACES because recruiting for the epidemiological study was lower than predicted.

Risk Reducing Behavior

Through these focus groups and interviews we identified issues central to the survey. In common to all respondents was the increase in the monitoring of the child's health, and in some cases caregivers changed or terminated careers to increase supervision. The goal of the monitoring was to "catch the asthma before it was too late", that is to employ rescue medication while they were still effective in increasing lung function. The need for constant monitoring entails both reduced earnings and psychosocial costs due to the strain on family and social relationships.

There was a wide range in responses to questions on risk reducing behavior employed by households. A surprising result of the focus groups and interviews was that when initially asked if the household had changed anything due to the asthmatic child's health, respondents tended to significantly underestimate their change in behavior. Then when directed through a series of specific changes or activities pertaining to reducing triggers, households revealed a range of changes from small to extensive. Our conclusion is that it is often very difficult for households to identify "what they do for asthma" because either the child had been experiencing respiratory distress for such a long time that there is no basis for comparison or the changes have become such a routine that it is difficult to compare their behavior over time.

One disturbing finding in the focus groups was the length of time between onset of symptoms and correct diagnosis of asthma. Despite national guidelines on diagnosing and managing asthma, the median time until diagnosis was over 1 year. In multiple cases, children were repeatedly hospitalized over multiple years before being correctly diagnosed with asthma. This delay reflects both a need for more training of healthcare providers (Halterman et al, 2000; Cloutier et al, 2002) as well as lack of continuity of care.

Past experience with healthcare providers was correlated with a sense of self-efficacy in controlling asthma symptoms. Those households that experienced a long delay between symptoms and diagnosis were less likely to feel that they were able to control asthma symptoms. In contrast households that were provided with asthma management plans had a sense of improved self-efficacy. Self-efficacy has been shown in previous studies to be positively correlated with risk reducing behavior. Thus in modeling compliance with medication, and mitigating and averting behavior, then length of time between symptoms and diagnosis may be an important factor.

An early hypothesis was that income, transportation and lack of health insurance were dominant barriers to general healthcare. We found that in our study group the most significant barriers to care were lack of access to asthma specialists due to insurance protocols and insufficient supply of urgent care facilities. In addition, "gatekeepers," either receptionists who schedule appointments within the medical practice or triage nurses in emergency rooms, were commonly cited as impediments to reaching physicians during asthma episodes.

Several respondents voiced concern over balancing all the actions that could reduce asthma morbidity versus instilling a sense of confidence or creating a sense of being "normal" for the child. This points out that the clinical guidelines for optimal household behavior may deviate from household behavior when the psychosocial costs of the risk reducing behavior are incorporated.

Risk Perception

Respondents were able to list common asthma triggers and to rate which they felt were most significant to their child (see Table 5). When the allergy testing is completed we will be able to compare stated risk of allergens to clinically measured objective risk.

During the focus groups we observed inconsistencies between subjective and objective risk from air pollution. Respondents felt strongly that air pollution was a significant trigger and was significantly worse during the summer months. However, in the Fresno-Clovis area the concentrations of particulate matter are higher during the winter months, posing a real threat to asthmatics. The discrepancy could be due to the public awareness of high ozone alert days in the summer and the lack of such campaign for particulate matter.

Table 5: Parents' Perception of Asthma Triggers

Rank	Environmental factors that made child wheezing worse	% of Yes responses
1	Weather (multiple options allowed)	44.8
2	Physical activity	44.8
3	Cold or flu	39.7
4	Cold air	37.9
5	Air pollution	36.2
6	Pollen, grasses	32.8
7	Windy conditions	29.3
8	House Dust	22.4
9	Outdoor smoke or fires	15.5
10	Molds	13.8
11	Perfume or Odor	12.1
12	Wood smoke	12.1
13	Cigarette smoke	12.1
14	When crops are being sprayed	10.3
15	Pets	10.3
16	When fields are being plowed	6.6
17	Others	5.2

Source: Authors' analysis of FACES baseline survey data.

Medical Intervention

A critical component of risk reducing behavior is compliance with prescribed asthma medication and monitoring of respiratory function using a peak flow meter. While respondents were able to list most of the medications their child took for asthma, it was apparent that there were wide discrepancies in understanding of the role of each medication. There was significant concern over the side-effects of inhaled steroids despite the clinical evidence that their benefits greatly outweigh their risks. In addition personal disposition was evident in both the manner in which the child's guardian interacted with the healthcare provider and with compliance. For example, while a written asthma management plan and peak flow meter are standard and critical tools for asthma management, less than half of the FACES cohort used either.

Table 6: Asthma Management

Has a physician or other health provider given a written plan for managing asthma?	48.6% Yes 50.0% No 1.4% missing
Does child use a peak flow meter?	40.3% Yes 59.7% No

Source: Authors analysis of FACES baseline survey data.

Counter to our expectations, there was not an ethnic disparity in the use of a written management plan (Table 7).

Table 7: Use of a Written Management Plan by Race

Race	Yes	No
Hispanic	15 (48%)	15 (52%)
Black	7 (58%)	5 (42%)
White	11 (44%)	14 (56%)
Total % with management plan (1.4%=missing)	48.6	50.0

Source: Authors' analysis of FACES baseline survey data.

Initial analysis indicates an association between parents' behavior and personal experience with asthma. For example more than half of the children were not seen by a medical care provider for a chest illness before the age of 2, which was associated with whether parents had history of asthma themselves as shown in Table Eight. Among 62.5% of families where both parent were diagnosed with asthma child was seen by a health care provider for chest illness before the age of two, as opposed to 27.3% in families where none of the parents had asthma. Child was taken to a HCP for chest illness more often in families where the mother had asthma as compared to families where the father had asthma. It should be noted that due to the small number of observations, whether the differences are significant is not determinable. Additionally we are not asserting a causal link. At the same time race did not play a role in whether the child was seen by a doctor for chest illness (Table Nine).

Table 8: Parental Asthma and Respiratory Illness of Children Before Age Two

Parental Asthma	% of total	Child was seen before age of two Yes	No
Neither	31.4%	6 (27.3)	16(72.7%)
Both mother and father	11.4%	5 (62.5)	3 (37.5%)
Mother but not father	35.7%	14 (56%)	11 (44%)
Father but not mother	21.4%	7 (44%)	9 (56%)

Source: Authors' analysis of FACES baseline survey data.

Table 9. Race and Respiratory Illness of Children Before Age Two

Race	% of total	Child was seen before age of two	
		Yes	**No**
Hispanic	43.0%	12 (38.7%)	19 (61.3%)
Black	16.9%	6 (50%)	6 (50%)
White	33.8%	12 (50%	12(50%)
Other (or missing)	5.6%	2 (50%)	2(50%)

Source: Authors' analysis of FACES baseline survey data.

Survey Two: Contingent Valuation

The second component of the economic valuation of reduced morbidity is a contingent valuation question. Critical to this instrument is that the scenario be relevant and realistic. From the discussions in the focus groups we developed two types on contingent valuation questions. In the first scenario we asked parents to trade work-hours for reduced number of bad asthma days. The second scenario proposed a hypothetical insurance program that would provide additional services that were predicted to reduce asthma symptoms. We will conduct additional focus groups and interviews to refine these questions.

IV. Future Research

Currently the team is awaiting the data from the first survey on risk perception and household behavior. We are in addition in the process of designing a contingent valuation instrument. Similar to the development of the first survey, we will use extensive focus groups and interviews to develop a valid instrument. Some aspects of previous CV instrument are discussed below.

Some of the studies employing WTP for a specific commodity include earlier studies by Chestnut and Row (1986) and Dickie and Gerking (1996). In the first study asthmatics were asked about their maximum WTP to implement a program that would abate pollution and will reduce the number of asthma bad days by half. The payment vehicle in this study was WTP for an increase in taxes per year. In the Dickie and Gerking (1996) study elicited maximum WTP to relieve one symptom for 1 day and WTP to reduce daily one-hour maximum concentrations of pollutants by $1/10^{-6}$ for 1 day.

Blumenschein et al. (2001) conducted a field experiment comparing hypothetical and actual purchase decisions for an asthma management program. Subjects received either a dichotomous choice contingent valuation question (where three bids were offered, $ 15, 40, and 80) or were given the opportunity to actually enroll in the program. In an earlier study (Blumenschein and Johannesson 1998), as well as in Blumenschein et al. (2002) the same authors used both a dichotomous choice and a bidding game approach to elicit willingness to pay for asthma cure. In another study by Barner J.C. et al. (1999) patients were presented with a hypothetical 8-week asthma management program and patients were asked how much they would be willing to pay for the program as well as how much time they would be willing to spend on the program.

Risk-risk valuation and risk income tradeoffs were proposed by Viscusi, Magat and Huber (1991) to value risk reduction for contracting a lung disease. Respondents were asked to choose between two alternative cities which differed in the probability of getting a lung disease and the probability of dying in an auto accident. Individuals were presented with different scenarios until they were indifferent between the alternatives. The point of indifference was used to measure the MWTP for decrease in the risk of lung disease as well as the ratio between the two risks. Krupnick and Cropper (1992) used the same valuation setting to measure the effects of familiarity with the disease on WTP and Sloan et al. (1998) used the same tradeoffs to estimate the value of risk of multiple sclerosis. In a more recent study, Blomquist and O'Conor (1997) emphasized the need to separate respondents into people familiar and people unfamiliar with the disease. They proposed a hybrid form of WTP elicitation and found that it worked among people familiar with asthma but was unreliable among respondents unfamiliar with the disease. In the WTP question, respondents were asked to choose between two hypothetical drugs A or B, that differed in their effectiveness and safety and then elicited WTP for a third, improved drug that has greater effect (but was equally safe) than drug A and was safer (but had the same effect) than B .

In summary, earlier contingent valuation studies have elicited WTP for programs aimed at reduction of asthma symptoms, while later research has focused on risk reduction and risk-risk tradeoffs. Elicitation of WTP needs to be conducted using a specific payment vehicle that makes the payment scenario tangible to respondents, and in case of risk valuation, the benefits from a proposed risk reduction need to be easily comprehensible by respondents.

V. Conclusion

Asthma presents social scientists with complex questions. This project seeks to integrate elements of the Health Belief Model and Theory of Reasoned Action to model household risk reducing behavior and risk perceptions. We can use these survey results to model a household health production function. In addition using the epidemiological data we can compare subject to objective risk assessments. The final stage of the project will be to administer a contingent valuation instrument on reduced asthma morbidity.

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Behavioral Reactions to Ozone Alerts:

What Do They Tell Us About Willingness-to-Pay for Children's Health?

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Twelve-year-old Justin Turnage's asthma flared up again this year, and his doctors say ozone is the likely culprit, said Turnage's mother, Deborah Leonard of Raleigh. Now Leonard hopes that board games and music lessons will keep her son indoors on ozone alert days.
"Summer is going to be very hard for him," Leonard said.
(James Eli Shiffer "Triangle Skies Smoggier," News & Observer, May 1, 2001)

1. Introduction

Ozone does not directly cause asthma, but triggers symptoms in susceptible individuals, including young children and asthmatics. The most direct averting action an individual can take to avoid the health problems associated with ozone is to stay indoors. In addition to the medical costs associated with treating and controlling asthma, high levels of ozone pollution limit the outdoor activities in which susceptible individuals, such as a young, asthmatic child can participate. In the language of economics, high ozone levels reduce an individual's or a family's choice set, and as the quote at the top of the page implies, this imposes welfare costs on the family beyond the expenses for medical treatment.

According to the latest report by the American Lung Association (ALA), while ozone levels have declined in some areas of the country ozone pollution is increasing in others (ALA, 2001b). Table 1 lists the 15 counties with the highest ozone levels and the number of orange, red, and purple ozone alerts between 1997-1999. According to the U.S. Environmental Protection Agency (EPA), in 1998 approximately 21% of children lived in counties where ozone standards were exceeded on at least one day (EPA, 2001). Asthma prevalence also increased over the decade of the 1990's. Among children in the U.S., asthma is now the most common chronic illness (EPA, 2001). An estimated 26.3 million people had been diagnosed asthma at some point in their lives according to data collected in the 1998 National Health Interview Survey presented by the ALA (ALA, 2001b). The 5-17 year old age group had the highest prevalence of physician diagnosed asthma, which is estimated to have increased from 130.1 per 1,000 people in 1997 to 135.0 per 1,000 individuals in 1998. Several studies provide evidence of the link between ozone and asthma. A recent study in the Journal of the American Medical Association (Friedman et al., 2001) documented fewer admissions of children to the emergency room for asthma attacks in Atlanta during the 1996 summer Olympics. Atlanta residents were encouraged not to drive and ozone levels were lower during that period than normal.

Several studies have looked at defensive behavior in response to high levels of ozone pollution. Bresnahan, Dickie, and Gerking (1997) used data from a panel of adults in the Los

Angeles area who were contacted between 2-5 times over a 12 month period and asked about their activities in the previous 2 days and their medical expenses. Their results indicate that individuals do change their behavior in response to poor air quality by reducing time spent outside on a day-to-day basis.

A recent survey conducted by RTI International in the summer of 2000 provides additional evidence supporting the results from Bresnahan, Dickie and Gerking (1997). Approximately 6,100 respondents from over 1,000 counties were asked about their knowledge of the ozone alert program. Forty-six percent of the counties represented in the survey experienced at least one day of code orange (or worse) air quality in 2000, covering 75 percent of the respondents. Thirty-seven percent of respondents in these counties were aware of the ozone alert system, compared with 28 percent of respondents in counties that did not experience a code orange (or worse) day.

Table 1. Number of High-Ozone Days in America's 15 Most Ozone-Polluted Counties

		Number of High Ozone Days in the Unhealthy Ranges, 1997–1999		
County	**State**	**Orange**	**Red**	**Purple**
San Bernardino	California	160	74	52
Riverside	California	154	54	24
Kem	California	167	55	4
Fresno	California	178	44	5
Tulare	California	180	19	0
Harris	Texas	78	43	21
Fulton	Georgia	92	18	8
Los Angeles	California	72	28	10
Rockdale	Georgia	70	31	4
Anne Arundel	Maryland	85	23	2
Mecklenburg	North Carolina	89	18	0
Sevier	Tennessee	91	11	0
Blount	Tennessee	88	12	0
Ventura	California	89	8	2
Knox	Tennessee	81	13	0

Source: American Lung Association (ALA). 2001a. "State of the Air: 2001." New York: American Lung Association.

In counties that had experienced a code red (or worse) day during the summer of 2000, 41 percent of respondents were aware of the system, compared with 33 percent in counties that had not experienced a code red (or worse) day. Of those who resided in counties that had experienced a code red day and were aware of the ozone alert system, 58 percent correctly reported that their county had experienced a code red day during that summer. On ozone alert days, 38 percent of the respondents reported driving less and spending less time outdoors, 19 percent reported only spending less time outdoors, 7 percent reported only driving less and 36 percent reported no changes in their behavior. In addition, people who are not working at least part-time, including homemakers, the unemployed, students and retirees were more likely to report reducing the time they spent outdoors on high ozone days. Because these groups have more opportunity to be outside and more control over their schedules, we might expect to see greater responsiveness on their part. Furthermore, people who reported excellent or good health were less likely to report reducing outside time on high ozone days compared to people with fair or poor health.

A number of studies have valued the benefits of reducing ozone through averting behavior or with a contingent value (CV) study. Dickie and Gerking (1991) examined the decision to seek medical care. They found that willingness-to-pay (WTP) for ozone levels that never exceeded 12 ppm was 2 to 4 times higher than medical cost savings associated with the reduction in ozone. Rowe and Chestnut (1985, 1986) asked a WTP contingent value question for a 50% reduction in “bad asthma days.” WTP estimates based on 65 responses from adult asthmatics and approximately 18 parents of children with asthma range from $11.81 to $53.80 to avoid one day of asthma symptoms ranging from no symptoms to moderate symptoms (in 1990 dollars). More recently, Yoo and Chae (2001) conducted a CV survey of WTP to reduce ozone levels in Korea, and Farber and Rambaldi (1993) conducted a CV survey to determine adult exercisers’ WTP to improve air quality. Johnson, Banzhaf, and Desvousges (2000) report WTP of CAN$158 for one day of asthma symptoms with significant activity restrictions and lower amounts for less severe restrictions.

Importantly, however, none of these studies has specifically examined behaviors and values related to protecting children from ozone exposure. There are many difficulties involved with estimating benefits for children. Children do not make decisions for themselves and do not have income, thus traditional WTP measures cannot be elicited from them. In the place of values elicited from children, researchers typically measure the WTP of parents to protect their children from health risks, often inferring WTP from decisions to purchase market goods that contribute to safety such as cars or bicycle helmets (Schulze et al., 2000; Jenkins et al., 2000).

This study was designed to fill this gap in children's health research. Its primary focus is to investigate how parents of young children alter their behaviors in responses to high ozone concentrations and how these behaviors are affected by the presence of high-risk (i.e., asthmatic) children in the household. In the process, it addresses a number of key research questions including:

To what extent are children's risks from exposure to high ozone levels offset by defensive/averting behaviors?

- How much do parents value reductions in potentially harmful ozone exposures to their children?
- What costs (direct and indirect) are incurred by parents and children as a result of behaviors to avert ozone exposures?
- To what extent are people aware of and how much do they benefit from the presence of ozone alert systems?

The primary data for this study was collected during the summer of 2002 through a series of surveys with selected households across the US. This paper describes the conceptual foundation for the study, the methods used for data collection and analysis, and the results of some preliminary analysis.

2. Conceptual Framework

Bresnahan, Dickie and Gerking (1997) use a household production approach to develop a model of decisions about seeking medical care and limiting time outdoors to avoid high ozone levels. Following their model, we can specify the child's utility function as:

$$U= U(H, X, A, Z)$$

where H measures health status, X represents market goods, A measures an activity such as outdoor leisure and Z measures exposure to ozone. In this very simple model, we assume that parents have altruistic feelings for their child and maximize their child's utility. The child's utility depends on his or her health and the activities he or she pursues during the day. Under the assumptions of Bresnahan, Dickie and Gerking, health is produced using activity, exposure to pollution, stock of preexisting health capital (K), and other human capital (S).

$$H = H(A, Z, K, S)$$

Finally, the parent faces a full-income budget constraint:

$$I + wT = q_x X + q_A A + q_M M(H) + wG(H)$$

Full income is composed of non-labor income (I) and the wage rate (w) multiplied by total time available (T). The variables q_x, q_A,and q_M represent time-inclusive prices for X, A and M(H) (medical care) and equal the sum of the money price and time required to consume one unit of the good ($q_j = p_j + wt_j$). Finally, G(H) is the time lost on market and non-market activities as a function of current health status. The parent maximizes the child's utility subject to the budget constraint. Under standard assumptions, the optimal level of A* can be derived from the first order conditions for utility maximization.

(1) $$A^* = A(q_x, q_A, q_M, w, T, I, K, S, Z)$$

3. Survey Design

To inform the model, we conducted a series of eight surveys with a common set of households across the country during the 2002 ozone season. The core of the data collection effort is a series of six activity diaries (i.e., time and activity surveys). Time and activity surveys are commonly used in transportation studies and in risk assessment and exposure analysis to estimate actual exposure levels that individuals experience based on their activity patterns.

Each panel member completed an initial survey at the beginning of the summer to collect some basic information and explain the activity diaries. After this, each member of the panel was sent six activity diaries. A debriefing survey/stated preference survey was administered in mid-December. The eight surveys adhere to the format described below:

- Survey 1 (June 2002)
  - Screener—identifies households who qualify for the sample.
  - Baseline Questionnaire—collects information about the household, their dwelling, neighborhood and health
- Surveys 2-7 (July – September 2002)
  - 6 Activity Diaries—record child's activities and health status for selected day

- Survey 8 (December 2002)
  - – Stated Preference Survey—presents hypothetical activity choice scenarios
  - – Debriefing—collects information on awareness and perceptions about ozone levels and alert system.

In the following sections, we describe the characteristics of our sample and provide more detail on the design of the surveys, in particular the time and activity surveys

3.1 Panel Selection and Mode of Administration

We focused our data collection efforts on two samples—children with asthma and their parents and children without asthma and their parents. Because of the acute effect of ozone on asthmatics, parents of children with asthma may be more educated about ozone pollution and the need to take defensive action (stay indoors) on high ozone days. Organizations such as the American Lung Association publish guidelines that recommend limiting time outdoors on high ozone days to avoid asthma and other respiratory problems. In addition, the ozone alerts themselves provide information on which subpopulations should be limiting time outdoors for each level of alert (see Table 2).

Table 2. Air Quality Index Color Code Guide

Air Quality	Health Effects
Good—AQI: 0-50 (Green)	No health effects are expected.
Moderate—AQI: 51-100 (Yellow)	Unusually sensitive people should consider limiting prolonged outdoor exertion.
Unhealthy for Sensitive Groups—AQI: 101-150 (Orange)	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
Unhealthy—AQI: 151-200 (Red)	Active children and adults, and people with respiratory disease such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion.
Very Unhealthy—AQI: 201-300 (Purple)	Active children and adults, and people with respiratory disease such as asthma, should avoid all outdoor exertion; everyone else, especially children, should avoid prolonged outdoor exertion.

Notes: AQI refers to the Air Quality Index. An AQI of 100 is equivalent to the National Ambient Air Quality Standard (NAAQS). An AQI greater than 100 is considered to be above the national standard or NAAQS. An AQI Calculation Table is available online to convert raw ozone concentrations to the Air Quality Index.

Source: U.S. Environmental Protection Agency (EPA). 2002. "Air Quality Guide for Ozone." <http://www.epa.gov/airnow/aqguide.pdf>.

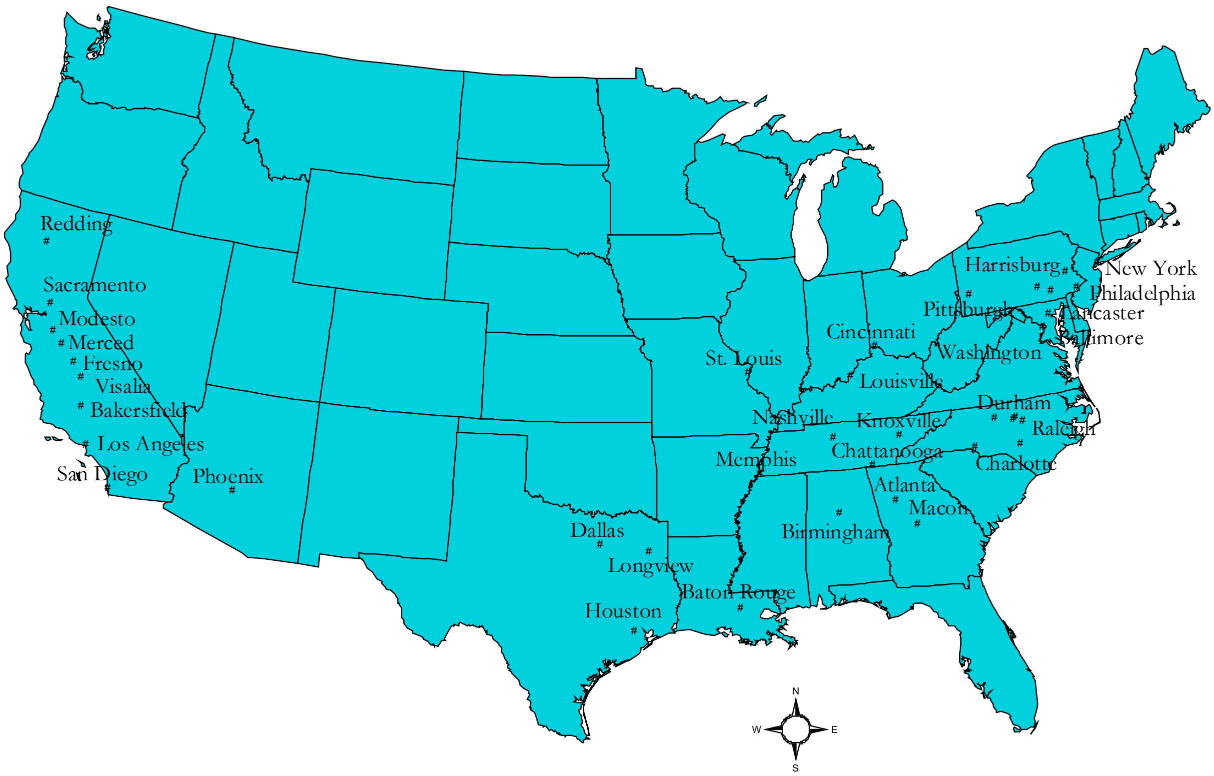
The respondents are all members of the Harris Interactive (HI) online market research panel. The Harris panel consists of individuals who self-select onto the panel and have agreed to participate in surveys over the internet. HI recruited the sample for this project and administered the survey over the internet. The panel includes families in which, during the summer of 2002, there was an asthmatic child or nonasthmatic child aged 2 to 12 years old and at least one parent stayed home with the child during the day. An initial sample of 777 households was recruited in June and began taking surveys in July. An additional 200 households were recruited in July and began taking surveys in August. Approximately one-half of the children in the panel are asthmatic. Response rates for the activity diary surveys were as follows:

- 95% of those who qualified based on a brief screening survey took baseline survey to form a panel of 977 individuals
- 977 people completed 2,940 diaries
  - 80% completed at least 1 diary
  - 12% completed 1 diary
  - 11% completed 2 diaries
  - 11% completed 3 diaries
  - 14% completed 4 diaries
  - 15% completed 5 diaries
  - 17% completed 6 diaries

We chose this population because we believe this sample provides the most direct measure of the efforts parents take to protect their children against the health risks of ozone. Very little data exists on the averting behavior of both children and adults on high ozone days. Children and especially children with asthma are a sensitive sub-population. We expect that in general these groups (or their parents) will engage in a higher level of averting action than other groups in the population. While the activities of this population may not generalize to other groups, such as working parents with children in daycare, by focusing on the actions of children who are home with their parents during the day, we expected to get the cleanest measure of the direct actions parents take to protect their children's health. The survey was conducted over the summer, when ozone is a problem and most school-age children are at home.

Respondents were drawn from the 35 metro areas in the US with the worst ozone pollution (roughly corresponding to the counties with the worst ozone pollution in Table 1). The ranking is based on the number of code purple, red or orange days in 2001 (ALA, 2001a). See Figure 1 for the locations of the 35 metro areas.

Figure 1. Metro Areas in the United States with the Worst Ozone Pollution.



3.2 Survey 1: Screener and Baseline Questionnaire

The HI panel was screened at the beginning of the summer for families who met the inclusion criteria. Those families who met the criteria completed the baseline survey. In this survey, we collected information about the household's demographic characteristics, dwelling in which the family lives, the child including the child's health and questions about the amount of time the child usually spends on different activities. In addition, the parents of children with asthma were asked a series of questions about the severity of the child's asthma, medications the child takes, and changes to their house and lifestyle they have made to help control their child's asthma.

3.3 Surveys 2-7: Daytime Activity Diaries

The core of the research project is the activity diaries. These diaries were to be filled out on-line by the parent within 48 hours of receiving the diary to minimize problems with recall. Unlike a mail-in paper activity survey, we know the date and time the respondent completed the survey. When a respondent missed a particular day or too much time elapsed, we asked the respondent to provide information on their activities for another day rather than asking them to remember what they had done several days ago. In total, each respondent was sent 6 diaries to complete.

The diary takes the respondent through their child's day from the time the child woke up until they went to sleep or 8:00pm (whichever came first). Respondents were instructed to choose from a menu of activities and indicate the starting and stopping time of each activity. The activities were drawn from the CHAD database, a database of activity diary studies maintained by EPA. The CHAD database provides some information on the average level of exertion (sufficient to calculate metabolic rates) associated with the activity, which will be useful for the exposure assessment.

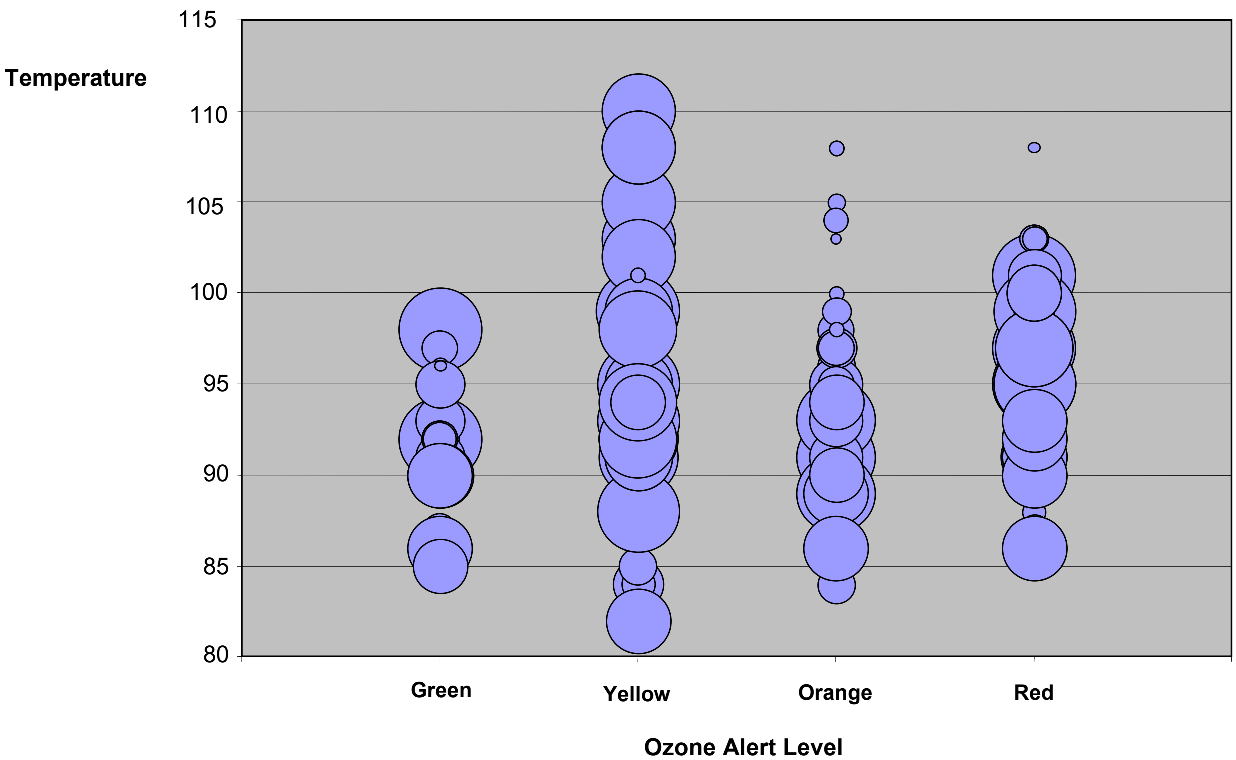
In addition to the start and stop time, respondents were asked to specify their assessment of the level of physical exertion associated with the activity, whether the activity took place indoors or outdoors, the location of the activity (at home or away from home with a general description of how far from home in terms of driving time), whether there was a cost to the activity and whether the activity was scheduled in advance. At the end of the diary, respondents were asked about symptoms their child suffered during the day. Parents of children with asthma were asked questions about their child's asthma and medication use during that day and over the past week.

To avoid sensitizing the panel to ozone pollution through participation in the survey, we did not inform the panel about the purpose of the survey beyond telling them that we were looking for data on their activities. We have linked behavior to actual ozone levels on reporting days.

The survey days were selected to include a variety of ozone conditions, where some of the low ozone days were chosen with the same temperature as high ozone days. Ozone alerts are predicted in the afternoon for the next day. Because the panel was connected by the internet, HI was able to respond quickly and send out surveys based on these reports. The strategy for choosing the days of the interviews was based on balancing the need to collect activity information under a variety of weather and ozone conditions with the cost of administering the survey and burden on the panel.

Figure 2 presents the range of ozone and temperature conditions captured during the study period. The larger circles correspond to cities with larger sample sizes. Ozone and temperature are highly correlated, with worse ozone conditions associated with higher temperatures.

Figure 2. Temperature-Ozone Distribution on Survey Days



Note: Larger bubbles indicate larger groups of respondents.
Los Angeles and San Diego respondents have been excluded from this figure.

3.4 Survey 8: Stated Preference Survey and Debriefing

We conducted the final debriefing and stated-preference survey in April 2003. The purpose of this survey was to collect information about other variables that are important for interpreting the time and activity data. Information collected includes the individuals' level of knowledge about ozone and the health effects of ozone, their self-reported response to ozone (whether they consciously changed their schedule on high ozone days), and their subjective assessment of the risks they and their children face from ozone pollution.

The activity diaries provide information about whether and how the child's schedule changes in response to ozone conditions. The primary averting behavior to avoid ozone exposure is to stay indoors. We expected that on high ozone days, some of the children on the panel would stay indoors more than on low ozone days. But the activity diaries do not directly collect information on the value the parents place on this lost outdoor time. To estimate that value, the debriefing survey contains one of two series of stated-choice tasks based on either a medicine commodity or city commodity. We discuss only the medicine version of the survey here.

Like some actual antibiotics, the hypothetical medicine commodity requires limited exposure to sunlight. Figure 3 contains the text that explains this feature of the medicine. Table 3 shows the attributes and levels used to construct the choice profiles. The experimental design consisted of three randomly assigned blocks of five choice sets with two alternatives each. We employed Zwerina, Huber, and Kuhfeld's (1996) algorithm to search for a near-optimal design. Figure 4 shows an example choice task.

Figure 3. Definition of Outdoor Time Attribute

> Assume that at the beginning of the summer, your family doctor tells you that [child's name] needs to take a medicine during the summer as a preventive measure. In other words, [child's name] is not sick, but [he/she] needs to take medicine to prevent an illness from developing. …
>
> [Child's name] would have to limit the time spent outdoors on the days [he/she] takes [his/her] medicine. Even on cloudy days or when [he/she] is wearing sunscreen, extended exposure to the sun will make the medicine less effective.

Table 3. Medicine Attributes and Levels

Attribute	Levels
Maximum number of minutes in the sun allowed per day	• 10min • 45 min • 1 ½ hours
Length of time child takes medicine	• 3 day • 12 days • 20 days
Total cost of medicine for the summer	• $10 • $40 • $75 • $150

Figure 4. Example Choice Task

Medicine Features	Medicine A	Medicine B
Number of days [name] would have to take the medicine.	3 days during the summer	12 days during the summer
Maximum recommended outdoor time on days when [name] takes medicine.	45 minutes	10 minutes
Total cost of medicine to you. (The cost not covered by insurance).	$150 for the summer	$10 for the summer
Which medicine would you purchase? (Please check <u>one</u> box.)	**Purchase A** ☐	**Purchase B** ☐

3.5 Supporting Data Collection Activities

In addition to the information collected from the panel we collected information on predicted and actual AQI levels and weather-related data such as high temperatures on survey days for each city. We also collected a copy of the newspaper in each city to document the manner in which air pollution and ozone pollution information is presented.

4. Preliminary Results

4.1 Activity Survey

Our sample consists of 977 parents. As reported above, 780 households (80 percent) of the sample completed at least one activity diary. Out of the 780 households, 486 (62 percent) responded to the valuation and debriefing survey. Table 4 reports demographic characteristics of the sample, including comparison between the households with asthmatic and non-asthmatic children. On average, a household had 2 children with an annual household income less than $75,000. One-third of the parents had college education or higher. Table 5 presents summary statistics for the children and their activities by asthmatic and non-asthmatic. The median age was 6 years old. Sixty-four percent of the asthmatic children and 50 percent of the non-asthmatics were male. Thirty-three percent of the asthmatics and 25 percent of the non-asthmatics participated in organized sports teams or lessons that practiced and played outdoors during 2002 summer. Besides organized sports teams and other scheduled activities, both asthmatic and non-asthmatic children spent 3 hours watching TV and 1 hour or more playing video games each weekday.

Based on equation 1, the optimal level of averting behavior is a function of prices, health capital and ozone exposure. We use two measures of averting behavior, the total hours that the child spends indoors during the day and the proportion of the child's day spent inside. The ozone forecast for the day represents the level of ozone exposure. We created a dummy variable for days that were code orange or red where the excluded category is days that were code green or yellow. Individuals who check the ozone forecast for the day may reduce their child's outdoor time on code orange or red days. Individuals who do not check the ozone forecast may observe their child suffering from symptoms and reduce the child's outdoor time. Leaving aside the use of medicine, we expect that the optimal level of averting behavior will increase in children with lower health capital, in our sample children with asthma. However, children with asthma may use either long-term daily medications or short-acting medications to control their asthma that could affect the relationship between spending time outdoors and health risks. Because the sample includes stay-at-home parents, the wage rate (or reservation wage to join the workforce outside the home) is not included in the equation.

Table 4. Sample Characteristics

	Non Asthmatic (n = 506)	Asthmatic (n = 473)	All Households (N=979)	U.S. Population
Children (median)	2	2	2	1
<$35,000	23%	16%	19%	42%
$35,000-75,000	40%	40%	40%	34%
% white	82%	88%	85%	75%
% high school grad	17%	19%	18%	32%
% coll grad or grad school	29%	37%	33%	25%

Table 5. Children: Characteristics and Activities

	All Children (N=979)	Asthmatic Children (n=473)	Non-asthmatic Children (n=506)
Average age	6	7	5
% male	57%	64%	50%
% outdoor sports (median hrs)	29% (6)	33% (6)	25% (5)
% outdoor other (median hrs)	15% (7)	19% (7)	11% (6.5)
% indoor sports (median hrs)	14% (3)	16% (4)	12% (3)
% indoor other (median hrs)	15% (3)	15% (3)	15% (2)
Hours Spent on Watching TV (median)	3	3	3
Hours Spent on Playing Video Games (median)	1	2	1

We used the proportion of the child's day spent indoors (%INDOOR) to estimate the level of averting behavior in response to high ozone levels and other factors that influence parents' decisions about their children's daily activities. Besides temperature (TEMP), we also monitored the ozone forecast for the selected days, which represented the level of ozone exposure. CODE_RED indicates high-ozone days and AWARE indicates whether the parent was aware of the color-coded ozone warning system. Three regional dummies (WESTCOAST, NORTHEAST, and SOUTHEAST) capture climatic and other geographic differences. In addition, we also include household and child characteristics in the analysis, including annual household income (INCOME), whether the child is male (MALE), child's age (AGE), whether the child prefers to play outdoors in the summer (OUTDOOR), and number of hours each weekday the child spent on watching TV and/or playing video games (TVGAME). The mean value and expected sign of each variable at diary level are reported in Table 6.

We excluded observations from Los Angeles and San Diego for the analysis. Both cities have more than one weather monitoring station. We have not yet identified which sample household lives near which station. so we have not included these observations in the preliminary analysis. In addition, diaries covering less than 4 hours on a given day were dropped from the sample.

Table 7 reports multivariate regression results, controlling for repeat observations from the same household. Overall, both asthmatic and non-asthmatic children regressions are significant at 1% level, but explanatory power is low. TEMP and CODE_RED are positive and significant for both asthmatic and non-asthmatic regressions, indicating that children spent less time indoors on cooler and non-code red days. Both effects are larger for children with asthma than for children without asthma. These are the only coefficients that are significant for both groups.

The interaction term (RED_AWARE) between CODE_RED and AWARE is negative in both regressions, but not significant. Asthmatic children who live on the west coast spent less time indoors while non-asthmatic children in the southeast spent more time indoors. The positive asthmatic interaction term WESTCOAST_AWARE indicates that parents who were aware of the ozone alert system and live on the west coast were more likely to have their asthmatic children spend more time indoors. Oddly, parents who were aware of the ozone alert system and live in the southeast were more likely to have their non-asthmatic children spend less time indoors.

Table 6. Mean Value of Dependent and Independent Variables and Hypothesized Coefficient Sign

Variable	Asthmatic	Non-Asthmatic	Hypothesized Sign
%INDOOR (%)	65.75	64.08	
TEMP (°F)	94.38	94.82	+
CODE_RED	0.29	0.28	+
AWARE	0.55	0.53	+
RED_AWARE	0.14	0.15	+
WESTCOAST	0.09	0.09	?
NORTHEAST	0.41	0.29	?
SOUTHEAST	0.28	0.34	?
WC_AWARE	0.03	0.04	?
NE_AWARE	0.23	0.15	?
SE_AWARE	0.22	0.23	?
MALE	0.50	0.72	+
AGE (years)	6.15	6.93	–
PREFERS OUTDOORS	0.41	0.38	–
TV/GAMES (hrs)	6.09	6.23	+
INCOME ($10,000)	7.09	6.27	?

An interesting result is that children with asthma who play more video games and watch TV also spend a greater proportion of their time indoors, while nonasthmatic children do not. It seems tautological that more time spent in an indoor activity will increase the proportion of indoor time. However, nonasthmatic children who play more video games apparently offset this effect by also engaging in more outdoor activities.

Among children without asthma, male children, older children, and children in higher-income households spend more time outdoors.

Table 7. Regression: Dependent Variable Proportion of Time Indoors

	Coefficient (Standard Error)					
	Asthmatic			Non Asthmatic		
TEMPERATURE	0.83	***	(0.18)	0.51	***	(0.19)
CODE_RED	6.01	*	(3.21)	4.53	*	(2.65)
RED_AWARE	-5.58		(4.20)	-3.79		(3.52)
WESTCOAST	-14.29	**	(6.06)	3.58		(5.48)
NORTHEAST	6.14		(4.27)	1.40		(3.36)
SOUTHEAST	-5.30		(4.97)	7.87	*	(4.13)
WESTCOAST_AWARE	17.30	***	(6.81)	1.10		(7.85)
NORTHEAST_AWARE	-2.32		(5.31)	1.89		(3.52)
SOUTHEAST_AWARE	4.40		(5.60)	-7.14	*	(4.33)
MALE	-3.05		(2.28)	-5.57	**	(2.24)
AGE	-0.47		(0.32)	-0.99	***	(0.33)
PREFERS OUTDOORS	-7.87	***	(2.47)	-3.79		(2.44)
TV/GAMES	0.72	***	(0.19)	-0.19		(0.12)
INCOME	-0.09		(0.26)	-1.04	***	(0.29)
CONSTANT	-15.79		(16.45)	27.91		(18.88)
Number of observations	669			853		
Probability > F-statistic	0.0000			0.0001		
R-squared	0.1204			0.0822		
Number of clusters	149			174		

3.5 Stated-Preference Survey

Table 8 reports results of random-effects probit analysis of the stated-preference data for all respondents, children with asthma, and children without asthma. A likelihood-ratio test for structural difference between the two subsamples is marginally insignificant (p=0.12). All coefficients are divided by the negative of the cost coefficient to eliminate scale differences among models. The number of summer days affected by the medication has a strong, negative, and significant affect on indirect utility for all three samples. The direct effect of the restriction on the number of outdoor minutes per day was insignificant and was dropped from the models. However, the interaction between days and minutes is significant and has the correct positive sign in all cases. The coefficients for both DAYS and DAYS*TIME are significantly smaller for the asthmatic sample than the non-asthmatic sample, indicating a smaller willingness of households with asthmatic children to pay for outdoor play time.

Cost was interacted with four variables to permit heterogeneity in the marginal utility of money and thus WTP. The income interaction has the correct positive sign, but is significant only in the pooled model. The asthmatic sample is willing to pay significantly less if the child is male and significantly more if the child prefers to play outside. In contrast, the non-asthmatic sample is willing to pay more if they live in the northeast, but none of the other cost interactions are significant.

Table 9 contains some illustrative WTP estimates for the pooled model using the worst combination of DAYS and TIME (20 summer days with maximum outdoor time of 10 minutes per day). Households are willing to pay an average of $73 to reduce the number of days from 20 to 12, holding the time restriction constant at 10 minutes. They are willing to pay an additional $29 to increase outdoor time to 45 minutes per day, holding affected days constant at 12. Moving from the worst combination of DAYS and TIME to the best combination in the experimental design (3 days and 90 minutes) is worth an average of $175. With the exception of the difference between $150 and $175, all estimates are significantly different from each other.

Table 8. Random Effects Probit: Dependent Variable Probability of Choice
Coefficients Scaled by $-\beta_{cost}$ (Standard Error)

	Pooled			Asthmatic			Non-Asthmatic		
Days	-8.740	***	(0.632)	-7.046	***	(0.705)	-11.952	***	(1.239)
Days*Time	0.070	***	(0.007)	0.064	***	(0.008)	0.086	***	(0.013)
Cost	-1.000	***	(0.143)	-1.000	***	(0.161)	-1.000	***	(0.286)
Cost*Income	0.037	*	(0.018)	0.028		(0.022)	0.050		(0.036)
Cost*Male	-0.384	**	0.150)	-0.175	*	(0.174)	-0.674		(0.289)
Cost*Northeast	0.488	**	(0.154)	0.632		(0.184)	0.260	***	(0.291)
Cost*Prefers Outside	0.477	*	(0.146)	0.339	*	(0.174)	0.612		(0.283)
Number of observations	1135			540			595		
Log likelihood	-648.08871			-292.73422			-349.6708		

Number of clusters	227	119	108

*significant at the α = 0.05 level; **significant at the α = 0.01 level; ***significant at the α = 0.001 level

Table 9. Money-Equivalent Utility Differences Relative to (Days=20, Time=10) Full Sample

Total Summer Days	Outdoor Minutes per Day	WTP	90% Confidence Interval	
3	90	$175	$146	$207
12	90	150	128	178
12	45	107	90	127
12	10	73	62	87
20	10	0	0	0

5. Future Directions

This paper outlines the research strategy and data collection efforts including a preliminary analysis of the data. Ultimately, we will use the revealed preference (RP) data from the activity diaries with the stated preference data from the conjoint survey to address the four key research questions identified in the introductory section. Further analysis of the RP data in particular will be used to measure how parents and children alter their indoor/outdoor and related behaviors in response to ozone alerts. Second, by combining RP and SP data, we hope to estimate parents' welfare losses from their child's exposure to high outdoor ozone levels. Preliminary results suggest modest differences between revealed and stated preferences for outdoor playtime between parents with a child who has asthma and parents with a child who does not have asthma. Other household characteristics also affect outdoor play preferences.

Third, through the RP-SP analysis, we will measure the implicit costs to parents of restricting their children's outdoor activities (independent of outdoor ozone levels). Because the SP data allows estimating the marginal utility of money, we can estimate parents' demand for childrens' outdoor time, at least in the context of the hypothetical commodity, and to estimate how this demand varies systematically across households.

A fourth component of the research project, which was not discussed in this paper, involves a risk assessment and exposure model. The modeling effort will follow the children through their day using a GIS-based system to capture actual exposure to ozone on the activity diary data. The model will be used to predict the net impact of behavioral changes on health risks from ozone exposures.

Finally, each of the components above will allow us to assess the informational benefits associated with ozone alert system. Preliminary results suggests a relatively low level of awareness of the system. The survey data will allow us to gauge both the awareness of and reactions to different levels of ozone alerts and how they vary across households and urban areas. The net benefits of the ozone alert system will include both the value of reductions in health risks associated with these defensive activities and the lost value (opportunity cost) associated with restricting outdoor and other activities.

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A Cross-Sectional Analysis of Asthma Medication Use and Air Pollution: A Preliminary Analysis

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Asthma is a chronic lung disease that is characterized by intermittent, recurring episodes of wheezing, breathlessness, tightness of the chest, and coughing. These episodes are caused by inflammation of the airways that carry air into and out of the lungs. Asthma is considered to be a growing problem in the United States, especially among children. The prevalence of asthma increased 46 percent between 1982 and 1993 in the United States. While increases in prevalence have been documented in all age, race, and gender groups, the increase has been most significant among children, individuals under the age of 18, in which prevalence has increased by a staggering 80 percent since 1982.

While the exact causes of the illness remain unknown, asthma attacks can be triggered by exposure to allergens (such as dust mites, pollen, mold, pet dander, and cockroach waste), strong fumes, respiratory infections, exercise, dry or cold air, as well as air pollution (including ozone and particulate matter). Despite recent efforts to reduce ambient levels of air pollution, approximately 46 million people lived in counties that did not meet the air quality standards for at least one of the six criteria pollutants in 1996. The combination of poor air quality with other triggers is often most extreme in urban centers where a disproportionate number of minority and low income households reside.

A relatively large number of studies exist that focus on the relationship between air pollution and serious asthma attacks resulting in Emergency Room visits or Hospital Admissions; however, very few studies exist that focus on mild to moderate asthma attacks. Those studies that do examine mild forms of asthma symptoms generally are diary studies that follow a small group of asthmatic individuals over time and focus on the effects of short-term increases in air pollution exposure. This paper presents the preliminary results of a cross-sectional analysis of the effects of chronic exposure to air pollution on the incidence of asthma attacks, as measured by the use of short-term "quick relief" medication.

Literature Review

The relationship between short-term increases in ambient levels of air pollution and asthma outcomes has been documented in a number of venues using two types of studies: daily time series studies and diary studies. Daily time-series studies are used to model the relationship between daily levels of ambient air pollution and daily counts of a health outcome. By focusing

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[1] The views expressed in this paper are those of the authors and do not necessarily reflect the position of the Environmental Protection Agency.

on a particular city or area, these types of studies limit the amount of data required since the population acts as its own control. For instance, there is no need to control for socio-demographic characteristics or behavioral patterns as these are thought to remain relatively constant in the population from one day to the next. Only weather and seasonal variation need to be included in the model in addition to the daily air pollution levels. Diary studies on the other hand, follow a group of individuals over time and ask that participants keep track of symptoms, behaviors, and medication use over the study period. Studies of this type must control for personal characteristics of the panel members, differences in behaviors, as well as weather and pollution.

Daily time-series studies have been used to model the relationship between air pollution and a number of health outcomes including daily mortality and other relatively severe respiratory outcomes such as hospital admissions, emergency room visits and doctor visits – with a relatively large segment of the studies focused on asthma. In a study by Walters et al. (1993), for instance, daily levels of SO2 and black smoke were found to have a positive association with hospital admissions for asthma in Birmingham, UK. A similar result was found in Birmingham, Alabama in a study focused on hospital admissions due to pneumonia and Chronic Obstructive Pulmonary Disease (of which asthma is a component) among elderly inhabitants (Schwartz 1994). Also found was a positive association between air pollution levels and doctor visits for asthma in London (Hajat et al. 1999). In Barcelona, Spain, a positive association between emergency room visits for Chronic Obstructive Pulmonary Disease and air pollution levels was found (Sunyer et al.). While these studies are indicative of the detrimental effects of short-term increases in air pollution on rather severe asthma outcomes, they give no indication of the chronic effects of air pollution exposure on respiratory health nor do they generally provide evidence of detrimental effects that are milder in nature.[2]

Diary studies, using data collected from a panel of individuals, can provide some indication of the effects of air pollution on less severe health outcomes. They model symptoms experienced by panel members as a function of air pollution levels. A number of studies of this sort have found positive and significant effects of air pollution exposure on exacerbation of asthma symptoms. Neukirch et al. (1998) found measurable short-term effects of low-level air pollution in Paris France on nonsmoking asthmatic adults diagnosed with mild or moderate asthma. Similarly, Peters et al. (1996) found that asthmatic children in Erfurt and Weimar Germany and Sokolov in the Czech Republic suffered more symptoms (cough, shortness of breath, wheezing) and reduced pulmonary expiratory flow when exposed to higher levels of air pollution, although same day effects were relatively weak compared to cumulative effects over 5 days. Ostro et al. (1991) also found a strong association between daily air pollution levels (specifically airborne acid aerosols, particulates, and sulfates) and increased asthma symptoms among a panel of asthmatics in Denver, Colorado. Similar results have been reported in the Utah Valley (Pope et al. 1991), Glendora California (Krupnick et al. 1990), and the Netherlands (Hiltermann et al.

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[2] Two exceptions to this statement are a study by Zeghnoun et al. (1999) conducted in Le Havre France and an ongoing study by Simon et al. (2002) in San Francisco, California. Both studies look at air pollution and the purchase of quick relief asthma medications.

1998) among other places.

While diary studies are useful in isolating the effects of short-term increases in pollution on milder outcomes, these studies face several difficulties. Among these difficulties, as noted by Schwartz et al. (1991) is the fact that daily symptom rates are often highly correlated from one day to the next and the heterogeneity among subjects causes dependencies in the data. Some study results are also limited by the availability of particulate pollution measures – relying on TSP data rather than PM10 data – while others are limited by panel size or length of study period.[3] Because these studies tend to have relatively short study periods (often less than 1 year), they do not generally provide any indication of the effects of chronic exposure to air pollution on asthma symptoms.

In contrast to the studies described above, our study examines the effect of longer term or chronic exposures to air pollution on asthma symptoms as measured by the purchase of quick relief asthma medications across the state of California. We hypothesize that chronic exposure to air pollution may make an individual more susceptible to asthma attacks, causing an increase in the use of quick relief medications. Rather than consider the effects of daily increases in air pollution levels, this study focuses on differences in average pollution levels across zip codes and the effect of these observed differences on the purchase of quick relief asthma medications.

Methodology

This study looks at the effects of differences in long-term or chronic air pollution exposures on the occurrence of asthma attacks, where asthma attacks are proxied by the number of prescriptions for quick relief asthma medication. The total count of prescriptions for quick relief asthma medication is explained using measures of asthma triggers and other cofactors. The study utilizes a dataset of asthma drug prescriptions for a large percentage of the pharmacies in the state of California and GIS layers of spatial factors.

In this study, our "health" outcome (filling asthma prescriptions) is not a "direct" effect of air pollution exposure, but rather a secondary effect. That is, the true sequence of events goes as follows: long-term exposure to air pollution makes an individual more susceptible to asthma triggers leading to an exacerbation of asthma symptoms which in turn causes an increase in asthma medication use. The increase in asthma medication use eventually (perhaps with a lag) leads to the filling of a prescription. Because the urgency with which a prescription will need to be filled will vary across individuals and their initial stock of asthma medication, making short term effects difficult to observe, we focus on longer periods of time during which increased air pollution should be correlated with increased prescriptions, over and above the amount necessary for normal stock replacement.

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[3] TSP or Total Suspended Particulates includes all suspended particulates regardless of size. PM10, on the other hand, is defined as those particulates measuring 10 microns in diameter or less. PM10 is considered a more relevant measure of particulate pollution for epidemiological studies. These particulates are thought to be the most detrimental since they can be inhaled deeply into the lung.

Prescription data are provided for each five-digit zip code in the state and are segregated by five-year age groups and the level of asthma severity of the patient. Asthma severity is classified as mild intermittent, mild persistent, moderate persistent, and severe, based upon the number and combination of prescriptions that the patient fills for both quick-relief and maintenance asthma medicine over the 12 month calendar year (NIH, 1997). Generally, asthma medications fall into one of two categories: (1) short-term treatments intended to provide quick relief in the event of an asthma attack and (2) long-term maintenance therapies intended to prevent asthma attacks. Mild asthmatics are those patients prescribed a quick-relief medication only. Patients with mild persistent asthma not only are prescribed a quick-relief medication but are also prescribed a single controller or maintenance therapy. Moderate asthmatics are prescribed two controllers operating by different modes of action in addition to the quick relief medications, while severe asthmatics are prescribed three controllers with different modes of action. Should an individual's asthma severity level shift over the 12 month period, the individual is assigned to the most severe of the categories for which he/she qualifies. A list of the quick acting and controlling asthma medication is listed in Table 1.

Asthma triggers included in the study include air pollutants (e.g., particulate matter and ozone), which are the primary factors of concern, as well as temperature. Additional cofactors included are population demographics (e.g., median household income, percent urban population), and seasonal or quarterly dummies. The inclusion of other spatial factors such as pollen and the road network were considered, but not included in this model.

Data Description

The number of prescriptions for quick acting asthma medication was obtained from NDChealth (hereafter, NDC), a Phoenix-based company that maintains prescription-related data for marketing research. NDC maintains two datasets of use for this study, a “retail pharmacy” database and a “patient” database. The pharmacy database contains dispensing records from approximately 36,000 pharmacies nationwide, and captures approximately 70% of the volume of traditional pharmacy-dispensed prescriptions. Hospital, military and mail order pharmacies and prescriptions dispensed to institutionalized patients are not included in this database, which may pose a problem in the future as mail order prescriptions grow, but is probably not important here. The patient database is a subset of approximately 14,000 of the pharmacies in the pharmacy database. The patient database is a more complete database, in many cases including the patients age and gender, along with a unique patient identifier so that the history of a patient may be followed. Not included in the database, and unknown to NDC, is any information that could personally identify a patient (such as a name, address or phone number) and NDC has been very careful not to release any individual patient data, even with the anonymous identifier.

For this study, the total counts of the number of prescriptions for quick-acting asthma medication in a five digit zip code for each quarter from 1998 to 2001 were used. Data are given by dispense quarter and the zip code of the dispensing pharmacy. These data are further disaggregated by the age of the patient, with age groups defined as: ages 0 to 4, ages 5 to 9, ages 10-14, ages 15-17, ages 18-44, ages 45-64, ages 65 and up, and age unknown as well as asthma severity.

The prescription data used in this analysis are limited in the following way. They only include counts of prescriptions for quick relief asthma medication from those pharmacies that "consistently" report this information. "Consistent" reporting is defined by NDC as pharmacies for which fewer than 11 days of data are missing in any 30 day period. While the number of consistently reporting pharmacies remains relatively stabile in a zip code over time, the number of pharmacies reporting across zip codes varies widely and may affect the number of prescriptions dispensed for quick relief asthma prescriptions.

To control for the number of pharmacies reporting while maintaining the privacy of the pharmacies themselves, NDC provided us with a proxy measure that would be strongly, if not identically, correlated with number of pharmacies in each zip code reporting asthma prescriptions. Specifically, they calculated the ratio of the number of pharmacies reporting asthma prescriptions to the number of pharmacies reporting prescriptions for either antibiotics or pain relief medications during the same time period. This ratio allows us to identify and control for fluctuations in asthma prescriptions attributable to variations in the number of pharmacies reporting rather than those that are attributable to changes in weather, air pollution or other factors.

The air pollution data come from the California Air Resource Board and are made publicly available. Daily observations on the levels of PM10, SO2, NOx, and ozone are available for 361 monitors across California. PM10 (in micrograms per cubic meter) and the 8 hour maximum value of ozone (in parts per million) were available with good spatial coverage across California. The 24 hour average value of SO2 (in parts per million) and the daily average concentration of NOx (in parts per million) were available for a subset of the sites. The daily observations for all of the pollution measures were averaged over the quarter for each monitor.

The weather data come from the National Climatic Data Center. Daily observations for the average, minimum, and maximum temperature, precipitation, as well as the dew point temperature, and the minimum and maximum relative humidity were obtained for 37 active weather stations across California. The dew point temperature and relative humidity measures were eventually dropped due to a lack of adequate spatial distribution. Since it is generally believed that cold weather events are correlated with asthma attacks, the average minimum temperature over the quarter was used in this analysis.

While the coverage of air pollution and weather data offer an acceptable representation of the state, each zip code does not necessarily contain an air pollution or weather monitor. An algorithm was needed to link the zip code with two disparate points: the zip code and the air pollution monitor or the weather station. Kriging methods to spatially interpolate the data were explored, but given the preliminary nature of this analysis, the simpler method of linking each of the zip codes with the nearest monitor and station that contained data within 25 miles was used. Zip codes were linked to monitor and stations for each of the four years individually, so a zip code could potentially draw data from more than one location over the course of the study. To be considered in a year, a pollution monitor was required to have PM10 data and a weather station was required to have precipitation data in the first quarter. Of potential concern is that zip codes were linked to monitors without regard for airshed, elevation, or wind direction, and spatial autocorrelation and spatial heterogeneity were not evaluated in this study. Future analyses will try to incorporate these elements as well.

Demographic data for each zip code were obtained from the 2000 U.S. Census. Total population counts by age and race, as well as other demographic data, were collected at the zip code level from both the SF1 (100-percent, short form) and SF3 (sample, long form) datasets. Ultimately, we decided to control for population by using prescriptions per capita as the left hand side variable; however, we included various characteristics of the population as explanatory variables, including the percent of the population in each race, population density, percent urban, and median income.

The summary statistics for the data used in this analysis are listed in Table 2. The unit of observation is the five-digit zip code. For the sixteen quarters from 1998 to 2001, data were available at one point or another for 852 of the 1919 zip codes in California. Together, 7,735 observations of quarterly counts for quick relief medications were available. When linked with the regressors, however, between 7639 and 7097 observations were available for primary analysis, and 3284 observations were available if SO2 and NOx were included.

Empirical Results

Since our prescription data were reported by five-digit zip codes of various sizes and population density, we control for this variation by normalizing the prescription counts by the size of the total population of the zip code using information from the 2000 Census. The effects of cold temperature extremes are captured using the average minimum temperature for the zip code over the quarter, and cyclical variation and seasonal allergies are controlled for using quarterly dummies. Demographics included here are race and median household income. Since we are explaining prescriptions per capita, the percentages of these demographic categories in each zip code are used. In addition, we have included both population density and percent of population in an urban area as explanatory variable, as well as an interaction between percent urban and median income. Finally, we have included a trend variable to control for annual changes that are not otherwise captured.

Since counts of quick relief asthma medications are relatively large for each quarter at the zip code level, we examine the effects of pollution using simple, weighted OLS regressions, where the weight is the ratio of the number of pharmacies reporting in each zip code during the quarter to the number of pharmacies reporting in the alternative market.[4] We built the model by first incorporating time and weather variables. In this case, the weather variable of interest is minimum temperature, as cold temperatures are thought to exacerbate asthma symptoms. We then added population density and demographic characteristics at the zip code level. Finally, we

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[4]The alternative market is defined as prescriptions for analgesics and/or antibiotics.

added pollution variables to our models. PM10 and ozone measures were introduced separately in the analysis before including them in the same regression. We then added SO2 and NOx to the final regression to see the effect. The results of the final regressions including the pollution measures are reported in Table 3.

Focusing first on the demographic variables, household income is positive and statistically significant in all of our models, indicating that households with higher incomes are more likely able to afford the prescriptions. Race also seems to matter, with Hispanics showing a greater likelihood of purchasing asthma prescriptions in California. On the other hand, being Asian or black has a negative effect on asthma prescriptions for quick relief medications. We had no predispositions as to the direction of the coefficient on the race variables, recognizing only that race could be a significant determinant of exposure to triggers and susceptibility to them. It could be that Hispanics live in areas with higher levels of pollution or are otherwise exposed more often to other asthma triggers compared to other segments of the population. Or, perhaps differences in the occupations held by individuals comprising the various race/ethnic groups exist that lead to differential exposure to asthma triggers. While population density has a consistently positive and statistically significant coefficient, the coefficient on percent of the population living in an urban area tends to be negative. We initially expected that urbanization would have a positive effect on asthma prescriptions since exposure to asthma triggers is often thought to be higher in urban environments.

Turning to our variables of interest, we find mixed results. Interestingly, PM10 has a consistently positive and statistically significant effect on asthma prescriptions for quick relief medications, with the exception of model 4 in which SO2 and NOx are included as well as ozone. Generally this means that higher levels of PM10 in one location are associated with a greater number of total prescriptions per capita for quick relief asthma medications, all else equal. In model 4, however, the effects of SO2 and NOx dampens the effect of PM10 considerably. SO2 and PM10 tend to be correlated, however, with SO2 a potential indicator of the acidity of the particulate pollution. Some argue that the acidity of the particulates contributes to the incidence of various health effects including asthma. Because of the relatively poor coverage offered by monitors reporting SO2 and NOx, it is important to note that the number of observations declined considerably compared to the other models reported here.

The effects of ozone on quarterly prescription counts of quick relief medications is not nearly as pronounced. In fact, we find no statistically significant effect of ozone measures in any of our models. Model 4 again provides a weak exception, with a barely statistically significant (at the 90 % level) coefficient on the ozone measure included in the regression. The sign of the ozone coefficient in Model 4 is puzzling, though, as it is negative.

Effects by Asthma Severity

Recognizing that maintenance therapies could be dampening the effects of air pollution on quick-relief asthma medication use and prescriptions, we stratified our data according to asthma severity. Using counts of prescriptions per capita for each severity level as the dependent variable, we ran four separate regressions using model 3 from Table 3. These results are reported in Table 4.

As suspected we see differential responses to air pollution levels by asthma severity. As in Table 3, PM10 has a consistently positive and statistically significant effect on asthma prescriptions for quick relief medications regardless of severity level. The magnitude of the effect does vary, however, with mild and severe asthmatics showing the largest response. This is not entirely surprising since mild asthmatics by definition do not take controller medications but rely only on the quick relief medications to ease their breathing. On the other extreme, severe asthmatics, while taking several maintenance therapies, may be more susceptible to exposure to asthma triggers including air pollution levels, requiring larger numbers of prescriptions for quick relief medications.

The effect of ozone levels on asthma prescriptions remains puzzling. When this variable is statistically significant, it has a negative sign– the opposite of what we were expecting. It may be that the effects of ozone exposure on asthma are more acute requiring daily time series models to capture. This is a subject of future investigation.

While the direction of the effects of our other explanatory variables remain relatively unchanged from our core model reported in Table 3, some of the differences in magnitude by severity level are quite interesting. For instance, median household income has a statistically significant and positive effect on asthma prescriptions across the board, but the magnitude of the effect is larger for mild and severe asthmatics. One explanation of this effect could be cost related in that households with lower incomes may choose to forgo prescriptions for mild asthmatics. For asthmatics with more serious, persistent symptoms, the income effect is less pronounced, indicating perhaps a willingness to purchase the prescriptions to alleviate these more intense symptoms in spite of their cost. For the severe asthmatics, the effect of median household income is again quite pronounced – approximately twice the size of the effect for the mild asthmatic. This may again reflect cost concerns in that the multiple medications prescribed to the severe asthmatic may result in a substantial expense. Instead, households with lower incomes may forgo the additional treatments, continuing instead to purchase the medication combinations prescribed to the moderate asthmatic.

Age Specific Effects

Given the dramatic rise in asthma among children, it is important to determine whether or not the effects described above are age-specific. Including age-specific cofactors (such as the percentage of specific age groups in each zip code) in the regression above was considered, but using the prescriptions by age group in separate regressions gives a much more complete picture. The difficulty in this disaggregation, however, is that while few zip codes have zero prescriptions in the aggregate, a zip code may report zero prescriptions for a given age group in a particular quarter. As can be seen by the number of observations equal to zero reported in Table 2, zero counts are a concern, particularly for the severe asthma category. This makes the linear model used in Table 4 inappropriate.

The standard model for count data with zero observations is a Poisson model. The results of this model for the children's age categories of 0-4, 5-9, 10-14, and 15-17 are reported in Tables 5, 6,7, and 8 respectively. Table 9 is the Poisson regression of the remaining prescriptions, included for completeness. Note that Table 9 includes the prescriptions for the adult category of age 18 and above, but also all of the prescriptions listed for those of "unknown" age. Since the dependant variable in the Poisson model is simply counts of prescriptions, we include population and land area in the model as explanatory variables and remove population density. Otherwise, all of the other explanatory variables used previously are included in the Poisson model as well.

In general, the Poisson models yield significant relationships, of the same form as in Table 4, between air pollution and the number of asthma prescriptions. Strikingly, this is true, with few exceptions across all age groups, for both PM10 and ozone. Of particular interest is the result found by comparing the magnitude of the first order term for air pollutants across age groups for any given severity level. When statistically significant, coefficients are generally larger for children than for adults. Exceptions to this result for ozone are the 0-4 age group with mild asthma and the 15-17 age group with severe asthma. The exception for PM10 is the 10-14 age group with severe asthma. Additionally, this result appears to hold across severity classes. Although we initially stratified our sample by severity level due to concerns that maintenance drugs could dampen the impact of air pollution on the use of quick relief medications, this does not appear to be the case. The implication of these general results is that children are more highly affected by air pollution than adults. To more thoroughly test this hypothesis, however, we would need to formally test if the coefficients are statistically different from one another across models.

A potential alternative explanation for higher coefficients for children is that child asthmatics are more quick to be medicated than adults. Because parents are making, or at the very least assisting in, the decision to go to the doctor and fill prescriptions, there is a concern that parental altruism could lead to higher rates of medication for children than for adults. That is, parents could be more concerned about providing their children relief from asthma symptoms than adults are for their own symptoms. We do not believe that our results provide evidence of this altruistic effect however since the coefficients on the 10-14 and 15-17 age groups are still higher than those for the adult age group. Since these teenaged groups are less reliant upon their parents to make their decisions, we would expect to see a drop off in magnitude for these groups if parents were in fact over-providing for their children. The absence of this decline leads us to believe that the alternative explanation is not the primary driver of our results.

As before, minimum temperature is not significant but holds the expected negative sign for most models. Population and land area are unsurprisingly positive and significant, but of a relatively small magnitude in effect. The sign of the coefficient for the race percentages are often reversed from Table 4, which will require further analysis.

One interesting result from these models is the reversal in sign for percent urban, median household income, and their interaction. Median income was positive in Table 4, which can be explained as the ability of wealthier households to afford prescriptions; but this is not the only story that can be told with income. Wealthier households also have the ability to pay to avert the asthma triggers, which would suggest a negative coefficient for income. The fact that the number of prescriptions for children declines with income suggests that wealthier parents are better able to avoid the asthma triggers for their children. Further study is clearly warranted.

Conclusion

With the growing concern about increasing asthma rates, studies that further our understanding of the causes of asthma exacerbation are timely. If, as our study shows, chronic exposure to higher levels of air pollution leads to increases in asthma symptoms and the use of asthma medication, then reductions in these air pollutants will produce benefits that have previously been difficult to quantify. The benefits of reducing *serious* asthma attacks can be analyzed by examining emergency room visits and hospital admissions. The benefits associated with a decline in the outcomes analyzed here, the reduced use of quick acting asthma medication, have been somewhat more elusive as they are not as easily observable as ER visits. In contrast to diary studies, which examine the effect of short-term exposure to air pollution, this study looks at the effect of longer term or chronic exposures to air pollution on asthma symptoms by examining prescription data at the zip code level for California.

The results of Tables 3 and 4 show a statistically significant positive association between total prescriptions per capita for quick-acting asthma medication and air pollution. Including measures for both ozone and PM10, and controlling for temperature and demographics, we find that PM10 is a more important driver in explaining the increase in prescriptions per capita than ozone.

In the Poisson model of prescription counts presented in Tables 5-9, however, both pollution measures are significant. Disaggregation by age class suggests that children are affected more by air pollution than adults, and this effect appears to be true across severity levels. Additional tests of statistical significance will be required in the future to be more certain of this effect.

This preliminary analysis shows that there are real consequences to long term exposure to air pollution. We would, however, like to refine our approach in a number of ways. First, the data used here only include pharmacies that report their prescriptions consistently, with no less than eleven days of missing data per month. Adding the additional “inconsistent” pharmacies will increase the number of zip codes analyzed and may reveal important interactions, but must be done carefully to control for the additional noise. Second, there are additional variables that we would like to consider including, such as PM2.5 and the number of days in which a zip code was above a chosen pollution threshold. Third, there are a number of spatial issues that we should address. Kriging techniques will eliminate the need to link zip codes to specific pollution monitors and weather stations. We should also consider spatial factors that are currently excluded, such as the north to south mountain line in California and the spatial impact of CSMAs. The model may suffer from both heteroskedasticity and spatial autocorrelation, and further analysis must be done. Finally, this data could be combined with cost information to get an estimate of the benefits. All of these factors are expected to improve the analysis and the usefulness of the results.

Table 1: Asthma Medication

Symptomatic Therapy (Quick Relief)
Albuterol
Bitolterol
Isoetharine
Metaproteronol
Pirbuterol
Terbutaline

Controller Therapy (Long-term preventative)
Inhaled Corticosteroids
  Beclomethasone
  Budesonide
  Flunisolide
  Fluticasone
  Triamcinolone
Leukotriene Antagonists
  Motelukast
  Zafirlukast
  Zileutin
Long Acting Beta Agonists
  Salmeterol
Xanthine Derivatives
  Aminophylline
  Dyphylline
  Oxtriphylline
  Theophylline

Table 2: Summary Statistics

Variable	*All Ages*					*Ages 0 to 4*				
	Total Prescriptions	*Asthma Severity*				*Total Prescriptions*	*Asthma Severity*			
		Mild	*Mild Persistent*	*Moderate*	*Severe*		*Mild*	*Mild Persistent*	*Moderate*	*Severe*
Number of Observations	*7735*	*7735*	*7735*	*7735*	*7735*	*7413*	*7413*	*7413*	*7413*	*7413*
Num. of Obs.= 0	*0*	*1*	*5*	*11*	*80*	*0*	*117*	*753*	*3083*	*5851*
mean	*654.6344*	*315.155*	*194.381*	*96.87964*	*48.21875*	*32.22474*	*20.36234*	*8.872791*	*2.404829*	*0.5847835*
standard error	*478.487*	*238.5405*	*141.9122*	*72.01196*	*40.0092*	*33.54975*	*22.52427*	*9.897485*	*3.666297*	*1.571809*
median	*540*	*255*	*161*	*80*	*38*	*22*	*13*	*6*	*1*	*0*
min	*1*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*
max	*3477*	*1819*	*975*	*509*	*297*	*416*	*300*	*115*	*46*	*26*
skewness	*1.280852*	*1.385644*	*1.242319*	*1.280196*	*1.498094*	*2.816224*	*3.161856*	*2.517794*	*3.026762*	*4.490084*
kurtosis	*5.031391*	*5.450395*	*4.903892*	*5.000356*	*6.157983*	*17.43484*	*21.43579*	*13.43679*	*18.81439*	*34.22082*

Table 2 (continued): Summary Statistics

Statistic	*Ages 5 to 9*					*Ages 10 to1 4*				
	Total Prescriptions	*Asthma Severity*				*Total Prescriptions*	*Asthma Severity*			
		Mild	*Mild Persistent*	*Moderate*	*Severe*		*Mild*	*Mild Persistent*	*Moderate*	*Severe*
Number of Observations	*7500*	*7500*	*7500*	*7500*	*7500*	*7526*	*7526*	*7526*	*7526*	*7526*
Num. of Obs.= 0	*0*	*93*	*397*	*1647*	*4013*	*0*	*72*	*391*	*1420*	*3150*
mean	*46.70533*	*25.71613*	*14.0568*	*5.108667*	*1.823733*	*54.44592*	*29.49043*	*15.52897*	*6.3941*	*3.032421*
standard error	*42.98077*	*24.56539*	*14.15905*	*5.935202*	*3.128466*	*47.55257*	*25.87634*	*14.98555*	*7.142006*	*4.452154*
median	*35*	*19*	*10*	*3*	*0*	*42*	*22*	*11*	*4*	*1*
min	*1*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*
max	*354*	*217*	*146*	*51*	*31*	*391*	*192*	*146*	*66*	*47*
skewness	*1.929676*	*2.076474*	*2.198623*	*2.095364*	*2.842234*	*1.760224*	*1.734572*	*1.952528*	*2.047073*	*2.57068*
kurtosis	*8.289729*	*9.382513*	*10.80206*	*9.473676*	*14.19708*	*7.588125*	*7.232487*	*9.045644*	*9.842268*	*13.16101*

Table 2 (continued): Summary Statistics

Statistic	*Ages 15 to 17*					*All Other Ages (Not including Unknown Age)*				
	Total Prescriptions	*Asthma Severity*				*Total Prescriptions*	*Asthma Severity*			
		Mild	*Mild Persistent*	*Moderate*	*Severe*		*Mild*	*Mild Persistent*	*Moderate*	*Severe*
Number of Observations	*7372*	*7372*	*7372*	*7372*	*7372*	*7203*	*7203*	*7203*	*7203*	*7203*
Num. of Obs.= 0	*0*	*150*	*940*	*2885*	*4968*	*0*	*0*	*0*	*5*	*59*
mean	*24.94886*	*14.64162*	*6.619506*	*2.587222*	*1.100515*	*525.0769*	*238.6608*	*157.6731*	*84.77398*	*43.96904*
standard error	*21.68575*	*12.91774*	*6.794598*	*3.439279*	*2.216614*	*360.2993*	*168.8212*	*109.4798*	*59.77791*	*34.86793*
median	*19*	*11*	*5*	*1*	*0*	*437*	*196*	*132*	*71*	*36*
min	*1*	*0*	*0*	*0*	*0*	*13*	*5*	*2*	*0*	*0*
max	*181*	*105*	*74*	*37*	*18*	*2631*	*1344*	*847*	*426*	*259*
skewness	*1.757481*	*1.653192*	*2.08444*	*2.202667*	*2.853334*	*1.241226*	*1.331471*	*1.253321*	*1.225283*	*1.443805*
kurtosis	*7.937582*	*6.829426*	*10.7228*	*11.39897*	*12.98792*	*4.827885*	*5.198832*	*4.973804*	*4.725747*	*6.050527*

Table 2 (continued): Summary Statistics

	Air Pollution Measures (Averaged over quarter)				*Minimum Daily Temperature (Averaged over Quarter*	*Demographic Characteristics (Zip Code Level)*				
	PM10, Daily Average	*Ozone (8-hour Maximum)*	*NOx, Daily Average*	*SO2, Daily Average*		*Median Household Income*	*Percent of Population Described as Black*	*Percent of Population Described as Asian*	*Percent of Population Described as Hispanic*	*Percent of Population in Urban Areas*
Number of Observations	*7674*	*7686*	*5760*	*4094*	*7735*	*7735*	*7735*	*7735*	*7735*	*7735*
mean	*34.31513*	*0.0392582*	*0.0623078*	*0.0025247*	*71.45207*	*50861.48*	*0.0643355*	*0.1192618*	*0.7050654*	*0.9721459*
standard error	*13.34303*	*0.0153724*	*0.0435055*	*0.0015707*	*1090.728*	*20244.88*	*0.0984705*	*0.1125274*	*0.2311541*	*0.0957774*
median	*32.86667*	*0.0368043*	*0.0510809*	*0.00242*	*52.22826*	*47573*	*0.0301147*	*0.0796252*	*0.7743347*	*1*
min	*6*	*0.00924*	*0.0024422*	*0.0000247*	*25.97826*	*8855*	*0.0014281*	*0.0011747*	*0.0277646*	*0*
max	*117.3297*	*0.111*	*0.233938*	*0.0096099*	*72844.09*	*164479*	*0.7851492*	*0.5902053*	*0.9782452*	*1*
skewness	*1.022263*	*1.008934*	*1.195364*	*0.6086475*	*62.44114*	*1.296063*	*3.664492*	*1.79449*	*-1.014786*	*-6.577531*
kurtosis	*4.668436*	*4.238362*	*4.035975*	*3.138443*	*3933.274*	*5.903643*	*19.6607*	*6.317696*	*3.160587*	*58.08569*

Table 2 (continued): Summary Statistics

	Population in Each Age (Zip Code Level)						*Geographic Characteristics*	
	Total	*Ages 0-4*	*Ages 5-9*	*Ages 10-14*	*Ages 15-17*	*Other Ages*	*arealand*	*popden*
Number of Observations	*7735*	*7735*	*7735*	*7735*	*7735*	*7735*	*7735*	*7688*
mean	*36925.78*	*2708.643*	*2921.787*	*2690.622*	*1528.824*	*27075.9*	*1.08e+08*	*0.002573*
standard error	*18392.4*	*1884.077*	*2033.976*	*1764.129*	*986.8849*	*12531.04*	*3.14e+08*	*0.0031668*
median	*33520*	*2280*	*2425*	*2297*	*1344*	*25492*	*1.80e+07*	*0.0020154*
min	*294*	*9*	*9*	*7*	*20*	*179*	*0*	*1.33e-06*
max	*105275*	*11955*	*12546*	*10151*	*5505*	*70049*	*3.68e+09*	*0.0420212*
skewness	*0.7853757*	*1.315397*	*1.309443*	*1.125955*	*1.049795*	*0.6008423*	*6.519869*	*5.466631*
kurtosis	*3.69066*	*5.062044*	*5.117194*	*4.533889*	*4.25487*	*3.245719*	*57.26882*	*56.75337*

Table 3: Weighted OLS Regressions of Total Prescriptions per Capita
Weight=Number of Pharmacies Reporting

Variable	Model 1	Model 2	Model 3	Model 4
Ozone (8 hour max)	0.0130 (0.0722)	--	-0.1075 (0.0727)	-0.1674* (0.0924)
Ozone^2 (8 hour max)	-0.2387 (0.6934)	--	0.0622 (0.6989)	-0.2853 (0.8221)
Particulate Matter (<10u)	--	0.0006** (0.0001)	0.0007** (0.0001)	0.0001 (0.0001)
Particulate Matter^2 (<10u)	--	-6.22×10^{-6}** (8.36×10^{-7})	-6.05×10^{-6}** (8.51×10^{-7})	-1.76×10^{-6} (1.36×10^{-6})
SO^2	--	--	--	0.8224** (0.2113)
NOx	--	--	--	0.0534** (0.0140)
Minimum Temperature	-2.98×10^{-7} (2.67×10^{-7})	-2.71×10^{-7} (2.65×10^{-7})	-2.46×10^{-7} (2.65×10^{-7})	-3.30×10^{-7} (2.40×10^{-7})
Population Density	0.2303** (0.0943)	0.1574* (0.0916)	0.0640 (0.0946)	-0.1040 (0.1901)
Percent Urban	-0.0546** (0.0086)	-0.0584** (0.0084)	-0.0584** (0.0085)	-0.6496** (0.0417)
Median Household Income	1.11×10^{-6}** (1.78×10^{-7})	1.10×10^{-6}** (1.75×10^{-7})	1.12×10^{-6}** (1.76×10^{-7})	8.51×10^{-6}** (8.17×10^{-7})
%Urban*Median HH Income	-1.19×10^{-6}** (1.82×10^{-7})	-1.15×10^{-6}** (1.80×10^{-7})	-1.19×10^{-6}** (1.81×10^{-7})	-8.61×10^{-6}** (8.29×10^{-7})
Percent Black	-0.0066** (0.0026)	-0.0020 (0.0026)	-0.0033 (0.0026)	0.0236** (0.0035)
Percent Asian	-0.0052** (0.0022)	-0.0066** (0.0021)	-0.0081** (0.0022)	0.0030* (0.0027)
Percent Hispanic	0.0234** (0.0014)	0.0256** (0.0014)	0.0260** (0.0014)	0.0155** (0.0018)
Quarter 2 (Apr, May, June)	-0.0022** (0.0008)	-0.0021** (0.0006)	-0.0003 (0.0008)	0.0042** (0.0013)
Quarter 3 (July, Aug, Sep)	-0.0046** (0.0008)	-0.0051** (0.0006)	-0.0034** (0.0008)	0.0015 (0.0013)
Quarter 4 (Oct, Nov, Dec)	0.0003 (0.0007)	-0.0011 (0.0007)	-0.0017** (0.0007)	-0.0017* (0.0010)
Trend	0.0002** (0.0001)	0.0002** (0.0001)	0.0002** (0.0001)	0.0003** (0.0001)
Constant	0.0646** (0.0085)	0.0532** (0.0084)	0.0559** (0.0084)	0.6510** (0.0414)
Number of Observations	7639	7628	7579	3284
R^2	0.2413	0.2519	0.2534	0.5149

Table 4: Weighted OLS Regressions of Prescriptions per Capita by Asthma Severity Level Weight=Number of Pharmacies Reporting

Variable	Mild	Mild Persistent	Moderate Persistent	Severe
Ozone (8 hour max)	0.0076 (0.0343)	-0.0615** (0.0230)	-0.0352 (0.0123)	-0.0183** (0.0063)
$Ozone^2$ (8 hour max)	-0.4843 (0.3301)	0.2733 (0.2210)	0.1807 (0.1186)	0.0925 (0.0604)
Particulate Matter (<10u)	0.0004** (0.00003)	0.0002** (0.00002)	0.0001** (0.00001)	0.00005** ($6.30x10^{-6}$)
Particulate $Matter^2$ (<10u)	$-3.24x10^{-6}$** ($4.02x10^{-7}$)	$-1.53x10^{-6}$** ($2.69x10^{-7}$)	$-8.42x10^{-7}$** ($1.44x10^{-7}$)	$-4.37x10^{-7}$** ($7.36x10^{-8}$)
Minimum Temperature	$-1.04x10^{-7}$ (1.25x10-7)	$-9.25x10^{-8}$ ($8.38x10^{-8}$)	$-2.73x10^{-8}$ ($4.50x10^{-8}$)	$-2.18x10^{-8}$ ($2.29x10^{-8}$)
Population Density	0.0616 (0.0447)	0.0176 (0.0299)	0.0032 (0.0161)	-0.0185** (0.0081)
Percent Urban	-0.0270** (0.0040)	-0.0221** (0.0027)	-0.0063** (0.0014)	-0.0030** (0.0007)
Median Household Income	$4.84x10^{-7}$** ($8.33x10^{-8}$)	$2.65x10^{-7}$** ($5.57x10^{-8}$)	$2.85x10^{-7}$** ($2.99x10^{-8}$)	$8.92x10^{-8}$ ($1.52x10^{-8}$)
%Urban*Median HH Income	$-5.08x10^{-7}$** ($8.53x10^{-8}$)	$-2.80x10^{-7}$** ($5.71x10^{-6}$)	$-3.01x10^{-7}$** ($3.07x10^{-8}$)	$-1.02x10^{-7}$** ($1.56x10^{-8}$)
Percent Black	$-5.32x10^{-6}$ (0.0012)	-0.0007 (0.0008)	-0.0017** (0.0004)	-0.0009** (0.0002)
Percent Asian	-0.0043** (0.0010)	-0.0018** (0.0007)	0.0009** (0.0004)	-0.0010 (0.0002)
Percent Hispanic	0.0110** (0.0007)	0.0075** (0.0004)	0.0049** (0.0002)	0.0025** (0.0001)
Quarter 2 (Apr, May, June)	-0.0013** (0.0004)	0.0006** (0.0003)	0.0003** (0.0001)	0.0001* (0.0001)
Quarter 3 (July, Aug, Sep)	-0.0032** (0.0004)	-0.0001 (0.0002)	-0.0001 (0.0001)	-0.00002 (0.0001)
Quarter 4 (Oct, Nov, Dec)	-0.0010** (0.0003)	0.0001 (0.0002)	-0.0004** (0.0001)	-0.0003** (0.0001)
Trend	0.0001** (0.00002)	-0.00001 (0.00002)	0.00004** ($8.61x10^{-6}$)	0.00003** ($4.44x10^{-6}$)
Constant	0.0244** (0.0040)	0.0226** (0.0027)	0.0058** (0.0014)	0.0031** (0.0007)
Number of Observations	7579	7579	7579	7579
R^2	0.2398	0.2352	0.2752	0.2061

Table 5: Poisson Regressions of Prescriptions Counts by Asthma Severity, Age 0-4
Weight=Number of Pharmacies Reporting

Variable	Mild	Mild Persistent	Moderate Persistent	Severe
Ozone (8 hour max)	10.97834** (0.7579566)	20.54198** (1.095515)	14.51552** (2.160324)	-5.556807 (4.617046)
Ozone2 (8 hour max)	-124.1338** (7.629936)	-140.9479** (10.66574)	-146.5154** (21.7495)	4.105722 (46.94952)
Particulate Matter (<10u)	0.0254418** (0.0008049)	0.0146184** (0.0011707)	0.0164327** (0.0024019)	0.0357992** (0.0051865)
Particulate Matter2 (<10u)	-0.0001945** (0.0000092)	-0.0001164** (0.0000133)	-0.000122** (0.0000275)	-0.0003103** (0.0000605)
Minimum Temperature	-0.00000031 (0.0000042)	-0.000012 (0.00000794)	-0.007008** (0.0021487)	-0.0120306** (0.0044281)
Population	0.0000139** (0.000000143)	0.0000146** (0.000000221)	0.0000115** (0.000000425)	0.00000283** (0.000000902)
Land Area	5.60e-11** (9.26e-12)	5.21e-11** (1.35e-11)	2.20e-10** (2.35e-11)	2.21e-10** (4.64e-11)
Percent Urban	0.3792007** (0.1462972)	-0.5283571** (0.1878531)	-0.0521455 (0.4021566)	1.496921** (0.5826956)
Median Household Income	-0.0000191** (0.00000318)	-0.0000244** (0.00000427)	-0.0000339** (0.00000869)	0.0000285** (0.0000119)
%Urban*Median HH Income	0.0000233** (0.00000322)	0.0000262** (0.00000433)	0.0000431** (0.00000879)	-0.0000283** (0.0000122)
Percent Black	1.763746** (0.0231235)	1.344907** (0.0377671)	1.45492** (0.0712859)	0.9173831** (0.1493707)
Percent Asian	-0.0656788** (0.022915)	0.179164** (0.0338249)	0.4977336** (0.0618611)	0.6452012** (0.1255217)
Percent Hispanic	-0.442947** (0.015432)	0.0482735** (0.0237485)	-0.1543095** (0.0457842)	-0.1006465 (0.0935472)
Quarter 2 (Apr, May, June)	-0.4872949** (0.0084444)	-0.4346739** (0.0127981)	-0.2642642** (0.0282335)	-0.1460141** (0.0594354)
Quarter 3 (July, Aug, Sep)	-0.7119725** (0.008591)	-0.6088005** (0.0129702)	-0.4013929** (0.0367868)	-0.3089985** (0.0765735)
Quarter 4 (Oct, Nov, Dec)	-0.2182028** (0.0065429)	-0.0244281** (0.0101834)	-0.2728652** (0.0202581)	-0.5376679** (0.0425356)
Trend	0.0348096** (0.0005428)	0.0461616** (0.0008227)	0.1054164** (0.0016332)	0.1559188** (0.003684)
Constant	1.441439** (0.1452816)	1.004536** (0.1871769)	-0.9154803** (0.4033416)	-3.354994** (0.5953013)
Number of Observations	7305	7305	7305	7305
Pseudo R2	0.27	0.1719	0.1429	0.1098

Table 6: Poisson Regressions of Prescriptions Counts by Asthma Severity, Age 5-9
Weight=Number of Pharmacies Reporting

Variable	Mild	Mild Persistent	Moderate Persistent	Severe
Ozone (8 hour max)	25.04567** (0.6661456)	29.17234** (0.8986673)	26.42362** (1.466198)	23.88336** (2.410876)
Ozone2 (8 hour max)	-236.7028** (6.636413)	-233.8192** (8.818661)	-216.934** (14.37449)	-177.3323** (23.72769)
Particulate Matter (<10u)	0.0261766** (0.0007097)	0.0193574** (0.0009517)	0.0166144** (0.0015273)	-0.0002486 (0.0024129)
Particulate Matter2 (<10u)	-0.0002214** (0.00000802)	-0.0001766** (0.0000108)	-0.0001489** (0.0000174)	-0.0000073 (0.0000278)
Minimum Temperature	-0.0000103** (0.00000442)	-0.0000119** (0.00000592)	-0.00000757 (0.00000871)	0.0000017 (0.000011)
Population	0.0000161** (0.000000126)	0.0000138** (0.000000172)	0.0000151** (0.000000287)	0.000015** (0.000000483)
Land Area	1.01e-10** (7.67e-12)	2.33e-11** (1.07e-11)	1.30e-10** (1.61e-11)	1.75e-10** (2.60e-11)
Percent Urban	0.503357** (0.1178582)	-0.1344909 (0.1502643)	-0.6599364** (0.2223536)	0.718834** (0.3413284)
Median Household Income	-0.00000436* (0.00000251)	-0.0000151** (0.00000338)	-0.0000186** (0.00000511)	0.0000104 (0.00000712)
%Urban*Median HH Income	0.00000853** (0.00000255)	0.0000156** (0.00000343)	0.0000191** (0.00000519)	-0.00000989 (0.00000726)
Percent Black	1.680733** (0.0210708)	1.8477** (0.0276487)	1.266928** (0.0496734)	1.224149** (0.0838741)
Percent Asian	-0.0508744** (0.0202658)	-0.0538819* (0.0277586)	0.3131667** (0.043206)	0.7048495** (0.0682401)
Percent Hispanic	-0.2934698** (0.0137165)	-0.1937725** (0.0185691)	0.1950645** (0.0310077)	0.7475832** (0.0530349)
Quarter 2 (Apr, May, June)	-0.2438594** (0.0075468)	-0.2571905** (0.0102463)	-0.223105** (0.0166626)	-0.2601726** (0.0265451)
Quarter 3 (July, Aug, Sep)	-0.3288345** (0.0075107)	-0.3087052** (0.010158)	-0.3110525** (0.0164871)	-0.4230715** (0.0263215)
Quarter 4 (Oct, Nov, Dec)	0.147668** (0.0060709)	0.1694812** (0.0083697)	0.0465003** (0.0137708)	-0.1586523** (0.0226232)
Trend	0.0267533** (0.0004748)	0.0317252** (0.0006429)	0.0593349** (0.0010717)	0.0939584** (0.001806)
Constant	0.8511665** (0.1171189)	1.038824** (0.1497897)	0.1434398 (0.2223432)	-2.493021** (0.3411868)
Number of Observations	7392	7392	7392	7392
Pseudo R2	0.267	0.2003	0.1302	0.1039

Table 7: Poisson Regressions of Prescriptions Counts by Asthma Severity, Age 10-14 Weight=Number of Pharmacies Reporting

Variable	Mild	Mild Persistent	Moderate Persistent	Severe
Ozone (8 hour max)	28.03876** (0.6175952)	25.78255** (0.8377723)	24.9128** (1.298766)	34.19182** (1.88376)
Ozone2 (8 hour max)	-238.5753** (6.038243)	-203.1505** (8.048794)	-203.1219** (12.47718)	-234.6526** (18.20284)
Particulate Matter (<10u)	0.0236093** (0.0006542)	0.0180628** (0.0008845)	0.0199478** (0.0013377)	0.0039002** (0.0018807)
Particulate Matter2 (<10u)	-0.0002218** (0.00000744)	-0.0001555** (0.00000996)	-0.0001527** (0.000015)	-0.0000521** (0.0000216)
Minimum Temperature	-0.0000102** (0.00000365)	-0.00000448 (0.00000412)	-0.00000303 (0.00000632)	0.00000565 (0.00000661)
Population	0.0000169** (0.000000119)	0.0000167** (0.000000164)	0.0000154** (0.000000258)	0.0000143** (0.000000368)
Land Area	1.26e-10** (6.75e-12)	8.84e-11** (9.41e-12)	1.85e-10** (1.35e-11)	1.17e-10** (1.93e-11)
Percent Urban	-0.1884366** (0.0946442)	-0.0807457 (0.1230779)	0.7162738** (0.1918656)	-0.3309048 (0.2470555)
Median Household Income	-0.0000101** (0.00000208)	-0.00000234 (0.0000027)	0.00000718* (0.00000412)	-0.00000828 (0.00000564)
%Urban*Median HH Income	0.0000116** (0.00000212)	0.00000279 (0.00000276)	-0.00000919** (0.0000042)	0.00000626 (0.00000576)
Percent Black	1.161845** (0.0209779)	1.189558** (0.0287297)	0.9960942** (0.0454172)	1.400747** (0.0617281)
Percent Asian	-0.2380888** (0.019031)	-0.3749473** (0.026684)	-0.3028831** (0.0402521)	-0.3933124** (0.0595809)
Percent Hispanic	0.1120475** (0.0128876)	0.0784604** (0.0176528)	0.4877225** (0.0276418)	0.3494201** (0.0390927)
Quarter 2 (Apr, May, June)	-0.2254476** (0.0070148)	-0.138979** (0.0096739)	-0.1730995** (0.0148544)	-0.3981783** (0.0208331)
Quarter 3 (July, Aug, Sep)	-0.2536546** (0.0069258)	-0.2035237** (0.0096004)	-0.2518753** (0.0146603)	-0.4719592** (0.0206247)
Quarter 4 (Oct, Nov, Dec)	0.1051401** (0.0057953)	0.1196589** (0.0081355)	-0.0479534** (0.012476)	-0.1766381** (0.0177604)
Trend	0.0289785** (0.0004429)	0.0307646** (0.0006113)	0.0559504** (0.0009569)	0.0722986** (0.0013776)
Constant	1.50311** (0.0943713)	0.92306** (0.1228649)	-1.060152** (0.191468)	-0.5046592** (0.2478894)
Number of Observations	7419	7419	7419	7419
Pseudo R2	0.2237	0.1822	0.1301	0.1067

**Table 8: Poisson Regressions of Prescriptions Counts by Asthma Severity, Age 15-17
Weight=Number of Pharmacies Reporting**

Variable	Mild	Mild Persistent	Moderate Persistent	Severe
Ozone (8 hour max)	29.71956** (0.8649563)	27.33543** (1.286507)	14.47834** (2.03114)	8.698405** (3.117208)
Ozone2 (8 hour max)	-236.204** (8.356989)	-186.2598** (12.29424)	-105.4592** (19.44391)	-78.27337** (30.2128)
Particulate Matter (<10u)	0.0154751** (0.0009089)	0.0059427** (0.0013446)	0.0012557 (0.0020533)	0.0264459** (0.003321)
Particulate Matter2 (<10u)	-0.0001425** (0.0000102)	-0.0000679** (0.0000152)	0.00000691 (0.0000232)	-0.0002815** (0.0000387)
Minimum Temperature	-0.0000114** (0.00000494)	0.00000057 (0.00000488)	-0.0000108 (0.0000117)	-0.0000149 (0.0000222)
Population	0.0000174** (0.000000173)	0.0000148** (0.000000261)	0.0000135** (0.00000042)	0.0000189** (0.000000622)
Land Area	1.45e-10** (9.39e-12)	8.43e-11** (1.43e-11)	5.23e-11** (2.33e-11)	3.07e-10** (2.96e-11)
Percent Urban	-0.4985458** (0.1269028)	0.0284296 (0.1741472)	1.657045** (0.2981351)	1.178507** (0.4284837)
Median Household Income	-0.0000129** (0.00000286)	0.00000297 (0.00000387)	0.000019** (0.00000622)	0.0000214** (0.00000908)
%Urban*Median HH Income	0.0000126** (0.00000291)	-0.00000643 (0.00000395)	-0.0000274** (0.00000636)	-0.0000272** (0.0000093)
Percent Black	0.4924911** (0.0329554)	0.3758033** (0.0496094)	-0.2861978** (0.0817554)	0.256651** (0.1179288)
Percent Asian	0.0228642 (0.0263798)	0.241977** (0.0392867)	-0.5079986** (0.0639874)	-0.1860021** (0.0926533)
Percent Hispanic	0.3924904** (0.0186063)	0.3152129** (0.0277944)	0.9438262** (0.0446383)	1.100225** (0.0677743)
Quarter 2 (Apr, May, June)	-0.2539285** (0.0099014)	-0.2323478** (0.0148334)	-0.1070033** (0.023374)	-0.1099388** (0.0350731)
Quarter 3 (July, Aug, Sep)	-0.320088** (0.009909)	-0.3221051** (0.014892)	-0.1877639** (0.0230491)	-0.2353972** (0.0345231)
Quarter 4 (Oct, Nov, Dec)	0.0941159** (0.0082749)	0.0920717** (0.0125823)	-0.018283 (0.01995)	-0.1739332** (0.0296074)
Trend	0.0210245** (0.0006325)	0.0294507** (0.0009492)	0.0543165** (0.0015128)	0.0716631** (0.0023154)
Constant	1.20086** (0.1269083)	0.3136288* (0.1746926)	-2.058707** (0.2975482)	-3.390688** (0.4285481)
Number of Observations	7266	7266	7266	7266
Pseudo R2	0.1673	0.1009	0.0643	0.0688

Table 9: Poisson Regressions of Prescriptions Counts by Asthma Severity, Adults and Unknown Age. Weight=Number of Pharmacies Reporting

Variable	Mild	Mild Persistent	Moderate Persistent	Severe
Ozone (8 hour max)	15.26694** (0.2143931)	10.04354** (0.2594564)	10.09516** (0.3530363)	11.07596** (0.494678)
Ozone2 (8 hour max)	-137.5383** (2.068485)	-89.2845** (2.462988)	-90.0965** (3.343758)	-93.8065** (4.698299)
Particulate Matter (<10u)	0.0118307** (0.0002222)	0.0042399** (0.0002723)	0.0047997** (0.0003668)	0.0100922** (0.0005134)
Particulate Matter2 (<10u)	-0.0000975** (0.00000252)	-0.0000398** (0.00000309)	-0.0000399** (0.00000416)	-0.0001046** (0.00000589)
Minimum Temperature	-0.0000093** (0.00000108)	-0.000016** (0.00000154)	-0.00000472** (0.00000145)	-0.0000154** (0.00000289)
Population	0.0000154** (0.000000044)	0.0000153** (0.0000000544)	0.0000154** (0.0000000744)	0.0000158** (0.000000102)
Land Area	1.38e-10** (2.40e-12)	1.38e-10** (2.95e-12)	1.30e-10** (4.00e-12)	1.56e-10** (5.34e-12)
Percent Urban	-0.0999528** (0.0384481)	-0.6880752** (0.0451822)	-0.5357108** (0.0595523)	0.0711288 (0.0833222)
Median Household Income	-0.0000332** (0.000000868)	-0.000041** (0.00000104)	-0.0000366** (0.00000136)	-0.000027** (0.00000189)
%Urban*Median HH Income	0.0000309** (0.000000879)	0.0000396** (0.00000105)	0.0000337** (0.00000138)	0.0000219** (0.00000192)
Percent Black	-0.5558639** (0.0089839)	-0.484152** (0.0110197)	-0.8177009** (0.0155494)	-0.3448258** (0.0200027)
Percent Asian	-0.3890154** (0.0065659)	-0.1740856** (0.0079606)	-0.3039745** (0.0108593)	-0.7124759** (0.0155441)
Percent Hispanic	0.8090284** (0.0046989)	0.8202236** (0.0058361)	1.015736** (0.0079707)	1.1424** (0.0109535)
Quarter 2 (Apr, May, June)	-0.2346234** (0.0024129)	-0.0663938** (0.0029677)	-0.0634297** (0.0040307)	-0.0832976** (0.0055787)
Quarter 3 (July, Aug, Sep)	-0.3617096** (0.0024305)	-0.1141889** (0.0029412)	-0.1068483** (0.0039732)	-0.1276086** (0.0054838)
Quarter 4 (Oct, Nov, Dec)	-0.0433887** (0.0020208)	0.0684658** (0.002569)	-0.0132208** (0.0035097)	-0.0756691** (0.004855)
Trend	0.0003705** (0.0001565)	-0.0150399** (0.0001917)	-0.0016361** (0.0002603)	0.0097948** (0.0003599)
Constant	4.334623** (0.0382833)	4.737721** (0.0450788)	3.821455** (0.0594479)	2.392236** (0.0831055)
Number of Observations	7097	7097	7097	7097
Pseudo R2	0.2405	0.2062	0.1817	0.1549

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Comments on Air Pollution and Asthma in Children

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Context

- Since 1990, at least 18 studies have been published examining the relationship between air pollution and symptoms in asthmatics
- Findings have been equivocal, although most have found significant relationships between at least one air pollutant and asthma symptoms
- Symptom measures vary, with some focusing on individual symptom indicators, like cough, and some focusing on symptom scales or asthma attacks/episodes

Impacts of Nonroad Diesel Emission Reductions on Asthmatics

Endpoint (Study population)	**Study**	**Avoided Incidence in 2030**
Asthma Attack Indicators		
Shortness of Breath (African American asthmatics, 8-13)	Ostro et al. (2001)	15,000
Cough (African American asthmatics, 8-13)	Ostro et al. (2001)	31,000
Wheeze (African American asthmatics, 8-13)	Ostro et al. (2001)	24,000
Asthma Exacerbation – one or more symptoms (Asthmatics, 5-13)	Yu et al. (2000)	530,000
Cough (Asthmatics, 6-13)	Vedal et al. (1998)	240,000
Asthma Attacks (Asthmatics, all ages)	Whittemore and Korn (1980)	160,000
Other symptoms/illness endpoints		
Upper Respiratory Symptoms (Asthmatics 9-11)	Pope et al. (1991	120,000
Moderate or Worse Asthma (Asthmatics, all ages)	Ostro et al.	120,000
Acute Bronchitis (Asthmatics, 9-15)	McConnell et al. (1999)	4,700
Chronic Phlegm (Asthmatics, 9-15)	McConnell et al. (1999)	12,000

Context

- We currently do not assign a separate monetized value to “asthma attacks” or other indicators of asthma exacerbations
  - Estimates are dated (Rowe and Chestnut 1986)
  - May not reflect current best practices
  - Often not a good match between what has been valued, i.e. a “bad asthma day” and what has been measured, i.e. a day with wheeze or an “asthma attack”
- Gives the impression that asthma impacts are unimportant relative to other health impacts

What do these 3 papers add?

- 2 valuation/epidemiological studies
  - Hanemann and Brandt stated preference will provide a specific WTP for asthma related symptoms plus an understanding of costs of averting and mitigating behavior
  - Mansfield et al. revealed/stated preference provides a lower bound check on WTP for ozone related asthma symptoms, reflected the value of reductions in averting behavior.
- 1 epidemiological/valuation study
  - Griffith et al. examination of link between air pollution and asthma medication use (could also provide a lower bound estimate of marginal cost of higher pollution levels)

Valuation

- Current estimates of values for asthma symptoms are based on:
  - Rowe and Chestnut (1986) WTP for a “bad asthma day” ($43)
  - Tolley et al. (1986) WTP for a day with coughing ($25)
  - Berger et al. (1987) WTP for avoided “coughing spell” ($80)
  - Dickie and Ulery (2002) WTP for a child’s “symptom day” ($160)
- Not clear whether any of these provide a direct match with the WTP for specific symptoms or clusters of symptoms associated with an air pollution related asthma exacerbation

Hanemann and Brandt

- Provides a consistent framework for estimating health outcomes and valuation, incorporating averting and mitigating behavior
- Provides information on both revealed and stated preferences
- Morbidity outcomes capture both incidence and severity
- However:
  - Does not appear to integrate information on ozone or other pollution predictions (alert days)
  - Full set of data won't be available for 4 years!
  - Not clear on the CV question format. Consideration of conjoint approach to allow for variation in the type and severity of symptoms to match the epi design.

Mansfield et al.

- Excellent temporal sampling design, especially in selecting survey days to control for ozone-temperature interactions
- Large sample with detailed activity diaries on days with high and low pollution levels
- Unique combination of revealed averting behavior data with stated preference data on value of averting behavior
- However:
  - Difficulties with benefit transfer because of the limitation to stay at home parents
  - Representativeness of the Harris Interactive panel is questionable
  - Would be useful to include ozone/PM directly in model rather than “code red” day dummy

Bottom line: Will the 2 new valuation studies provide us with acceptable estimates of WTP?

- Hanemann RP will work IF we can get epi functions that have treated exposure averting behaviors as endogenous (the FACES study seems like it might provide this). SP would benefit from a conjoint design. Long time frame for study still leaves us in limbo…..
- Mansfield et al. specification yields some relatively modest results → a code red day only reduces time spent outdoors by around 43 minutes for asthmatic children, and 32 minutes for non-asthmatic children. Based on the SP results, this is valued at around $4 for asthmatic children and $3 for non-asthmatic children. Fairly low relative to other estimates.

Asthma Epidemiology

- Most asthma studies use a small sample (<200) with a diary approach
- Examination of medicine use has been limited
- Medicine use may provide an endpoint for which cost information is readily available

Griffith et al.

- Creative use of available data
- Use of quarterly averages for pollution effects to capture longer term "excess" prescriptions seems appropriate
- Suggestions
  - Prescriptions are actually a measure of demand, conditional on asthma attacks triggered by high pollution levels
  - Derive the demand functions using a household production function so that the econometric specification will have a grounding in economic theory and can be more easily compared/combined
  - Prescriptions per capita is potentially not as relevant as prescriptions per asthmatic, especially for younger age groups where asthma prevalence is higher
  - Use of alternate ozone metrics, e.g. cumulative number of hours over 60 ppb, may show a stronger relationship.
  - PM2.5 may be a better indicator than PM10
  - Should include interactions between quarter and air pollution metrics to control for potential exposure differences
  - Controls for numbers of prescriptions for maintenance medications might be important effect modifiers, representing substitutes for averting behaviors or expected rescue medication use

Implications of Griffith et al. for impact assessment

- Based on the Model 2 results in Table 3, a program like the proposed Nonroad diesel rule which would reduce annual mean PM2.5 (and PM10) levels by about 0.5 ug, might result in over 250,000 fewer prescriptions per year. (note that CA alone has over 2.1 million prescriptions for "quick relief" medicines each year)
- The age and severity stratified Poisson results seem to make more sense for ozone, which may indicate that the pooled OLS model is not the correct specification

What Can We Learn by Integrating?

Everyone should use a household production framework

- Makes life easier for those trying to compare/contrast results
- Ensures that averting and mitigating behaviors are considered

The Role of Medication Use in Assessing the Benefits of Air Pollution Programs is Important

- Hanemann and Brandt results show that use of medicine to mitigate risks from exposure is potentially important
- Griffith results show that the impacts of air pollution on “quick relief” prescriptions is significant
- Remaining issue is how use of prophylactic medicine modifies the effects of air pollution on “quick relief” medicine use

Averting Behavior Matters

- Hanemann and Brandt show that some parents are aware of air pollution as a potential trigger for asthma. They include exposure averting behavior in conceptual model for WTP – however, need to assure that measures of averting behavior include those specific to certain triggers, i.e. air pollution
- Mansfield et al. show that time spent indoors by asthmatic children is related to information on ozone alerts, and that parents are able to provide values for that lost time outdoors.
- Not clear how Griffith et al. results might be impacted by averting behavior. Might be able to use ozone alert days in a quarter as a measure of likely averting behavior.

Conclusions

- Hanemann and Brandt are taking an important step by integrating the epidemiology and economic valuation studies, however, the estimating equations for the epi study should be derived from the same behavioral framework, perhaps including prices and income as exogenous variables
- To measure the benefit of air pollution reductions, a full understanding of how knowledge of future air pollution affects averting behavior needs to be integrated into the epi and valuation models. Johnson et al. are providing that type of understanding.
- Complete benefits models should take into account the endogenous nature of the full pathway including event aversion (preventative medicine), exposure aversion (reducing time outdoors), response mitigation (use of rescue medication), and response (loss of school days, doctor visits).
- All three of these papers use data from CA. A comparative analysis bridging all three datasets will be very informative.

Laurie Chestnut, Discussant Comments Session V, Air Pollution and Asthma in Children October 21, 2003

Common to all three studies

- All three of the studies consider one or more behavior choices that avert or mitigate potential health effects of air pollution for people with asthma. These represent new contributions to the literature on valuation of asthma cure, management and symptom reduction. Considering behavior choices is important because:
    - Benefits estimates based solely on epidemiology dose-response estimates miss most averting and mitigating costs, because the studies capture the health effects that occur after averting and mitigating has taken place.
    - This behavioral context provides an opportunity for revealed preference analysis.
    - Stated preference survey design is enhanced when a realistic context is given to the valuation questions, which household behavior and choices provide.
    - Surveys can be used to collect information useful for estimating household production models. These questions may be easier to answer than direct valuation questions.
- These studies will extend and deepen the literature where there are a limited number of empirical estimates available for:
    - WTP values for reducing the frequency of asthma symptoms
    - WTP values for asthma cure and asthma management
- All the studies face many challenges in dealing with asthma, which is a complex condition:

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Many factors and-------------> Onset of asthma -------------> Aggravation of asthma
potentially pollution                                                   ^
                                                                        ^
                                                        pollution and other triggers
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    - Symptoms are intermittent
    - Great deal of heterogeneity among asthmatics regarding:
        - sensitivities to various triggers
        - frequency/severity of symptoms

Hanemann and Brandt – Specific Comments

- Study is focusing on asthma symptoms and exacerbations in children with asthma, and on household response and prevention efforts. Work is being conducted in association with an ongoing asthma patient research panel.

- Household production model

  - Conceptually sound

  - Good use of survey to obtain data on household behavior and perceptions

  - Challenges:

    - joint benefits of averting/mitigating activities, e.g. air conditioning

    - heterogeneity of sensitivities to triggers

    - timing dimension challenging to capture, e.g. symptoms, environmental conditions, activities, and household responses will all vary day-to-day

- Contingent Valuation

  - Good to use multiple valuation approaches with same subjects. Will have behavior information as well as answers to direct valuation questions.

  - Risk perception information should be helpful

  - Challenges

    - defining change in asthma symptoms is complicated by wide variation in frequency and severity of symptoms across subjects and over time.

    - linkages to epidemiology study results on asthma symptoms will be helpful for policy analysts, but sometimes difficult to define in valuation context.

Mansfield et al. – Specific Comments

- Good conceptual framework: How much do parents change children's time outdoors in response to ozone warnings? Sample includes about equal numbers of children with and without asthma.

- Internet survey approach with pre-selected panel allows efficient sampling of days with a range of ozone/weather conditions.

- Regardless of the WTP results, the study should proof informative regarding the public's response to the ozone warning system.

- Challenges:

  - Are about 3 days per subject enough for the planned analysis? This means the study is essentially a cross-sectional analysis making it harder to statistically identify the effect of ozone warnings.

  - Sensitivities to ozone vary among those with asthma—the asthma/non-asthma subject split may not be the best. Perceptions about sensitivity to air pollution are probably more important.

  - Odd preliminary results for the AWARE dummy variable indicating awareness of the ozone warning system. Might those who are more concerned about air pollution also be more aware of the system, making awareness more of an endogenous variable?

  - WTP to keep outdoor time is not the same thing as WTP to reduce asthma symptoms. The authors will need to think about how this information is useful to policy analysts. Should this WTP value be added to WTP to reduce pollution-related symptoms? How is the WTP value applicable in assessing benefits of pollution control?

Griffiths et al. – Specific Comments

- Addressing the question of whether purchases of quick relief asthma prescription medicines vary by location in relation to air pollution concentrations.
  - Quick relief asthma medicines are generally used in response to the onset of specific symptoms, rather than as a regularly used preventative medication.
  - Implications if the study finds an association is that asthma aggravations are more frequent in locations with higher pollution.
  - Use of quick relief medicine is a mitigating behavior expected to prevent symptoms from getting as severe as they might otherwise have.
- As with any cross-sectional study design, challenges are collinearity and unidentified confounders:
  - Quick relief prescriptions (counts or per capita rates) will capture higher prevalence of asthma as well as more frequent symptoms, unless the number of patients with asthma in each location is known.
  - Relative mix of controller and quick relief medicine usage may vary across locations because of differences in health care providers, socioeconomics, etc.
  - Density, poverty, traffic, pollution and asthma prevalence and management practices may be inter-related. This may have something to do with differences in preliminary results between PM10 and ozone. PM10 tends to be correlated with urban density, ozone less so because it tends to drift from original emission sources.
  - There may be differences across locations between average pollution concentrations and frequencies of pollution spikes.
  - Not normalizing the age group analysis by population size in an area could introduce population-related distortions. Using counts works fine for time series analysis where the population is stable day-to-day, but more problematic for a cross-sectional analysis.

Summary of Q&A Discussion Following Session V

Ronnie Levin (U.S. EPA, Region 1) commented that a study has been done in France on GI medications and drinking water quality "that has done some of what you're doing with time series and prescriptions—it's sort of a combination of time series and drug dispensures over time."

Ms. Levin also commented on the heterogeneity issue, which Laurie Chestnut dealt with, saying, "Yes, it's preferable for analytical purposes to use continuous vs. dichotomous variables. On the other hand, what *parents* get is dichotomous. So, if you want to not only test the *system* but really want to test the *effect*, it's the dichotomous variable that matters." She suggested perhaps just coding it, because "you lose information by reducing it all to continuous measures."

Shifting her comments to the asthma study, Ms. Levin stated that "17 percent of repeat hospital visitations are *not* people who are not following the orders—those are people who have severe asthma that is not controlled." She added that despite our desire and best efforts to reduce our exposures, both indoors and outdoors, that's not always an option, and she mentioned that available medications often don't provide real options either (she particularly cited the behavioral side-effects that many children experience on steroids). Furthermore, Ms. Levin noted that "high-performing athletes who have asthma" are exceptions, no more representative of typical asthma sufferers than Lance Armstrong, the most recent winner of the Tour de France, is representative of cancer survivors. She also clarified that "respiratory infection *does* cause asthma and people may use that as a reason to get through the gatekeeper, but these *really are* associated, and they're associated for lots of physiological reasons."

Ms. Levin acknowledged that parents of asthmatic children face tough challenges (saying "no, you can't go outside" or "you have to take this medicine"), and said it's important to recognize options. "Parents can mitigate their kids' behaviour without keeping them inside—they can reduce the activity level and still let them go outside. In all of this, there are sort of heterogeneity issues." She concluded with these statements: "One thing on the use of continuous vs. the ozone alerts—you're right, you want to test whether the ozone alerts are working, and you have to keep it in those discreet categories. But, I think you're missing an important dimension of the data. . . . Even if the parents don't know about the ozone alerts, the ozone itself can give them an alert by giving their kids symptoms, and that's what the Dickie and Bresnahan study shows: just using the marker of ozone levels, people *do* show reactions, and that's very evident in the data."

Sylvia Brandt responded, "Right, but one's a predictor and one's post hoc, so it's a different *timing* issue as well."

Glenn Harrison (University of Central Florida) offered what he considered "a number of small comments. First, to pick up on Michael's point about doing a real-world dimension contingent evaluation instead of stated preference. There are precursors, actually—this

Health Partners HMO again in Minnesota, plus several web sites for asthmatics actually do provide emailed alerts that are, to some extent, tailored." Dr. Harrison wondered why Dr. Hanemann expressed concern "about the hypotheticality and abstract state of preference but *not* about the contingent evaluation, since this is possible to do and eventually deliver."

A second issue raised by Dr. Harrison was in regard to household production functions, methodological factors common to a lot of the studies presented. Addressing Dr. Hanemann, he commented, "I heard what you're *saying* but perhaps what you're *talking about* is the difference between something being locally flexible as opposed to being applied and perhaps globally irregular or globally ill-behaved. . . . If you could just talk a little bit more bout that issue, that would be good.

Dr. Harrison continued with these comments: "Related to that, actually, I still have a sense, notwithstanding Bryan Hubbell's comments, that there's a lot of what I call 'toothbrush modeling' going on in this field, where everyone will say, 'I swear allegiance to the household production function,' but, frankly, that just lets you do anything you want to do . . . it's no constraint whatsoever, and that's the important thing that you were getting at, that there needs to be perhaps some *minimal* constraint. . . . So, in the spirit of looking for minimal constraints couldn't one, in the context of the *stated* preference stuff, use the counterpart of the Garp, the weak axiom of cost minimization, as a minimal test for some sort of rationality in the choices that you're looking at? That might provide a very useful metric for the quality of the responses that you're getting that is comparable across virtually all data sets."

Dr. Harrison agreed with what he termed the "very good comment about the repeat visits" and added, "You need to be *extraordinarily* sensitive looking at those data. If people, for example, are funded under Medicaid, . . . if you want to get repeat prescriptions or there's a slight change, you have to have another visit, and that's actually a major issue, and so the funding source interacts mightily there. Your point is well taken, but I wouldn't overemphasize that 17 percent."

Directing his final comment to Charles Griffiths, Dr. Harrison cited "a wonderful data set called the National Ambulatory Care Survey data set . . . which combines prescribing details in DCs and the ICD9 codes for the same patient by a doctor, not by self reports or anything like that." He added that these data cover "many, many years and you know the location." He cited the case of a graduate student of his who was able to use the data to help correlate respiratory illness with criteria air pollutant levels. He closed by adding that there's a companion data set from a survey of numerous hospitals that provides information on outpatient and ER prescriptions. He commented that although this data set is "not quite as nationally representative as the ambulatory care one, it would be a wonderful corollary source to look at."

Michael Hanemann responded, "I'll answer a *subset* of those comments. Let me just amplify what I meant with the health production functions. You see people doing something and then you see consequences—you see health effects. That's intentional behavior, and there's a connection, but it's a mistake to think necessarily that the person *knew* that *this* behavior would lead to *that* consequence . . . and it shows the behavior in a fine-tuned way." Dr. Hanemann added that he thinks it's more an issue for evaluation because it involves interpretation after the event "because *often* the marginal evaluation is conducted by measuring the marginal cost of an outcome, and that *assumes* . . . sort of fine-tuned optimization, which might be out of place." He expounded on this by adding that someone might say, "Yes, I spent $10, but the reason I didn't spend more than $10 is because this is the only thing I knew to do" rather than "the $10 was for *this* outcome. So," he said, "I think one wants to look at behavior and everyone wants to look at production functions, but I think you also want to look at *preferences*, and I think you want to be cautious about excessive evaluation of the margin based on an *x* cost estimate in marginal costs."

Addressing another of Dr. Harrison's comments, Dr. Hanemann stated, "Your suggestion about tests of rationality and consistency certainly makes sense." He continued by responding to Dr. Harrison's comment regarding the hypotheticality of stated preference in this fashion: "You know, what's hypothetical is in the mind. . . . The important thing, I think, is addressing and engaging the respondent—looking him in the eye and saying, 'Here's a trade-off.' And the trade-off could involve statements that are *entirely* at variance with the facts, and yet people can respond to them as though they are meaningful. So . . . the issue is not 'does this item really exist?'—the issue is 'does the person think there's a commodity there which is within his grasp?' And if you can get the person to wrap his mind around it, you're in reasonably good shape. The *trick* is to make the thing *match* the person's circumstances."

Dr. Harrison replied, "On that, I agree that there's an added artificiality of the matrix, given an SP. That's your point."

Don Kenkel (Cornell University) directed his question to both of the first two studies and said he "was wondering if there are data on other types of averting behavior" besides just staying indoors. He continued, "Smoking cessation is one that pops into my mind, but to show you that I'm not focusing just on smoking, I was also struck by the list of important causes of asthma and noticed that pets weren't even on there." He said he thought that maybe that's because people who find out that their kids have asthma immediately get rid of their pets, and he said this raises a couple of issues: "One is that this is another revealed preference kind of argument—you're giving up something—you're sacrificing something—the pet, in this case. You're giving up utility, and so that's another way of getting at the value of asthma." Dr. Kenkel closed by adding, "The other issue, especially for Reed Johnson's work, is really the *relative* indoor air quality vs. outdoor air quality—maybe it's better being outdoors on a bad ozone day than it is being indoors with the three cats and the mom smoking."

Sylvia Brandt responded by saying, "In our survey, we have about twenty different kinds of averting behaviors as well as five different pages of fixed things you can invest in to reduce exposure. The issue about the pet is actually a really good example of where families *do* make trade-offs. This came out in a lot of the focus groups, this balancing of *normality* versus asthma episodes, and so there are households where, yes, the child is allergic to dander—and that was one of the asthma triggers listed under allergies—but it's worth using the control or rescue medication at times the child needs it to keep the sense of a normal household. So these are some of the issues of trade-offs that we *are* looking at.

Unidentified woman: "Related to this last question: As you said, asthmatics spend more time indoors than non-asthmatics. What if that explains why they're asthmatic, because they're spending way too much time indoors? Is that something to consider?

Michael Hanemann: "No."

Sylvia Brandt responded, "I think it's often compensating behavior. A lot of the children we talked to basically became video game players because they *couldn't* go outside and play with the other kids."

Woman: "So, it's not like diabetes."

Bryan Hubbell (U.S. EPA/OAQPS) directed his comments to Reed Johnson and said, "I wondered why you actually got a lot of endogenous variables on your right-hand side—you had the TV and the games, which could be very much a function of severity of the asthma, as could the preference of being outdoors."

Reed Johnson: "I agree."

Hubbell: "There actually wasn't severity in any of your models, which was surprising."

Johnson: "Not yet."

Michael Hanemann added, "That's also why it's valuable to have something like asthma, which has a clinical diagnosis that goes along with it, so even if it's a self report, no one's going to declare that unless they've had a doctor tell them that."

Closing Remarks

Mark Dickie, University of Central Florida

First of all, thanks, of course, to all the sponsors. All of this was done with EPA money, so I want to thank all the offices of EPA that put this on and Ed Chu, Will Wheeler, Nicole Owens, and Kelly Maguire for lassoing everybody in and keeping things going in the right direction in organizing this. I'd also like to thank some folks from outside who have made sure that everything ran on schedule—the people from the contractor in from EPA, especially Tina Connelly and Denise DeShen, for all their effort in making this come off logistically, as well as John and David and Annie from SCG. Of course, I'd like to thank all of you for your participation and for the interesting and important research that was presented and for all of the great questions and discussion and so on.

You know, if you asked anybody to do this, I think we'd all sort of have a different list of what should be summarized as being important or interesting from the workshop. These are my subjective perceptions of the highlights, offered in sort of chronological order.

I'd first like to echo Ed Chu's comment that he made the first thing the first morning: the increase in the amount of research attention that children's health valuation has gotten now. Back in 1999 there really were almost no studies, except a couple by Tom Crocker and Mark Agee and then a few that sort of incidentally included kids or some kind of kid component along the way of doing some other type of research, whereas now there was all this stuff presented here, and there are things that weren't on the agenda that really could have been presented here, and there's a lot of research that's just getting started now.

A second thing is, of course, many of the presentations, especially on the first day, highlighted the importance of really understanding the structure of the household decision process. In Bill Schulze's paper that doesn't really matter because in his model you get the same willingness to pay expression to estimate whether you use his Nash bargaining model or a Becker type of approach, but I think that's not a general result. I know in Ted Bergstrom's paper it really matters what the household decision process is in terms of just what it is we should measure. That's a question that a lot of people have been asking since 1997, since the Executive Order—what should we measure when we're out to value kids' health? Whose willingness to pay counts? I think Ted Bergstrom's paper really advances our understanding of who we need to be talking to and what we need to count and do we add it up or take the minimum, and so on. I think that would highlight, too, the importance of testing between different models and how well they capture the household decision process, along the lines of what Sandy Hoffman was proposing to do in her talk.

A very much related idea is the importance of understanding how people in the household respond to environmental risks, and that was something that came up so many times in the workshop, starting with Mary Evans' paper and then on and on and on with the household production stuff and the asthma paper all about behavioural reactions and the revealed preference papers on the value of a statistical life. I think it's clear that we need to understand better how households react to these risks and how we can use that information for valuation, and Michael Hanemann pointed out some of the difficulties of doing that with the household production framework, even though that was featured kind of prominently here.

Understanding household behavior probably includes understanding the behavior of children and teenagers themselves, which is something we tend to ignore, but especially as kids get older and have more autonomy and they're doing things like driving one of the family vehicles, or choosing whether or not to wear their bicycle helmet, or going as a teenager to a tanning salon to get a suntan, or managing their own asthma medication. You know, we typically think of the parent as sort of controlling the behavior in the household, but that's clearly not true all the time, so I think maybe some more attention to the stuff that Bill Harbaugh was talking about and what drives children's behavior would really be relevant to the outcomes that children experience and maybe to how we value them, as well.

The fourth thing on my "top five list" was what can we learn from other areas of research such as family economics, health economics, psychology, and decision sciences? All those appeared in one presentation or another over the past couple of days.

And then finally, I think in the VSL session in each case the idea of somehow consistently treating morbidity and mortality risks came up as an important feature. In the first two studies it was injuries or death in a car or on a bike, and then in the last two it would be illness or death. Consistently treating those two is often going to be necessary to adequately value either one because of the connection between them.

So, that is my stab at a summary of some key points from the research.