INTRODUCTION

THE FAST ENVIRONMENTAL REGULATORY EVALUATION TOOL: FERET

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Abstract

The Fast Environmental Regulatory Evaluation Tool (FERET) is a template that facilitates the analysis of regulatory alternatives to improve the environment, health and safety. FERET can be used to assist both regulatory development and public participation. The current module builds upon a user supplied regulatory design to estimate the impacts, costs and benefits of changes in air pollution or direct changes in health outcomes. FERET provides a computational structure, access to peer reviewed literature, and supporting documentation. The prototypical user of FERET is expected to be an analyst in a regulatory agency, non-governmental organization, or regulated entity who is under budgetary and time constraints to complete an evaluation. That person, possibly you, is expected to have a Master's degree or higher in a relevant field although at least one part of impacts or valuation will likely to be outside of their field. As the information base and structure is similar to recent EPA reports on the costs and benefits of the Clean Air Act; FERET is calibrated to those results. Methods using tons of pollution reduced or direct improvements in health can also be used.

FERET is designed to: 1) encourage best practice, 2) be (relatively) transparent and modifiable, 3) incorporate a peer reviewed approach of EPA as a default and 4) utilize databases of the research literature in both health impacts and economic valuation.

Summary outline **Page**

1.0 Introduction:

FERET is a template to produce a benefit-cost and impact statement on the basis of a regulatory design to reduce air pollution or accidents. FERET has several sections and databases: a health section, whose purpose is to estimate the change in disease incidence from a change in baseline air pollutant concentration, and an economics section, whose purpose is to value the benefits of reducing disease. In both sections, quantitative databases of the research literature are provided. FERET then estimates the health impacts, the present value of benefits, costs, net benefits and provides access to diagnostic and reporting capabilities.

The current module addresses regulations designed to reduce conventional (criteria) air pollutants and physical accidents. Key elements of FERET are:

- Conceptual structure: FERET is based on the economic foundations of benefit-cost analysis.
- Best practice: FERET is designed to encourage best practice based on several published guidance documents and to provide supplemental material.
- Benefit estimates are based on changes in external or third party costs. Such benefits are largely health based but the analysis may include other factors such as visibility. Several alternative methods are provided to estimate benefits based on the regulatory design supplied by the user. The alternatives include: 1) estimating changes in morbidity and mortality through concentration-based dose-response functions and then valuing those adverse health impacts, 2) valuing quantities (tons) of pollutants reduced, and 3) directly valuing health end-points without the use of dose-response functions.
- Costs: Costs are comprised of the before tax cost of compliance (see Appendix on welfare economics) and any non-market costs incurred by the consumer. (Non-market benefits to the consumer are included in benefits.) Based on the regulatory design, the user may directly enter a distribution for costs or a supplemental model called PROJECT (also provided) can be used to estimate the present value of costs.
- Help files: Brief help files explain particular aspects of FERET. Comment "red triangles" are also provided on key cells in each worksheet to guide data entry. A User's Manual and this introduction are provided. Other guidance on the development of benefit-cost analysis is provided through electronic copies of material such as recent EPA studies and guidelines from the Office of Management Budget.
- Uncertainty: Bibliographies of quantitative health and economic studies are provided. FERET samples from the studies selected by the user (various default options are available) in order to produce a statistical distribution of the impacts and the present value of benefits, costs, and their difference, the net present value.
- Added capability: FERET is an open access structure incorporating Excel and Crystal Ball (a simulation tool added into EXCEL.) Users can conduct sensitivity analysis, review assumptions, and write reports within Crystal Ball. Additional graphing and analytical capabilities are available in Excel.
- Ability to customize: Users can easily select model inputs from provided health or economic studies, or add user-specified studies and impacts.

- Output: FERET produces statistical data on impacts, the value of those impacts, and net present value; in short, the exact type of information desired to carry out a benefit cost analysis. But what information matters to decision-makers and stakeholders? The Federal government and various states now require some form of benefit-cost analysis for some regulations, as do some particular pieces of legislation. Guidelines for Environmental Impact Statements refer to adding benefit-cost analyses to such statements, and various stakeholders are interested in such analyses. Many stakeholders are interested in individual impacts such as reductions in premature mortality or hospital admissions. FERET is designed to help a user meet such demands in a relatively short amount of time in an easily documented format. Before presenting results, a careful consideration of qualitative elements, distributional impacts, sensitivity testing (by manually entering alternative values for specific model inputs, such as discount rates, or by using Crystal Ball to identify the key assumptions), and documenting any elements added to FERET are useful steps. In effect, FERET helps carry risk assessment one step further, but the step of risk management is still to be determined by stakeholders and decision-makers.

2.0 Benefit-Cost Analysis and Social Welfare

FERET is designed to provide quantitative information on environmental impacts, broadly defined, and to value those impacts in the framework of a benefit-cost analysis. Benefit-cost analysis is a long established technique with a broad literature base addressing both estimation and conceptual issues[1].

The conceptual underpinning of benefit-cost analysis is a field called "welfare economics." The central question in welfare economics is when a society's well-being is improved after some action is taken such as a new regulation. Such analyses are problem specific but a common starting point is to assess actions in the context of one or a few competitive markets while allowing for external non-market effects such as pollution damages. Among the central assumptions in such an analysis are those of a competitive market (such as many buyers and sellers[2]) and the assumption that welfare is increased as long as those who gain can potentially compensate those who lose (the Kaldor-Hicks criteria[3].)

The structure of FERET can be shown (see Appendix) to be consistent with the welfare theoretic basis of benefit-cost analysis as FERET computes net benefits as the difference between reductions in external costs and costs of compliance in the context of changes in a few markets (partial equilibrium analysis). For example, the dominant benefits from the reduction of conventional pollutants are health impacts avoided--the reduction in external impacts. Costs are typically measured by industry control costs. Compared to typical benefit-cost analyses, FERET allows an improved analysis of the distribution of benefits and costs. Taxes are not explicitly addressed in the primary analysis because

[1] For example Zerbe and Dively (1994); Hanley and Spash (1993); Farrow, Goldburg and Small (2000).
[2] See for instance, Varian (1992).
[3] See sources in footnote 1, also, Farrow (1998).

they are almost entirely transfers between the government and taxpayers (and consequently can be omitted from the calculation), whereas compliance costs in FERET include taxes[4] because while tax transfers net out (are equal) among gaining and losing parties, the full cost of compliance must still be paid.

Other distributional issues involve who bears the costs and who receives the benefits. Although the basic structure of FERET identifies the compliance cost as those of industry, such costs are eventually wholly or partially passed on to consumers, and minority or low income groups may bear a disproportionate burden of external costs. FERET can be used to assess the costs or benefits to sub-sets of a population by varying user-specified population characteristics. Also, the choice of a discount rate for benefits or costs in different years can be easily set by the user, help files are provided, and sensitivity analysis is encouraged.

Best Practice

The theory and practice of benefit-cost analysis continues to evolve. There are a range of technical articles, textbooks, and guidance documents on the subject. As part of this package, FERET provides copies of publicly available guidance on benefit-cost analysis such as that by the Office of Management and Budget in the Executive Office of the President, and the guidance used by the Environmental Protection Agency. Outside critics have also developed various criteria defining best practice[5]. FERET is designed not only to improve on standard practice but to move to best practice. To that end, we list (in **bold**) suggestions for improving benefit-cost analysis developed by a distinguished group of economists (Arrow, et. al., 1996) and explain how FERET addresses these suggestions (full text of these suggestions is in the FERET supplemental documents or available at www.aeibrookings.org).

- **"Benefits and costs of proposed policies should be quantified wherever possible. Best estimates should be presented along with a description of the uncertainties."**
  FERET provides the template structure to quantify costs and benefits. Best estimates, often interpreted as either the mean or the median value, are provided as standard output in FERET with an integrated analysis of uncertainty.

- **"A core set of economic assumptions should be used in calculating benefits and costs associated with environment, health, and safety regulation. Key variables include the social discount rate, the value of reducing risks of dying and accidents, and the value associated with other improvements in health."**
  In FERET, the analyst sets the discount rate and other economic parameters with various help files to assist in that choice. Further, instead of depending on a single economic value, FERET provides a bibliography of values. The user has the opportunity to select one or many studies as the basis of key health and economic

[4] FERET provides a cost estimation program developed by EPA called PROJECT that provides cost estimates that can remove the effect of taxation from the cost of the firm.
[5] See for example, Arrow, et. al. (1996); and Farrow and Toman (1999).

variables. As a default, the user can select studies chosen by the EPA in their analysis of the costs and benefits of the Clean Air Act (U.S. EPA, 1997; 1999).

- **"Information should be presented clearly and succinctly in a regulatory impact (benefit-cost) analysis. Transparency is necessary if benefit-cost analysis is to inform decisionmaking."**
  FERET, while not writing the text for a benefit-cost analysis, is an openly structured template in which the effects of different benefit or cost assumptions can be easily examined by independent reviewers. Written in Excel, it is (relatively) transparent in its form and operation. Its report writing capability also assists in the transparency of its results.

- **"It is important to identify the incremental benefits and costs associated with different regulatory policies."**
  FERET is designed to assess the impact of regulations through a "with and without" kind of analysis that is the basis for assessing incremental benefits. While guidance is provided on this topic, only the analyst can establish the sequence of regulatory designs that identify various levels of “incremental” regulation. Once defined, the regulatory design is entered in the User Input page and becomes the basis for an incremental analysis.

- **"While benefit-cost analysis should focus primarily on the overall relationship between benefits and costs, a good benefit-cost analysis will identify important distributional consequences of a policy."**
  FERET can be used in several ways to identify the distributional aspects of a regulation. For instance, the characteristics of the “exposed population” in the user input page can be altered to examine net benefits/costs to subsets of the overall population, perhaps based on income or race. Health and valuation studies can also be selected that focus on subsets of the population such as children. Finally, information on the direct incidence of costs among business, consumers, and the government can be identified.

- **"Not all impacts of a decision can be quantified or expressed in dollar terms. Care should be taken to ensure that quantitative factors do not dominate important qualitative factors in decisionmaking."**
  FERET provides a special area in its Regulatory Design worksheet to enter qualitative factors that may affect decisions. These factors are presented in the output summary page alongside the quantitative result. Also presented is a calculation showing how large these factors need to be in order to change the sign of the analysis from positive to negative or vice versa.

- **"The more external review regulatory analyses receive, the better they are likely to be."**
  FERET’s default assumptions are based on EPA’s peer reviewed studies of the retrospective and prospective studies of the Clean Air Act. FERET is also being circulated for testing among interested users. Most importantly, FERET provides a

common structure for stakeholder participation in regulatory debate. If one stakeholder develops an analysis, their assumptions can be readily apparent in FERET (we suggest use of the tracking changes feature of Excel). Other stakeholders may conduct an external review of the original analysis with an analysis of their own.

- **Beyond best practice:** FERET provides a number of capabilities beyond those specified in guidance documents. For instance, the most important model input assumptions can be quantitatively identified through the sensitivity analysis features of Crystal Ball. In the analysis, the user can select more than one value for key parameters and use the results of several studies, the optimal level of regulation can sometimes be calculated, and graphics and statistics are provided as output.

3.0 Basic Structure of FERET: The Case of Certainty

The structure and mathematics of FERET are relatively simple. We first discuss FERET's structure when model inputs are well defined (i.e., no uncertainty.) We then discuss how uncertainty over key parameters can be accommodated by FERET.

The structure and mathematics under certainty are:

1. Economic theory provides a basis for focusing on changes in external and compliance costs before taxes (see appendix on welfare economics).

2. Context: The regulatory design comes from the user. The regulatory design drives the model inputs such as changes in air pollutant concentration levels relative to baseline and a compliance scenario that determines cost.

3. FERET mathematics:

Objective: To estimate the present value of net benefits (PV benefits minus PV costs) and report quantitative and qualitative impacts

1. Present value benefits are defined as the avoided external costs. The annual benefits of impact i, $B_{i,}$ are estimated as:

$B_i = \Delta y_i * V_i$ where Δy_i are changes in impacts (cases for health) valued at V_i while the present value of benefits are the sum over all impacts (I) and time periods (T):

$PVB = \sum_{t=0}^{T} \sum_{i=1}^{I} \frac{B_{it}(1+g)^t}{(1+r)^t}$ where PVB is the present value of benefits, i is any rate of growth in real benefits (e.g. due to increased population growth) and r is a real (excluding inflation) discount rate. B_t may be zero in some early years if there is a latency period or a delay in implementation. Note that latency or implementation delay are user-specified inputs.

As a default, FERET estimates health impacts through concentration response functions, typically of the form

$\Delta y_i = -y(e^{-b\Delta X} - 1)$ where ΔX is the change in concentration of a pollutant and β is the concentration response coefficient for each disease endpoint and pollutant relative to the baseline (no action) case and is estimated from epidemiological data. This form of the concentration response function is discussed in more detail later in the introduction and in the help files. The EPA cost and benefit studies (EPA, 1997; 1999) and McClellan (1999) also contain discussions.

2. Present value costs (PVC) are compliance costs by industry and any non-market costs (external costs) to consumers. These costs are context specific to the regulatory design. Some analysts may have their own models of costs in which case they can enter their own cost distribution directly. FERET also provides an EPA model (PROJECT), used in courts for over a decade, which takes the following form:

Define Total cost in year t as C_t = fixed Cost + variable cost.

The user is prompted for other assumptions (with help available in documentation from EPA and on the FERET CD) on the life of the buildings and equipment associated with fixed costs. . Taking that replacement cycle into account, the model computes the present value of cost (PVC):

$$PVC = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$

Taxes can also be considered in the model if the user wishes to identify some distributional impacts such as those among industry, government, and the consumer. The basic FERET analysis sets the tax rate to zero based on welfare economic results presented in the Appendix to this introduction.

The user may compute PVC at either the industry level, or for a typical firm. If the latter, space is provided to enter the number of firms in the user input page to scale up costs to the total covered by regulation.

Present value of net benefits (PVNB, the bottom line) is then estimated as:

PVNB=PVB-PVC.

Intermediate information is obtained on all environmental and health impacts considered in the model. We note here that a cost-effectiveness analysis (least cost of achieving a given objective) can be carried out by setting the benefit impacts to zero and just studying costs of the regulatory alternative. Alternatively, benefits can be the focus of analysis by placing a zero in the distribution for costs (and modifying summary cells that require cost data.)

Schematically, the basic structure is outlined in Figure 1. The figure shows the key elements of FERET in boxes labeled one through five. Central to the use of FERET is a regulatory design identified by the analyst. In the case of standard air pollutants, this takes the form of defining changes in air pollutant concentration due to the proposed regulation in the "User Input" worksheet (or alternatively changes in tons or health impacts—see "Direct Impacts" worksheet.) Key economic assumptions are also entered on the user input page such as the discount rate and date of implementation. Cost data from the regulatory design are then entered in worksheet two. The user can incorporate their own estimates or alternatively, use the EPA developed PROJECT model (included with the FERET CD) to develop estimated costs of compliance. At this stage, if the user wishes to accept EPA defaults for health dose response functions and economic valuations, FERET can be run and results obtained. Outputs from the simulation are shown as Box 5 in Figure 1. The results include a statistical distribution of the net present value of the regulation and also distributions for the environmental impacts. Various sensitivity tests and report writing capabilities of the program can also be used at this point.

A user with more time or an inclination to investigate the sensitivity of using EPA default studies can use information associated with modules 3 and 4, on health impact and economic valuation. In these modules (which comprise several worksheets), the user can change which health or economic studies are used in the analysis by simply selecting or deselecting the study. Information about each study is provided. Alternatively, the user may wish to enter their own information. Blank rows that are already linked to the appropriate benefit and cost elements are provided for this purpose.

Key FERET Worksheets

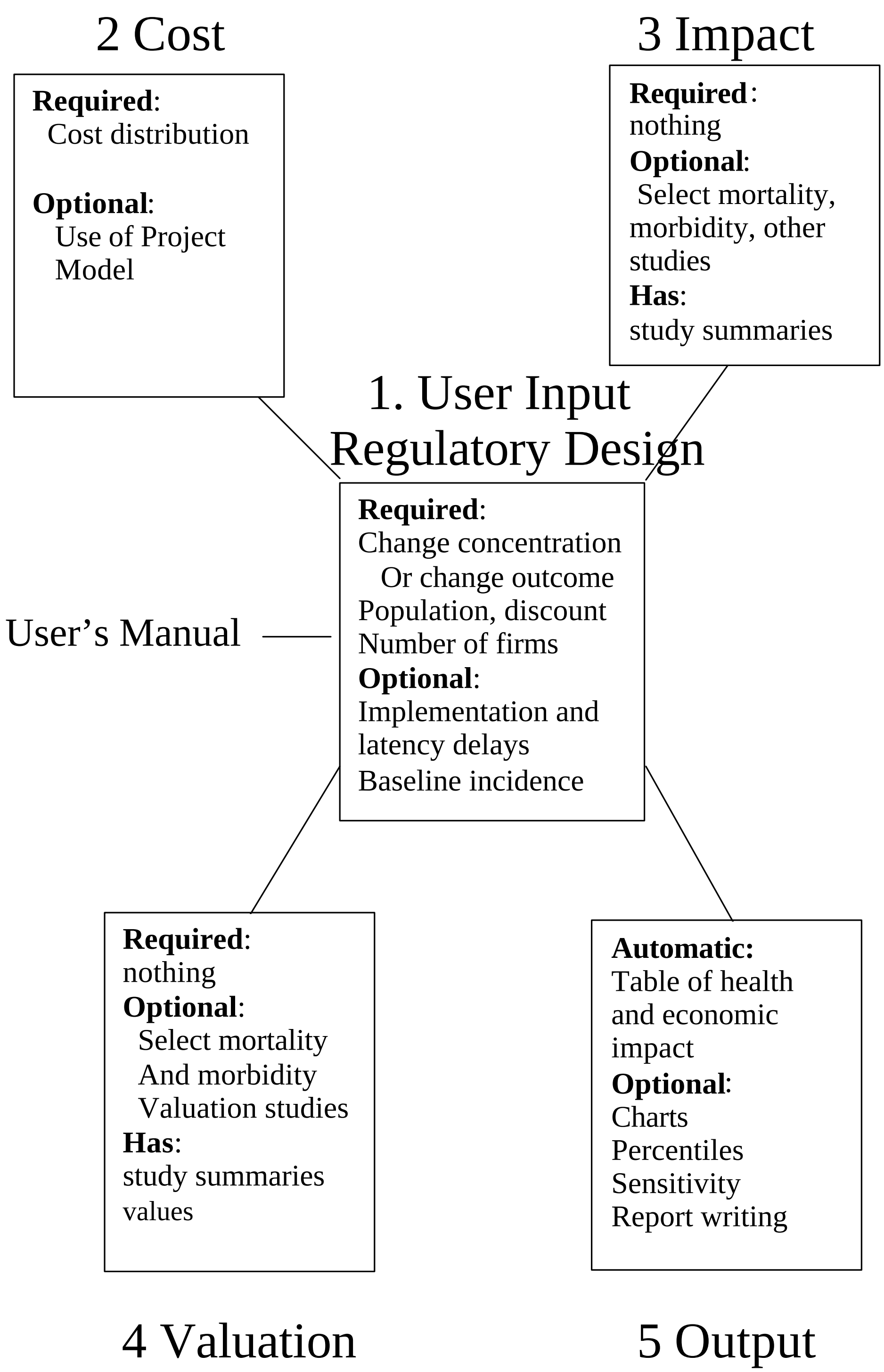


Figure 1. Key FERET worksheets.

4.0 Basic Structure of FERET: Incorporating Uncertainty

There is uncertainty over a variety of model input parameters likely including the change in concentration (ΔX), the concentration-response function for adverse health impacts (β), compliance costs (C), and the value of impacts (V). If there is only one source of a distribution for each input parameter, Crystal Ball (the simulation add-on to Excel) directly uses this distributional information for each parameter. The various intermediate and final calculations would be in the form of distributions instead of point estimates, reflecting the aggregated uncertainty of model assumptions. This is the approached used for ΔX (concentration) and C (cost).

However, for β (health response) and V (valuation) there are numerous studies that can be selected as model input, each with a distribution for that parameter. FERET has a study selection process which, on each trial, will select one health and one valuation study and sample from the parameter distribution of each study. The random selection process is repeated for each cycle of the model computations. The total number of trials is user-specified. The resulting "meta" distribution takes into account the uncertainty across all considered studies.

FERET provides the EPA default list of studies (EPA "Prospective", 1999) but the user can easily "turn off" any study from the bibliography and it will not be sampled during model simulations. Alternatively, the user can select non-EPA studies or even add their own studies for inclusion. This ability to examine the sensitivity of the model to EPA inputs exemplifies the ease of user customization of FERET. As documentation, we provide some key characteristics of each study (demographics, location, etc.) and the full citation and abstract.

Figures 2 and 3 go through the steps to generate a single "trial" or "observation" in FERET. As shown in Figure 2, and focusing on only one pollutant, FERET first samples from the impact of the regulatory design on concentration (step 1). FERET then randomly selects from among the health studies contained in the bibliography that are chosen for inclusion and then samples from the distribution of the concentration response function of that study (steps 2 and 3.) When the sampled values are substituted into the study concentration response function, the result is a change in the number of cases (for most functions, the baseline number of cases is needed as a user input.) This information is calculated using either EPA provided incidence rates or national baseline incidence rates already integrated into FERET. If more local information is available, this information can be changed. Valuing the change in cases follows similarly in steps 4 and 5 where a valuation study is randomly selected from among those selected, and then an observation is drawn from the distribution of the value from that study. When the value is multiplied times the change in the number of cases, the monetized benefits of the environmental improvement are recorded for that one trial. FERET then samples from the distribution of compliance cost. The difference between the cost and the benefit, after putting both values in present value terms[6], is the net present value of the action.

Figure 3 describes the same series of steps and inputs of the analysis, but also allows a broader "flow chart" view of the entire FERET analysis and the contributions of data and distributions from separate worksheets to the calculation of net benefits and costs. Over many trials of the simulation, differing studies are chosen and their corresponding concentration-response coefficients used to calculate the change in cases. Over many trials, new distributions of the overall beta and change in cases of a particular health endpoint are created. The economic valuations are similarly sampled. The bottom line is again, a distribution of environmental and monetary impacts, including the present value of net benefits.

FERET is presumably similar to but more aggregate than the consultant's model that underlies EPA reports (1997, 1999) available as supplemental reading with FERET. FERET is also related to the Tracking and Analysis Framework (TAF) which analyzes pollution from the utility industry and which runs in a program format called Analytica (www.lumina.com/taf.)

Output Reporting and Sensitivity

FERET automatically provides a summary table with mean, 5th and 95th percentiles for the health impacts and the present value, which are the information most frequently used in a benefit-cost analysis. Adjacent material provides qualitative information entered by the user from the regulatory design worksheet.

Help files direct the user to fuller use of Crystal Ball which has significant built in capabilities for sensitivity testing, display of information and report writing including verification of assumptions and outcomes. The user has complete access to these capabilities and control over their specification.

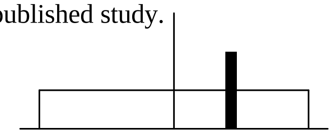
Finally, how a decision-maker uses the information is case specific. Standard economic analysis will suggest taking those actions with a positive mean present value. In fact, there are distributional and other issues that make the conclusion less clear. Typically the analyst and the decision-maker will want to know about the sensitivity of the results to changes in model assumptions, such as the discount rate, which is easily done in FERET. Others might feel that the direction of the qualitative impacts is clear and might change a decision from that based only on the monetized impacts. Finally, some individuals may want to consider a modified decision criteria, perhaps due to budget constraints or some type of precautionary principle. FERET assists you in the risk and benefit-cost analysis. It is not a risk manager or a decisionmaker.

[6] The typical case will generate annual benefits which are put into present value terms using the regulatory design parameters of the timing of the action and Excel's present value (PV) formula. If the PROJECT model is used to generate costs, then the costs are already in present value terms.

Figure 2: FERAT conceptual flow chart:

Distributions can take many forms defined by the analyst or author of published study.

1. Samples from impact of regulatory design ΔX_i
   (e.g. change in concentration, can be any distribution or point)

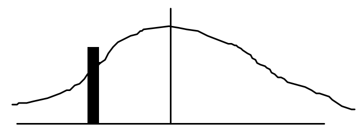


$\Delta \mathbf{X_i}$

2. Randomly selects health study (among those selected to be true)

$\mathbf{S_i}$

3. Samples from concentration-response function of β_i
   selected study



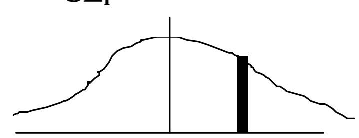
b_i

Result after substitution in study response equation: one “observation” = D **cases**$_i$

4. Randomly selects economic study (among those selected to be true)

$\mathbf{SE_i}$

5. Samples from valuation function of
   selected study V_I

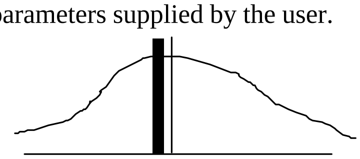


$\mathbf{V_i}$

Result: Benefits (value of damages avoided) $\mathbf{B}_i$**=** D **cases**$_\mathbf{i}$ ***** $\mathbf{V}_i$

Which is transformed into present value (**PVB**) using discount and other parameters supplied by the user.

Cost: samples from present value cost distribution

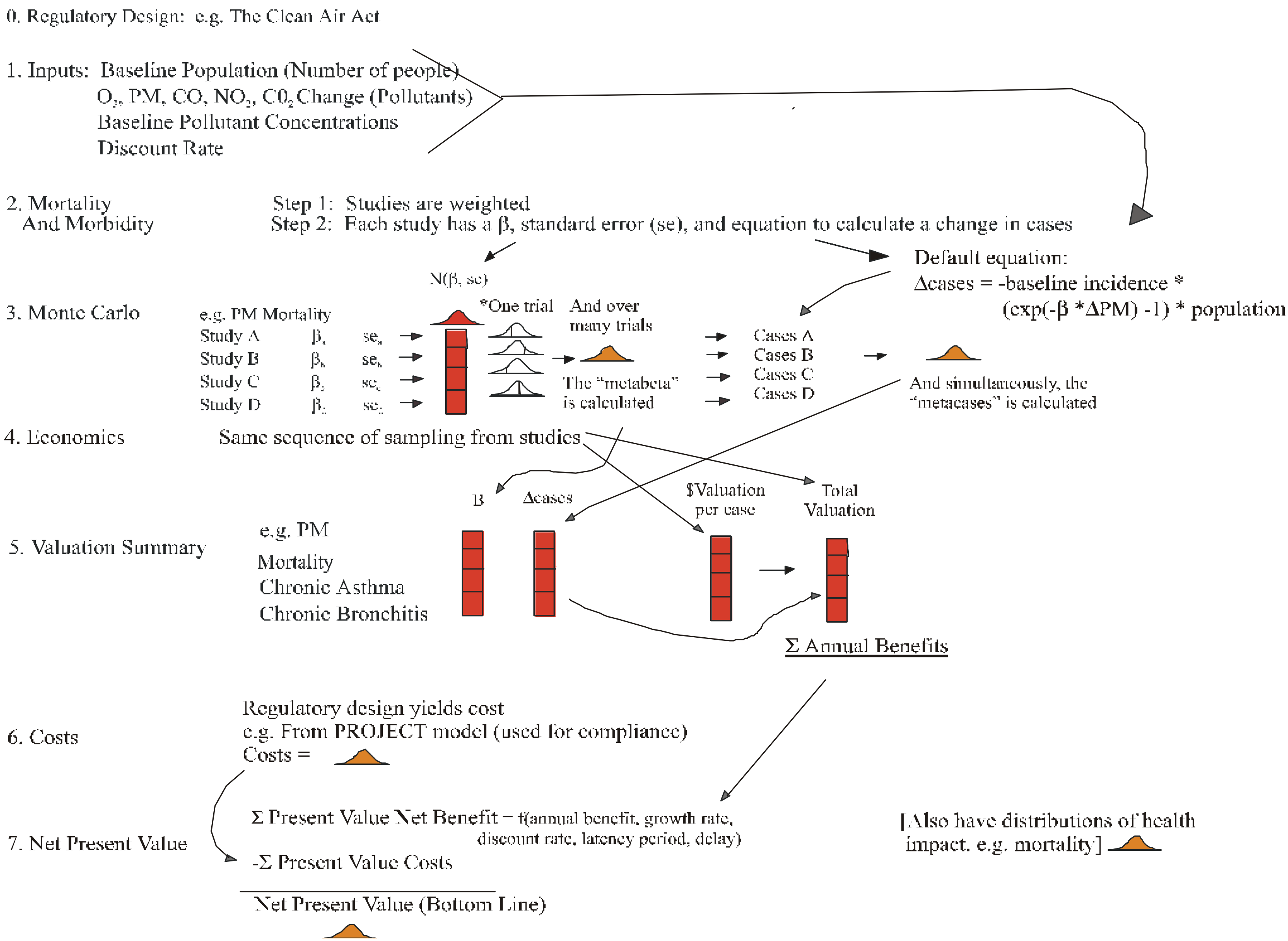


$\mathbf{C}_i$

Result one “observation” of: Net Present Value as Benefit-Cost $\mathbf{PVB}_i\mathbf{-C}_I$

FERAT will obtain many “observations” in the same way with one simulation trial leading to one observation. Typically, FERAT is run hundreds of times.

The Structure of FERET



5.0 Advanced Issues in Health Impacts

EPA's Benefit-Cost Structure for Criteria Air Pollutants

To demonstrate the central features of cost-benefit analysis applied to environmental health policy analysis, FERET has been designed around the US EPA's retrospective (1970-1990) and prospective (1990-2010) cost-benefit analyses of the Clean Air Act. Specifically considered in that analysis were improved air quality changes in the concentration of particulate matter that was less than 10 microns (PM_{10}) and particulate matter that was less than 2.5 microns ($PM_{2.5}$), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO) in the 48 contiguous states. Other non-health and ecological endpoints considered in those analyses, such as visibility and freshwater lake eutrophication, were also discussed although they were of less empirical importance. This version of FERET has an unlinked worksheet on the latter items.

Quantitative Risk Models Used in Predicting Disease Incidence

Equations from published studies that predict disease incidence as a function of pollutant concentration are a central component of FERET. To properly use these embedded equations, the user must define the change in the baseline concentration for each air pollutant, the size of the population impacted by the proposed regulatory change and the exposure-response functions that relate pollutant concentration to disease incidence. If the user does not pick particular functions, the defaults are studies used by EPA. Once defined in FERET, the change in pollutant concentration is used with the selected exposure-response model(s) to predict a change in disease incidence rate, which is then combined with the population size to estimate the resulting change in disease incidence (change in cases). This change is then combined with economic valuations of the cost of disease to estimate the distribution of potential economic benefits from reducing air pollutant concentrations. In the sections that follow, the basic elements of the quantitative risk model, the assumptions made (and their potential effect on the predictions of disease incidence), and the interpretation of the model output are described.

Basic Elements of Exposure-Response Modeling and Uncertainty Analysis

Quantitative models are simplified mathematical relationships that attempt to describe cause and effect relationships that are observed in the real world. Although the word 'simplified' may be interpreted to mean that the process of modeling such real world relationships is simple, this is not the case. Rather, the term 'simplified' suggests that the process of developing quantitative models involves a process of reducing complex relationships to manageable ones that have sufficient precision to be informative. When applied to predicting the incidence of human disease from environmental exposures, each researcher uses a mathematical relationship between exposure and disease incidence, for example the relationship between particulate matter (PM) and mortality.

Many different factors other than the pollutant of concern may influence the likelihood that an individual will experience an adverse health effect on any given day. Such predisposing factors include age, gender, the presence of other diseases, or individual lifestyle habits. Other risk factors might include exposure to co-pollutants that can exacerbate the chance of disease, the exposure duration, the route of exposure, and the peak exposure concentration. To account for such factors, researchers use multivariate regression analyses to isolate the effect of the exposure of interest from the identified confounding factors (hence the term multivariate) and to establish the relationship between exposure of interest and disease incidence in some specific population being studied. The FERET model uses as a default EPA selected regression models that have been described in the human health (epidemiological) literature as the basis for the exposure-response functions used in estimating disease incidence. The effects of several key confounders remain to be examined both in the literature and in FERET, including the co-variation in exposure across pollutants and co-variation in effects across health outcomes.

Computationally, FERET operates in Microsoft Excel 97 (in Windows 98) or Excel 2000 for the PC (or on some PC emulators for a Macintosh such a VirtualPC). The PC platform allows the user to take advantage of an add-in program to Excel, Decisioneering's Crystal Ball (FERET was made with version 4.0 Pro and later, 2000 Pro v5.0), which functionally enhances the basic Excel spreadsheet. Crystal Ball is a software package designed to allow the user to perform simple Monte Carlo analysis, which is an analytical tool used to capture and propagate uncertainty in quantitative models. By taking advantage of this capability, FERET allows the user to examine the aggregated impact of uncertainty on the model output (predictions). The ability to capture uncertainty in quantitative models is particularly valuable in models used to predict human disease from environmental exposures because of the lack of information and the assumptions required for the analysis, and because of natural variability in exposure and disease response between individuals.

To take advantage of this capability, the analyst can specify certain model inputs as probability distributions such as the change in concentration of an air pollutant or the size of the total exposed population. Examples of available distribution forms include the normal, lognormal, uniform, or weibull distributions. Although there are numerous available forms that can be used to specify input distributions, most research has used a "no minimum threshold" form that is discussed in more detail later (see also McClellan, 1999). Caution should be used in selecting the form for any given input, as these distributions have a substantial impact on the model predictions. In selecting distributions, it is also important to document the input parameters and distributions used (as well as the scientific or statistical reasoning behind these choices) in order to allow transparency and repetition of results. For guidelines on how to best perform Monte Carlo analyses see EPA (1997) (available at http://www.epa.gov/nceawww1/monteabs.htm) or Burmaster (1994). For information on defining distributions see Seilor and Alvarez (1996), EPA (1999) or the Crystal Ball user's manual.

Air Concentration Modeling

FERET does not have an integrated exposure model. Rather, the analyst must develop an exposure analysis prior to using FERET that reflects the regulatory design[7]. Specifically, the analyst must directly input in FERET either a point-estimate or a distribution for the change in baseline concentration of each air pollutant on the primary input page (see FERET worksheet page "User Input"). FERET also provides for entering the impact of regulations on the tons of pollutants controlled or on the number of health cases directly avoided. As an example we have

[7] Alternatively the user could specify tons reduced or health impacts avoided.

constructed a basic FERET analysis (file Basic Example) and a complex example that was calibrated to EPA's results for the year 2010. The analysis is also available on the FERET CD as file FERET2010.xls. Since FERET is designed using a spreadsheet platform, FERET can be easily customized to include an appropriate concentration model.

Exposure (Concentration)-Response Modeling

Exposure-response models are used to estimate the reduction in disease incidence with reduced human exposure to airborne contaminants relative to a baseline exposure concentration. To specify these models, the US EPA drew from published scientific literature. Peer-reviewed studies researching chronic exposure (one year or longer), prospective cohorts studies with a large population and studies performed in the US were preferred. Studies also needed to include economically valuable health effects to be included in EPA's studies. FERET includes each of the EPA-specified exposure-response models, which may be found in the FERET worksheet pages "Health-Mortality" and "Health-Morbidity". For graphical representations of these models, see also the mortality and morbidity exposure-response graphs in the Appendix worksheets in FERET. The authors of the models assume that exposure is best estimated as a steady-state average concentration for each air pollutant, and the concentration units are $\mu g/m^3$ (micrograms per cubic meter) in air (or parts per billion, ppb) except for CO, which is measured in ppm (parts per million). The US EPA provides a thorough description of the derivation of the exposure (concentration)-response models used in their cost-benefit analysis and the assumptions used in their analyses (See pages D7-D17 in the US EPA prospective analysis of the CAAA for details. This document may be found at the US EPA website at http://www.epa.gov/oar/sect812 and is also included in the FERET CD.). Although the reader is referred to that literature for a review of these issues, provided below is a brief discussion of the models and discussion of the analytical options in FERET available to the user under User Options.

If the user does not change any of the default studies, then the set of studies used by EPA are being accepted. Some users may wish to select different studies based on some aspects of the assumptions discussed below.

Briefly, the concentration-response models used by EPA and incorporated into FERET are generally of the form:

$$Y = Be^{\beta \bullet [X]}, \qquad (1)$$

where the parameter B is the baseline incidence rate of the adverse health event (with no exposure, concentration of the toxicant of interest is zero), β is the slope factor derived from a particular epidemiological analysis, and [X] is the air concentration of the toxicant of interest. Y is the observed incidence rate (per unit population). This common mathematical form implies that there is no lower threshold to the impact of changes in concentration on health. Some analysts argue that such a threshold exists in which case they should substitute their preferred studies or functional form into blank rows provided in FERET and provide zero or reduced weight on the more standard form discussed here.

Equation 1 can be re-written by taking the natural logarithm of both sides of the equation,

$$\ln Y = \ln B + \beta \bullet [X] \quad (2)$$

To estimate the change in the disease incidence rate, one can evaluate equation 2 under the baseline case (prior to intervention, designated by the subscript 1) and after intervention (designated by the subscript 2), and take the difference, as represented by the following equations:

$$\ln Y_1 - \ln Y_2 = \beta \bullet [X_1] - \beta \bullet [X_2] \quad (3)$$
$$\ln (Y_1/Y_2) = \beta \bullet \Delta X \quad (4),$$

where $\Delta X = [X_1] - [X_2]$. By taking the exponent of both sides of equation 4, one may derive:

$$Y_1/Y_2 = e^{\beta \bullet \Delta X} \quad (5)$$
$$Y_1 = Y_2 \bullet e^{\beta \bullet \Delta X} \quad (6)$$
$$Y_1 - Y_2 = Y_2 \bullet e^{\beta \bullet \Delta X} - Y_2 \quad (7)$$
$$Y_1 - Y_2 = Y_2 (e^{\beta \bullet \Delta X} - 1) \quad (8)$$
$$\Delta Y = Y_2 (e^{\beta \bullet \Delta X} - 1) \quad (9),$$

where $\Delta Y = Y_1 - Y_2$, which specifies the incidence rate or the rate of disease in a specified population size. By solving equation 6 for Y_2 in terms of Y_1 and substituting into equation 9, the change in baseline disease incidence rate may be estimated in terms of the baseline disease incidence as shown below:

$$\Delta Y = Y_1 - Y_1/(e^{\beta \bullet \Delta X}) \quad (10)$$
$$\Delta Y = -Y_1 (1/(e^{\beta \bullet \Delta X}) - 1) \quad (11)$$
$$\Delta Y = -Y_1 (e^{-\beta \bullet \Delta X} - 1) \quad (12)$$

Because ΔY represents the calculated disease incidence rate in a given population, this rate needs to be scaled by the exposed population, P, to estimate the population incidence of disease so that the change in cases for this standard form is defined by $\Delta Y * P$. A number of the studies used subsets of the population, such as adults over 65 years of age. FERET lets the user take into account fractions of the population to define any subset of the entire population in the health worksheets. Sensitive subpopulations, such as asthmatics, are already considered in the calculation of population fraction where applicable. As a default (per EPA), disease incidence rates are only calculated for the population examined in the original peer reviewed literature, although this may underestimate true health benefits in the entire population.

User Options

Although FERET provides a number of default options for use with the health module, the user has a high degree of flexibility in modifying the inputs and structure of the analysis. Described in this section are key options available to the user that will help them tailor FERET to their specific analysis.

Selection/Weighting of Exposure-Response Functions

FERET includes a library of exposure (concentration)-response functions that have been taken from the EPA's benefit-cost analysis. As stated by EPA, these functions have been drawn from the available epidemiological and public health literature. For each study that is included in the FERET library, information is provided regarding the study, including a full citation and abstract, a breakdown of the health endpoint measured, the number of pollutants in the regression model, the change in pollutant measured, the location of the study within the US, the population under study, the ICD-9 codes used to classify a health endpoint, the change in mortality/morbidity reported within the study for each health endpoint, the relative risk, and the functional form of the exposure-response equation used. These details are provided to allow a user to customize the analysis, e.g. for health endpoint, population, location, or pollutant.

A regression parameter (beta) and standard error are either provided within each study or can be calculated using the relative risk. The beta is assumed to be normally distributed, with the mean and standard error as given by EPA based on their review of the studies.

Fraction of Exposed Population

The user may also wish to modify the exposed population. While FERET provides default fractions of the total U.S. population in the 48 contiguous states identified by study authors and the EPA, some users may wish to extrapolate study results to a larger population, for instance to all children instead of only to children between 7 and 12 years, if this assumption is warranted. This assumption should be documented. The population exposed can be modified by altering the fraction of the total exposed population for the particular study under consideration in the "Health-Mortality" and "Health-Morbidity" spreadsheets.

Other Health-Based Assumptions

A number of assumptions lie behind the output of the FERET health module. In general, these assumptions are those used by EPA or the authors of individual studies. The preceding section described the derivation and use of the concentration-response relationships used to estimate population disease incidence. Implicit in the use of these models are assumptions regarding the extrapolation of the exposure (concentration)-response function as reported for a specific population to a second population, the validity of using the derived exposure (concentration)-response function to estimate disease incidence from exposure concentrations that may lie outside the concentrations used to derive the original function, assumptions that exposure occurs at steady-state, and the independence of health effects from pollution exposure. Many model assumptions have been addressed in the EPA's prospective analysis, and the reader is encouraged to carefully examine this information in order to fully appreciate the assumptions made in using the FERET health module and their potential impact on the model output.

6.0 Advanced Issues in Economic Valuation and Cost

As textbooks take hundreds of pages to explain various details of economic valuation and cost, only a summary is presented here. Among a wide list of available material on the subject are

Zerbe and Dively (1994) and Hanely and Spash (1993). FERET users may wish to refer to the books listed below for more in-depth discussions. Here, the focus is on controversial elements of benefit cost analysis including: 1) the accounting stance (whose costs and benefits) and distributional issues, 2) valuation methods, 3) the discount rate, and 4) benefits transfer.

The Accounting Stance—Whose Benefits and Costs—and Distributional Issues

Standard practice in benefit-cost analysis is to compare a situation with and without a regulation (or project.) This defines the "incremental" impact of the regulation, noting that sometimes the regulation can be broken into several components, each of which can be subject to a benefit-cost analysis. One issue is, whose benefits and costs count? And how much do they count? Benefit-cost analysis differs from a financial analysis developed by a for-profit company primarily in its intent to capture the benefits and costs to all individual within the region being studied. The well established practice is that benefits and costs are added up equally for all affected individuals. This approach is called the Kaldor-Hicks potential compensation principle in that if the benefits exceed the costs, then the winners can potentially compensate the losers and society could be better off by implementing the regulation. As compensation seldom occurs, various alternatives have been investigated to weight the benefits and costs differently for different people, often based on income, job classification, or race.

FERET's modeling structure is based on standard practice. However, various distributional analyses can be easily obtained from FERET. For instance, the net benefits for individual groups can be determined by developing a FERET run that uses their exposures and costs. Secondly, the breakdown of net benefits to industry, consumers and government can be obtained by isolating taxes in PROJECT and any other distributional differences from the standard set-up. Should the analyst wish to apply distributional weights to different groups, he or she could create several FERET runs, weight the net benefits according to their subjective preferences, and provide a modified result.

Valuation Methods

First, if a market for a good or service exists, there is a large body of economic thought as to why the market value is an appropriate value to use for social analysis (see for example, Varian, 1992; or Zerbe and Dively, 1994). However, the economic core of the implementation problem for benefit-cost analysis is the estimation of values that are not revealed in the market place, and environmental, health, and safety applications are precisely those for which markets may be limited or non-existent. Economists have developed a variety of approaches to this problem including valuing indirect markets, as for travel related to recreational opportunities, and survey methods (Freeman, 1993; Farrow, Goldburg and Small, 2000). Survey methods, the most well-known of which is contingent valuation, are controversial although they have passed an intensive review of a blue ribbon commission. Analysts may wish to include or exclude studies based on how values were obtained. This is easily done in FERET by simply selecting the studies desired for use in the User Input, health and economic study pages. The method of analysis is listed in FERET worksheets along with other information about the study.

There is also debate about the units of measurement in various cases. While many analyses focus on the value of a statistical life, others focus on life years saved, noting that a regulation may affect people with differing lengths of life still to be lived. These topics are an area of ongoing research in the economics profession. FERET defaults to using the value of a statistical life as its basic mortality unit as that measure was used by the EPA in its Clean Air Act studies (1997, 1999). However, several studies are included on the value of statistical life years or an analyst may determine that the value of a statistical life extends for a given number of years.

Discounting (more detail is provided in the User's Manual under this topic)

Regulations typically affect benefits and costs in many time periods. There is evidence and a body of theory that benefits and costs received in different time periods are valued differently. The adjustment to add values from different years is called discounting. At a technical level, one concern is that values should be consistent, either including or excluding inflation. This involves choosing a nominal discount rate if inflation is included and a real discount rate if it is not. More guidance is provided in the User's Manual under discount rate although you are more likely to use a real discount rate in FERET. More fundamentally, there are philosophical and empirical questions about the form of discounting. Standard practice, and that suggested by FERET as the default, is to discount both costs and benefits at the same rate using a geometrically declining weight, and then to conduct sensitivity analysis of the impact of varying the discount rate. Discounting is actually carried out by the standard Excel function "PV" using the rate set by the user. The effect of mortality latency, delay in implementation, or the population growth rate is an adjustment to the discounting calculation.

An added issue is the year in which discounted values are reported. FERET reports economic values in year 1990 dollars. However, values can be reported for any chosen year between 1990 and 2000 (blank cells are provided for later years) for a secondary, summary report on benefits, costs and net present value.

Benefits Transfer

The basic structure of FERET is to use existing economic studies that value various health and environmental outcomes and then apply those values to the problem identified by the user. This approach is called benefits transfer and is most accurate when the original studies are done under conditions similar to those the user are trying to analyze. Sometimes adjustment factors such as income are available. In its essence, the user is trying to develop an estimate before something occurs (the regulation) and is using available information to inform the estimate. This can be interpreted as a Bayesian statistical approach where it is well known that the development of prior beliefs (here informed by studies) is very important in determining the accuracy of the outcome. The user should be careful in using studies that might have little to do with the location or exposed population of interest. There is no exact answer to this problem of what studies to use. We note that the default is the set of studies that EPA used for its national assessment and which went through a peer review process although at different times EPA has used different studies.

Cost and welfare

The welfare change defined in Figure 1 of the Appendix is visually defined as the area between two cost curves that are bounded by a demand curve. Standard practice is sometimes obscure regarding the quantity for which the costs are being calculated. With reference to Figure 1, it is seldom clear if the change in cost is being evaluated at the baseline (before regulation) quantity, the after regulation quantity or somewhere in between. Given the specific assumptions underlying Figure 1, the conceptually correct approach would be the **change** in costs at the after regulation quantity plus one half the **change** in cost between the baseline and after regulation quantities. In line with other analyses of welfare loses, the "rectangular" changes in welfare tend to be significantly larger than the "triangular" portions. Alternatively, if there is no change in quantity, then the issue can be ignored.

Other hazards: The user is also encouraged to review the guidance documents from various government agencies that are provided as part of the FERET package in the Supplemental folder. Our experience is that confusion can often occur by omitting a relevant impact, or by counting an impact several times (double counting.) An example of the latter is when new jobs might be included in an economy close to full employment (see OMB guidance on the FERET CD); an example of the former might be omitting impacts on children. FERET provides blank rows in a variety of places to enter benefit or cost impacts that may not already be included.

7.0 Conclusion

FERET can inform risk management decisions by pointing out the balance between benefits and costs of alternative regulatory designs, assessing with what probability the net benefits may be positive, helping to identify the magnitude of distributional issues, quantifying environmental impacts, and identifying key assumptions that drive the outcome. However, FERET is not itself a decisionmaker; it is a decision support tool. We hope it will help you and your organization improve the quality of environmental, health and safety regulation.

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As described in the User's Manual, full functionality of FERET 1.0 requires Microsoft Excel and Decisioneering Crystal Ball. Neither the developers of FERET nor the publisher of the book, *Improving Regulation*, receive financial benefit from the use of these programs.

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Appendices

Further Research

In constructing the FERET template, based heavily on the methodology of EPA's several cost and benefit studies of the Clean Air Act, we have identified a variety of gaps in best practice. These gaps are unlikely to be of concern to analyst wishing to capture best practice, but the gaps do identify research areas to advance the quality of benefit-cost analysis. The major gaps we have identified are:

- Independence of health effects: little is known about the correlation of multiple health effects from pollution exposure. FERET, following the EPA approach, assumes that the health effects of different pollutants and of different health endpoints are generally independent of each other while only including mortality from particulate matter. While we have identified some initial means to address this, it remains an issue both for health impacts and for their valuation.
- Epidemiological modeling: the ability of regression analysis to capture confounding factors from multiple pollutants and to model more complex function forms, such as those with a lower threshold, is still evolving. Advances in this area could significantly alter the estimates based on current best practice.
- Child health emphasis: At present, this template uses variable population inputs that are selected by the user. These can be modified to focus on child-specific impacts and net present value. Several studies in the literature "library" used in FERET focused on child-specific impacts, e.g. neonatal mortality (child-specific impact) or the presence of upper respiratory symptoms (studied only in children). Other researchers only examined impacts within a larger population of all ages, such as asthma attacks. Future work in FERET would expand and emphasize this rapidly expanding area of research.
- The transferability of studies from one part of the country to another, and their role in identifying a Bayesian prior for the impact of regulations is an area of current research in environmental economics.
- The valuation of impacts, whether health or environmental, continues to evolve. Survey based methods such as contingent valuation are being extended in new directions while other researchers continue to question the validity of such approaches. FERET, using the EPA studies, includes valuation estimates from labor market and contingent valuation studies.
- Distributional impacts, sometimes discussed as environmental equity or sustainability, are only seldom incorporated into benefit-cost analysis. New methods could be developed.
- Multi-media impacts: some regulations affect air, water and soil. Further research could expand FERET into applications that integrate these impacts.

The Geometry of Welfare Analysis

Welfare economics:

Welfare economics (see references in footnote 1) is a complex branch of economics that assesses the net gains to society by measuring what is called total surplus (composed of producer and consumer surplus) and taking into account matters outside of the market-place such as the external costs of pollution. A simplified geometric analysis is shown here to illustrate how FERET is based on welfare theoretic measures of the change in well-being to the region being analyzed based on standard economic assumptions.

Figure 1 below illustrates a common type of geometric analysis using assumptions of: perfect competition for a market output q with price p, a constant marginal cost of production, and also applying the Kaldor-Hicks potential compensation criteria such that benefits and costs can be added together to whomsoever they accrue. Greater detail on this type of analysis can be found in Zerbe and Dively and related texts. These assumptions are a common starting point although advanced users may wish to consider greater complexity if dealing with markets in which imperfect competition is an important factor or there are other causes of market failure besides that of external costs. In Figure 1, the initial per unit cost of production is given by S_0, and those after increases due to compliance costs by S_1. Similarly, the initial level of external cost is given by E_0 and the later external cost by E_1. Note that these are analyzed separately for ease of exposition.

The change in welfare is assessed by comparing the area under the demand curve, the willingness to pay, less the external cost and the private cost, before and after the change in regulation. Table 1 shows the geometric area associated with each element and the resulting welfare change. The economic measure of the regulation, given in the "change" column, is the difference between the change in external costs and the change in compliance cost bounded by the area of the demand curve. Given the specific assumptions underlying Figure 1, the conceptually correct approach would be the **change** in costs at the after regulation quantity plus one half the **change** in cost between the baseline and after regulation quantities. In line with other analyses of welfare loses, the “rectangular” changes in welfare tend to be significantly larger than the “triangular” portions. Alternatively, if there is no change in quantity, then the issue can be ignored. As FERET computes the net benefit as the difference between the change in external costs and the change in the cost of compliance it can be interpreted as a welfare theoretic based model although care should be taken with the cost of compliance estimation.

Figure 1 Geometric Welfare Analysis

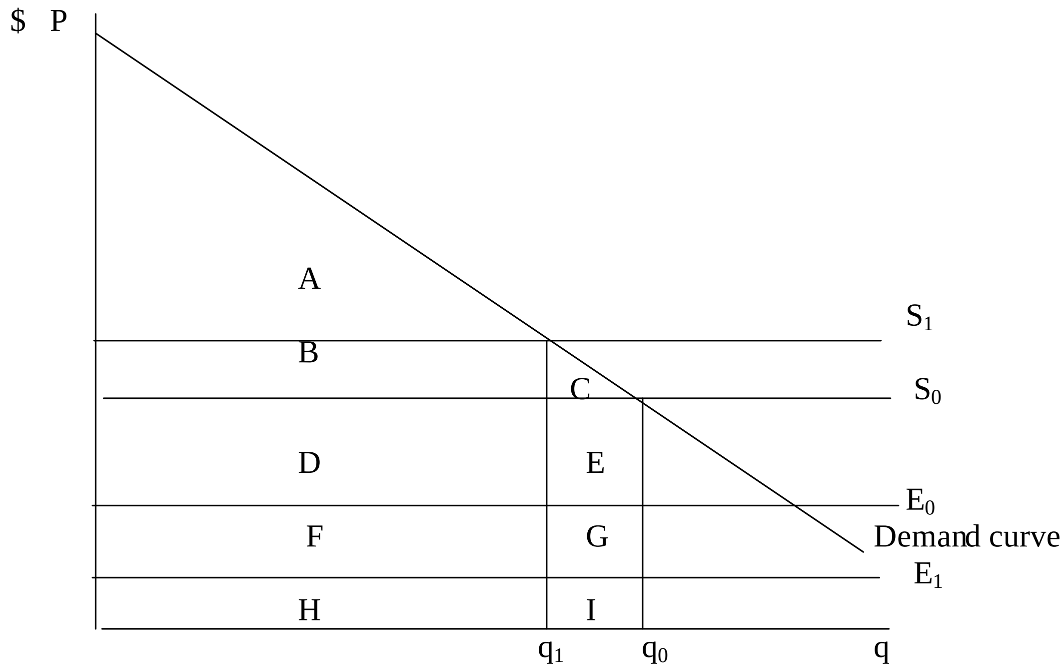

Table 1: Basic welfare economics of FERET

Welfare Category	Initial status	New status	Change	FERET
Willingness to pay: WTP	A+B+C +D+E + F+ G+H+I	A+B+D+F+H	-C-E-G-I	
Minus External cost: EC	F+G+H+I	H	-F-G-I	**FERET computes change in EC as the benefit**
Minus Private cost: PC	D+E+F+G+H+ I	B+D+F+H	B-E-G-I	
Welfare change (Benefit-Cost as WTP less EC less PC)	**A+B+C-F-G-H-I**	**A-H**	**F+G+I-B-C**	**Welfare effect is the (positive) change in external cost less the change in cost as bounded by the demand curve.**

Taxation

Taxation is an issue that can be handled in several ways in benefit-cost analysis. While the analyst can track changes in tax revenue between the government and various sectors of the economy, taxes are a transfer between parties that have distributional impacts (who gets the money) but typically does not have efficiency impacts in a partial equilibrium setting[8]. An analysis similar to that above is shown in Figure 2 and Table 2. The result is that welfare is unaffected by taxes and the benefit-cost analysis can ignore their flow. Ignoring the flow of taxes in this social level of analysis means that the compliance cost should be estimated ignoring taxes; specifically, the PROJECT model should be run with zero net income taxes (or the "not for profit" option should be selected which automatically sets the taxes to zero.)

Figure 2 differs from Figure 1 by excluding external effects (here the focus is on taxation). The cost is also more complex in order to introduce the net income of a firm (often called producer surplus in economics) and its taxation through the corporate income tax at both federal and state levels.

Figure 2 Geometric Welfare Analysis: Corporate income tax

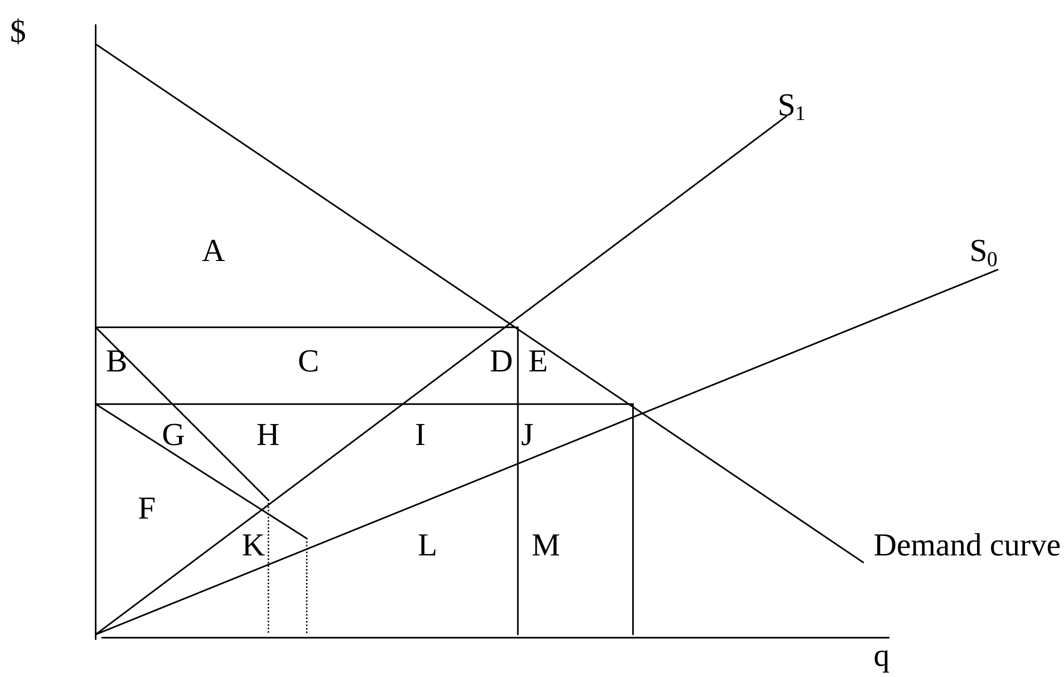

Table 2: Welfare analysis with taxation

[8] Advanced users might consider as a cost the welfare burden of taxation as discussed in the benefit-cost texts.

Welfare Category	Initial status	New status	Change	FERET/Notes
Willingness to pay: WTP	**A+B+C+D+E +F+G+H+I+J +K+L+M**	**A+B+C+D+F +G+H+I+K+ L**	**-E-J-M**	
Private cost: PC	**L+M**	**D+I+K+L**	**D+I+K-M**	
Taxes **Firm** **Government**	 **-F-K** **+F+K**	 **-B-G-F** **+B+G+F**	 **-B-G+K** **+B+G-K**	**Corporate income taxes have zero net effect**
Welfare change (Benefit-Cost as WTP less PC plus taxes	**A+B+C+D+E +F+G+H+I+J +K**	**A+B+C+F+G +H**	**-E-J-D-I-K**	**The welfare change is the change in cost as bounded by the demand curve before any adjustment for taxes. Changes in External Costs would then be added to this effect.**

Note that the definition of the welfare change first computes what is called total surplus (WTP less cost) and then adds the net effect of the taxes. An alternative and equivalent approach is to add up the impacts on consumers (consumer surplus), plus the firm's producer surplus, plus government revenues (e.g. see Zerbe and Dively.)