Chapter 5 - Setting the Foundation: Scope, Baseline and Other Analytic Design Considerations

This chapter provides an overview of a broad set of issues related to the design of an economic analysis. These include (1) the appropriate scope of a benefit-cost analysis (BCA), (2) how to specify the baseline, (3) how to account for behavioral and technological change, (4) what to assume about regulatory compliance and (5) how to address analytic uncertainty, among others. Identifying key issues or questions surrounding these decisions early in the regulatory development process is important because they can have a profound impact on analytic outcomes. Subsequent chapters on benefits (Chapter 7), costs (Chapter 8), economic impacts (Chapter 9) and environmental justice and other distributional analyses (Chapter 10) delve into these considerations in more depth. The discussion of analytic design considerations focuses on their application to prospective analyses, though they are equally applicable to retrospective analysis of existing regulations (see Text Box 5.1 for more discussion).

5.1 Scope of Analysis

Several early analytic decisions determine the scope of a BCA of a regulation. Specifically, analysts must consider whose costs and benefits to count in a regulatory analysis and the types of markets and non-market effects that should be evaluated, including those that cannot be quantified.

A comprehensive approach to benefit-cost analysis is required to assess whether it is conceivable for those who experience a net gain from a regulatory action to potentially compensate those who experience a net loss.[1] These benefits and costs may occur in private markets as well as through changes in externalities. Analysts should carefully consider how various benefits and costs may materialize as a result of the regulatory action by looking beyond effects on regulated entities and changes in the regulated contaminant(s). Without a comprehensive accounting of benefits and costs, the analysis may provide misleading conclusions regarding the sign and magnitude of net benefits and the relative rankings of the analyzed regulatory options (Farrow 2013).[2] As discussed

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1 These gains and losses are measured by an individual's willingness to pay or willingness to accept. See Section A-3 for a discussion of the Kaldor-Hicks potential compensation test that underlies the economic practice of BCA.

2 EO 12866 and OMB's Circular A-4 (2023) require and affirm that all benefits and costs resulting from a policy change should be considered in a BCA. For example, Circular A-4 states, "Your analysis should look beyond the obvious benefits and costs of your regulation and consider any important additional benefits or costs, when in later chapters, the BCA also should clearly identify each source of benefits and costs and present it in a disaggregated and informative way (see Chapter 11).

While in principle the analyst should account for all benefits and costs, in practice, not all changes in economic welfare can be quantified and monetized due to limitations in tools, data and resources. In these cases, analysts are advised to prioritize quantifying those effects that are likely to have the greatest influence on net benefits and the relative ranking of the options under consideration. Since the results of a BCA are therefore likely incomplete, they should be presented and interpreted with care. The BCA should identify effects that could not be quantified or monetized (along with an explanation of why they were not included), describe evidence on the potential magnitude of the benefits and costs from these effects, and explicitly document and discuss any other analytic limitations and omissions. Furthermore, equal effort should be made to account for both benefits and costs so the analysis provides an assessment of net benefits that is balanced and as accurate as possible. While this section provides guidance on the scope of a BCA, Chapters 9 and 10 provide guidance on the scope of economic impact and distributional analysis.[3]

5.1.1 Standing

One of the first scoping questions an analyst must answer is, who has economic standing? Or put another way, whose gains and losses should be accounted for in the analysis? The most inclusive answer is all persons who may be affected by the policy regardless of where (or when) they live. Regulatory analysis often focuses on the costs that accrue to regulated sources, regardless of the nationality of the owners of affected physical assets, and the benefits to individuals that reside within the country's national boundaries. This approach reflects the fact that these are the two groups primarily affected by most regulations.[4]

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feasible. An additional benefit may be a favorable regulation that is unrelated to the main purpose of the regulation..., while an additional cost may be an adverse impact...that occurs due to a regulation and is not already accounted for in the obvious costs of the regulation. These sorts of effects sometimes are referred to by other names: for example, indirect or ancillary benefits and costs, co-benefits, or countervailing risks."

3 While Section 5.1 focuses on the scope of a BCA, the same set of issues applies broadly to economic impact and distributional analysis. An exception is that it may be worthwhile to estimate certain welfare effects for a distributional analysis even when those effects do not fundamentally change the net benefits of regulatory options under consideration.

4 Regulations often only apply to activities within a national border by residents and firms who have consented to adhere to the same set of rules and values for collective decision-making. In addition, most domestic policies are expected to have relatively negligible effects on other countries (Gayer and Viscusi, 2016; Kopp et al. 1997; Whittington et al. 1986).

Text Box 5.1 - Retrospective Analysis

The principles for prospective analysis also apply to estimating benefits, costs, or economic impacts from existing regulations. A retrospective analysis can provide an opportunity to understand whether a regulation has achieved its objectives — for example, whether the regulation improved societal welfare as expected. Retrospective analysis may identify compliance pathways, behavioral responses, or consequences that may not have been fully anticipated at rule promulgation. Retrospective analyses may also suggest ways to improve prospective analysis — for instance, if certain consequences of regulation are routinely underestimated ex-ante, methods to anticipate these effects may be developed. Ultimately, retrospective analysis may result in improvements in regulatory design.

While the importance of retrospective analysis in policy evaluation and regulatory reform is well-recognized, ex-post studies of EPA regulations are relatively rare (U.S. EPA 2014; Aldy 2014; Morgenstern 2018; Fraas et al 2023). Absent systematic data collection, retrospective analyses of the benefits, costs, or economic impacts of regulations have been conducted opportunistically (Fraas et al 2023; Aldy et al 2022; Cropper et al 2018). In addition, retrospective assessments have struggled with issues such as "how to evaluate a highly heterogeneous industry with a limited set of information, how to form a reasonable counterfactual, and how to disentangle the costs [or benefits] of compliance from other factors" (U.S. EPA, 2014). Another challenge has been identifying metrics that can be measured ex post that are relevant to the regulatory outcomes of interest (Morgenstern 2018).

Because of the many challenges inherent in conducting robust retrospective analysis, studies of EPA regulations are often relatively narrow in scope in that they only evaluate a subset of the questions of interest. For example, a study may examine how emissions have changed post-regulation but due to data limitations, may not evaluate the extent to which changes in risk or health outcomes have occurred. Likewise, researchers may identify the mix of compliance strategies that were used or offer insights into specific aspects of unit costs but not have enough information to assess their costs in aggregate (Fraas et al 2023).

Given sufficient data, analysts can use a variety of techniques to conduct rigorous retrospective review. One approach is to use statistical techniques to control for other exogenous factors that affected firm or consumer behavior over time. If a set of similar facilities remained unregulated over the time period, then it may also be possible to compare the regulated firms' behavior to a reasonable counterfactual. If data for several years before and after the regulation became effective is available, it may also be possible to analyze how benefits or costs changed over time. This would potentially allow one to evaluate whether a regulation induced technological change or affected employment, for example. Though used less in published retrospective analysis, another approach is to use computational models to address statistical and data challenges. Even when the model chosen is scientifically defensible, fit for purpose, appropriately parameterized and reasonably transparent, separating out the effects of the regulation from other changes that would have occurred anyway (i.e., in the counterfactual) is still a challenge.

The EPA is exploring additional steps to better institutionalize the practice of conducting retrospective review and analysis. For example, this could be through the development of a systematic approach to identifying the types of rules most amenable to retrospective analysis, best practices for retrospective analysis, and how to identify analytic requirements for such analysis. Data needs could be identified and avenues for ex-post data collection integrated into the regulation (while also accounting for the cost and time needed for firms to collect such information). In this way, the EPA could learn from past experience and improve both policy designs in future regulatory actions and analytic approaches in future prospective analyses.

In certain contexts, however, it may be important to include effects beyond national boundaries. This is particularly relevant to consider when evaluating a regulation's impact on a global public good.[5] It is also important to be cognizant of analytic challenges when attempting to disaggregate benefits and costs accruing to domestic and foreign citizens and residents. For example, to limit economic standing to citizens and residents of the United States, one may need to determine how to treat multinational firms with plants in the United States but shareholders elsewhere and how to estimate the extent to which impacts on foreign companies and citizens have feedback effects on U.S. citizens and residents.[6]

The basis for the decision about the scope of the analysis should be transparent and clear and should focus on capturing the significant effects of a regulation. Analysts should ensure that the application is supported by the available data and that standing is consistently applied when estimating costs and benefits; in other words, if a group has standing for estimating costs, it should also have standing for benefit estimation.

5.1.2 Market Effects

Another scoping question is: which markets will be affected by the regulation? The ways in which a regulation may affect different markets helps inform the analytic approach to take (see Chapters 7 and 8 for more discussion). Ideally, the analyst should comprehensively capture all costs and benefits of a regulation. In practice, this may not always be feasible due to limitations in available data, methodologies, or resources. When prioritizing which costs and benefits to include, consider the effect of the regulation on related markets.

A "distorted" market is one in which factors such as pre-existing taxes, externalities, regulations, or imperfectly competitive markets move consumers or firms away from what would occur under perfect competition.[7] In the absence of market distortions, focusing on the impacts within the market may be sufficient. While a policy may have effects on other markets, market-clearing conditions ensure that they are effectively canceled out from an aggregate welfare perspective (Farrow and Rose 2018; Just et al. 2004).

Every market is distorted to some degree. In particular, effects in related markets are important to consider when there are both pre-existing distortions in these markets and there are significant

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5 For example, when emissions of a pollutant contribute to damages around the world regardless of where they are emitted, it is important to consider how U.S. mitigation activities may affect international reciprocity and cooperation in addressing the same pollutant, as any international mitigation actions will provide a benefit to U.S. citizens and residents. There may also be cases where international or domestic legal obligations require or support calculation of regulatory effects accruing beyond national boundaries. For more discussion of when the effects of U.S. policy on non-residents might be relevant in regulatory analysis, see OMB (2023).

6 For example, impacts that occur outside U.S. borders can impact the welfare of individuals and the profits of firms that reside in the U.S. because of their connection to the global economy. This can occur through effects on supply chains, international markets, trade, tourism, and other activities. Other challenges might include how to account for leakage due to regulatory requirements that are not harmonized across countries or how to treat impacts on U.S. citizens or assets residing outside U.S. borders. See National Academies (2017) for a detailed discussion of challenges in the context of quantifying the effects of changes in greenhouse gas emissions.

7 Perfectly competitive markets are characterized by the following conditions: all economic agents have complete information; there are no barriers to entry or exit; firms have constant returns to scale; and there are no taxes, subsidies or policies that create a wedge between the price suppliers receive for a good and the price consumers pay for it. The term "externality" is discussed in Chapter 3.

cross-price effects between the regulated sector and these other economic sectors (Harberger 1964; Boardman et al. 2018; U.S. EPA 2017). Related markets may include those for major inputs to the regulated sector, products that use the regulated sector's output as an input, and products that are substitutes or complements to the regulated sector's output. A key question for the analyst to consider given market distortions is: when is it reasonable to assume away these effects (e.g., Hahn and Hird 1990)? Evidence suggests that effects outside of the regulated sector, and therefore changes in welfare, may be substantial even with a relatively small sector-specific regulation (Marten et al. 2019; Goulder and Williams 2003). The presence of a distortion alone, however, may not warrant a broader analytic approach, particularly if the value of information from accounting for its effect on costs and benefits is relatively small. Analysts should take special care to justify their choice of which markets to explicitly analyze as part of the regulatory analysis and identify key assumptions and limitations underlying this choice.[8,9]

5.1.3 Externalities

BCA should aim to comprehensively evaluate all benefits and costs resulting from the regulation, which includes welfare effects from all changes in externalities due to changes in environmental contaminants as well as any other externalities.[10] If some of these effects cannot be quantified or monetized, they should be evaluated qualitatively (including a discussion of their potential magnitude).

Welfare effects from changes in externalities could be favorable or adverse. Analogous to how a regulation's interactions with existing market distortions (e.g., pre-existing taxes, asymmetric information) could lead to additional social costs, a regulation could ameliorate or exacerbate other pre-existing externalities. Changes in other environmental contaminants may arise from the compliance methods of regulated sources. For example, the use of an abatement technology by regulated sources to reduce emissions of a pollutant into one medium (e.g., air) may change the emissions of another pollutant into the same medium (e.g., from the same smokestack) or cause changes in emissions of pollutants into another medium (e.g., water).

Changes in other environmental contaminants may also occur as a result of market interactions induced by the regulation. For example, more stringent vehicle emissions standards can lead to changes in upstream oil refinery emissions. Section 5.5.6 discusses the importance of ensuring that projected changes in contaminants are consistent with expected market behavior, considers

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8 Analysts should also keep in mind that even in cases where effects in other sectors contribute little to the overall social cost or benefits of the policy, they may have important distributional consequences that warrant a broader analytic treatment than one that focuses solely on the directly regulated market. See Chapters 9 and 10 for more discussion.

9 Choosing the model that is most appropriate for capturing the key impacts of a policy is sometimes referred to as "horses for courses." Just as the best horse for a race depends on the features of the course, the best economic model(s) to evaluate the benefits and costs of a regulation depend on the features of the regulation and the affected markets. Text Box 5.3 discusses model selection criteria more generally.

10 These effects are among the distortions discussed in Section 5.1.2 as the presence of an externality represents a deviation from perfect and complete markets. Such a deviation may be ameliorated or exacerbated by behavioral changes induced by a regulation. The costs and benefits from unaddressed externalities differ from the costs and benefits of the production of marketed goods in that the welfare effects due to changes in an externality are not reflected in the market prices of those sectors and activities that cause the externality. See Chapter 3 for further discussion of externalities.

interactions with other regulations and provides several common examples of how changes in other contaminants arise in analyses of U.S. Environmental Protection (EPA) regulations. This guidance also applies to expected changes in externalities other than those associated with environmental contaminants. For example, changes in vehicle emissions standards may reduce the marginal cost of driving due to greater fuel efficiency and lead to an increase in vehicle miles traveled that affects road safety, congestion, and other transport-related externalities. These welfare effects should also be accounted for in the BCA and, if they cannot be accounted for because of limited resources, data, and other limitations, they should be described qualitatively.

When presenting the results of the BCA, identifying benefits and costs that are specifically contemplated by the statutory provision under which the regulation is being promulgated — when it is possible to do so — provides transparency. For example, in a BCA of a regulation promulgated under a Clean Air Act provision whose objective is reducing hazardous air pollutants (HAPs), it is helpful to clearly distinguish the air pollution benefits resulting from reductions in HAP emissions from other welfare effects resulting from the expected compliance strategies of regulated entities.[11] Yet, when calculating net benefits all welfare effects should be included, as it is the total willingness to pay for all changes induced by a regulation that determines whether the regulation increases economic efficiency.

5.2 Baseline

Establishing the baseline of an economic analysis is a critical step for accurately evaluating benefits and costs. Because a BCA considers the impact of a policy or regulation in relation to the baseline, its specification can have a profound influence on the results of the analysis. The level of detail presented in the baseline is also an important determinant of the type of analysis that can be conducted when evaluating regulatory options.

5.2.1 Baseline Definition

The baseline is defined as the best assessment of the way the world would evolve absent the proposed regulation. It is the primary point of comparison for assessing the effects of the regulatory options under consideration. Specifically, the BCA models two states of the world: the expected state without the regulation (the baseline scenario) and the expected state with the proposed regulation in effect (the policy scenario(s)). The effects of each policy scenario are measured by examining the differences in net benefits between the scenarios and the baseline.

The baseline describes the expected future of the environmental problem and level of environmental contaminants along with the affected markets and population in the absence of the proposed regulation. While the policy scenario is described in a similar fashion to the baseline, it reflects different environmental and/or market outcomes.

Figure 5.1 illustrates the difference between the baseline and a policy scenario, although there may be multiple policy scenarios under consideration. An economic analysis begins with a description of the state of the world in the current period as a foundation before any analytic scenarios are constructed. The current state of the world includes a description of the environmental problem as

11 This means that if the air pollution reduction also reduces harmful deposition of the pollutant into the water, the benefits from reducing water pollution should be distinguished from the benefits arising from the reduction of the pollutant in the air.

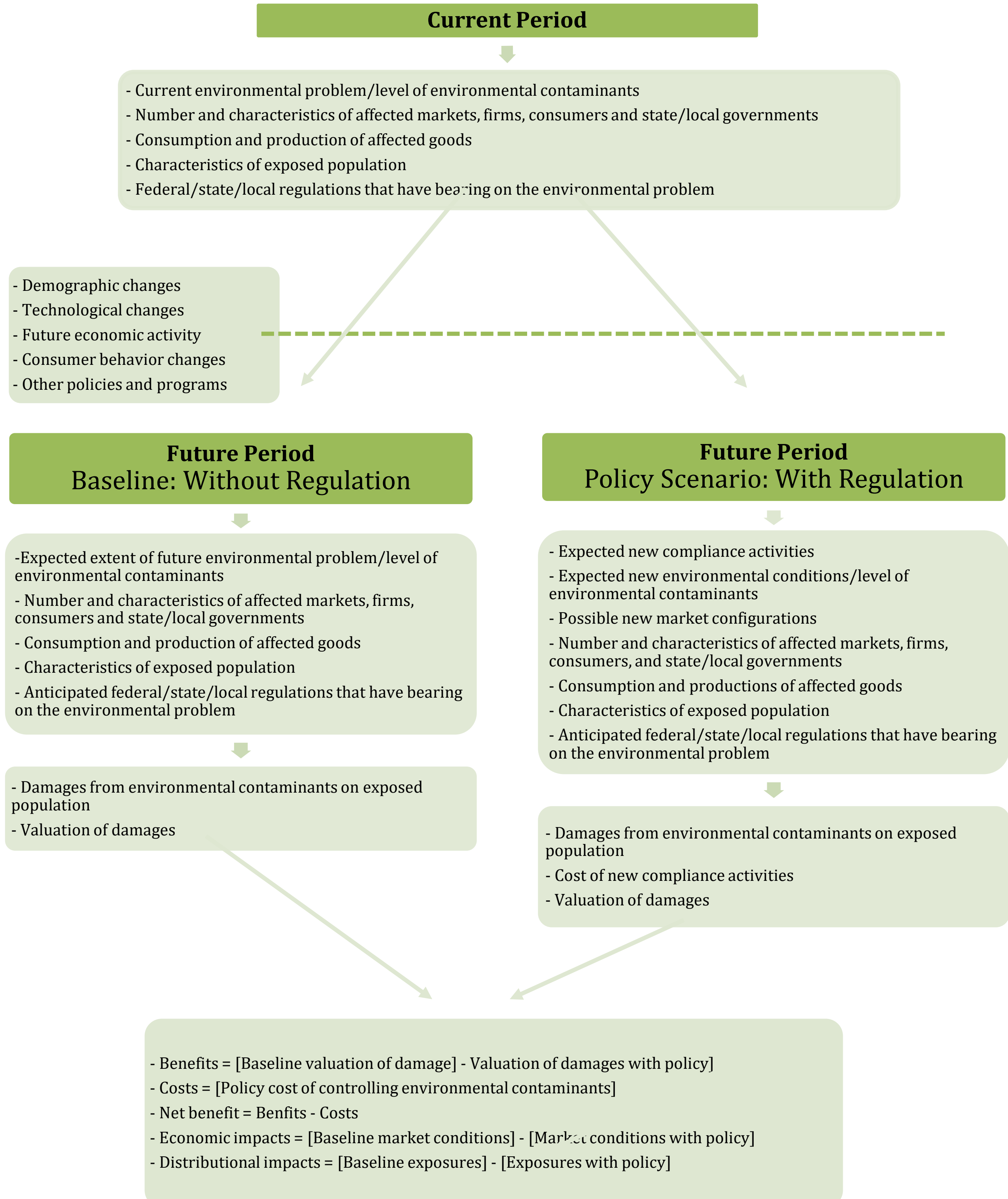
well as other variables such as the level of environmental contaminants; the number and characteristics of the affected markets, firms, consumers and state and local governments; the consumption and production of affected goods within and beyond the regulated market; characteristics of the exposed or otherwise affected population; and existing federal, state and local regulations that may affect the environmental problem. Based on the description of the current state of the world, the next step is to develop a projection of the future state of the world without the regulation, which is referred to as the baseline. This step is done by characterizing how economic and environmental conditions are expected to change over time. Changes may occur in demographics, the pace and direction of technology, energy and other prices, sector-specific economic activity, consumer behavior and other related policies and programs that are already in place. The baseline should reflect likely outcomes, or "business as usual" — not an outlier scenario. The policy scenario is evaluated in a similar fashion, but the economic and environmental conditions reflect the future state of the world with the regulation in place. The two scenarios are then compared.

It is important to note that the comparison of the world with the policy, to the world without the policy is distinct — and quite different — from a comparison of the state of the world before the action to the state of the world after the action. In other words, the baseline is a future scenario without the regulatory program under consideration; it is not a scenario assuming no change from current conditions. The economy and other factors may change over the time horizon of analysis even in the absence of regulation, so a proper baseline should incorporate assumptions about the changes in the economy that may affect relevant benefits and costs.

In most cases, future economic and environmental conditions in the baseline are expected to have changed solely in response to factors unrelated to the regulation under consideration. On occasion this may not be the case. For example, a regulation under consideration may extend the compliance period of an existing regulation. In this case, the baseline specification might incorporate the expiration of the existing program. However, changes between the baseline and policy scenario should be solely attributable to the introduction of the regulation. The economic and environmental characteristics specified in the baseline should be used in the policy scenario unless the policy scenario is anticipated to change those characteristics. This is what makes the baseline the relevant point of comparison for the policy. In general, the construction of the baseline needs to be balanced to equally identify factors that may meaningfully affect both benefits and costs. For example, the analyst should not assume a great deal of technological innovation in one sector (e.g., the pollution abatement sector) and ignore potential technology improvements in other sectors.

The final step in an analysis, as illustrated in Figure 5.1, is to use the information from the baseline and policy scenarios as a basis for estimating the benefits, costs, economic impacts, and distributional impacts of the regulatory option(s) under consideration. The damages from exposure to environmental contaminant levels in the baseline and policy scenarios can be valued using appropriate economic techniques (see Chapter 7: Analyzing Benefits). The value of the change in damages in the policy scenario are the benefits of the policy. The new compliance activities and other effects identified in the policy scenario can be used to quantify the costs of the policy (see Chapter 8: Analyzing Costs). The figure provides examples of economic and distributional impacts that may occur (for additional examples and explanation, see Chapters 9 and 10).

Figure 5.1 - Structure of a Benefit-Cost Analysis



5.2.2 Guiding Principles of Baseline Specification

In specifying the baseline, analysts should employ the following guiding principles:

1. Clearly specify the environmental problem that the regulation addresses and the regulatory approach being considered in the statement of need.
2. Identify all required variables for the analysis.
3. Clearly specify the current and future state of relevant economic and regulatory variables.
4. Focus on the components of the analysis that have the greatest influence on the results.
5. Clearly identify all assumptions made in specifying the baseline conditions.
6. Detail all aspects of the baseline specification that are uncertain.
7. Use the baseline assumptions consistently throughout the analysis of a regulation.

Though these principles exhibit a common-sense approach to baseline specification, the analyst is advised to provide statements on each of these points. Failure to do so may result in a confusing presentation and misinterpretation of the economic results.

Clearly specify the environmental problem that the regulation addresses and the regulatory approach being considered in the statement of need. As discussed in Chapter 3, the analysis should begin with a statement of need for regulatory action and an evaluation of policy options. The statement of need provides a description of the problem being addressed and the significance of that problem, the failures of private markets or public institutions that warrant agency action, and an assessment of whether Federal regulation is the best way to correct the problem. This statement should also include a description of the current regulatory environment and the regulated entities and other affected parties. The evaluation of policy options should describe all policy options or potential regulatory or non-regulatory approaches that were considered and how they were chosen.[12] The statement of need and description of the policy options will help clarify the appropriate baseline to be used.

In general, the baseline will assume no change in behavior to comply with the new regulation or existing regulations; but in some cases, a different baseline may be considered. For example, if an industry is *certain* to be regulated by some other method (e.g., by court order or state action) but that regulation has not yet been implemented, then the baseline should include it. Also, it is common practice to assume full compliance with existing regulatory requirements in the baseline even if there is noncompliance, although a separate analysis assuming less-than-full compliance may determine the implication of this assumption (see Sections 5.5.4 and 5.6.1 for more discussion of this issue).

Identify all required variables for the analysis. To ensure that the baseline scenario can be compared to the policy scenario, there should be a clear understanding of the path from regulation to economic behavior to environmental changes to impacts on humans or ecosystems. The models, parameters and variables required for the baseline analysis should be chosen so that they can inform all subsequent analyses.

Differences between the baseline and policy scenario may include changes in use or production of toxic substances, production processes and costs, pollutant emissions and ambient concentrations, and incidence rates for adverse health and environmental outcomes associated with exposure to pollutants. This does not mean that the analyst must identify all the variables that could possibly change, but the analyst should recognize all relevant variables needed to compare the baseline

12 See Chapter 4 for a description of various regulatory and non-regulatory approaches.

scenario to the policy scenario. At a minimum, the analyst should identify the variables that are expected to have the largest impact on costs and benefits within and across policy options.

Specify the current and future state of relevant economic and regulatory variables. Future baseline trajectories of certain types of economic variables such as energy prices, the level and growth of economic activity and population growth may be important for modeling the effects of a regulation. Even small changes in the rate of economic growth may, over time, result in considerable differences in emissions and control costs. Assuming no change in the baseline economic activity may lead to incorrect results.[13] Likewise, assumptions about the future growth and age distribution of the population affected by a regulation are important for predicting the number of individuals exposed or even the magnitude of aggregate damages. Other variables, such as broad trends in consumer spending patterns and technological growth, are also important for modeling the effects of a regulation but are more difficult to estimate. In these cases, the analyst should specify the baseline levels for these variables and changes over time and explicitly discuss all assumptions. If other policies or programs influence baseline conditions, they should also be in the baseline. For example, changes in farm subsidy programs may influence future pesticide use. Accounting for the way existing regulations affect compliance behavior and economic and environmental outcomes of a new regulation assures that the BCA properly accounts for the cumulative effects of all relevant regulations. In an ideal analysis, all potential influences on baseline conditions, and on the costs and benefits of policy options, would be examined and estimated. However, it is up to the analyst to determine if these influences warrant consideration in the regulatory analysis (e.g., because they may change the rank ordering of the analyzed options). If certain influences are known but not considered significant enough to be included in the quantitative analysis, they should be discussed qualitatively. However, in certain circumstances it may be worthwhile to quantify them to confirm or demonstrate that they are small.

Concentrate on the components that have the greatest influence on the results. The analyst should concentrate analytic efforts on components (e.g., assumptions, data, models) of the baseline that are most important to the analysis, taking into consideration factors such as the time given to complete the analysis, the person-hours available, the cost of conducting the analysis, and the availability of models and data. If several components of the baseline are uncertain, the analyst should concentrate on components that have the greatest influence on the costs and/or benefits and can be refined through additional analysis or data collection. Analysts should pay special attention to the components that will be used to calculate costs and benefits and those that are important in the evaluation and selection of a policy option.

Identify all assumptions made in specifying the baseline conditions. The analyst should explain key assumptions in detail, including those related to changes in consumer and producer behavior, and how these trends may be affected by the regulatory options. Analysts should look for trends in economic activity or pollution control technologies that occur for reasons unrelated to environmental regulation. For example, as a consumer's income increases over time, demand for some commodities may grow at rates faster than the rate of change in income, while demand for other goods may decrease. Where these trends are expected to have significant influence on the evaluation of regulatory alternatives, the analyst should explain and identify the assumptions used

13 For example, if the regulated industry is in significant decline, or is moving overseas, this information should be accounted for in the baseline. In such cases, incremental costs to the regulated community (and corresponding benefits from the regulation) are likely to be less than if the targeted industry were stable or growing.

in the analysis, with the goal of laying out the assumptions so that other analysts (with access to the appropriate models) would be able to replicate the baseline specification.

Detail all aspects of the baseline that are uncertain. Because the analyst does not have perfect foresight, baseline conditions cannot be characterized with certainty. To the extent possible, estimates of current values should be based on actual data and estimates of future values should be based on clearly specified models and assumptions. Where reliable projections of future economic activity and demographics are available, this information should be used and referenced. In general, uncertainties underlying the baseline conditions should be treated in the same way as other types of uncertainties in the analysis.

It is also important to discuss information that was not included in the analysis due to scientific uncertainty. For example, a regulated pollutant may have a suspected health or ecological effect but no available human dose-response function. In this case, the effects generally are not quantified in the analysis, but why the effects were excluded should be discussed — especially if the expected magnitude is such that it could significantly affect the net benefit calculation. Analysts should also explain how scientific uncertainty affects model choice and parameter values. Important aspects of the analysis which are not included in the baseline due to scientific uncertainty should be included in an uncertainty section(s) of the analysis (see Section 5.6 below). Significant uncertainty in important variables may require the construction of alternative baselines (discussed below). While sensitivity analysis is usually a better choice, multiple baselines may provide insights when evaluating different policy options.

Use the baseline assumptions consistently for all analyses of a regulation. The economic and environmental characteristics used in the baseline should be consistent with those used for the policy scenario(s). For example, the calculation of both costs and benefits should draw upon estimates derived using the same underlying assumptions about future economic and environmental conditions. If the benefits and costs are derived using multiple economic and environmental models, then the baseline conditions applied in those models should be compared to ensure that they are consistent. Likewise, when comparing and ranking alternative regulatory options, comparison to the same baseline should be used for all options under consideration.[14]

In some cases, it may be useful to single out a sector for more detailed analysis, or a follow-on analysis might be needed to assess impacts on a specific set of households based on their socioeconomic characteristics, region, or sector. In this case, it may not be possible to specify a baseline that is fully consistent with the primary analysis, but the analyst should endeavor to make them as similar as possible. The analyst also should explicitly describe the differences between the two baselines and any uncertainty associated with them.

Use consistent dollar years across the baseline and policy scenarios. The baseline and policy scenarios should be presented consistently and should use a recent common dollar year throughout the analysis. The dollar year is the year to which the purchasing power of a dollar is indexed. This is important because inflation decreases the purchasing power of money. So, if costs and benefits are reported in 2022 dollars, for example, this means that the value of those costs and benefits are denominated to be comparable to market prices in 2022. All nominal values, which are those not adjusted for inflation, should be converted to real values by adjusting them to the same dollar year

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14 In the less common case in which more than one baseline scenario is modeled, the analyst must avoid the mistake of combining analytic results obtained from different baseline scenarios. To limit confusion on this point, if multiple baseline scenarios are included in an analysis, the presentation of economic information should clearly describe and refer to the specific baseline scenario being used.

using an appropriate index of inflation, and the index(es) used should be explicitly stated.[15] Similarly, if the costs in an analysis are reported in a particular dollar year (e.g., 2020 dollars) but the benefits are reported in a different dollar year (e.g., 2022 dollars), one of the estimates should be adjusted for inflation so that they are reported in the same dollar year. The choice of dollar year should always be made clear. In addition, the reporting year for annual costs and benefits, distinct from the dollar year, should be made clear in both the text and tables. For example, if an economic analysis is using a 2022 dollar year, but the costs and benefits for the rule are reported for the year 2024, both the text and tables should be clear that the values are for 2024, in 2022 dollars.

5.2.3 Multiple Baselines

In most cases, a single, well-defined baseline is generally all that is needed as a point of comparison. However, there are a few situations where it may be informative to compare the policy options to more than one baseline. Multiple baseline scenarios are needed when it is difficult to identify a single, reasonable description of the world in the absence of the proposed regulation. For instance, if the current level of compliance with existing regulations is not known and may substantially influence the net benefits, then it may be necessary to compare the policy scenario to both a full compliance baseline (the standard assumption) as well as a partial compliance baseline. Also, if the impact of other rules currently under consideration fundamentally affects the analysis of the rule being analyzed, then multiple scenarios with and without these rules in the baseline may be necessary. For example, for the 2019 rule to repeal the 2015 rule defining “Waters of the United States,” the degree to which states would continue to regulate their waters at the 2015 standard was uncertain. Since the states' decisions dramatically affected the avoided costs and forgone benefits of the repeal, multiple baselines were used to illustrate the range of potential impacts (U.S. EPA 2019).

The decision to include multiple baselines should not be taken lightly since it may result in a complex set of modeling choices and analytic findings. Multiple baselines increase the possibility of erroneous comparisons of costs and benefits if the modeling choices and results are not communicated clearly. The number of baselines should be limited but still cover the key dimensions of the analysis and any phenomena in the baseline that are uncertain. Each baseline-to-policy comparison should be internally consistent in its definition and use of baseline assumptions.

5.3 Multiple Rules

Although regulations that have been finalized clearly belong in the baseline of a proposed rule, the baseline specification may be complicated by regulations other than the one being promulgated nearing completion. It is important to consider how these other regulations affect market conditions and the degree to which they might influence the costs or benefits associated with the policy of interest. This is true not only for multiple rules promulgated by the EPA, but for rules passed by other federal, state, and local agencies. In addition to agencies that regulate environmental behavior, other agencies that regulate consumer and industrial behavior, such as the

15 Commonly used indices include the Bureau of Labor Statistics' Consumer and Produce Price Indices (CPI and PPI), the Bureau of Economic Analysis' Gross Domestic Product (GDP) deflator, and engineer cost indices. The most appropriate index will depend on the application.

Occupational Safety and Health Administration (OSHA), Department of Transportation (DOT) and Department of Energy (DOE), develop rules that may affect some of the same entities as EPA regulations.

5.3.1 Linked Rules

When rules affect the same industry or when multiple rules are needed to achieve a policy objective, it may be possible to analyze these rules together, provided that they can be promulgated at the same time. For example, the EPA may issue a rule covering both the effluent limitation guidelines (ELGs) for an industry, providing technical requirements, and requirements under the National Pollution Discharge Elimination System (NPDES), providing details of the permitting system (e.g., U.S. EPA 2002). Since the ELGs and NPDES work together to achieve one objective, it makes sense to analyze them together. In some cases, linked rules may affect the same industry but have different enabling statutes. For example, in 1997, EPA issued a single rule for the pulp and paper industry covering the National Emission Standards for Hazardous Air Pollutants under the Clean Air Act and the Effluent Limitations Guidelines for Pretreatment and New Source Performance Standards under the Clean Water Act (U.S. EPA 1997).

The best approach for linked rules that are promulgated at the same time is to include them all in the same analysis. Analyzing multiple rules as if they were one rule simplifies the baseline specification by comparing them to the world in which none of the linked rules are in place. However, it is important to make sure that evaluating them together does not conceal significant differences in the net benefits of the individual requirements. For example, a linked rule might establish emission limits for several different pollutants each with distinct control technologies and separate benefits. In this case, the analyst should follow the guidance on policy options presented in Chapter 3. When a rule includes several distinct regulatory provisions, the benefits and costs of each provision should be analyzed both separately and jointly, estimating the net benefits of a regulatory option with and without that specific provision.

When statutory requirements and judicial deadlines complicate promulgating multiple rules as one, coordination between distinct rulemaking groups is still possible. The sharing of data, models and joint decisions on analytic approaches may make a unified baseline possible so that the total costs and benefits resulting from the package of policies can be assessed in a way that avoids omissions or double counting.

In some cases, there is a link between rules that are not being promulgated at the same time. A new rule may affect the associated compliance behavior of an existing rule. For example, regulations that establish Maximum Contaminant Levels (MCLs) for drinking water may affect Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) cleanup standards, as the MCLs are the in-situ cleanup standards for surface and groundwater water (42 U.S.C. 9621). In this case, the general guidance that all benefits and costs should be assessed in BCAs of regulatory actions should be followed.

5.3.2 Unlinked Rules

In some cases, it is not feasible to analyze a collection of rules being developed at the same time in a single analysis. This may be true for rules originating from different program offices or different regulatory agencies, or when the timing of the various rules is not clear. In this case, each rule should be analyzed separately, but the order in which the rules are being analyzed should be stated explicitly. If two rules are issued in sequence but some of the costs of complying with the second rule are incurred in the process of complying with the first rule, then these costs should be included in the baseline and should not be considered as costs of the second rule. Only the incremental benefits and costs should be included in the second rule. For example, in 2005, the baseline of the Clean Air Mercury Rule (CAMR) included mercury emission reductions from the previously issued Clean Air Interstate Rule (CAIR) (see Text Box 5.2).

The assumption commonly made when rules cannot be evaluated together is to consider the actual or statutory timing of the rules and use this to establish the sequence in which they are analyzed. However, this may not always be possible. For example, a rule may be phased in over time, complicating the analysis of a new rule going into effect during that same period. For this case, the baseline for the new rule should include the timing of each stage of the phased rule and its resulting environmental, health and economic changes.

In the absence of an orderly sequence of events that allows the attribution of changes in behavior to a unique regulation, there may be no clear way to allocate the costs and benefits of a package of policies being developed at the same time to each individual regulation. By implication, there is no theoretically correct order for conducting a sequential analysis of multiple policies that are promulgated simultaneously. In this case, analysts should make a reasonable assumption and explain it, detailing which rules are included in the baseline (see Text Box 5.2). If the impact of other rules on the costs and benefits of the rule under consideration is small, then this may be all that is necessary; it may not be worth additional time and resources to reconcile the baseline of rules being developed at the same time. On the other hand, when the impact on the costs and benefits is large or if there are few overlapping rules, then a sensitivity analysis can be included to test the implications of including or omitting other regulations.

In this sensitivity analysis, it may be possible to use the overlapping nature of the regulations to allow for some regulatory flexibility in compliance dates and regulatory requirements. Furthermore, if the benefits and costs of each rule in the sequence are expected to differ significantly based on the order in which they are evaluated, a sensitivity analysis that changes the order of their evaluation may provide insights into how to design each to maximize the net benefits of the rules collectively.

5.3.3 Accounting for Benefits and Costs that Accrue Across Multiple Rules

When the EPA targets the same contaminants or industries through a sequence of regulations, the benefits and costs of these actions are additive. To ensure consistency in regulatory accounting, regulatory analyses should fulfill an “adding-up condition" when comparing a single large regulation to multiple smaller regulations that imply the same requirements for the same set of entities. The adding-up condition means that the sum of the estimated incremental benefits (and costs) from a set of small regulations analyzed separately should be the same as the incremental benefits (and costs) from the same actions evaluated jointly in a single regulation. Benefits and costs from previous rules should be included in the baseline so that they are not double counted in a new regulation.

The adding-up condition was originally proposed in the context of contingent valuation studies (Diamond and Hausman 1994; Kling and Phaneuf 2018) and has been applied to valuation of water quality improvements (Newbold et al. 2018). If analysts do not impose an adding-up condition and fail to account for improved environmental quality in the baseline when valuing incremental improvements from successive regulations, then inconsistent results could arise if people value marginal improvements more when the environmental good is scarce.

Text Box 5.2 - Accounting for Other Regulations in the Baseline

Because the benefit and cost estimates of one regulation may be affected by those of others, it is important to consider if they should be incorporated into the baseline. As a rule, analysts should be transparent and use objective reasoning when deciding to account for other regulations in a baseline. Transparency requires that all assumptions are clearly stated. Objective reasoning requires that speculation be avoided. If there is uncertainty about an anticipated rule, then two baselines — one with the anticipated rule and one without — might be considered. If only one baseline is considered due to time or resource constraints, then it should be constructed using only final rules and, in some cases, imminent rules that are expected with a high degree of certainty in the absence of EPA action. General guidelines to follow are given below.

All final rules, including those that have not fully taken effect, should be included: The analysis should assume firms will comply with already promulgated rules. For example, on March 15, 2005, the EPA promulgated the Clean Air Mercury Rule (CAMR) to reduce mercury emissions from coal-fired power plants (U.S. EPA 2005b). Five days earlier, on March 10, 2005, the EPA finalized the Clean Air Interstate Rule (CAIR) (U.S. EPA 2005a). While the primary purpose of CAIR was to reduce sulfur dioxide (SO_2) and nitrogen oxides (NO_x), the control technologies necessary to achieve these reductions also lowered mercury emissions. Because the final CAIR rule had been issued, the analysis for CAMR assumed that the mercury reduction from CAIR was in the baseline. This meant that the estimated incremental reduction in mercury from CAMR was much smaller than if CAIR had not been included in the baseline.

Including imminent final rules may be appropriate if the impacts are known with a high degree of certainty: If another (final) rule is imminent and will take effect prior to the effective date of the new rule under consideration, then the imminent rule should be included in the baseline, but only if its requirements and impacts are known with a high degree of certainty. The analyst should not speculate that another rule will be implemented. In addition, the analyst should be clear as to what assumptions have been made to include the imminent rule in the baseline.

Proposed rules should not be in the primary baseline: While a proposed rule signals the intent to issue a final rule and the Agency maintains a schedule to do so, there is no guarantee that the final rule will be issued or that it will follow the planned schedule. Even if the Agency does issue a final rule, it may differ significantly from the proposed rule, which means that the assumptions embedded in a baseline using a proposed rule will not accurately reflect the likely future effects of the final rule. An alternative baseline for a proposed rule may have another proposed rule in it, however, if the two rules are expected to be finalized in the same sequence and the existence of the first rule may influence the benefits and costs of the second substantially.

Future regulatory actions of other jurisdictions should be considered carefully: Actions by state and local governments and even international organizations can affect the costs and benefits of federal rules, particularly if they are regulating the same sector or pollutant. In this case, the analyst must use professional judgment to determine what would happen in the baseline (i.e., in the absence of EPA action) and how the regulatory response of other jurisdictions may change in the policy scenario.

State regulations that have been finalized should be included in the baseline. The more difficult case occurs when a state has a legal obligation to implement a regulation but either has not done so or is in the process of doing so. For example, the EPA occasionally issues rules establishing numeric water quality standards for some states when the states themselves have not done so. One might argue that the state regulation should be in the baseline since they had the legal obligation to issue the criteria, but this is not the case. The EPA's justification for action is that it assumes the state will not act. In this example, only if the state would issue the water quality standard in the absence of EPA action can a reasonable case be made for including the state action in the baseline.

Compliance with a finalized international agreement cannot simply be assumed in the baseline, especially if some EPA action (such as codifying the international standard) is required for it to become effective. The costs and benefits associated with any behavioral response by firms to the EPA action should be part of the policy scenario. In the case where firms will meet the international standard on their own, even without EPA action, then the compliance with the standard can be included in the baseline but establishing that this behavioral response will occur requires justification.

In some cases, environmental regulations yield relatively small changes in health or the environment that may not be noticeable to the public until multiple regulations have achieved a large aggregate improvement. Just as it is important to account for small average costs imposed by regulations — which can be economically significant when aggregated over a sufficiently large population — it is conceptually correct to account for small improvements in public health and the environment. For instance, the EPA's Science Advisory Board (U.S. EPA 1998) noted that, "small effects distributed across a large population exert large total health effects," and recommended that the Agency quantify changes in IQ resulting from regulations that reduce lead exposure, including changes of less than a single IQ point on average per child.

Some benefits only occur after a threshold has been reached. However, a specific benefits threshold may not be met with a single rule. In such cases, it is reasonable to account for the benefits of making progress toward a goal, even if the threshold is not met in the rule under consideration. Otherwise, if the benefits are associated only with the rule that passes the threshold, it may be impossible to justify the previous rules that made incremental progress.

For example, the EPA has calculated the benefits associated with improving river miles for various designated uses (e.g., swimming, fishing, and boating) in several rules. In each case, some river miles were improved for the designated use, while other miles were improved, but not enough to change their designated use. Analyses of earlier rules claimed benefits only if a river mile changed its designation, implicitly giving a value of zero to partially improved river miles. More recent analyses have included estimates of the partial benefits from incremental improvements toward the threshold. Either approach can be used, but accounting for the benefits of partial gains provides useful information to decision makers and the public and allows the Agency to justify incremental progress to a threshold. Once partial gains have been valued in one rule, then subsequent rules cannot claim full credit for crossing the threshold. Doing so would double count those benefits.

In the special case when new data or methods make estimates of benefits or costs for earlier rules obsolete, the analyst should develop a baseline based on the new information and discuss all changes made since the previous regulatory analysis.

5.4. Time Horizon of Analysis

The time horizon of analysis is the period over which the baseline and policy scenarios are compared. The time horizon is defined by the starting and ending points.[16] A guiding principle is that the time horizon should be chosen to capture all the benefits and costs for the policy

16 The time horizon for analysis may also be called the "time period of analysis" or "time frame of analysis."

alternatives analyzed, subject to available resources.[17] This principle is consistent with the requirement that a BCA sufficiently reflects the welfare outcomes of those affected by the policy. If the time horizon is too short, the estimate of the net benefits will be of incorrect magnitude and perhaps of the wrong sign because benefits and costs often occur over different periods of time. The analysis should clearly describe the time horizon used for the analysis and it should be clearly identified whenever present or annualized values are reported (see Chapter 6).

The appropriate time horizon will depend on the economic and legal conditions unique to the regulatory context under consideration. In many cases, the time span of the physical effects that drive the benefit estimates, duration of market effects from compliance activities, the duration of impacts on other externalities, and the economic lifetime of any pollution control investments will be key factors in its determination. Legal conditions that affect the time horizon of analysis include the timing of compliance dates. While selecting the appropriate time horizon is challenging, the analysis should identify the time horizon chosen and explain why it is expected to capture all benefits and costs. It should also identify the extent to which the sign of net benefits or the ranking of policy options by their magnitude of net benefits may be sensitive to the choice of the analytic time horizon.[18]

The starting point for the analysis should be based on when conditions between the baseline and policy scenarios diverge, and thus benefits and costs of the regulation begin to be realized. Two possible choices for the starting point are when an enforceable regulatory requirement becomes effective or when the final rule is promulgated. These dates are convenient starting points because they are clearly defined under administrative procedures and represent specific deadlines. However, the starting point of the analysis should precede the date when regulatory requirements become effective if firms or households are expected to make anticipatory investments or other behavioral changes after the rule is finalized and leading up to the effective date.[19] Likewise, for a regulation with requirements that become effective over time, benefits and costs should be accounted for during the period prior to when the legal requirements are fully implemented. A time horizon of the analysis that begins when a regulation is fully implemented is insufficient for accounting for all benefits and costs in the case where behavior changes prior to compliance dates, and thus the starting point of the analysis should be earlier.

The duration of when costs and benefits occur should generally be used to determine the ending point for the analysis. In theory, the longer the time horizon, the more likely the analysis will capture enough of the benefits and costs of the regulation to reliably estimate net-benefits and compare alternatives. However, other factors, such as the relative uncertainty in projecting

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17 Chapter 6 provides a formal method of identifying the ending point of the time horizon of analysis. A symmetric method may be used to identify the starting point. In addition, Chapters 7 and 8 also provide detailed guidance on selecting the time horizon of the analysis for benefits and costs, respectively.

18 To compare the benefits and costs of a proposed policy, the analyst should estimate the present discounted values of the total costs and benefits attributable to the policy over the time horizon of analysis. Chapter 6 provides guidance on how to discount benefits and costs.

19 In most circumstances, a starting point that precedes final rule promulgation is unnecessary, but an earlier starting point may be desirable if significant behavioral changes were made in anticipation of the final rule. Two possible starting points that precede promulgation of the final rule and are clearly defined legal milestones are when authorizing legislation was signed into law and when the EPA formally proposed the rule. However, when using a starting point that precedes regulatory requirements, it is important for the analysis to identify which behaviors occurred specifically because of the anticipated federal rule versus those that happened for other reasons. This will likely be difficult to do.

conditions in the distant future, may also need to be considered. Forecasts of economic, demographic, and technological trends are required over the entire time horizon of the analysis. Because long term forecasts are less reliable than near term forecasts, the analyst should balance the advantages of capturing important effects against the disadvantages of decreased reliability of forecasts further out in time, although those sources of uncertainty may meaningfully affect benefits or costs and should be accounted for if so. The period in which a regulation is fully implemented should not be used as the ending point if benefits and costs will occur thereafter. Furthermore, regulated entities will consider expected future conditions when choosing their compliance strategies, and a longer time horizon will capture the information they will use when choosing their compliance approaches.

Analysts should ensure consistent accounting of benefits and costs considering differences in when they accrue over time. To ensure consistent accounting, all the costs from activities that lead to quantified benefits should be accounted for in the analysis and vice versa. Ensuring consistency implies that the ending point may differ for assessing costs than for assessing benefits when the accrual of costs and benefits does not coincide.[20] For example, the human health benefits of a policy to reduce leachate from landfills may not occur for many years after the cost of compliance is incurred either because decreases in groundwater contamination take time or because even after contamination is reduced some health improvements do not manifest immediately. In other contexts, while control costs are incurred upfront, changes in pollution may lead to health and ecological benefits that continue to accrue over time.

Generally, the analysis should account for costs until at least the end of the economic lifetime of any pollution control methods adopted for regulatory compliance.[21] Costs will then be consistent with the total abatement, and in turn benefits, achieved by these pollution control methods.[22] Similarly, the length of the cost analysis should capture any turnover in markets for regulated goods (e.g., vehicles) and the length of time those goods are in use. This guidance may be challenging to implement in an analytic framework that captures the possibility of additional regulated sources appearing in the future, but the possibility of entry and exit of sources should still be included. Again, the analysts should weigh the value of additional benefit and cost information gleaned from a longer time horizon of analysis against uncertainty about future economic conditions.

Some statutory provisions have schedules for when regulations need to be reviewed, and an ending point corresponding to this review date may be a tempting choice. However, care should be taken when using regulatory or statutory deadlines to determine the ending point of the time horizon of analysis. For example, these provisions may not envision the regulation being loosened but only tightened, and therefore the requirements under consideration are expected to persist over time, at

20 However, as explained in Chapter 6 annualized benefits and costs should be calculated using the same assumed time period over which the annualized values apply.

21 The economic lifetime is the length of time a piece of equipment is expected to be operational before it is worn out and needs to be replaced. This guidance is particularly important when compliance costs are amortized over an economic lifetime or financing period. When compliance costs are amortized the benefits during one segment of the amortization period may be notably different than over another segment of the amortization period. The analysis will be misleading if the choice of segment affects the relative benefit to cost estimate (as well as the total benefits and costs of the regulation).

22 As discussed in the previous paragraph, if the benefits from these controls do not arise until later (i.e., are latent), the end date for the benefits analysis should be later than the end date for the cost analysis.

least at the promulgated level of stringency, potentially yielding additional benefits and costs.[23] Similarly, the benefits and costs of a regulation should be evaluated beyond when a particular statutory requirement is satisfied if the regulation will continue to affect behavior. A time horizon that reflects the span over which the baseline diverges from the policy case and accounts for all the benefits and costs is appropriate even if the period extends beyond the scheduled review.

In certain circumstances where benefits and costs are not expected to notably change over time, it may be analytically convenient to estimate benefits and costs over a shorter time period (e.g., one year) if they are representative of the benefits and costs over a longer time horizon of analysis (e.g., a decade). In other cases, it may be analytically challenging to estimate benefits and costs for each period over the entire time horizon; thus, benefits and/or costs are estimated for only a few periods that are each representative of longer periods.[24] In these cases, the analysis should still identify the entire time horizon over which the representative periods of analysis are applicable and discuss any limitations or uncertainty introduced by this approach. The representative periods of analysis should be chosen such that they adequately identify the relative net benefits of the various options under consideration. Focusing on one or a subset of periods without careful consideration of whether those periods are representative of all benefits and costs over longer time periods may lead to potentially misleading findings of the magnitude, and possibly even the sign, of net benefits. For example, treating the annual benefits and costs in the year a rule becomes fully implemented as representative of the benefits and costs in all years may lead to a misleading net-benefits estimate if the annual benefits or costs incurred prior to the full implementation year are quite different.[25,26]

5.5 Representing Economic Behavior

To measure the benefits and costs of a regulation, it is important to characterize the behavior of firms and households in both the baseline and the policy scenarios. In particular, assumptions about how firms and households (1) engage in technological change, (2) comply with regulations,

23 Furthermore, if there is a credible reason to assume that the regulation will be loosened in the future then this possibility should be acknowledged in the analysis and the compliance choices of regulated sources should reflect this possibility (e.g., regulated sources would be more likely to adopt easily reversible compliance strategies if they thought the regulation may be loosened in the future). Another reason to evaluate the benefits and costs of the rule beyond the statutory review date is if the rule currently under consideration is expected to be accounted for in the baseline of any analysis with a time frame beyond the statutory review date, including the rulemaking following the statutory review.

24 The representative periods may be chosen to characterize periods of different length. For example, if benefits and costs increase quickly in the near term and are then generally constant afterward, representative periods used to characterize the near term are applicable to short period (e.g., a couple of years), while representative periods used to characterize the long term are applicable to longer periods (e.g., a decade).

25 This outcome is possible even if the benefits and costs in the full implementation year are representative of later years. If they are not representative of benefits and costs incurred in later years then, again, the net benefits estimate may be misleading.

26 Comparing an annualized value to an annual value also may be potentially misleading. The annualization period chosen is arbitrary so long as it is long enough to accounts for all benefits and costs, and a longer annualization period would lead to lower annualized benefits or costs. For example, comparing an annual benefit to annualized costs over a long time period may give the impression that net benefits are positive when they may not be. Also, if annualized values are reported, they should be reported for both benefits and costs. See Section 6.1.6 for further discussion.

(3) participate in voluntary actions, and (4) affect levels of other contaminants in the baseline and policy scenarios can also influence costs and benefits.

5.5.1 Behavior of Households and Firms

Predicting firm, household, and other organizational responses to regulation requires a model of economic behavior. Analysts should assume behavior consistent with utility or profit maximization unless there is evidence supporting other behavioral assumptions (see Section 4.4 and Section 5.5.2 for more discussion of behavioral anomalies).

When modeling the response to regulation, it is important to capture how regulated firms may choose to comply with new requirements. For instance, firms could change production practices, output, location, or even exit the industry. Likewise, it is important to capture household responses, such as changes in the products they buy, where they live, or the types and frequency of averting behaviors (e.g., purchasing bottled water or staying inside on bad air quality days). These responses also may result in changes in market prices and externalities, which could further alter economic behavior. Behavioral response to the regulation may also precede compliance dates, which can make it difficult to disentangle how much of the behavior is attributable to the regulation.

Future economic conditions are inherently uncertain, and households, firms, and other organizations will account for these uncertainties when responding to regulations (as well as in the baseline). Their decision-making under uncertainty may differ from what would occur if future conditions were known with certainty. For example, when facing uncertain future economic conditions, regulated entities may avoid making irreversible investments, which provides them greater flexibility to adjust their future compliance strategies. This may occur even if under most likely future economic conditions an irreversible investment is the least-cost compliance strategy. Without accounting for such uncertainty, an analysis may predict greater investment in an irreversible compliance method than would be expected to occur.[27]

Capturing behavior when uncertainties are present is analytically challenging. For example, information is needed on the risk preferences of households and firms. Economic modeling tools are considerably more complex (or must sacrifice other details) to model decision-making that accounts for uncertain future conditions. When uncertain future conditions are likely to have a significant effect on the behavior of households and firms, the analysis should describe these sources of uncertainty and how they may affect estimates of benefits and costs.

Depending on the types of behavioral responses that are anticipated, the analyst will need to identify and select the most appropriate economic and environmental model(s) for the regulatory analysis. Uncertainty in model results tends to be higher when a model is either exceedingly simple (e.g., because it misses key interactions or feedbacks) or increasingly complex (e.g., due to data

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27 This behavior is an example of option value (Dixit and Pindyck 1994). An option value is the value of delaying an action to learn if it is the best choice. Regulations may impose benefits and costs by eliminating options in the future that may have value to society or private firms and households even if those options would not be exercised under likely future conditions.

requirements). Analysts should seek balance: "the optimal choice generally is a model that is no more complicated than necessary to inform the regulatory decision" (U.S. EPA 2009).[28]

Models used to inform EPA decision-making should be reliable, transparent, defensible, and useful (U.S. EPA 2009). For instance, any modeled changes in behavior should be supported by empirical estimates of demand, supply, cross-price, and income elasticities.[29] When the literature presents a range or identifies factors that could significantly affect these estimates, analysts should also examine the sensitivity of benefit and cost estimates to different elasticity assumptions. See Text Box 5.3 for a discussion of other considerations when selecting models for estimation of costs and/or benefits, including the extent to which a model adequately represents key markets of interest and the representativeness of other significant assumptions. See Section 5.6 for guidance on how to conduct uncertainty analyses for BCA and other economic analyses.

5.5.2 Potential for Cost Savings

If firms and households behave in ways consistent with profit and utility maximization, they will adopt available cost-effective technologies or practices absent regulation. Even if they are not in widespread use when a new regulation is developed, cost-effective technologies may be adopted under baseline conditions in the future as information about their effectiveness spreads. When households and firms voluntarily undertake these changes without the regulation, the regulatory action cannot be credited with any private cost savings resulting from their adoption. In cases where a regulation is estimated to result in net private cost savings, it is important to provide evidence of why these cost-saving measures would not already be undertaken in the baseline.

When evidence to explain this phenomenon is not available, analysts should consider whether the finding of private cost savings is defensible and whether all costs are being accounted for. For instance, a regulation may impose "hidden" costs that are not easily quantified in a standard engineering cost model but still represent welfare losses for firms or households that offset cost savings from adopting a technology. Lower operating expenditures from a new technology required by a regulation might be offset by increases in other costs if the new technology breaks down more frequently, requires special training to operate, or has other undesirable features. If data are available on such costs, analysts should include them in the analysis.

In some cases, evidence may suggest that firms or households do not adopt cost-saving measures because of market failures (e.g., asymmetric information). If the regulation addresses these market failures, it could lead to net private cost savings. In these instances, analysts should provide a clear description and evidence of the market failure and how the new action addresses it.

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28 "Models are constructed to provide the simplest analysis possible that allows us to understand the issue at hand [...] The real world is typically much more complex than the models we postulate. That doesn't invalidate the model, but rather by stripping away extraneous details, the model is a lens for focusing our attention on specific aspects of the real world that we wish to understand" (McAfee and Lewis 2009).

29 Demand elasticities show how the quantity of a product purchased changes as its price changes, all else equal. Cross-price elasticities show how a change in the price of one good can result in a change in the price of another good (either a substitute or a complement), thereby altering the quantity purchased. Income elasticity allows a modeler to forecast how much more of a good or service consumers will buy when their income increases. See Appendix A for more information about elasticities.

Text Box 5.3 - Model Choice

When selecting models for use in regulatory analysis, analysts should evaluate the following:

Is the model based on sound science? Prior to use in regulatory analysis, the model should be subject to credible and objective peer review to ensure that it is consistent with scientific and economic theory and based on the best available data and empirical evidence. Many of the questions that follow can also be put to peer reviewers to evaluate the particulars of a specific model and/or appropriateness of the model within a specific policy context.

Is the model "fit for purpose"? Analysts must identify the best model(s) for the analysis and thoroughly explain why it is applicable given the features and expected effects of the rule. A model may be based on sound science but still inappropriate for evaluating the features of interest.

Is the model supported by the best available data? The suitability or representativeness of underlying data to evaluate the effects of a specific policy is also an important consideration. For instance, data quality and resolution may limit the ability to use some models in a regulatory context. For this reason, it is important to identify what data are available or can be collected to adequately parameterize the model (U.S. EPA 2009). Analysts should use assumptions and calibration/estimation of key parameters that are peer reviewed.

Does the model reasonably approximate the systems or market(s) of interest? A model should capture the most salient details of the policy and the systems or markets affected. A model selected to evaluate a regulation should be no more complicated than is necessary to inform decision-making. If model capabilities add complexity without substantially improving performance, the more transparent option is to eliminate them (NRC 2007).

Is the model transparent? In addition to model tractability, it is important that documentation of all aspects of the model be publicly available, including details about model structure, key assumptions, sources and values of key parameters, and limitations. When possible, models and their underlying data should be publicly available. When a model is not publicly available, for instance due to the confidential nature of underlying data, it is important to explain the reasons for relying on these sources of information.

Can key model assumptions or parameter values be evaluated? Analysts should use sensitivity analysis to explore the robustness of results to key input values, specifications, or assumptions, particularly when the literature is inconclusive regarding the most defensible approach or estimates. Sensitivity analysis may be application specific: parameters that may matter little in one context may be key drivers of results in other contexts (U.S. EPA 2009).

Conducting uncertainty analysis is also important, as it "investigates the effects of lack of knowledge and other potential sources of error in the model" (U.S. EPA 2009). Sensitivity and uncertainty analysis inform users about the confidence that can be placed in model results. In some cases, analysts also may need to rely on multiple models. Section 5.5 provides detailed guidance regarding when sensitivity and uncertainty analyses are appropriate.

What are the key limitations of the model? Every model has its strengths and weaknesses. It is important that decision makers and stakeholders understand a model's limitations. What does the model capture? What is not captured or only captured with large bounds of uncertainty? These should be communicated within the analysis in a way that is easy for a non-technical audience to understand.

The economics literature has also documented specific instances in which households or firms act in ways that appear to run counter to their self-interest (Shogren and Taylor 2008; Shogren et al. 2010; Croson and Treich 2014). However, research also indicates that market experience can eliminate behavior that is inconsistent with profit-maximization in certain settings (List 2003; List 2011). If estimated net private cost savings could be due to widespread suboptimal behavior, analysts should provide empirical evidence specific to the affected market. In addition, care should be taken to ensure that assumptions that underlie modeled household behavior are consistent with actual behavior.[30] In the absence of such evidence, analysts should assume rational profit- or utility-maximizing behavior by firms and households in the primary analysis, which would eliminate the possibility of estimating net private cost savings as a result of regulation.[31] Sensitivity analysis can be used to consider other behavioral assumptions if warranted.

It is also important for analysts to make consistent assumptions about firm and consumer behavior under the baseline and policy scenarios unless there is reason to believe the regulation will change underlying behavioral patterns. For example, the economics literature has found mixed evidence on whether car buyers fully account for future gasoline expenses when choosing fuel economy.[32] A fuel economy standard could reduce the impact of undervaluation of fuel economy on consumer decisions, but if such behavior occurs in the baseline, it is likely to persist regardless of regulatory requirements. Chapter 4 Section 4.4 offers more discussion about possible insights from behavioral economics for policy design.

5.5.3 Technological Change

It is important to capture future changes in production techniques or pollution control that may influence the baseline and policy scenarios and consequentially both costs and benefits. Technological change can be thought of as having at least two components: genuinely new technological innovation, such as the development and adoption of a new alternative pollution control method; and learning effects, in which experience leads to cost savings through improvements in operations, capability or similar factors. Analysts should recognize that the longer the time horizon, the greater the uncertainty regarding the potential for and characteristics of technological change (or learning) within a sector. Thus, it is important to balance the need to account for the effect of innovation on the costs and benefits of regulation against the defensibility of those analytic assumptions.

Technological change in other sectors of the economy may also be important to account for in the analysis. For example, while the cost of phasing out ozone-depleting substances has declined over time due to technological improvements in substitutes, innovation in mitigating factors, such as improvements in skin cancer treatments and efficacy of sunscreen lotions, have also occurred. Further, the analysis should include the costs associated with research and development (R&D), including the potential to crowd out other investments that would have occurred absent the

30 See Ketcham et al. (2016) for an example where the finding that consumers do not act in their own self-interest was actually driven by the inflexibility of the functional form assumed.

31 An exception would be when the regulation involves a transfer, such as a subsidy or rebate to purchase a product, that leads to a net-cost savings for the firm or household. However, absent the value of the transfer, the net-cost savings would still be negative under profit- or utility-maximizing behavior.

32 Recent studies continue to find a wide range in how consumers value future gasoline expenses in their vehicle purchase decisions (Allcott and Wozny 2014; Busse et al. 2013; Sallee et al. 2016; Gillingham et al. 2021; Leard et al. 2023).

regulation, to correctly value cost-reducing technological innovation, but only if the costs are induced by the regulation. Distinguishing R&D induced by the regulation from changes in other investment decisions is often difficult. While innovation is expected to occur in the baseline and policy scenarios, rates of technological change may differ across scenarios due to innovations that reduce the cost of compliance. In cases where small changes in technology could dramatically affect the costs and benefits, or where technological change is reasonably anticipated, the analyst should consider exploring these effects in a sensitivity analysis. This might include probabilities associated with specific technological changes or adoption rates of a new technology, or it may be an analysis of the rate required to alter the policy decision. Such an analysis should show the policy significance of emerging technologies that have already been accepted, or are, at a minimum, in development or reasonably anticipated.

In some cases, there also may be empirical evidence of reductions in costs as firms accumulate experience in production or abatement over time. Historic and projected estimates of learning are often represented by "learning rates". A learning rate is typically defined as the percentage reduction in costs for each doubling of production (or production capacity). It is not advisable to assume a constant, generic learning rate or rate of technological progress, even if the rate is small, simply because the continuous compounding of this rate over time can lead to implausible rates of technological innovation and cost reduction. Furthermore, while learning may reduce compliance costs over time, it is not widely believed that cost become negative as discussed in Text Box 5.4. Before incorporating learning effects, the analyst should carefully examine the existing evidence for relevance to the specific context. Estimated learning effects can vary due to many factors, including already accumulated experience with a technology, industry, and the length of the time period considered. Also, because estimates of learning rates are based on doubling of cumulative production, including learning effects will have a greater influence on analyses with longer time horizons. See Chapter 8 for further discussion.

5.5.4 Compliance

One aspect of analytic design that can be complex is what to assume about the extent of compliance with current and future environmental regulations. Assumptions about compliance in both the baseline and policy cases can significantly affect the results of the analysis and should be clearly described. Assumptions about compliance rates for a new regulation for a sector should generally be based on past compliance behavior for related regulations for the sector. When an industry has not been regulated before, data will not typically be available to gauge the likelihood of compliance with a new rule, but compliance should be expected to be consistent with similar regulations of similar entities. In most cases, a baseline and policy scenario that assumes full compliance should be analyzed along with evidence-backed scenarios including alternative assumptions about compliance.

Text Box 5.4 - Technological Change, Induced Innovation, and the Porter Hypothesis

There are many proposed mechanisms by which environmental regulation could cause technological change. One mechanism is by induced innovation: the induced innovation hypothesis states that as the relative prices of factors of production change, the relative rate of innovation for the more expensive factor will also increase. This idea is well accepted; for example, Newell et al. (1999) found that a considerable amount of the increase in energy efficiency over the preceding few decades was caused by the increase in the relative price of energy over that time.

A similar idea has also been described (somewhat less formally) as the "Porter Hypothesis" (Porter and van der Linde 1995; Heyes and Liston-Heyes 1999). Jaffe and Palmer (1997) delineate three versions of the hypothesis: weak, narrow and strong.

The weak version of the hypothesis assumes that an environmental regulation will stimulate innovation, but it does not predict the magnitude of these innovations or the resulting cost savings. There is mixed evidence in support of the weak version of the Porter hypothesis (Ambec et al. 2013; Martinez-Zarazosa, et al. 2019). This version of the hypothesis is very similar to the induced innovation hypothesis.

The narrow version of the hypothesis predicts that flexible regulation (e.g., incentive-based) will induce more innovation than inflexible regulation and vice versa. There is empirical evidence that this is the case (Kerr and Newell 2003; Popp 2003; De Santis and Jona Lasinio 2016). Analysts may be able to estimate the rate of change of innovation under the weak or narrow version of the hypothesis, or under induced innovation. Note, however, that these types of innovation may crowd out other forms of innovation. By raising the cost of pollution, the regulation makes it profitable to find cheaper compliance strategies, but finding these strategies also has its own opportunity cost (e.g., firms use their engineers, scientists, and other experts to develop more cost-effective compliance strategies instead of developing some other technology).

The strong version of the Porter Hypothesis predicts cost savings from environmental regulation under the assumption that firms do not maximize cost savings without pressure to do so. While anecdotal evidence of this phenomenon may exist, the available economic literature has found no statistical evidence supporting it as a general claim (Jaffe et al. 1995; Palmer et al. 1995; Jaffe and Palmer 1997; Brännlund and Lundgren 2009; Ambec et al. 2013; Dechezlepetre and Sato 2017). For the strong version to be true, it requires special assumptions and an environmental regulation combined with other market imperfections that are difficult to generalize. Thus, analysts should not assume cost savings from a regulation based on the strong version of the Porter Hypothesis.

When there are significant compliance issues with an existing regulation, an assumption of under-compliance in the baseline for a new regulation should be included when supported by evidence from monitors, inspections, or enforcement actions.[33] Analysts may establish a "current practice"

33 For example, in the Lead Renovation, Repair, and Painting Program Rule (U.S. EPA 2008), the EPA assumed a 75% percent compliance rate for estimating costs and benefits based on compliance in the construction industry with previous occupational health and safety regulations.

baseline incorporating data on actual compliance rates rather than assume full compliance. Current practice baselines are particularly useful for regulations intended to address compliance problems with existing policies. Assuming a full-compliance baseline that disregards under-compliant behavior could obscure the value of these types of regulations.[34] If the policy being evaluated is not designed to address the underlying reason for non-compliance, then under-compliance data may be applicable to the policy case as well as the baseline.

If under-compliance is assumed either in the baseline or in the policy case, then identifying the reason for non-compliance is important and could affect the sign of the regulation's net benefits and the distribution of benefits and costs. For example, non-compliance could occur selectively where compliance costs are high. If compliance is not systematically correlated with costs, then the compliance assumption is less likely to change the sign of the regulation's net benefits.

When analyzing new requirements for an industry subject to existing regulations, it is important to carefully specify the assumptions about baseline compliance to avoid double counting benefits and costs. This could arise if the same set of actions occurs across multiple regulations. Assuming full compliance with existing regulations in the baseline makes it easier for analysts to focus on the incremental effects of the new regulatory action without double counting. If there is evidence of under-compliance in the baseline, analysts should consider whether the regulation is structured to reduce the compliance problem[35] or whether the problem is likely to persist in the policy case. If it will persist and this behavior is not captured, the net benefits of a regulation will not be estimated correctly. For example, if analysts repeatedly factor under-compliance into the baselines for a sequence of emissions tightening rules but assume that entities will fully comply under the policy case, inconsistent results will arise. Summing the benefits and costs from the sequence of rules will overstate the benefits and costs because each rule takes credit for a portion of the same actions.

Conversely, there may be cases in which firms over-comply with regulations. Over-compliance in the policy scenario should be assumed in limited circumstances. As with under-compliance, it is important to identify the reason for over-compliance and assure it is consistent with expected behavior. The analysis should not typically assume that a regulation will motivate abatement greater than what is legally required. However, over-compliance may occur if firms wish to reduce the risk of non-compliance (e.g., facilities may overcontrol due to local pressure) or because least-cost compliance methods achieve greater reductions than required (e.g., shifting to a different process that does not pollute rather than installing abatement equipment) among other reasons. In such cases, the benefits, and costs of over-compliance in the policy case should be accounted for. If more additional regulations are considered later, current practices can be used to define baseline conditions for the new regulation unless these practices are expected to change.

To summarize, analysts should include a baseline and policy scenario that assumes full compliance, but under-compliance in the baseline or policy scenario should also be analyzed when there is supporting evidence. Over-compliance can be assumed in limited circumstances. Whenever scenarios other than full compliance are included in regulatory analysis, the analyst should discuss the sensitivity of the results to the compliance rate assumption.

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34 For instance, banning lead from gasoline was precipitated, in part, by the noncompliance of consumers. When consumers put leaded gasoline in vehicles that required non-leaded fuel, this resulted in increased vehicle emissions (U.S. EPA 1985).

35 See Section 3.2 for a brief discussion of relevant enforcement methods to consider, Chapter 4 for some examples, and Section 8.2for a discussion of compliance assumptions in a cost analysis.

5.5.5 Voluntary Actions

Occasionally, polluting industries adopt voluntary measures to reduce emissions. Firms or sectors can undertake such actions independently, or they might participate in formal, government-sponsored programs. Such voluntary measures are adopted for a variety of reasons, including to improve public relations, to avoid regulatory controls, to reduce other legal risks or to access resources associated with joining a formal program. When this is the case, it is important to account for these actions in the baseline for new regulations and to be explicit about the assumptions of firms' future actions. If participation in voluntary programs was motivated by the threat of the regulation, then a new regulation could affect future participation in these programs.

Typically, voluntary emission reductions that are expected to occur without a new regulation may be included in the baseline consistent with the guidance on over-compliance above. This is not always possible, however, as voluntary actions are often difficult to measure (Brouhle et al. 2005). It can be difficult to determine whether pollution reduction measures that precede compliance dates represent anticipatory effects that are attributable to a regulation or if they are voluntary measures that would have occurred without the regulation. Sensitivity analysis could shed light on the importance of assumptions about voluntary emission reductions under the baseline if this is a significant source of uncertainty.

5.5.6 Changes in Other Environmental Contaminants

It is common for EPA regulations to cause decreases and increases in environmental contaminants that are not the subject of the regulation. These changes may occur for a variety of reasons that the analyst should consider. This section provides guidance specifically on identifying and accounting for changes in these other contaminants by drawing out the implications of properly accounting for the baseline and behavior discussed above. Projections of changes in the levels of environmental contaminants should be consistent with expected economic behavior. These changes should be based on expected outcomes of least cost compliance, existing economic relationships, and continued compliance with existing regulations. The analysis should take a balanced approach to identifying increases and decreases in other contaminants that may be affected by the regulation relative to efforts to account for other welfare changes that may result.[36] Any benefits or costs from these changes in other contaminants should be accounted for in a BCA.

As mentioned in Section 5.1.3, changes in environmental contaminants other than those subject to the regulation may result from the compliance approaches used by regulated entities.[37] For example, the use of an abatement technology to reduce one air pollutant may simultaneously

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36 The benefits from changes in environmental contaminants other than those related to the statutory objective of the regulation have sometimes been called "co-benefits" and these contaminants sometimes called "co-pollutants". However, these terms are imprecise and have been applied inconsistently in past practice, and as such should be avoided (unless these terms are used explicitly in statutes). Similarly, benefits from changes in environmental contaminants other than those related to the statutory objective of the regulation are sometimes referred to as "ancillary benefits,". This term should be used cautiously in an analysis because it may be interpreted as having economic, legal or policy meaning that is unintended.

37 Section 5.1.3 also emphasizes that changes in externalities other than those due to changes in environmental contaminants should be accounted for in a BCA. These other externality changes are not as common across regulations as changes in other contaminants but may be particularly important in certain regulatory contexts such as changes in transportation externalities from emissions standards on vehicles (e.g., congestion or safety) or changes in ambient conditions such as temperature and noise.

reduce or increase other air pollutants from the same source, and/or could change the emissions of the same or another pollutant into a different medium (e.g., water). It is also possible for changes in other environmental contaminants to occur as a result of market interactions. For example, a regulation may cause consumers or firms to substitute away from one commodity towards another, whose increased production may be associated with additional emissions of an environmental contaminant as well as the costs of abating it. Other examples include when a regulation induces beneficial reuse of a waste product and thereby reduces production and the associated emissions and costs of the product that the waste replaces; a controlled pollutant might be a precursor to multiple secondary pollutants; or when the use of a hazardous product is banned, and its replacement also poses a hazard.

Care should be taken when estimating changes in other contaminants to ensure they are consistent with expected market behavior and technological change. For example, consider an abatement technology that may potentially reduce emissions of multiple pollutants. The analyst should consider whether the technology will achieve similar reductions in all of these pollutants in a new application as it had in previous applications, or if the regulated entities will tailor it to control the regulated pollutant(s) in the new application so as to reduce the technology's cost.

As with estimating changes in contaminants subject to a regulation, analysts should also consider the implications of existing pollution control regulations on other contaminant levels and costs. For example, consider the case where a regulation on one pollutant leads to installations of a technology that reduces a second pollutant, and that second pollutant is subject to an allowance trading program with a cap that is economically binding (i.e., there is a positive allowance price). In this case, the regulation may not ultimately lead to reductions in the second pollutant. Instead, reductions in the second pollutant at regulated entities that install the new technology may be offset by reductions in abatement activities by entities subject only to the cap.[38] To the extent that any new regulation affects the cost of complying with an existing regulation, as would occur in this example, these changes in cost should be accounted for in the analysis.

If a regulation is expected to increase environmental contaminants not subject to the regulation, they should be accounted for in a BCA even if an anticipated future regulation is expected to mitigate them. This guidance follows directly from establishing the baseline and accounting for all benefits and costs. It is important to account for these changes for completeness, such that the sum of the benefits and costs of rules evaluated in sequence should sum to the costs and benefits of the rules if evaluated collectively as discussed in Section 5.3.3.

Finally, as discussed in Chapter 3, if the regulation is expected to induce large benefits from changes in contaminant(s) beyond those arising from its primary statutory objective, an analysis of a policy option where those contaminant(s) are regulated, either separately or simultaneously with the contaminants that are the primary statutory objective of the regulation, may be useful to determine whether there are more economically efficient ways of obtaining these benefits.

38 There may still be benefits (or negative benefits) from changes in the timing and location of emissions of these environmental contaminants even if the cap continues to bind. Chapter 4 describes how allowance trading programs work.

5.6 Uncertainty

Uncertainty is inherent in BCAs, particularly when estimating and valuing environmental benefits for which there are no existing markets.[39] The primary issue is often not how to reduce uncertainty, but how to account for it and present useful conclusions to inform policy decisions. While households and firms can be expected to incorporate uncertainty in decisions and responses will reflect their risk preferences (see Section 5.5.1), BCA itself should not adopt any particular risk stance because the Potential Pareto criterion requires BCA to reflect the values of those affected. An additional imposition of risk preferences in the BCA itself is, therefore, inconsistent with the underlying basis of BCA.

BCAs should present information on the expected or most plausible outcomes and associated uncertainty (Dudley et al. 2017). It is important to recognize that point estimates alone cannot provide policy makers with information about whether these estimates are robust to alternate assumptions, nor can they convey the full range of potential outcomes. Treatment of uncertainty is an essential component of analysis that enhances the communication process between analysts and policy makers.

The guiding principles for assessing and describing uncertainty in analysis are transparency and clarity of presentation. Although the extent to which uncertainty is treated and presented will vary according to the specific needs of the analysis, some general minimum requirements apply to most BCAs. In assessing and presenting uncertainty, analysis should:

- Present outcomes or conclusions based on expected or most plausible values;
- Provide descriptions of all known key assumptions, biases, and omissions;
- Perform sensitivity analysis on key assumptions;
- Include sensitivity analyses that examine both higher and lower values rather than only one or the other;
- Justify the assumptions used in the analyses; and
- Make full use of available probability distributions of key parameters.

Sensitivity analysis on key assumptions may be all that is needed for an uncertainty analysis, or it may be only the initial assessment. Statistical confidence intervals and probability distributions, if available, are used to describe the statistical uncertainty associated with specific variables and to provide a more complete characterization of uncertainty. The outcome of the initial assessment may be sufficient to understand the influence of key parameters on outcomes and to inform the policy decisions. If, however, the implications of uncertainty are not adequately captured in the initial assessment then a more sophisticated analysis should be undertaken when the data allow. The need for additional analysis should be clearly stated, along with a description of the methods used for assessing uncertainty.

Probabilistic methods such as Monte Carlo analysis can be particularly useful because they explicitly characterize analytical uncertainty and variability (e.g. Brandimarte, 2014). Where probability distributions of relevant input assumptions are available and can be feasibly and

39 Stemming from definitions given in Knight (1921). economists have often distinguished risk and uncertainty according to how well one can characterize the probabilities associated with potential outcomes. Risk applies to situations or circumstances in which a probability distribution is known or assumed, while uncertainty applies to cases where knowledge of probabilities is absent. However, these definitions are not always adhered to in economics. Also, note that the economic definitions for these terms may differ from those used in other disciplines.

credibly combined, BCAs should characterize how the probability distributions of the relevant input assumptions would, on net, affect the resulting distribution of benefit and cost estimates. In this case, the analysis would consider sources of uncertainty jointly rather than singly.

However, probabilistic methods can be challenging to implement when data needed to characterize distributions are limited.[40] In the absence of data to specify distributions for specific parameter values, it is more transparent and defensible to use simpler sensitivity analysis. Note that for some rules OMB Circular A-4 requires a formal quantitative uncertainty analysis that provides some estimate of the probability distribution of regulatory effects.[41]

The analysis should make clear that the statistical uncertainty captured by the Monte Carlo or other probabilistic analysis generally does not account for model uncertainty, the degree to which mathematical models represent real-world systems. For example, when quantifying changes in a specific health effect from a reduction in an environmental contaminant, the statistical uncertainty analysis assumes that a particular dose-response model is the "true" model; that is, as if we are certain there is a causal relationship and that the dose-response function used in the analysis is the truth. There are some approaches to incorporating model uncertainty in probabilistic analyses, such as model averaging.[42] More often, model uncertainty (including uncertainty over whether an environmental contaminant causes a specific type of health impact) will need to be captured and described independent of the statistical uncertainty analysis. When possible, alternative model specifications that are supported by or consistent with underlying biological, engineering, or economic evidence or theory should be used to illustrate the consequences of assuming a different model.

It is important to recognize that there may be cases where there are competing assumptions, estimates or models considered as equally plausible that cannot be combined or weighted probabilistically. In these cases, it can be appropriate for the results driven by these factors to be presented co-equally in the BCA. However, the number of outcomes will generally grow multiplicatively with the number of inputs treated equivalently. For example, if there are three alternative inputs that are evaluated and treated separately and equivalently, and each of these can take two values, then there would be eight co-equal net benefits estimates to present, making it difficult to interpret BCA results. Therefore, the presentation of co-equal results in BCA should be done sparingly, with sensitivity analysis as the preferred treatment where possible. Presenting co-equal results should be reserved for particularly important analytic inputs and should always be fully described and justified whenever it is done.

5.6.1 Performing Sensitivity Analysis

Sensitivity analysis is a systematic method for describing how net benefit estimates or other outputs of the analysis change with assumptions about input parameters. Some basic principles for sensitivity analysis include:

- **Identify key parameters**. For most applied analyses, a full sensitivity analysis that includes every variable is not feasible. Instead, the sensitivity analysis will often need to be limited to

40 Jaffe and Stavins (2007) provide a useful overview of probabilistic analysis of uncertainty in regulatory analysis, including challenges and limitations.

41 See Circular A-4 (OMB 2023) for additional details on this requirement.

42 Moral-Benito (2015) provides an overview of model averaging in economics.

those input parameters considered to be key or particularly important, which may be economic parameters (e.g., valuation estimates) or inputs from other disciplines that feed into the benefits analysis (e.g., dose-response, exposure). A determination about which parameters are key should be informed by the range of possible values for input parameters and each one's functional relationship to the output of analysis. The analyst should specify a plausible range of values for each key variable and describe the rationale for the range of values tested.

- **Vary these key parameters**. The most common approach is a partial sensitivity analysis that estimates the change in net benefits or other economic outcomes while varying a single parameter, leaving other parameters at their base value. A more complete analysis will present the marginal changes in the economic outcome as the input parameter takes on progressively higher or lower values. When an input has known or reasonably determined maximum and minimum values, it can be informative to investigate if outcomes are robust to these alternative input values.

  Varying two parameters simultaneously can often provide a richer picture of the implications of base values and the robustness of the analysis but can be more difficult to communicate effectively. Analysts should consider using graphs to present these combined sensitivity analyses by plotting one parameter on the x-axis, the economic outcome on the y-axis, and treating the second parameter as a shift variable.[43] Results of the sensitivity analysis should be presented clearly and accompanied with descriptive text.

- **Identify switch points.** Switch points are defined as those conditions under which the economic analysis would recommend a different policy decision. For BCA, the switch point would typically be the input parameter value where estimated net benefits changes sign. Switch point values for key input parameters can be very informative. For instance, they can be compared to the available literature to assess whether the values are plausible or well outside known distributions or observations. While switch points are not tests of confidence in the statistical sense, they can help provide decision-makers with an understanding of how robust the analytic conclusions are.

- **Assess the need for more detailed analysis**. Finally, sensitivity analyses may be used as a screening tool to determine where more extensive effort may be needed. For example, the plausible range of values for an influential uncertain parameter may be narrowed with further research or data gathering, which can be used to better characterize the parameter's uncertainty. If several parameters independently have a large influence on the results of the analysis when they are varied, then a more sophisticated treatment of uncertainty that allows for joint consideration of their effects may be necessary. One option is to combine alternative values for multiple parameters into a scenario that differs from the primary analysis. It is important that the selected values be consistent with one another and that choices are explained and well-documented. It is also important to consider that combining extreme values for multiple inputs (e.g., minimum values) can produce a scenario that is unlikely so the analysis should include some description of the plausibility of the combination of values.

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43 When the analysis contains many highly uncertain variables, presentation may be facilitated by noting the uncertainty of each in footnotes and carrying through the central analysis using best point estimates.

5.6.2 Approaches to Consider When Data Are Missing

When key data elements are unavailable in an analysis it will not be possible to estimate central values or perform sensitivity or quantitative analysis around those values. In these cases, it is important to assess and qualitatively characterize the importance of the missing information in the analysis. There are also analytic approaches to consider when data are missing.

- **Break-even analysis**. Break-even analysis can be used when one element is missing in an analysis. Essentially, break-even analysis identifies the switch point value for the missing element where the net benefits change sign.[44] Unlike the case above, however, the switch point value cannot be associated with any point an underlying distribution. Break-even analysis may best be explained by example. Suppose a BCA shows that net monetized benefits are negative, but there is a key health endpoint with an established per-unit estimate of economic value but without risk estimates that would allow quantification of the health endpoints. In this case it is possible to estimate the number of cases of the health endpoint avoided (each valued at the per-unit value estimate) at which overall net benefits become positive, or where the policy action will "break even."

  The same sort of analysis can be performed when analysts lack valuation estimates, producing a break-even value that should again be assessed for credibility and plausibility. Break-even analysis can also be used for missing costs when net quantified benefits are positive, shedding light on what the value of the missing cost estimate would need to be for net benefits to be negative.

  Break-even estimates can be assessed for plausibility either quantitatively or qualitatively. For example, the break-even unit value estimate for a specific health endpoint may be compared to values for effects considered to be more or less severe than the endpoint being evaluated. For the break-even value to be plausible, it should fall between the estimates of these more and less severe effects. Policy makers will need to determine if the break-even value is acceptable or reasonable.

  Break-even analysis is most useful when there is only one missing value in the analysis, or when it is applied to a large or important missing value. For example, an analysis missing risk estimates for two different health endpoints (but with valuation estimates for both), would need to consider a "break-even frontier" that allows the incidence of both effects to vary. While it is possible to construct such a frontier, it may be difficult to determine which points on the frontier are relevant for policy analysis.

- **Expert elicitation.** Expert elicitation is a formal process for obtaining and combining judgments from experts on missing inputs in the economic analysis.[45] The values elicited, and the uncertainty around these values if characterized in the elicitation, can then be used in the economic analysis for those missing inputs. Typically, expert elicitations include multiple experts to capture a range of backgrounds and diversity of knowledge, but ultimately the responses of these experts are combined into a single estimate or probability distribution for the input of interest. There are established approaches for the elicitation, including how to define the target questions, conduct expert interviews and analyze the

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44 Boardman et al. (2018) describes determining break-even points under the general subject of sensitivity analysis and includes empirical examples.

45 OMB Circular A-4 (2023) suggests analyses consider drawing upon expert judgment using Delphi methods, a form of expert elicitation.

responses. Expert elicitations conducted for BCA should follow best practices and carefully document the elicitation process, results and how those results are applied in the BCA.

Formal expert elicitation can be time-consuming and require substantial resources so it should be reserved for those cases where its value, in terms of improving the BCA for decision-making, merits the resources needed. Less formal approaches for drawing upon expert judgments for missing values may also be useful if those approaches are clearly identified and described in the economic analysis, including any known limitations. See Colson and Cooke (2018) for an overview of expert elicitation.

5.6.3 Other Considerations Related to Uncertainty and Risk

There are additional issues related to uncertainty that may merit consideration, including how to account for responses to risk information, how to evaluate policies or regulations that provide information, and how to consider the value of information that may become available later.

- **Uncertainty may affect private decisions.** Households and firms can be expected to incorporate uncertainty when making decisions such as what actions to take to reduce their own exposures to risk or what investments to make in response to regulation. As with other aspects of behavioral responses, to measure benefits and costs of a regulation it is important to clearly characterize the behavior of firms and households. As described in Section 5.5.1, analysts should generally assume utility or profit maximization under uncertainty, taking preferences over uncertainty as given. For households, for example, this generally means a model of expected utility maximization with whatever degree of risk aversion best represents the affected households. In practice it also means that existing estimates of willingness-to-pay will reflect the risk preferences of the populations analyzed. See Section 5.5.1 for more information on representing economic behavior and behavioral responses.
- **Lay and expert risk perceptions**. Lay perceptions of risk may differ significantly from scientific assessments of the same risk. An extensive literature has developed on the topic.[46] Because individuals respond according to their own risk perceptions, it is important for the analyst to be attentive to situations where there is an obvious divergence in these two measures. In such cases, analyses should clearly state the basis for the economic value estimates used in their analysis and should also consider describing the known differences between public risk perceptions and scientific risk assessments. It may also be useful for the regulation to provide information to the public that may reduce these differences and that may allay public concerns.
- **Provision of information**. Some policy actions focus on providing information to individuals on risks to health and welfare. If this information allows them to make better decisions that improve household welfare, there is an economic benefit to providing this information. When this is the case, revealed preference approaches can make new information appear to have a net negative effect on household welfare because households may undertake new (and costly) activities in response. For example, information on drinking water quality may lead consumers to buy and use costly filtration systems at home, which could be misconstrued to mean that providing the information diminished consumer welfare. An appropriate framework for evaluating the benefits of information provision

46 For a general overview see Renner et al. 2015.

under these circumstances is to assess the costs of sub-optimal household decisions under the less complete information.[47] Analysts should carefully consider these issues when they evaluate policies that focus on information provision.

- **Option value**: Some environmental policies involve irreversible decisions made in the face of uncertainty. If information that reduces this uncertainty can be expected to develop over time, then there is a positive value to waiting until this information becomes available.[48] In this case, the value originates from the option to hold off making the decision until uncertainties are resolved or reduced. An analysis can show the potential costs of making a decision without this new information. The potential gains from waiting may best be evaluated in a value-of-information framework where the gains in net benefits from having better information can be compared to the costs associated with gathering this information, which includes any forgone benefits due to postponing environmental protection.[49]

  Generally, it is difficult to quantitatively include these option values in an analysis, but the concept is useful and may be highlighted qualitatively if circumstances warrant. Further, this is an important concept to keep in mind when considering policy approaches. As described in Section 4.6.5 it may be useful to examine approaches such as voluntary programs or pilot projects designed to gather information to make a more informed analysis of the benefits and costs of regulatory approaches.

47 Foster and Just (1989) describes this approach more fully, demonstrating that compensating surplus is an appropriate measure of willingness-to-pay under these conditions. The authors illustrate this with an empirical application to food safety.

48 This is sometimes known as quasi-option value, starting with the seminal work of Arrow and Fisher (1974). A slightly different framing is "real options" analysis following Dixit and Pindyck (1994). These approaches yield option values that differ slightly but capture the same concept. Traeger (2014) describes the precise relation between the two and how they can be considered in benefit-cost analysis.

49 Examples of value of information analysis include Marchese et al. (2018) and von Winterfeldt et al. (2020).

Chapter 5 References

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