SCOPE 27 - Climate Impact Assessment

12 Microeconomic Analysis

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12.1 INTRODUCTION

The purpose of this paper is to review the methods available for economic impact analysis of changes in exogenous conditions that affect economic activities. We specifically focus on the use of these methods for the evaluation of the economic impact of natural or human-induced climate variability and change. For the most part, we are deliberately vague concerning the specification of exposure units—the type of economic activity, the particular human population and the geographic area being impacted by the climate variation. We are also deliberately vague concerning the source and the nature of the climate variation whose impact is to be analyzed. The techniques we discuss, however, are flexible enough to be suitable for a wide variety of climatic impacts and a broad range of exposure units.

It is generally acknowledged that climate is an important natural resource that supports both production and consumption activities around the globe. An early recognition of this role of climate appears in Landsberg, 1946; more recent discussions can be found in Taylor, 1974; d'Arge, 1979; and World Meterological Organization, 1980. It is also generally acknowledged that climate is a hazard that can impose severe economic costs, globally as well as locally. For example, Burton *et al.* (1978) studied the economic effects of three climate-induced natural hazards (drought, flood, tropical cyclone) on pairs of industrialized and developing countries. The economic impact of natural disasters on human resources in developing countries and on economic resources in industrialized countries is reported in World Meteorological Organization, 1980. The economic impact of drought in the Sahel region of Africa has been studied by many scholars, including Kates (1981), García (1981), and García and Escudero (1982).

Despite this widespread acknowledgement of the dual role played by climate, however, there has been insufficient recognition of the fact that climate is fundamentally different from other exogenous shocks affecting economic activity. These special features affect how the analyst should represent the role of climate and its variations in evaluating its impacts on economic activities. Consequently, we begin our review in Section 12.2 with a discussion of the role of climate in economic activities. Before we can consider the implications of climate for the economic behavior of households and firms, it is essential to define climate and to understand the ways in which climate affects the economy at this disaggregated level. After these relationships are described, it is then possible to describe the specific objectives of economic impact analyses and the models used to undertake them.

Economic impact analysis means different things to different analysts and policy-makers. In the broadest terms it is a set of procedures for gauging the implications of changes taking place outside an economic system for the economic activities that take place within it. A clear evaluation of the prospects for using economic impact analysis to understand the prospective social and economic consequences of our climate resources requires that the conceptual foundation of economic impact analysis be described in some detail. In Section 12.3 we briefly discuss four types of models that have been used to conduct economic impact analyses—input-output, macroeconometric, microsimulation, and systems-dynamic models. Input-output models have been extensively used at regional and national levels in a wide variety of countries, and at a global level by Leontief *et al.* (1977). Macroeconometric models are also widely used at regional and national levels, although typically not for the purpose of examining the implications of climatic impact. Examples of macroeconometric models abound in the literature. Models have been constructed for the economies of most countries. Among the most well known of these models for the United States are the Wharton EFA and Data Resources Institute models. The Korean Agricultural System Simulation Model (KASM) illustrates the use of microsimulation models, while the SAHEL model of the human-ecological dynamics of the Sudano-Sahel region of West Africa provides an example of the systems-dynamic models (see Glantz *et al.*, Chapter 22). Each of these types of models is examined in Meadows and Robinson (forthcoming). In our discussion of these models we avoid referring to specific examples, but rather focus on the way in which each type of model establishes a linkage between the exogenous shock to the economic system and the response of that system.

One approach to the analysis of economic impacts is to measure the benefits and costs of an impact, or of alternative responses to an impact, or of alternative strategies to avoid or mitigate an impact. For example, d'Arge (1979) reports the results of a variety of benefit/cost analyses of human-induced climatic changes, many of which originally appeared in d'Arge *et al.* (1975). Other applications and critical evaluations of benefit/cost analysis to climatic impact can be found in d'Arge and Smith (1982), and d'Arge *et al.* (1980).

In some areas of economic policy-making (for example, regulatory impact analyses prepared as a part of the standard-setting process within the United States Environmental Protection Agency), economic impact analyses and benefit/cost analyses have served quite different roles. The same distinction has not been used in evaluating climate impacts. In this case, benefit/cost analyses have generally been treated as a type of economic impact analysis. These differences in vocabulary need not confuse our objectives. The reasons for these distinctions in other policy uses of economic impact and benefit/cost analyses follow from differences in the ways their results can be interpreted.

Economic impact analyses attempt to measure the effects of an exogenous change on the allocation of resources. If climate patterns change in the midwestern United States, will agricultural activities be maintained at the same levels? Will more or less irrigation, labor, fertilizer, etc., be used? The answers to these questions are descriptions of the changes in resource usage that would result from the change in climatic conditions. They do not necessarily imply that the individuals affected by these changes will have either enhanced or reduced levels of economic well-being as a result. By contrast, benefit/cost analyses seek to organize the information associated with a change (whether a conscious policy change or an external change outside man's control) in order to make judgments as to whether it improves the resource allocation (that is, increases the levels of economic well-being experienced by individuals and realized through the use of given resources). Therefore, in Section 12.4 we discuss the main features of benefit/cost analysis.

Finally, we discuss briefly in Section 12.5 the special features of climate that affect the use and interpretation of impact methodologies. The three most prominent features of climate are its stochastic nature, stressed by d'Arge and Smith (1982), Heal (1984), and McFadden (1984); the potentially broad geographic scope of its impact, which makes interjurisdictional cooperation desirable but difficult if different jurisdictions are affected differently; and the temporal nature of its impact (see also d'Arge *et al.*,1980). Each of these features of climate requires that traditional impact methodologies be modified.

12.2 CLIMATE IN ECONOMIC ANALYSIS

12.2.1 A Definition of Climate

Climate describes the probable weather patterns that can be expected, on the basis of past experience, to prevail at a specific location during a given period of time. It can comprise a detailed array of features of these weather conditions, including temperature, rainfall, humidity, cloudiness and the like. In formal terms we can consider climate as a set of random variables used to describe the outcomes of a stochastic process—the interaction of atmospheric circulation with solar radiation and the oceans and land masses—to determine a pattern of weather events. Our description is based on the supposition that there is sufficient regularity in the processes determining climate that we can assume that these random variables have probability distributions with finite means and variances. Naturally these parameters will be specific to both the geographic location under consideration and the time of year. These definitions follow directly from Hare's description (Chapter 2 in this volume).

Within this framework it is possible to distinguish a variety of types of climate variation. To begin, it may be desirable to assume that the parameters associated with the probability distributions for the random variables describing the climate are themselves subject to change. Cycles of wet or dry conditions that occur with sufficient regularity may be considered (in this framework) to be the result of a particular functional relationship between the mean precipitation and time. Weather patterns may nonetheless exhibit variation about this cycle. The important point to note in this distinction is the ability to discern over time a pattern for the average weather conditions that describes how they are changing.

In order to define climate variation it is necessary to specify an appropriate time span. Although distinctions such as short-term (interannual), medium-term (decadal), and long-term (century) are useful, the current meteorological convention is to use 30-year `normals', updated each decade. In practice, the use of 30-year normals gives fairly stable values of central tendency and variability for most features of climate. As we shall explain below, however, the use of such long time-frameworks is not always convenient for economic impact analysis, and it is of little relevance for the analysis of the economic impact of climatic hazards.

Within the context of any normal, we can identify three characteristics of climate—noise, variability, and change. Climate noise refers to the differences that occur in climate parameters between periods, as a sole result of the positioning of the start and end of the averaging periods. It has no real significance, and is henceforth ignored. Climate variability refers to fluctuations of the climate parameters within the averaging period, and is described by the `spread' parameters of the probability distribution of the climatic random variables. These parameters describe the nonsystematic fluctuation in weather conditions and whether certain descriptions of the features of climate exhibit variations that move together. Finally, climate change refers to movements between successive averaging periods in the climatic parameters in excess of what noise can account for. Climate change is measured by the trend over averaging periods in various climatic parameters, and represents a systematic pattern of weather conditions (see Hare, Chapter 2 for further details).

For the purpose of our analysis we also distinguish natural sources from human-induced sources of climate variability and change. A human-induced variation occurs when one or more of the parameters of the probability distributions is affected directly or indirectly by human activities. These activities induce a change in the functioning of the atmospheric system. While such variations can occur over short or long periods of time, they are not the result of an evolution of the atmospheric interactions determining climate. This distinction may seem arbitrary and unnecessary for any physical description of climate and its effects on economic activities. It is, however, important to our analysis of the interaction between climate and economic activities, since it implies that there is the potential for a two-way relationship between the climate system and human economic activities.

12.2.2 Economic Implications of the Definition of Climate

The definition of climate leads naturally, and usefully for our purposes, to the interpretation of climate as a regional public good. That is, climate is a resource whose features and variation provide services to each economic agent (such as firms and households) in a given location without reducing the total amount of these services available for other agents in that location. (See Haurin,1980, for a similar treatment of climate.) Obviously, the services provided by climate can be either beneficial or deleterious. Once an economic agent has selected a geographic location, it receives the climate services relevant to that region. Climate services are not the result of conscious consumption and production decisions by households and firms; they are the natural endowments to each region that influence these consumption and production decisions. Thus, in contrast to other public goods, such as police and fire protection or national parks, we are not concerned with determining the socially optimal level of provision of the services to meet the needs of consumption and production. Consequently, one might ask whether there is an economic problem associated with climate resources. That is, since we do not consider that the services of climate are provided by human actions and therefore subject to control, it may not be sensible to consider the economic implications of alternative climate regimes. Indeed, to the extent that there is full information on climate conditions, we would expect that firms and households would take these conditions into account in their decisions as to where to locate, what to produce and consume, and so forth. We do not expect to find farmers planting citrus trees in locations with unsuitable climate, or consumption activities sensitive to cold conditions to locate where low temperatures can routinely be expected.

To answer our own question, there is of course an economic problem associated with climate resources. The economic problem is not one of optimal *provision,* since climate is a regional public good, but rather one of *adjustment* to climate endowment, variability and change. It is, nonetheless, important to recognize the public attributes of climate because they preclude private markets from providing direct information on the value of climate services. Rather, this information must be derived by indirect means, through a recognition of the adjustment mechanism available to households and firms by means of migration and other responses. These adjustments are fundamental to the methods used for analyzing the economic impacts of climate and its variation.

It is reasonable to expect households and firms to react to climatic shocks in the same basic manner that they are supposed to react to other exogenous shocks to their economic environment. The cases where these conditions are most easily recognized involve agricultural production. For example, if production activities require controlled temperature or humidity conditions, they will be located (other things being equal) where these conditions can be maintained at least cost. Several authors have provided empirical evidence that individuals do consider climate among other environmental amenities in considering the real wages they are willing to accept (see Hoch, 1974; Rosen, 1979; Cropper and Arriaga-Salinas, 1980; Smith, 1983). If these empirical associations do reflect workers' attitudes toward climate, they will also influence labor supply conditions facing employers in different locations and thereby indirectly influence locational decisions.

The opportunities available to economic agents for behavioral response are governed by a number of factors. One factor is the length of time over which the response is observed. Long-term responses are termed `adaptations' by geographers and `full adjustments' by economists, while short-term responses are termed `adjustments' by geographers and `partial adjustments' by economists. The essence of the distinction in either parlance is that the planned or desired long-term response (through disinvestment, migration and reinvestment) to climatic shock is only partially completed in the short term. For examples of this temporal distinction see Wigley *et al.*, Chapter 21. The process of response is also influenced by the nature of the economic society being impacted by climatic shock—that is, the nature of the exposure unit. Thus, a technologically advanced, industrial society typically has more options available to it than does a pastoral or a self-provisioning society. For examples of this distinction see Burton *et al.* (1978); see also Chapter 21, this volume. A detailed analysis of response to climatic shock in self-provisioning societies is available in Jodha and Mascarenhas (Chapter 17, this volume). A third factor affecting the opportunities for behavioral response to climatic shock is the policies adopted by governments to deal with it. Such policies can influence the nature of the climatic shock (for example, the timing, magnitude and/or location) if it is human-induced, as in the cases of carbon dioxide, chlorofluoromethanes and other pollutants. They can also influence the nature of the response to either natural or human-induced climatic shock. Various policies for controlling, mitigating and adapting to the carbon dioxide problem are explored in Nordhaus (1980), Lave (1981) and Noll (n.d.).

How can economic models be structured to reflect these influences on the behavior of economic agents? The answer to this question depends rather importantly on how we define the climatic influences themselves. In our discussion of economic behavior we have implicitly accepted the view that economic agents make their decisions as if they were acting rationally in the pursuit of their own self-interest. Economists generally assume that households adjust their commodity demands and their labor supplies in an effort to maximize utility, and that business firms adjust their input demands and output supplies in an effort to maximize profit. Since household commodity demands and labor supplies can be expected to depend on climate, so too can the maximized utility of households. Similarly, since firm input demands and output supplies can be expected to vary with climate, so too can the maximized profit of firms. For most economic systems these behavioral models offer viable descriptions of the factors motivating economic responses. In some economic systems, where overt markets are not sanctioned, it may be more difficult to determine household preferences and firm objectives based on the goals pursued by households and businesses. Nonetheless, if households and businesses pursue any goals at all, then their optimizing behavior as reflected in their demands, supplies, and optimized objectives can be expected to depend on climate. Although goals and methods of pursuit may vary across economic systems, the essential dependence of purposeful, goal-seeking behavior on climate does not.

In such a framework the distinction between climate as a fixed flow of services (described by variables such as temperature, rainfall, etc.) versus a random flow of services (described by frequency distributions of these variables) delivered to firms and households is important. In the former case optimal behavior can be defined as conditional on a specific set of values for the variables defining climatic conditions. In principle, any change in one of these variables would imply a corresponding change in the optimal behavior patterns of the economic agents involved.

This conclusion is easily demonstrated with a formal example. Consider a general statement of the objectives of a profit-maximizing firm given in equation 12.1:

$$\max \quad \{P \cdot Q - \sum_{i=1}^{n} r_i X_i : Q \leq f(X_1, \ldots, X_n, \bar{C})\} \tag{12.1}$$

In this statement it is assumed that the firm employs inputs $X_i \geq 0$, $i = 1, \ldots, n$, available at fixed prices $r_i > 0$, $i = 1, \ldots, n$, to produce a single output $Q \geq 0$ for sale at fixed price $P > 0$. The activities involved in transforming inputs into output are assumed capable of being described by a production function f(•), a function that describes the maximum output levels that can be achieved for any combination of inputs. Finally, we have included in our statement of the problem the influence of climate, by assuming that the maximum output obtainable from various input combinations is conditioned on the realized vector $\bar{C}$ of climate variables. Using conventional methods of optimization, we can describe the maximum profit π^* that can be realized with this production constraint for alternative output and input prices and for alternative realizations of the vector of climate variables as

$$\pi^* = \pi^*(P, r_1, r_2, \ldots, r_n, \bar{C}). \tag{12.2}$$

Moreover, since maximized profit depends on input and output prices and on the realization of climate, so too do the input demands and output supply that maximize profit, and we have

$$Q^* = Q^*(P, r_1, \ldots, r_n, \bar{C}).$$

$$X_i^* = X_i^*(P, r_1, \ldots, r_n, \bar{C}), i = 1, \ldots, n. \tag{12.3}$$

To the extent that climate variables influence production activities in a manner suggested by equation 12.1, they must also affect maximum profit, as well as the profit-maximizing output supply and input demand given by equations 12.2 and 12.3. Consequently, a change in any one climate variable, say the *k*th feature of climate, $\bar{C}_k$, which might be average temperature, may imply by equation 12.3 a reorganization in the patterns of input usage and an adjustment in the amount of output supplied. The partial derivatives of Q^* and X_i^*, $i = 1, \ldots, n$, with respect to $\bar{C}_k$ describe these adjustments, while the partial derivative of π^* with respect to $\bar{C}_k$ describes the consequences of such a change for the firm's profit. This approach to modeling the effect of climate on production activities by deriving the effect of climate on observable supply and demand equations is described in more general terms and in greater detail by Diewert (1982). A similar construct can be developed to model the effect of climate on utility-maximizing households.

Once we generalize the description of climate, by recognizing that it is described by a set of random variables, then we must inquire as to whether we can expect economic agents to deal differently with climate changes that are not certain as opposed to those that are. The answer is that we can. Analysis of climate in stochastic terms requires more complex models to incorporate some conception of how economic agents respond to climate-induced uncertainties.

Some insight into what such models might imply as compared with frameworks that treat climate variables as realized, and hence stochastic, can be derived from an analogy. An early paper by Stigler (1939) on the significance of uncertainty for business behavior considered the implications of uncertainty in the output level to be produced at a given plant for the way in which the plant might be designed to produce output. Conventional micro models unconcerned with uncertainty assume that firms know exactly what output levels they are required to produce at each plant. Thus, a plant can be designed so as to minimize cost for *the output level* it is producing. If the output level is not certain, however, the situation changes completely. Stigler argued that it is entirely reasonable to expect that firms seek to design plants that minimize cost over the most likely range of output rather than for a single output level. This alternative view provides a plausible conception of business behavior in the presence of demand uncertainty. It recognizes the need to accommodate, with little change in average cost, a range of production levels. Indeed, it may well be that the mean average cost over these output levels exceeds that realized with a single output level. Yet the best strategy remains the one associated with designing the plant to accommodate a range of outputs. Stigler referred to such modifications in plant design as a means of promoting *plant flexibility*.

The difference in unit cost between the two types of plant designs is the `price' of the flexibility in the firm's operations. McFadden (1984) used the same type of framework to illustrate how climate considerations can be incorporated in a neoclassical cost function when climate is treated as a random variable. Indeed, using a fairly simple three-activity model, where demand for output varies with the random climate variable, he has clearly demonstrated the impact of variability in climate on both the technological design of the plant and the resulting cost. Climate variability in this framework provides an incentive to diversify activities and, with it, increases cost. However, these cost increases are *not* as great as they would be if only one activity were used to produce output over the range implied by the climate variability.

With a stochastic conception of climate, economic models describe the responses of economic agents to climate uncertainty as consisting of a restructuring of their activities to permit them to accommodate a range of values of the climate variables. The specific details of each type of economic agent's responses are likely to be related to a variety of factors, including:

1. each agent's perception of the nature of the likelihood for variation in climate attributes (that is, the individual's perception of the multivariate probability distribution describing the climate random variables);

2. each agent's attitude toward the risk of economic losses as a result of climate uncertainty; and

3. the costs of incorporating flexibility (that is, the ability to accommodate a range of climatic conditions) in the particular activities involved.

Thus, information, attitude, and the cost of resiliency are important determinants of the pattern of flexibility present in any sector and, in turn, the nature of the response to a change in climate. This conclusion must, however, be carefully interpreted. First, since this framework conceives of climate as a vector of random variables, any change in climate may not necessarily lead to an immediate change in the weather patterns which the economic activities have been designed to accommodate. The arguments we have described earlier, as well as McFadden's (1984) formal models, assume that all economic agents *know* the exact nature of the probability distributions for the climate random variables from the observed weather patterns.

Consider an example. Suppose there is a change in the atmospheric system that leads to a higher average temperature in a given region. Such an alteration implies a lower likelihood of the cooler temperatures that a given economic activity may have been designed to accommodate and a higher likelihood of warmer temperatures. Depending on the magnitude of the change in the mean, it may not be detected immediately by economic agents, since the resulting weather conditions may still be capable of being accommodated by the system. Of course, this conclusion depends on the extent of flexibility in the activity which, in turn, depends on each of the three factors discussed above. The important aspect of the comparison for our purposes is that the economic impact of a climate change may not be as immediate as would be implied by the nonstochastic conception of climate. Furthermore, the magnitude of the effect depends upon what the economic agents in the region perceive to be the likely variation in temperature and on their willingness to assume the risks of any economic losses associated with variations in temperature.

The complications to economic modeling that arise from treating climate services as random variables are important because they affect our ability to judge the economic impact of climate variability and change in response to human activities.

12.3 ECONOMIC IMPACT ANALYSIS

12.3.1 General Background

In most economies, policy-making relies on economic impact assessments to judge the effects of proposed policy initiatives or of factors outside a government's control that might nonetheless impinge on the economic activities taking place within its national boundaries. Because these studies have been undertaken for a wide variety of problems as well as to serve a diverse array of objectives, definition of what comprises an economic impact analysis is difficult. We stated, at the outset, that economic impact analyses attempt to gauge the magnitude and sectoral composition of the resource allocation changes that accompany an external change to an economy. To the extent that these changes require greater resources used to accomplish the same objective, then the external change has required adjustments that divert resources for one use to another where they were not previously needed. When the changes under study are the result of direct actions, it is often assumed that they represent attempts to improve an existing source of inefficiency in the economy. Consequently, for these cases, it is conventional practice to compare the benefits associated with the resource allocation changes with the costs of those changes.

Thus economic impact analysis attempts to measure the extent and types of adjustment that accompany an exogenous change, and benefit/cost analyses provide the basis for appraising the desirability of the change as if it were discretionary.

An example of an impact analysis would be an assessment of the influence of foreign steel manufacturers' export pricing behavior on the domestic steel industry of a nation. A second example would be an analysis of the consequences of a particular domestic regulatory program on specific industries.

These types of economic impact analysis seek to predict the nature of the changes in economic activities that accompany the external action. Often the particular action under study has not taken place before, so that analysis must relate the action to a parallel change that has occurred. In other words, the analysis must provide a mechanism for `second-guessing' the response of economic agents. Of course, the process of second-guessing is easier if one can describe formally the behavior of these agents, as in equations 12.1–12.3 above, for example.

Applying such formal descriptions can involve detailed empirical analyses of the past responses of economic agents, as well as judgments about the limitations of these models as descriptions of economic behavior under alternative circumstances. For example, most economic theories distinguish the responses economic agents make in the short run from those possible in the long run. The distinction rests primarily with the cost of adjustment to certain resource allocations. Businesses do not easily modify their capital stocks. Movement from one location to another, by businesses or by households, is costly and difficult. Institutional constraints on economic behavior are not relaxed quickly. Therefore in gauging the economic consequences of an action one must recognize that the complete adjustment described by long-run economic models, such as that described in equations 12.1–12.3 above, does not provide an adequate characterization of short-run economic responses.

Economic impact analyses are typically organized to highlight the economic groups (or sectors) that gain resources and those that lose them. Attention is also focused on the degree of adjustment that such actions impose on particular types of economic agents.A good example of the use of such analyses to gauge the `strain' imposed on segments of the economic infrastructure can be found in the analysis of boomtowns from the development of energy resources in the western United States (see Cummings and Schulze, 1978). Presumably, the objective of economic impact analysis in this case is to judge whether the local, private economic agents are capable of *efficiently* responding to the increased resource demands arising from the development.

To undertake this analysis, it is preferable to have a formal description of the economic activities affected by the action. Such descriptions must be consistent with the institutional restrictions governing resource allocations. Thus, in a market economy the model can be a characterization of the markets involved, while in a planned economy the model characterizes the planning mechanisms.

12.3.2 Describing Economic Activities

There are two essential ingredients to an economic impact analysis. The first is a formal description, usually a mathematical model, of the economic activities that are assumed to be affected by the action under evaluation. The second is a mechanism for linking the action to be evaluated to the model of economic activities. While the decisions made on these components to the analysis are clearly intertwined, for ease of exposition we deal with each separately, deferring the second to Section 12.3.3.

Four classes of models have been used to provide empirical descriptions of economic activities: input–output, econometric, microsimulation, and systems-dynamic models. We describe below, in simple terms, the main features of each of these classes of models. Since the models within each class are heterogeneous, our descriptions are intended only to highlight some of the most important features of the models for economic impact analysis of climate variability and change.

12.3.2.1 Input-Output Analysis

Input–output analysis is based on a recognition that production activities are interdependent. The outputs of some industries are inputs to others and vice versa. Thus, judgments as to the input quantities required to produce a given level of output for any particular industry depend on the input requirements for all industries. Of course, the specific degree of interindustry dependence is an empirical question. The objective of input–output analysis is to provide a consistent modeling framework for describing these interdependencies.

Input–output analysis incorporates the interconnections in production by enumerating the requirements for each potential input and output in the economy which is to be described. This economy may, in principle, be any size. The quality of description in each case depends on the accuracy of its characterization of the production activities taking place at that level. Input–output analysis generally assumes that the relationships of each unit of input to each type of output are constant (over the range of applications in the model).

The structure of input–output models imposes consistency between the defined production levels for each good or service and the internal (that is, interindustry) and external demands for them. If $a_{ij} \geq 0$ designates the requirements for input *i* to produce one unit of commodity *j; X_j* represents the amount of commodity *j* that is produced; and $d_j \geq 0$ corresponds to the external (that is, by households, government, and the foreign sector) demand for commodity *j*, we can describe input-output analysis with balancing conditions. These conditions are illustrated for an economic system consisting of *k* industries and an external sector by

$$
\begin{aligned}
X_1 &= a_{11} X_1 + a_{12} X_2 + \ldots + a_{1k} X_k + d_1 \\
&\;\vdots \\
X_k &= a_{k1} X_1 + a_{k2} X_2 + \ldots + a_{kk} X_k + d_k
\end{aligned}
\qquad (12.4)
$$

The model clearly recognizes that we cannot use more than we produce and that production activities often require some of their own outputs. For example, electricity generation requires some of the generated electricity for its production activities, but there remains a positive net output.

Input–output analysis was designed to facilitate planning the levels of the Xs that are required to meet some predetermined demands—the *ds*, given the constraints of production technology embodied in the a_{ij}s. It is not a full description of all the interactions involved in the equilibrium determination of all quantities and prices in an economy. There are no feedbacks from the description of production activities (and their implied costs) to final economic demands. Moreover, the approach treats interindustry interaction as purely a function of technical relationships. In a more general characterization of production activities we might recognize that the a_{ij} are not constants, but depend upon how firms organize their production activities. Jones (1965) offered one of the first analytical descriptions of the general equilibrium interaction of economic activities in these terms. The empirical models of the role of energy in economic activities developed by Jorgenson and his associates (i.e., Hudson–Jorgenson, 1974; and Jorgenson–Fraumeni, 1981) reflect such considerations. These extensions are to be distinguished from input–output models that postulate that some or all of the a_{ij}s can change. The empirical models of Jorgenson provide a behavioral framework for describing why they change and, therefore, for predicting how they can be expected to change under specified conditions.

Input–output analysis, without these refinements, considers whether it is possible to solve the equations for the X_js, given the a_{ij}s and the d_js. That is, is there a potential mathematically consistent description?

The use of input–output models for economic impact analysis maintains that the changes induced by the action are determined exclusively by technical production considerations. The mutual interaction described by markets is ignored and the associated feedback effects are implicitly assumed to be unimportant. These are serious shortcomings, which must be balanced against the ease of application and detail of most input–output models.

12.3.2.2 Econometric Models

Econometric models, considered as a class of modeling structures for economic impact analysis, comprise the most heterogeneous category. For our purposes it is probably best to organize our discussion of them according to each model's relationship to a behavioral framework. More specifically, microeconomic theory provides analytical descriptions of the behavioral responses of economic agents to exogenous changes in conditions affecting them. These descriptions are provided by the demand and supply functions we derived earlier in equations 12.1–12.3, for example.

The correspondence between the econometric model and economic behavior is closest when the analysis relates to the most disaggregate level—describing the behavior of representative businesses or households. While analysts may legitimately question in some cases the processes through which such models have been estimated (that is, using micro data on individual economic agents or `averages' for broad classes of agents), the frameworks themselves can be evaluated by their consistency with the economic behavior they are designed to depict.

As the level of aggregation increases and the correspondence between the specified components of an econometric model and the behavioral responses of economic agents diminishes, it is more difficult to interpret the models, evaluate their plausibility, and, especially important, use them in all forms of economic impact analysis. This last issue will be particularly important to benefit/cost analysis because without a direct association between the empirical models used to predict effects of external actions and a behavioral model, it is not possible to translate those predicted effects unambiguously into a consistent measure of change in economic well-being.

Regional econometric models (see Harris and Hopkins, 1972, as an example) are the most popular econometric structures used in economic impact analysis. These structures typically seek to describe economic activities for an arbitrarily defined regional unit, such as a county or district. They do so without clear behavioral foundations for the models. Regional models are based on hypothesized associations between economic aggregates that are assumed to be realized as `approximations' to the responses taking place at the micro level. While there are good reasons to organize the description of economic activities according to the nation in which they are undertaken, the same economic rationale for small regional units, such as counties or districts, defined because these units are the basis for the data available, is more suspect. (For a discussion of this issue in terms of regional energy models see Freedman, 1981.)

An important distinction which can be used to classify econometric models is whether they describe the processes through which a set of economic variables is jointly determined or focus instead on the impacts of exogenous variables on the measures of economic activity. A member of the first class of models is generally described as a structural model, while a member of the second is a reduced form model. Most structural models are used to describe aggregated economic activities, that is, a region, nation, or, along another dimension of aggregation, an industry. It is, of course, possible in principle to solve structural models for their implied reduced form models.

To illustrate the distinction between structural and reduced form models, consider a very simple macroeconomic model introduced by Lawrence Klein (1950) as one of the first econometric applications of Keynesian economics. It includes:

1. a consumption function describing aggregate consumption (C_t) as a function of aggregate profit (P_t) and the aggregate wage bill (the sum of private wages W_{pt} and government wages W_{Gt});

2. an aggregate investment function relating investment expenditures (I_t) to current and past levels of profit and the past capital stock (K_t);

3. a wage equation relating private wages to current and lagged levels of private output (that is, disposable income Y_t plus taxes T_t less the government wage bill W_{Gt}) and

4. definitions of investment and total output in terms of components of income (W_{pt}, W_{Gt}, P_t) and in terms of the types of goods produced (C_t, I_t, G_t = government spending, T_t). Equations 12.5a through 12.5f detail the model.

$$C_t = a_1 + a_2 P_t + a_3 (W_{Pt} + W_{Gt}) \qquad (12.5a)$$

$$I_t = b_1 + b_2 P_t + b_3 P_{t-1}, + b_4 K_{t-1} \qquad (12.5b)$$

$$W_{pt} = c_1 + c_2 (Y_t + T_t - W_{Gt}) + c_2 (Y_{t-i} + T_{t-1} - W_{Gt-1}) \qquad (12.5c)$$

$$I_t = K_t - K_{t-1} \qquad (12.5d)$$

$$Y_t = W_{pt} + W_{Gt} + P_t \qquad (12.5e)$$

$$Y_t = C_t + I_t + G_t - T_t \qquad (12.5f)$$

The subscript *t* refers to the *t*th year. This structural model includes six linear simultaneous equations for the determination of consumption, investment, the private wage bill, capital, profit and disposable income. Time-series information on the relevant variables would be used to estimate the model's parameters (i.e., the *as, b*s and *c*s).

We might also solve the model relating current values of each endogenous variable (i.e., C_t, I_t, K_t, P_t, W_P, and Y_t) to the values of these endogenous variables determined earlier in time (i.e., at $t-1$, $t-2$, etc.) and to exogenous variables determined outside the model (i.e., G_t, T_t, W_{Gt}). This description of the same endogenous variables is the reduced form model.

One of the most important difficulties in applying the econometric models associated with aggregated relationships for economic impact analysis arises in establishing the linkage between the action under study and its implications for the model. Unless it can be expected to change the features of one or more component equations in these models, because of the effects on the microeconomic responses underlying these equations, there is no sound means of making the change. For example, in the simple model described above, where would climate most logically enter?

12.3.2.3 Microsimulation Models

This aggregation problem provides much of the motivation for interest in microsimulation models. These models attempt to mimic economic activities at the micro level with a manageable number of economic agents. That is, they describe commodity demands and labor supplies of a limited number of households in an optimizing framework, with distinctions among households in the model made on the basis of characteristics thought to be important to the analysis (such as income or location). Similarly, a limited number of firms are described as the suppliers of goods and services consumed by the households and the employers of the labor services supplied by the households. The models generally assume ideally functioning markets.

What distinguishes many of the microsimulation models is how they specify the two dimensions of the economic interactions of a market-oriented economy and how they define an equilibrium condition. One of the most appealing approaches for structuring models uses a numerical general equilibrium (NGE) framework (see Scarf, 1973; and Shoven and Whalley (1984), for an overview and review). In these structures, the equilibrium condition is defined by the non-negative price vector (for goods and services) that assures all excess demands are nonpositive. At these prices the market demands can be satisfied with the available supplies.

In principle this approach offers detailed micro descriptions of economic agents' behavior *and* permits an assessment of the full impact of proposed actions with a consistent accounting of the economic interactions. This also implies that benefit/cost analysis can be based on these models. These gains, however, are not realized without cost. The NGE models rely on the analyst's ability to characterize a limited number of representative economic agents so that the sources of economic interaction are manageable within the NGE framework. Given the rapid acceptance of these models for policy analysis and their flexibility in dealing with policies that impact at the level of individual economic agents, this limitation does not appear to have posed problems in most policy-related uses (e.g., Whalley 1977, 1980).

12.3.2.4 Systems-dynamic Models

A final category of models—systems-dynamic frameworks—has gained considerable attention since the controversial Meadows *et al.* work, *The Limits to Growth,* was published in 1972. They are based on the notion that it is easier to characterize the dynamic relationships within large complex economic systems than it is to describe the behavioral and institutional motives that give rise to these relationships. In general, these models have not survived the test of a careful analysis of their implicit behavioral assumptions when they have been used to describe economic processes (see, for example, Nordhaus, 1973). Therefore, we do not regard these structures as a sound basis for consistent economic impact analyses. A discussion of applications is available in Robinson, Chapter 18, this volume.

12.3.3 Linking the Action to the Model

In order to use any of the modeling structures just described for evaluating the economic impacts of some action (or change in the external conditions affecting economic activities), the models must be altered to reflect the changes implied by the action. For example, if a change in climate is expected to change precipitation so that agricultural production will be altered, the exact nature of these changes must be known. In the context of input-output models, this implies that we must know which input requirements coefficients change and by how much. In an econometric model based on a demand and supply framework, we require some mechanism for linking the climate variation to the demands for or the supplies of the affected commodities. With numerical general equilibrium models, the linkage that must be known is the association with, for example, the agricultural production function; the model then translates the changes in production conditions into the implied supply changes.

The linkage in each case is broadly similar, but the form it takes is model-specific. How does one obtain the information for determining the appropriate linkages to be specified? The answer to this question depends on the action to be evaluated. We can specify three broad, interlinked sources of information:

1. observed patterns of past economic activities and responses to comparable changes (in the action);

2. theoretical models of the process linking the action to activities that are associated with economic behavior;

3. informed judgment.

12.4 BENEFIT/COST ANALYSIS—A TYPE OF ECONOMIC IMPACT ANALYSIS

12.4.1 General Background

Two objectives have provided consistent motivation for economic impact analysis as a part of the policy-making process. The first is an efficiency objective—to appraise whether the external action impinges upon the ability of the economic system to allocate resources to their highest valued uses. The second objective arises from equity concerns—both among income groups and, perhaps more importantly, among regions and/or sectors comprising the economic system.

Economic impact analysis as we have discussed it in Section 12.3 primarily serves this second objective. That is, a description of the reallocation of resources associated with an external action does permit one to assess the regions, sectors and (if sufficiently detailed) the income groups losing resources, as well as those remaining unaffected or gaining from the action.

These descriptive analyses do not, however, permit one to evaluate the efficiency effects of the action. Their objective is to measure changes in the levels of activities without necessarily attempting to measure either individuals' valuation of the changes or increments to firms' costs as a result. A judgment on the efficiency of an action usually implies that it can be controlled (directly or indirectly). The action is subject to choice. There are circumstances in which one would wish to use this reasoning for climate changes. For example, once it is recognized that man's activities can alter climate, then one can consider evaluating the merits of restrictions to those activities.

Benefit/cost analysis does permit judgments to be made that are consistent with evaluating the efficiency effects of certain actions. It does so in a rather special sense which deserves elaboration. Benefit/cost analysis is the practical implementation of welfare economics and therefore maintains that consumer values provide the basis for implementing the efficiency maxim—resources must be allocated to their highest valued uses. Theoretical statements of the problem of welfare economics (that is, the Pareto efficiency conditions) imply that practical implementation of them for efficient resource allocation decisions requires a comparison of the marginal benefits with the marginal costs of those actions under the control of the policy-maker making the judgment. (For further discussion see Bohm, 1973 and Pearce and Nash, 1981; Krutilla, 1981, has also recently offered a historical perspective on the evolution of the analysis.) Unfortunately, in practice the marginal benefit and marginal cost functions typically are not known; judgments are made on the basis of the net benefits (total benefits less total costs) of an action. Nonetheless, Bradford (1970) has convincingly argued that benefit/cost analysis using net benefits can be considered a check on the efficiency of any existing resource allocation. If there are positive net benefits from the change under evaluation, the existing position cannot be efficient in the Paretian sense. Such judgments do not assure that the new resource allocation is the welfare-maximizing one. They do imply, for a reasonably wide class of functions for describing benefits and costs, that the change under consideration provides an improvement.

To illustrate the relationship between the analysis implied by a theoretically ideal approach versus a conventional benefit/cost analysis, consider Figure 12.1. On the vertical axis we have plotted dollars and on the horizontal axis some measure of the activity, A (*i.e.*, controlling the emission of a pollutant thought to influence regional climate) under policy control. $B(A)$ describes the aggregate benefits from the activity and $C(A)$ the aggregate costs. The maximum net benefits $[B(A) - C(A)]$ arising from A are realized for this illustration at A^* where marginal benefits equal marginal costs. Bradford's (1970) interpretation of benefit/cost analysis is that it establishes whether a change represents a movement toward efficiency. This is easily illustrated with the diagram. Suppose the level of activity is OA_1 and we are considering actions that will lead to OA_2. The aggregate net benefits associated with the change from position A_1 are given by the difference between the aggregate net benefits at A_2 (FH) and those at A_l (EG), or (GH - EF). If positive the movement is toward the efficient level OA^*. We can consider movements either from below or from above A^* with these benefit and cost functions and realize that they are positive only when the movement is in the `right' direction. Thus, economic impact analysis directed toward efficiency judgment must be conducted in benefit/cost terms, and can be conducted using the net benefits approach.

12.4.2 Measuring Net Economic Benefits

This rationale for benefit/cost analysis seems fairly clearcut, but as a practical matter it relies on the analyst's ability to gauge economic agents' true valuations of the actions and their full costs, that is, the $B(A)$ and $C(A)$ functions. To do so, benefit/cost analysis has developed a set of measures that have achieved some degree of professional acceptance. It should, however, be acknowledged at the outset that these measures rest on theoretical foundations which are based in comparative analysis of static situations. Among the most important assumptions of this mode of analysis are that the changes under evaluation are small and that adjustments to them are instantaneous and complete.

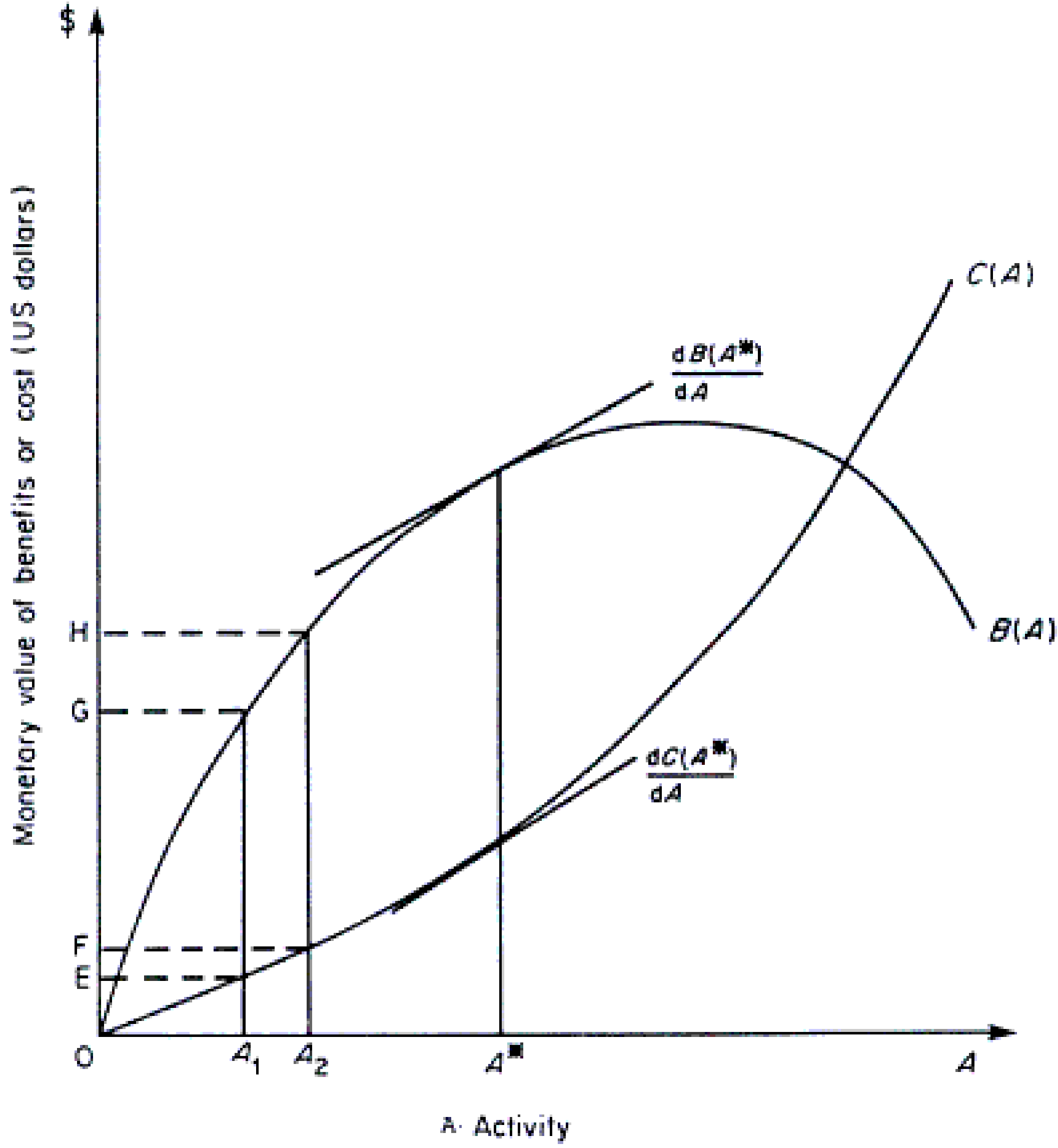

Figure 12.1 A typical distribution of benefits, *B*(*A*), and costs *C*(*A*), of an activity under policy control, with rising costs and diminishing benefits. *A** is the amount of activity with the largest net benefit, the point where marginal benefits equal marginal costs. An analysis of benefits increase by changing a policy of A_1 to A_2 demonstrates a movement towards efficient use of resources

The measurement of these net economic benefits is based on the behavioral relationships that economists use to characterize the responses of economic agents in markets—demand and supply functions. The demand function describes the maximum amount an individual (who is treated as synonymous with a household for our purposes) is willing to pay for each amount of a good or service. In perfectly competitive markets the supply function describes the incremental cost of providing each additional unit of the good or service. Considering demand first, Figure 12.2A plots a demand function in the traditional mode (that is, with price on the vertical axis; the function describing demand in this form would actually be referred to as an inverse demand function). OPRTO is the maximum amount an individual is willing to pay for OT units of the good. Given a fixed price per unit for all goods consumed, say OM, total expenditure is OMRT, leaving an excess of the total willingness to pay over expenditure of MPR. This is generally referred to as *consumer surplus* and is our measure of the excess benefits (over what is paid) realized by the consumer from the consumption of OT units of the good or service. A similar surplus can be defined for firms (provided the analysis is conducted in the short run, where at least one input to production is not easily adjusted). Figure 12.2B illustrates this case. The supply schedule is the incremental cost of each unit, thus the area under the schedule is the total cost of producing any given level of output, say OT. With a fixed price, say OM, the total receipts from sales of OT are OMRT less costs of ONRT yields a surplus of NMR—the *producer surplus.*

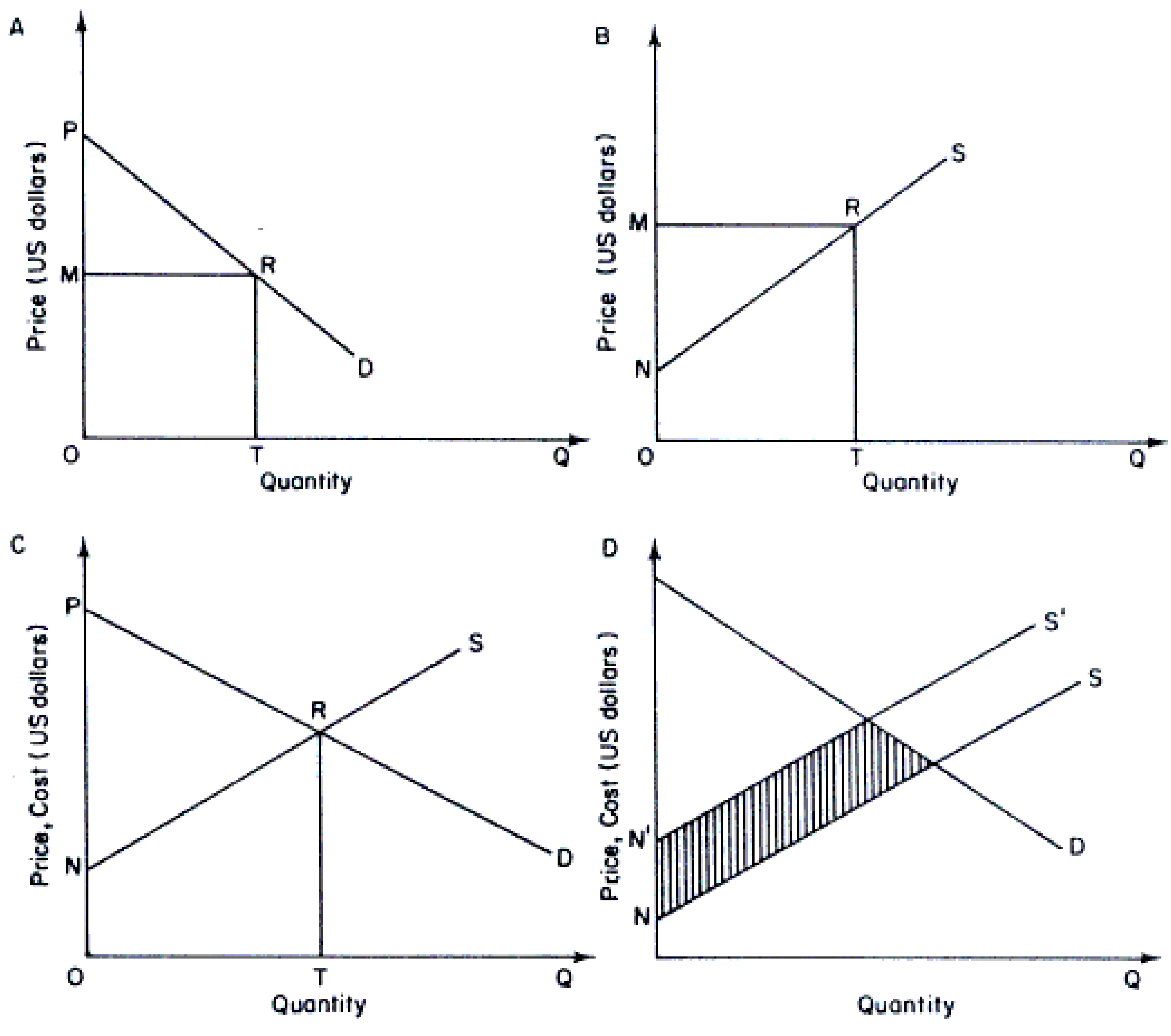

Figure 12.2 A traditional demand function (2A), supply function (2B), equilibrium point (2C) and effect of changes in supply for economic surplus (2D). 2A: A traditional demand function. For OT units, OPRTO is the maximum amount an individual is willing to pay; OMRT, the actual expenditure; and MPR, the consumer surplus. 2B: A traditional supply function. For OT units, OMRTO is the maximum receipts, ONRT the actual cost, and NMR the producer surplus. 2C: Market equilibrium at price of RT,

and quantity, OT, with economic surplus, NPR. 2D: Illustration of a negative effect of a climate change, reducing supply from NS to N'S'. Shaded area designates loss in economic surplus

Putting the two functions together to describe the equilibrium price and quantity in a market as in Figure 12.2C, the *economic surplus* or net benefits from producing and selling OT is the sum of consumer and producer surpluses—NPR.

To determine the benefit function *B*(*A*) described earlier, we need to determine how this area (or economic surplus) changes with the level of the activity *A*. The cost function simply describes the cost of realizing each level of activity *A*. Establishing these linkages between the activity and the change in economic surplus is one of the most difficult aspects of benefit/cost analysis.

Our discussion of climate in Section 12.2 anticipated this outcome. The behavior of a firm sketched in equation 12.1 maintained that climate affects production activities. As a consequence, climate also affects the firm's maximum profit level, as indicated in equation 12.2, and its profit-maximizing output supply equation and input demand equations, as indicated in equation 12.3. It follows directly that the supply function drawn in Figures 12.2B and 12.2C is a function of climate. Thus changes in $\tilde{C}$ will shift S, as from NS to N'S' in Figure 12.2D. The shaded area represents the [negative] change in economic surplus.

The assumptions underlying this transition are important. If our characterization of behavior is incomplete, as the considerations in Section 12.2 might lead one to conclude, or if we question the assumptions of small changes and localized (partial equilibrium) analysis, then we must also reconsider the conventional approaches to evaluating economic benefits and costs.

12.4.3 Integrating the Components of Economic Impact Analysis

It is important to recognize that to the extent that both dimensions of economic impact analysis —projecting the resource reallocations associated with the action (or change) and evaluating the net economic benefits of the action—are needed, they are not necessarily within the same model. Indeed, for the case of impact analyses undertaken as a part of the policy-making process, it is unlikely that they will have a common model. Different analysts will be involved in each component. However, the failure to use a single model in these two components of impact analysis is not solely a matter of the organization of the analysis staff. The cause is probably best tied to the fact that the preferred models for the first component of impact analysis—input-output and aggregated econometric models—*do not* permit consistent benefit measurement in terms of the concepts discussed in Section 12.4.2.

12.4.4 Valuing Nonmarketed Outputs

Climate has been described as a regional public good. It does not exchange on organized markets, and thus we cannot rely on these markets to provide direct information on consumers' valuation of climate services. There are, however, a set of methods that can be used to infer these valuations. They have often been described as indirect market approaches to determining the valuation of goods or services that do not exchange on markets. Since services of climate as a resource are an ideal example, we will summarize in what follows some of the key features of these approaches.

All of the approaches to indirect market valuation require some type of assumptions that must be made to restrict the relationship between economic behavior as represented in a model and that observed in the real world. In some cases, these restrictions derive from specific assumptions on the nature of consumer preferences. In others they are technical associations between some marketed good or service and the nonmarketed good or service under study. Table 12.1 provides a simple taxonomy for the three approaches for determining the valuation of the nonmarketed good.

The first of these is usually associated with the work of Mäler (1974) and Bradford and Hildebrandt (1977). It requires an assumption that the utility function used to represent individual preferences has certain specific properties (such as weak complementarity). In the Mäler example, the property imposes a type of jointness in the consumption of the nonmarketed good and some marketed good or service. With such a restriction, it is possible to infer from information on the consumption pattern for the marketed good, the nonmarketed good's marginal valuation and, with it, the demand for the nonmarketed good. With this demand function it is possible to measure the total valuation as the aggregate willingness to pay for the good or service at any level of provision.

The second type of assumption is used where the delivery of the nonmarketed good or service is technically associated with some private good. In purchasing the private good, one is assured some level of the nonmarketed good. This case is perhaps most relevant to climate. That is, the exchange process for land (residential and industrial) reflects the attributes of the sites, including climatic conditions, air pollution and so on. Economists usually assume that the individuals and firms buying (or renting) land are aware of its attributes and understand their implications for all possible uses of the land. As a consequence, it is reasonable to expect that this information will affect demand and supply functions. Thus, the equilibrium prices for sites comparable in all relevant physical dimensions except climate will, under ideal conditions, reflect the equilibrium `value' of the differing climatic conditions.

Table 12.1 A classification for benefit measurement methods

Types of linkage between regulatory action and observed effects	Types of assumptions required	Measurement methods
Physical linkages	Responses are determined by	

(no role for behavioral responses)		engineering or technological relationships	Damage function
Behavioral linkages (behavioral responses are essential)	Indirect links	Restrictions on the nature of individual preferences or technically observed associations in the delivery of goods or services	Hedonic property or wage model
	Direct links	Institutional	Contingent valuation Contingent ranking

Source: Desvousges *et al.*, 1983.

The last class of approaches may well be the most heterogeneous. It involves the use of mechanisms to alter directly the constraints facing an individual or a business so as to induce each to reveal their respective valuation for the nonmarketed good or service. This alteration can be either `real' or `hypothetical'. For example, one might consider the demand-revealing incentive schemes to be `real' changes in the constraints imposed on individual choice by taxing the individual (or the firm) in response to the revelations. The contingent valuation (or bidding game) methods for soliciting individuals' valuation of nonmarketed goods rely on responses to hypothetical information (see Brookshire *et al.*, 1976,1981). In these cases, the individual is confronted with a series of questions concerning proposed or hypothetical changes to the character of a nonmarket good or service. They may be changes in quality or quantity. The questions seek to elicit the individual's willingness to pay. As a rule, they also incorporate a series of checks for the biases that can be present in attempts to solicit directly an individual's valuations of nonmarket goods.

Each of these approaches reflects recognition that changes in nonmarketed goods and services do affect the behavior of economic agents. The patterns of production and consumption of marketed goods and services will change in response to alterations in their availability. However, this information can be effectively used only if the analysis is conducted at a level (that is, extent of disaggregation) that permits one to observe the behavior of `representative' members of each class of economic agents.

12.5 APPLYING THE METHODS FOR ECONOMIC IMPACT ANALYSIS TO CLIMATE VARIABILITY

Any application of the methods for economic impact analysis to evaluate changes in the services provided by climate resources requires that these methods be modified to conform to the special features climate poses for the analysis. More specifically, we can identify at least three attributes of climate that are relevant to the analysis. First, as we noted in Section 12.2.2, climate is best regarded as a vector of random variables. The available microeconomic tools for analyzing the behavior of economic agents in the presence of uncertainty suggests that their behavior depends on how they perceive the uncertainty and on their attitudes toward risk (see Hey, 1979, for a good summary of the theory of microeconomic behavior under uncertainty). These behavioral responses to a stochastic change in the external conditions facing risk-averse households or firms do not generally coincide with the reactions arising from comparable certain changes (that is, of a magnitude equal to the expected value of the uncertain changes). Nearly all applied welfare theory deals with analysis of the efficiency of resource allocation decisions without the complications of uncertainty. Thus, there is a limited number of theoretical analyses of the appropriate implementation of benefit/cost procedures for these cases.

If the action or change to be evaluated cannot be anticipated, but still conforms to the other assumptions underlying economic impact analysis, then it is reasonable to expect that conventional approaches can be used with little alteration. By contrast, when the change is in the parameters describing the multivariate probability distribution for climate features, and we know how economic agents perceive the change, we must expect that the methods would need to incorporate explicitly those behavioral responses that arise for changes in the stochastic environment that affect their economic activities.

The difficulties posed for economic impact analysis by the stochastic nature of climate are partially offset by the fact that more impact-related questions can be asked when the action is random than when it is fixed. One such question that cannot be asked unless climate is treated as a vector of random variables involves the effect on economic agents of a reduction in the uncertainty surrounding any attribute of climate resulting, perhaps, from continued scientific research.

A second aspect of climate that affects the application of economic impact analysis is the scope of the change. Much conventional economic impact analysis is of a partial equilibrium nature, and is reasonably narrow in scope. However, climate variability and change are much broader in scope, their effects cannot be confined to single industries or regions, and their analysis thus calls for a general equilibrium approach. This is especially limiting to the application of benefit/cost methods, since these methods largely rely on partial equilibrium analyses of welfare changes. Moreover, it may also serve to accentuate the inconsistencies if different models are used to appraise the resource reallocation effects of the change versus the benefit/cost evaluation.

Finally, the timing also is important, because conventional methods are typically directed at comparative statics or involve fairly *ad hoc* specifications of dynamic adjustment. In either case, they are not likely to provide a satisfactory description of economic behavior in response to changes over a long period in the parameters describing a given climate regime, since such changes are unlikely to be either sudden or small.

12.6 CONCLUSION

At this time we can do little more than point up the problems with existing methods. To date no program of research has been established to evaluate the practical significance of any of these problems. It is nonetheless reasonable to suggest that models offering a consistent description of both the resource reallocation and the welfare changes (net benefits) associated with any particular action are more likely to be robust for expansion in scope. Equally important, a resolution of the practical significance of uncertainty and of the timing of adjustment patterns to economic impact analysis will be forthcoming only as a result of micro analyses of individual economic agents' behavior, not aggregated models.

For the present, economic impact analyses of climate variation have been forced to rely on conventional methods (see d'Arge,1979, for example) and to ignore the problems climate poses for their estimates. Further research into the importance of these limitations is needed to judge the significance of these pragmatic responses to economic impact analyses of climate-related changes.

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