Logistics Management Institute

The Economic Benefits of International Environmental Investments
Establishing a Framework

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Executive Summary

The United States has invested hundreds of billions of dollars in aid to developing nations. International aid programs focus on economic development — principally, on major capital projects designed to support industrial and infrastructure initiatives. Those projects are considered an investment and thus are required to show a direct return. But the lasting value of such investments and their impacts in other areas, such as the environment, are unknown.

International aid programs may also have an environmental component; environmental assistance funds are directed primarily toward capital projects designed to address public health issues. Because showing a direct return on an environmental investment has been considered to be impossible, environmental projects are funded through a grants process that may consider environmental impacts (e.g., cleaner air or water); indirect economic effects (i.e., jobs, increased productivity, etc.) of environmental projects are seldom considered in terms of economic returns. Moreover, as is the case for economic investments, the effects of environmental investments on the economies of those nations are unknown: the environmental effects of construction and industrialization have not been assessed.

One of the principal reasons that the environment and the economy continue to be seen as mutually exclusive — at least from an environmental perspective — is that environmentalists have been either unable or unwilling to make the connection between environmental and economic benefits. Yet their connection is obvious: a sound environment can have economic benefits such as improved public health. Certainly those economies that depend on outdoor tourism require sound environments; unless the environment is sound, potential tourists will stay away.

Because the connection between the economy and the environment has generally remained unexplored, we investigated whether the indirect benefits of environmental investments could be identified and quantified, thus enabling the inclusion of environmental issues in traditional economics-oriented decision-making processes. The specific objective of our research was to establish a framework, or model, in which environmental considerations and economic considerations could be integrated to demonstrate the cost-effectiveness of environmental investments. We planned to build on an existing model, either adding economic concerns to an environmental model or environmental issues to an economic model. However, we were unable to find any existing environmental assessment models or economic development models that we could use as a generally accepted framework upon which to model the link between the economy

and the environment. Consequently, we modeled the environmental sector as a module of the Threshold-21 simulation that is being developed by the Millennium Institute to investigate sustainable development issues.

The general concept of our environmental model is that varying levels of activity and technology in the economic sectors create varying levels of associated pollutant emissions, which in turn affect the quality or quantity of the resource pool — air, water, soil, and natural resources. Those impacts are moderated by investments in pollution control equipment and other environmental compliance procedures; they are further modified by the levels of regulatory control and enforcement that are in place. We expressed those interrelationships in an equation.

The inputs to our environmental model are the economic outputs from the various economic sectors of the Threshold-21 model. Likewise, outputs from the environmental module are inputs to the economic modules. The more detailed outputs of the environmental model are the resource quality measures; each of the resources has a quality index that accumulates pollutant-specific impacts.

The next steps are to implement our environmental model and then integrate it with the Millennium Institute's Threshold-21 model through the linkages to that model's economic sectors. We believe that, when completed, the Threshold-21 model will be a useful tool for improving integrated planning and decision-making, assessing alternative strategies for investments to achieve sustainable development, and building consensus on specific actions for sustainable development. That information could serve as a useful guide for policy-makers in assessing the degree to which funds should be allocated to environmental issues and the avenues through which those investment might be made most effectively.

Our research has not yet been completed. Thus far, we have found that there are major gaps in the knowledge base. In order to develop our model, we have used selected data and assumptions to cover those knowledge gaps. We are publishing these interim findings and concepts in order to identify those knowledge gaps to the wider research community and solicit general participation in addressing these issues.

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Acknowledgment

As is our usual practice, we have credited the principal researchers and authors on the cover. However, the development of the model described in this report owes a great deal to the participation of the entire Energy and Environment group at the Logistics Management Institute. The overall framework was reviewed and critiqued by the group director, Paul Dienemann, and extensive contributors were made by Robert Baxter, Sonny Oh, Linda McConnell, Christopher Werle, and David Wunsch.

In addition, of course, we should recognize the collegical contributions of Gerald Barney and Weixiang Qu of the Millennium Institute.

CHAPTER 1

Interrelationship of the Environment and the Economy

The complexity of society and the interdependence of society's activities has long been recognized. However, perhaps because of the difficulty in capturing this intricate system, most policy studies and almost all quantitative analyses address subsets of policy issues. While this approach allows for a comprehensive treatment of those subset areas, it ignores (or assumes constancy in) all of the other policy areas that could affect the area under study. The result of this type of approach is a proliferation of indirect or unobserved impacts and unintended consequences. The problem exists at all levels of public enterprise, from local government to global initiatives. Moreover, the problem is not confined to policy issues. For example, the United States has invested hundreds of billions of dollars in aid to developing nations, but the lasting value of such investments or their impacts in other areas – such as the environment – are unknown. Conversely, the effects of environmental projects on the economics of those nations also are unknown: the environmental effects of construction and industrialization have not been assessed.

An axiom of the international development community is that sustainable economic activity is achieved by teaching a man how to fish, not by giving him a fish. That axiom has a parallel in the environmental community: pollution should be prevented at the source, thus solving the problem forever, rather than creating a lifetime of annual expenditures for fallible pollution control technologies. However, obtaining adequate funding for environmental activities is difficult – particularly when public agencies are being required to retrench – because investments in pollution prevention are not seen as being drawn from the same funding pool as direct economic investments.

The reluctance to invest in programs and projects to protect the environment can be seen worldwide. Even in the United States, which has institutionalized the requirement for compliance with stringent environmental regulations, increasingly conservative legislatures are prepared to entertain discussion on the ideas that much of our present level of environmental spending achieves little, impedes productive employment of resources, and must be curtailed.

An underlying assumption on both sides of the debate is that, while environmental regulations and expenditures may be morally necessary, they represent a drain on productivity and offer few economic benefits. The debate about appropriate levels of environmental protection and the associated costs is conducted on moral or ideological grounds addressing such issues as a legacy for future generations, humankind's place in the natural order, property rights, untrammeled capitalism, etc. — in short, every reason but the idea that environmental and economic benefits can coincide.

Most national economies strive toward public betterment, and the poorer nations look to the example and history of the wealthier nations. Not for nothing are those nations also referred to as the industrialized nations. Those wealthier nations now have the wherewithal to indulge in discretionary spending for perceived aesthetic goods such as environmental protection (and, perhaps, are wiser from having made mistakes in the past); they believe that, without external assistance for such discretionary items, the poorer nations will (just as the wealthier nations did) invest in economic growth regardless of environmental consequences. As a result, international aid programs often include an environmental component, and that component reflects the antieconomic view of environmental issues.

International aid programs focus on economic development — principally, major capital projects designed to support industrial and infrastructure initiatives. Those projects are considered an investment and thus are required to show a direct return. International aid programs also may include an environmental component. However, available environmental assistance funds are directed primarily toward capital projects designed to address public health issues; not at pollution prevention programs. Moreover, because funding agencies assume that environmental projects cannot pay for themselves — indeed, showing a direct return on an environmental investment is inherently impossible — they fund those projects through a grants process; indirect returns on environmental projects are never considered.

One of the principal reasons that the environment and the economy continue to be seen as mutually exclusive — at least from an environmental perspective — is that environmentalists have been either unable or unwilling to make the connection between environmental and economic benefits. Yet their connection is obvious: a sound environment can have economic benefits. Certainly those economies that depend on outdoor tourism require sound environments. Unless the environment is sound, potential tourists will stay away; witness, for example, the number of people in the United States who are reluctant to travel to Mexico (which is both nearby and affordable) because of their concerns about illnesses related to water consumption.

Because the connections between the economy and the environment are generally unappreciated, the Logistics Management Institute (LMI) decided to investigate whether the indirect benefits of environmental investments could be identified and quantified, thus enabling the inclusion of environmental issues in traditional economics-oriented decision-making processes. The specific objective of our research was to establish a framework, or model, in which environmental considerations and economic considerations could be integrated to demonstrate the cost-effectiveness of environmental investments. That information could serve as a useful guide for policy-makers in assessing the degree to which funds should be allocated to environmental issues and the avenues through which those investments might be made most effectively.

In planning our research, we anticipated that environmental organizations would be able to make a successful case for funding (if such a case exists) only if they could state their case in economic terms. We also believed that the model used to develop the case for environmental funding must be noncontroversial in order to be useful and adopted; that is, the model must be acceptable to both economists and environmentalists. Therefore, we planned to select an existing model considered to be a standard within either or both communities and then to enhance it as necessary. We could add economic concerns to environmental models, or we could add environmental issues to economic models. Our first step, then, was to identify and review the environmental assessment and economic development models that enjoy credibility and consensus, especially within the funding communities that are ultimately the decision-makers of interest. The next step was to develop a model linking the economy and the environment.

This report presents the results of our work to date. Chapter 2 discusses our review of environmental assessment and economic development models, and Chapter 3 describes our concept for modeling the econo-environmental link. The last chapter briefly discusses additional steps that must be taken to complete the development of a useful model. By preparing this report while the work is still in progress, we hope to initiate discussion about our concept and make the ultimate product of our research more effective.

CHAPTER 2

Review of Econo-Environmental Modeling

This chapter presents the results of our effort to identify environmental assessment and economic development models that have legitimacy and currency in the community of major international funding agencies. It also discusses some models that are designed to account for some externalities of economic development programs and projects.

ENVIRONMENTAL ASSESSMENT MODELS

In view of the great volumes of data collected as a result of U.S. environmental regulations, we had anticipated the availability of process models that at least, accounted for the creation and effects of pollution from regulated activities. And, from the efforts over the past years to regulate air attainment areas and watersheds, we had hoped that regional models would exist addressing the accumulation of pollution from multiple sources. While such models and data sets may exist, we did not locate them.

In seeking out the available models, we used a number of on-line searches as well as references in data compendia. We also interviewed staff members of the U.S. Environmental Protection Agency (USEPA) and several environmental groups and consulting companies. We found any number of other data sets and models, including the many referenced in *Access USEPA* (a compendium published by the U.S. Environmental Protection Agency). However, for our specialized purposes, we found little utility in the many existing environmental models.

Generally, the models we found assume a known emission from a single point and are used to assess the migration and sometimes the potential effects of that release. A few models address larger scale issues, chiefly global issues; however, we were not ready to accommodate transboundary issues in our modeling process. In short, we found no environmental assessment models that would serve our needs.

The World Bank requires the preparation of an environmental analysis for individual projects. This analysis is reportedly limited to environmental factors (air and water quality, biological resources, etc.) and does not address economic variables. The analyses are proper documents, conducted on a case-by-case basis, and are not systematically structured; in no sense can they be considered a model. The environmental analysis generally is viewed by nonenvironmental staff within the funding agencies as being "just another administrative obstacle."

The process is, in other words, much like the environmental impact documentation required for federal actions by the National Environmental Protection Act (NEPA).

Economic Development Models

To identify economic development models applied by international funding organizations, we interviewed knowledgeable people in the international development community and searched professional journals and other publications.

Interview Results

Interviews with knowledgeable individuals yielded a unanimous negative finding. Some interviewees indicated that they are unaware of any economic development models, and another four individuals stated that the international lending community does not apply any economic development models at the project, local, or national level. Analyses are generally limited to forecasting each project's financial performance from an underwriting (lender/creditor) standpoint — that is, the project's ability to carry its operating and/or capital costs and, where applicable, to provide a rate of return on invested capital. Typically, the financial analysis takes the form of a project cash flow analysis analogous to a developer's proforma in the real estate lending community or a business financial plan for service or manufacturing-oriented investments.[1]

Results of Literature Search

When asked about the utility of applying an economic development model, interviewees gave a variety of responses. The specific questions included the overall utility of such a model; the level at which such a model might be applied; and whether it would be applied to individual projects, to groups of projects, or at the sovereign level.

Within the development agencies, project-level staff were interested in the concept but had only a limited idea of how they might apply it. Staff in nongovernmental organizations (NGOs) and development organizations not involved in funding responded favorably to the idea, perhaps because, while they work closely with the international funding organizations, they tend to be the most critical of certain investment decisions and policies that have been made by the funding agencies. Accordingly, they seemed to feel that such a model might introduce different (or at least clearer) decision rules into the process.

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[1] This corresponds with researcher Michael Siegel's experience as a project development officer and manager of a statewide economic development program for the State of Maryland in the late 1980s.

Among the issues raised by interviewees, some predominated:

- Political sensitivity by funding agencies toward making policy and international political decisions open to cost-benefit analysis

- Practical concerns of funding agencies about "getting the money out" and not placing another level of analysis on top of an already cumbersome project review and approval process

- Lack of sufficient data in many developing countries to construct a detailed model

- Tendency of economic impacts of individual projects to "wash out" at the sovereign level

- Complexity of modeling feedback loops between projects and their associated environmental/economic factors

- Tendency for such a model to be applied to evaluate allocation of resources among competing projects within a country or between two countries

- Need to weight differential economic impacts of identical projects in two different countries (or regions) with a wide gap in living standards for wage and income differentials.

In our survey of articles in professional journals, we found some promising titles. However, when we reviewed the articles, we found that they were either not applicable or only partly or tangentially related to our study. Because we were unable to identify international economic development models, we searched for national or regional models used in the United States and elsewhere in the developed world. The body of work on modeling national and regional economic multipliers and relationships and on applying these models to various projects is extensive. Input/output (I/O) models and economic base models exemplify these. We searched specifically for domestic examples of whether such forms of economic analysis have been extended to apply to environmental factors and to other externalities of economic development projects.

We found that no articles provide a model, but several articles identify some of the problems and issues, and suggest some approaches, in quantifying external impacts of economic development projects. Those articles focus on the following:

- "Hedonic" effects of parks, recreational areas, and viewsheds on property values

- Value of public goods to private individuals, using willingness-to-pay pricing models

- Health and productivity impacts of environmental improvements, particularly clean air

- Economic benefits of fisheries (primarily salt water)

- "Welfare" effects of economic development and environmental improvements

- Changes in trade or export/import flows, gross domestic product (GDP), or national income

- Economic impacts of environmental degradation (i.e., oil spills), using "damages" assessments.

The article that comes the closest to discussing the issue of measuring economic benefits and associated environmental issues states the following:

> Another potentially major source of demand for (analysis of) benefit transfers comes from international aid organizations, such as the World Bank and the U.S. Agency for International Development. These organizations are trying to value the environmental effects of projects in developing countries for which they are considering making loans or grants. *Because there are few original studies of the benefits of environmental improvements in developing countries, the organizations are attempting to use the results of benefits studies in developed countries to estimate the value of the environmental effects of projects in developing countries.* It is debatable whether benefit transfers are legitimate for valuing certain types of nonmarket commodities in developing countries. This is because the basic tenet of individual sovereignty underlying benefit estimation in the United States and most other developed countries may not be applicable in societies that place emphasis on group welfare. Nevertheless, it may be better to make benefit transfers involving the environmental effects of foreign aid projects than to make no attempt to quantify these effects.[2] (emphasis added)

The most comprehensive attempt to value externalities of domestic development projects is in progress: *Estimating Fuel Cycle Externalities* is a seven-volume set of papers being prepared by Oak Ridge National Laboratory and Resources for the Future (RFF) for the U.S. Department of Energy and the Commission of European Communities.[3] The Oak Ridge/RFF study lays out a useful analytical framework for estimating externalities of fuel and power-generation cycles applying a five-step, "damage function" approach that can be summarized as follows:

- Characterize fuel cycle activity and discharges

- Estimate changes in pollutant concentrations by modeling dispersion and transformation

[2] Interview with Dr. Krupnick, member of the President's Council of Economic Advisers until 1994.

[3] *Estimating Fuel Cycle Externalities* is being published by UDI/McGraw Hill. As of this writing, two volumes had been completed.

- Calculate impact on ecosystem, health and other resources of value (i.e., structures)

- Translate estimates into economic terms to establish damages and benefits

- Assess extent to which these externalities are not included in price change of the commodity.

A telling quote from the introduction to Volume 2, *Analytical Methods and Issues,* relates to the application of this analytical approach:

> Analysts generally believe this to be *the best approach for estimating externalities, but it has hardly been used!!* The reason is that it requires considerable analysis and calculation, and to this point in time, *the necessary equations and models have not been assembled.* (emphasis added)

Two papers in Volume 2 are relevant to our study:

- "Benefits of Visibility Improvements," Paper 12 by A. Krupnick, RFF, 1995.

- "The Measurement of Employment Benefits," Paper 17 by D. Burtraw, RFF, 1995.

Paper 12 focuses on quantifying benefits of visibility improvements utilizing a contingent value/willingness-to-pay approach and, to a lesser extent, hedonic (property value) indicators. (Employment and income effects are not addressed.) Krupnick cites two studies: one on Boston harbor[4] found a positive (although small) linkage between water quality improvements and benefits to recreationists, and one on the Chesapeake Bay[5] found a positive link between water quality improvements and values to fishermen and beachgoers. Krupnick also refers to a voluminous amount of work on damage by acid rain to recreation areas and points out that most studies of the value of various types of recreation days pertain to individual sites or clusters of sites in a region. Only a limited number of studies are reported to seek estimates at the national level.

Paper 17 addresses the issue of employment impacts of development projects. Burtraw states that measurement of employment impacts is among "the most confused and contentious issues in benefit-cost analysis and applied welfare economics generally." The core issue for analysis of economic impacts at the macro level is cited by others, but Burtraw puts it as well as anybody: "Many of the alleged employment benefits at the local level are offset by lost benefits at other locales, and do not count as employment benefits according to economic theory."

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[4] V. K. Smith, et al., "Estimating Water Quality Benefits: An Econometric Analysis," *Southern Economic Journal*, Vol. 50, No. 2, October 1993.

[5] N. E. Bocksteal, et al., *Benefits from Improvements in Chesapeake Bay Water Quality*, University of Maryland, 1988.

Giving a historical perspective to this statement, Burtraw observes that,

> Misuse of the term "employment benefits" by advocates of large hydroelectric projects in western states fueled a reaction in the 1960's among academic economists that led to efforts to discredit the consideration of employment benefits generally [because] . . . there are few if any real economic gains associated with employment benefits . . . Since the concept was so likely to be misused, it might be preferable to discredit its use at all.

Burtraw takes the position that neither presumed inclusion of "hidden benefits" nor their exclusion is proper and lays out a methodology based on empirical data pertaining to labor markets. He focuses the construction of this methodology on determining whether

> . . . the social opportunity cost of new employment is less than the market wage. This would be the case, for example, if one expects unemployment or underemployment to persist in a specific region of the economy or occupational category affected by the new investment. In this case, new employment opportunities produce a net increase in social wealth rather than just a transfer of income.

Models Accounting for Some Externalities

The number of attempts to model externalities of economic development programs and projects is limited. In this section, we describe four such models: Virginia Impact Projection (VIP) model, Regional Science Research Institute (RSRI) model, Long-term Interindustry Forecasting Tool (LIFT) model, and Institute for Economic Analysis (IEA) model. The models are one of three types: econometric, I/O, or a hybrid combining both.

Econometric models rely on time series or comparative regression analysis of dependent and independent variables. If one wanted to determine the relationship between, say, industrial output (independent variable) and income (dependent variable), one could do a time series regression of a single country (or subregion) to determine the amount, strength, and confidence of this relationship. Alternatively, regression analysis could be done cross-sectionally for a requisite number of representative countries or subregions. Regression results can be used to plot a line or curve that reflects the numerical relationship between an independent and dependent variable. The slope of the curve or line can then be a variable in an equation yielding a nonlinear relationship. As the independent variable changes, the unit response in the dependent variable can also change.

I/O models rely on survey or other techniques to determine interdependent relationships between industrial (and sometimes household) sectors. A matrix is developed with values in each cell representing the amount of output in one sector that would be produced with a given level of input in another sector. I/O models can be highly data intensive. Some have in excess of 500 sectors, although others have been designed with far fewer. I/O models can be utilized at the national or subregional level. Much of the art in developing I/O models is the ability to refine reported data, segment it into finer and finer pieces, and maintain its consistency with more highly aggregated data. Many I/O models, however, are static; they assume the existing relationships between sectors will remain constant.

Hybrid models may combine elements of both techniques and sometimes incorporate dynamic estimation of some key variables. For example, the IEA model generates investment indigenously as a function of capacity utilization. Investment is then used as a variable in other equations that calculate additional outputs.

Virginia Impact Projection Model

The VIP model was developed in the early 1980s by Dr. Thomas G. Johnson of the Virginia Polytechnic Institute, Department of Agricultural Economics, to estimate regional (substate) economic, demographic, and fiscal impacts. As an econometric model, it accepts primary input data (drivers) that it then transforms through several econometrically specified equations to produce secondary drivers. These drivers are then linked to community-specific fiscal variables to estimate public-sector fiscal impacts (revenues and expenditures). At the heart of this model (and other econometric models) are the internal equations, coefficients, and relationships that produce the secondary drivers and final outputs. The model's equations, coefficients, and relationships were developed based on time series regression analysis of empirical data for Virginia's independent cities and counties. The model provides either a 4- or 10-year forecast capability that can be used to examine the "with" and "without" action alternatives. Table 2-1 displays the data structure of the VIP model.

In the instance where this model was applied to estimate impacts of major road improvements in a rural area of southwestern Virginia, it was used in combination with two other models to develop the requisite inputs. Engineering consultants developed estimates of traffic flows, while employment impacts and gravity models were used to allocate employment impacts across geographic areas and develop estimates of changes in local property values. Allocation of traffic and employment impacts was an iterative process as these two variables are highly dependent upon each other.

Among its strengths, the VIP model

- uses time series and cross-sectional regression-derived variables for labor-force estimation,
- includes robust econometric equations incorporating multiple variables to derive intermediate and final outputs,
- recognizes spatial variables,

Table 2-1.
VIP Model Data Structure

Primary	Intermediate	Final
Employment multiplier	Population	Property tax base (real and personal)
Contiguous employment	In-commuters	Sales tax revenue per capita
Contiguous labor force	Out-commuters	Other tax revenue
Roads	Enrollment	Nonlocal aid
Labor force within 40 miles	Labor force	Police expenditure
Service index	Per capita income	Jail expenditures
Number unemployed	Per capita income squared	Court expenditures
Number unemployed	Numberof businesses per capita	Fire protection expenditures
	In-commuters per capita	Welfare expenditures
	Out-commuters per capita	Health and mental health expenditures
	Sales per capita	Recreation expenditures
	Population squared	Development expenditures
	Miles per SMSA	Public works expenditures
	Percentage of town population	Administration expenditures
	Percentage of town population squared	Per pupil education expenditures
	Real property per capita	
	Personal property per capita	
	Total federal aid per capita	
	Crime per capita	
	Solved crimes per capita	
	Percentage change in population	
	Fire protection rating	
	Population density professional-to-volunteer ratio	
	Percentage of nonwhite population	
	Mortality rate	
	Development group (type)	
	County (city) area	
	Business level per capita	
	Graduates per 100 population	

Note: SMSA = Standard Metropolitan Statistical Area.

- recognizes a time dynamic for determination of labor force, and
- includes a highly developed fiscal section.

The model also has several weaknesses. Specifically, it

- relies on the user to determine the appropriate employment multiplier;
- requires reestimation of coefficients for application in states other than Virginia;
- requires an external estimate of the linkage among employment, investment, and location of employment; and
- does not incorporate environmental variables.

Moreover, the model is described by Dr. Johnson as "not user friendly." The VIP model is no longer available on a stand-alone basis. Rather Dr. Johnson works with clients to customize it to their needs.

Regional Science Research Institute Model

The RSRI model is a proprietary U.S. regional I/O model designed by Dr. Ben Stevens. The RSRI model relies on the national I/O table adjusted for regional variations using a series of regional purchase coefficients. Inputs to the model made for selected sectors of the I/O table are dollar amounts. For a construction phase, these amounts may be construction costs; for an operations phase, they may denote the value of output. The I/O table then calculates the effects of the inputs, or "disturbances," on the other portions of the I/O matrix based on coefficients determined exogenously by survey or estimation methods. The RSRI model also includes a household sector in its I/O matrix, allowing analyses of the effects of household changes on industrial sectors or independent analyses of household variables.

A unique feature of the RSRI model is its use of translators, which can simplify the process of inputting data for a project involving multiple industries (sectors). For instance, if the economic impacts of a sports stadium were being modeled, inputs would be required for scores of sectors. The translators automate the allocation process. That is, RSRI has predetermined the distribution of inputs across sectors for many types of projects.

Like most standard I/O models, RSRI's model is static. The coefficients are changed exogenously only when changes are observed in the survey or estimation techniques used to develop them and thus represent current conditions. In a rapidly developing region (or nation), these coefficients can be expected to change as production becomes more internalized or as exports increase as a result of greater industrialization. Accordingly, application of an I/O model to forecast economic changes in a country or region undergoing rapid development will likely require the use of nonlinear coefficients that reflect this progression.

The RSRI model is available for any single state, a multistate region, and the entire United States. It can be purchased from RSRI for $7,500 or rented for a year for $500 plus 50 percent of the regular purchase price. Rentals for lesser terms are available for smaller amounts. Optional translators are $100 to $250 each. A completely operational demonstration model for an unnamed region is available for $25.

Long-Term Interindustry Forecasting Tool Model

The LIFT model was developed at the University of Maryland. Designed for making macro-level and sector forecasts of the U.S. economy, this PC-based model has three components — product, price or income by industry, and labor requirements — and combines I/O and regression-based econometrics in a dynamic format. (From our preliminary review of this model, it was unclear whether the model might have application at the subnational level.)

The model has three significant features of interest to our study:

- It has highly developed variables reflecting government involvement in the economy.
- It relies on dynamic coefficients that are sensitive to the rate of growth. Investment demand and I/O coefficients change within the model as functions of the rate of growth of output.
- It specifically includes foreign trade variables and effects in its inputs and outputs. The foreign trade element is linked to exchange rates, demand, and growth factors.

Exogenous variables for the LIFT model are as follows:

- Money supply
- Civilian labor force
- Employment of domestic servants
- Exchange rate scaler
- Foreign demand scaler
- Federal defense expenditures
- State and local expenditures

- Federal employment (defense and civilian)
- State and local employment
- Employment in federal government enterprises
- Employment in state and local government enterprises
- Multiple job holders
- Time adjustment for labor productivity
- Population (stratified)
- Percentage of household heads aged 25 to 35
- Percentage of total households with two earners
- Households
- Death rate
- Average corporate tax rate
- Investment tax credit rate
- Scaling variable for interest rate differential
- Disposable income per capita (Canada, Japan, and Germany)
- Gross capital outflow.

While the LIFT model is suitable for domestic (U.S.) application, it would likely require substantial reworking of relationships and coefficients before it could be applied to external (foreign) economies. It is not known if a version of the model has been adapted by its developers for external use. Whether the model is available to third parties also is unknown.

Institute for Economic Analysis Model

The model developed by IEA, which is based at New York University, uses a simplified I/O matrix and also incorporates Natural Resource Accounts (NRAs). NRAs were developed by the United Nations for incorporating natural resource variables within the structure of national I/O models. The objective was to link economic activities with their use of the natural resource base. NRAs are satellite accounts to the System of National Accounts, which are the equivalent of the industrial-sector matrix, and were also developed by the

United Nations.[6] NRAs can be further disaggregated into stock accounts, which represent inventory values, and flow accounts, which represent use.[7]

NRAs constitute a system of accounts and quantified coefficients for natural resource variables that have been developed specific to each country and industry sector thereof based on case studies. For example, water pollutants produced and land used by the agricultural sector would be quantified for each major agricultural (or industrial) activity. When divided by units of production or use, these yield coefficients of pollutants or land use per unit of activity or output.

NRAs can be used to adjust GDP (or national domestic product [NDP]) to account for degradation of natural resources to arrive at an environmentally adjusted domestic product (EDP). They can also provide a monitoring framework for natural resources and may also be used for policy analysis and planning. To date, their application has been limited mostly to estimating EDP in some countries. IEA appears to be one of the domestic organizations most experienced with the development and application of NRAs within the framework of I/O models.

Countries that have developed and actively apply NRAs are France, the Netherlands, and Norway. Other countries that have developed NRAs but do not regularly maintain them include Botswana, Costa Rica, Japan, Mexico, and Papua New Guinea. Reportedly, Canada, United States, Germany, Indonesia, Philippines, Sweden, and Thailand have initiated efforts to develop NRAs.

Applications utilizing NRAs that incorporate dynamic coefficients have apparently not yet been developed. NRA applications tend to be static models in the sense that the relationship between industry sectors and their respective relationships with NRAs are based on a fixed point in time. Neither have NRAs been developed to examine feedback effects of investment in environmental infrastructure — for instance, increases in productivity among the constituent industry sectors and concomitant household effects as a result of environmental infrastructure improvements. Rather, at the national level, NRAs treat investment in environmental infrastructure as a negative by subtracting such investments from GDP. While this treatment may be accurate for that year, it potentially ignores productivity and other enhancements in subsequent years.

NRAs can be further refined to provide analytical capability at the subnational level. However, NRAs are highly data intensive at both the national and subnational level. Therefore, the key to developing NRAs is the development of the relationships (coefficients) between industry and household sectors and their natural resource outcomes. Development of these relationships would likely require extensive case study analysis of subject or representative countries.

[6] Satellite accounts can be developed for any set of subaccounts that can be defined and that lend themselves to quantification. A Social Account (SA) is an example. SAs are analogous to NRAs but are applied to various social indices such as crime, education, fertility, household size, and the like.

[7] The Threshold-21 model developed by the Millennium Institute, to which our model is a functional module, is also heavily dependent on this stock-flow account concept.

Development of feedback loops may also require case studies of multiple countries at various stages of development and industrialization.

The IEA model is dynamic with respect to investment. That is, investment is determined endogenously to the model as a function of capacity utilization. IEA reports that it is currently trying to make various household variables endogenic as well. To date, IEA has modeled the economies of the United States, Indonesia, and Botswana.

The model was developed with Mathematical software and requires this software to run. The model is available for review upon request from IEA. Because it was developed for IEA's internal purposes, the model is unlikely to have a user-friendly interface, and supporting documentation may be limited.

Summary

The principal findings from our search for accepted, specific models that could provide a framework for linking the economy and the environment are as follows:

- Application of an I/O model to a rapidly developing country would likely require the development of nonlinear coefficients for dependent variables.
- Incorporation of an environmental-economic feedback loop in models containing NRAs has not yet been accomplished.
- A standardized, internationally applicable, and well-developed I/O model framework incorporating NRAs appears to exist in the form of the IEA model.
- Application of I/O or econometric models to individual countries or subnational regions will likely require an extensive effort to develop locally applicable coefficients, multipliers, and relationships.
- Other I/O models in use domestically have developed a system of dynamic variables or nonlinear coefficients, and the IEA model incorporates at least one dynamic feature itself.

Based on these findings, we concluded that none of the major models met our requirement for general acceptance and that they offered little (aside from a fundamental approach) that could be used as a framework for a model that we might develop.

CHAPTER 3

Development of Model Linking the Economy and the Environment

Our intent in modeling the link between the economy and the environment was to enhance an existing model rather than creating a new one. However, as noted in Chapter 2, we were unable to locate a modeling process sanctioned by any international funding agencies. In the absence of an existing model with such standing, LMI decided to enter into a partnership with the Millennium Institute, which has been developing a model designed to demonstrate the interrelationships of economic and social activities commonly considered as discrete. The Millennium Institute hopes to use that model – called the Threshold-21 model – as a tool for building consensus on actions for sustainable development, improving tools for integrated planning and decision-making, and assessing alternative strategies for investments to achieve sustainable development.

The Threshold-21 model is built to represent economic sectors that correspond roughly to the structure of international programs. For that reason, activities tend to be measured in economic terms (such as dollars of gross domestic product) rather than in material terms (thousands of tons of goods produced). The model operates at the macro level. Specific processes are addressed only to the extent that they affect the outputs of concern; more detailed process modeling is undertaken only when it is needed to draw distinctions at the macroanalytic level. This approach allows the model to use national-level indicators that are generally available and avoids the thorny issue of the dispersion of activity within a country (although the Millennium Institute hopes to broaden the model over time to address both subnational and international perspectives).

The economic sectors represented in the Threshold-21 model as of early 1995 when we began working with the Millennium Institute are

- goods production,
- demographics,
- military,
- energy,
- agriculture,
- nutrition,
- health care,

- housing,
- transportation, and
- education.

In some economic sectors, the model accounts for some environmental impacts. However, in each case, the impact is portrayed only within the context of a particular sector, and usually, the impact being portrayed is only a subset of the total impact. For example, the model accounts for particulate emissions only in its representation of the agriculture sector. In short, where the Threshold-21 model treats environmental impacts at all, it treats them in isolation, ignoring the total effect, or it allocates the entire impact to a single emission source. To ensure that the environmental impacts of economic activities are fully and accurately represented in the Threshold-21 model, we decided to model the environmental sector as a definable unit that would be a separate module of the Threshold-21 model. That is, we would first build a supportable framework, then would integrate it into the existing overall model, constructing appropriate linkages to the economic sectors.

Understanding the complexity of trying to model the environment as a system, we wanted to avoid being pulled into the morass of trying to build a complete ecosystem model. The initial approach, therefore, was to identify clear linkages between economic sectors and environmental impacts and to model only the relevant components of environmental processes. This chapter describes the general structure of our model and the inputs and outputs.

General Structure of the Environmental Sector Model

The general concept for our environmental sector model is that varying levels of activity and technology in the economic sectors create varying levels of associated pollutant emissions, which in turn affect the resource pool. Those impacts are moderated by investments in pollution control equipment and other environmental compliance procedures; investments in pollution remediation (cleanup) go directly to reducing pollution (although they do not reduce current use of pollutants). The impacts are further modified by the levels of regulatory control and enforcement that are in place.

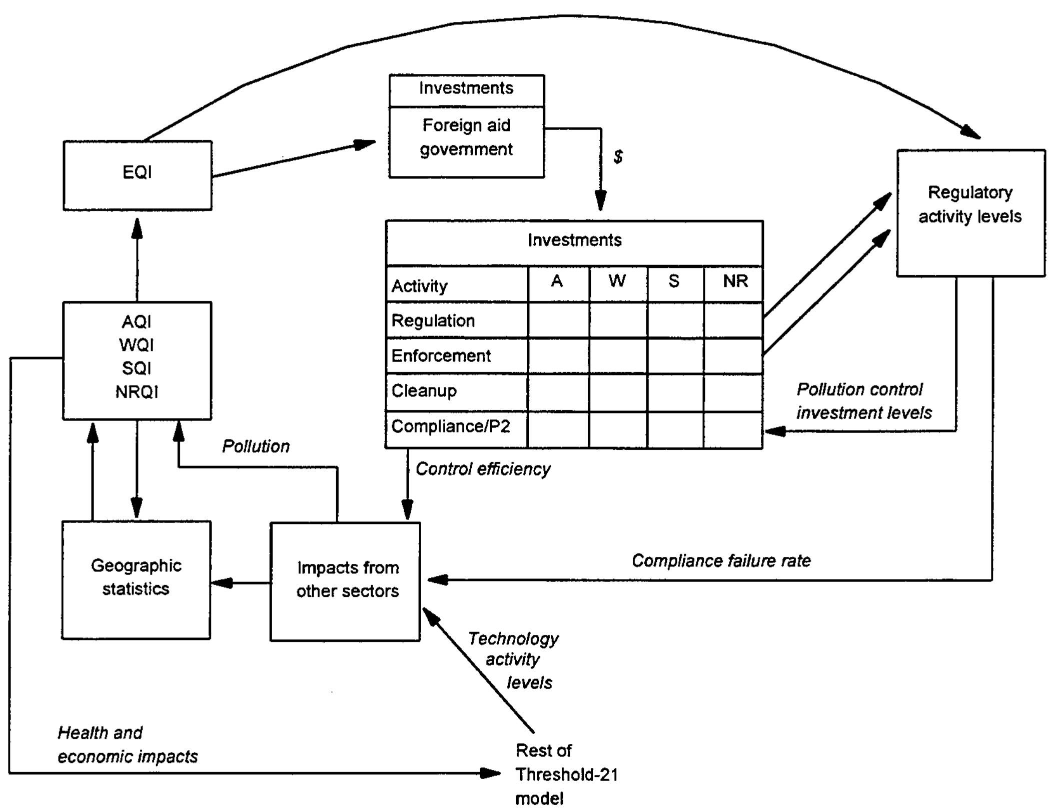
The resource pool consists of traditional "media" resources: air, water, soil, and natural resources.[1] We measure the effect of emissions on air and water in terms of quality, since their quantity is not depleted by pollution. We measure the effect on soil in terms of both the quality of the soil for agricultural purposes and the prevalence of contaminated soils. Finally, we measure the impact of pollution on natural resources in terms of how much they have been depleted. For

[1] Protection of cultural resources also is important, but we were unable to develop any way of measuring these resources or of including them in the model.

any given resource pool, then, the generalized equation we used for our model is as follows:

Pollution {media} = (Sum across all economic sectors of production levels × technology level × pollution control effectiveness) – (cleanup investments) – (regulatory controls × enforcement levels).

The general structure of the model is shown in Figure 3-1. The resource impacts are reflected in "geographic statistics." That section of the module captures national assets or data that define the general environment of the country: land area, land uses, coastline, freshwater volumes, rainfall, temperature, etc. Some of those factors are not needed for a single-country assessment but will be essential when the Threshold-21 model is expanded to address global issues. Other factors, such as land area, are important in calculating the level of activity and technology used in some economic sectors or in assessing the impacts of polluting activities.



Notes: A = air; E = environment; NR = natural resources; P2 = pollution prevention; QI = quality index; S = soil.

Figure 3-1.
Structure of the Environmental Module

Because our environmental sector module is to be an interactive component of the overall Threshold-21 model, outputs from the environmental module become inputs to some key factors that support the economic module. However, we found relatively few specific outputs (i.e., impacts of environmental pollution that directly affect economic activities). Those that we have included are the impacts of pollution on public health and on the tourism/recreation sector of the economy.[2] Likewise, the inputs to the environmental sector module are, in fact, outputs from the economic sectors. That is, when viewed in isolation, each sector can be considered to have inputs and outputs. However, when the modules are viewed as part of the overall Threshold-21 model, these inputs and outputs are really working variables that are used interactively among sectors (i.e., among the modules of the overall model) as the simulation cycle proceeds.

INPUTS

The inputs to the environmental sector module are, as noted earlier, the levels of economic activity within the various sectors, modified by the technological levels at which those economic activities are being carried out; the levels of environmental investment; and the regulatory framework within which these activities are occurring. The following subsections describe how we plan to quantify those inputs. Generally, because these inputs cannot be measured directly, we developed a scaling system.

Economic Activity

A detailed assessment of the general activities in each economic sector that could cause environmental impacts resulted in the tables shown in the Appendix. Although specific data are needed to measure each of these activities in isolation, we usually found that each activity was an inevitable part of a process that could be measured at a more generalized level. Thus, the pollution impacts from the manufacturing sector occur through a variety of distinct processes but ultimately are a direct result of the volume of total manufacturing activity.[3] The fact that one can break pollution impacts down to attribute them to specific industry types offers the potential for later model enhancement, but given a general "goods production" sector such as is found in the Threshold-21 model, no value would be added by the extra data collection and detailed modeling that would be required.

In assessing economic activities, we also identified the types of pollution impacts that might result from them. Where major economic sectors produce clearly different pollution profiles, the pollution data allow us to segregate these

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[2] Tourism/recreation was not originally included in the Threshold-21 model. That model will now be able to incorporate that sector.

[3] We use the phrase "pollution impact" to refer to all measured natural resource impacts, including those such as soil degradation that are not generally considered "pollution."

sectors; so, where the economic data also permitted such segregation, we matched specific subsector input variables to specific pollutant outputs. Where the activity levels or pollution outputs could not be segregated effectively, we remained at the higher level of aggregation. (We did not concern ourselves initially with the relative significance of such impacts.) Pollution-producing activities in the economic sectors are listed in Table 3-1. Those serve as the principal independent variables in the model equation shown earlier. A more detailed listing of the impacts is provided in the Appendix.

Table 3-1.
Environmental Module Inputs from Economic Sectors

Economic sector	Input variable	Activities represented
Agriculture	Area in agricultural production	Soil preparation, irrigation, pesticides and fertilizers, and harvesting
	Change in forested area	Soil clearing (mechanical or burning)
	Livestock count	Livestock operations
Industries	Gross domestic product for mining and manufacturing	Industrial operations
	Toxic release inventory	Industrial wastes
Energy	Consumption of coal, oil, and gas	General uses of energy (industries and households); does not include motor fuels
Households	Number of households	General unregulated or unrecorded pollution-producing activities
	Municipal wastewater processed	Sewage impact of households
Transportation	Road miles (paved and unpaved)	Dust emissions
	Fuel consumed	Use of internal combustion engines

Production Technology

The impacts of economic activity on pollution are affected by the level of technology of the economic sector. Thus, producing a million tons of finished products in a manual crafts economy has less impact than producing the same million tons through intensively mechanized processes, while an even more sophisticated production process may have less impact than the manual process. To measure the effect of technology on the environment, we decided to establish a set of multipliers that run from near zero for a crafts-type economy to a much higher figure for a smokestack-industry economy. Those multipliers are, of course, taken in comparison to an arbitrary baseline level of production, which for the purpose of this research, we defined that of the United States in 1995?

Recognizing that dollar-based figures lose their value when transferring ideas across international borders, we used a qualitative scale to express a country's level of technology in each of the major sectors. To establish the scale initially, we decided arbitrarily that the United States would fall between 5.0 and 8.9 on the scale in any given sector. We then adjusted the quantitative data to fit these qualitative requirements. As an initial measure, we used the degree of automation as an indicator of the levels of technology that are in place. For the manufacturing sector, we used the value added per employee; for agriculture, we used the acres farmed per employee. We assumed that technological levels in the household, transportation, and energy sectors correlate closely to those in the industrial sector; therefore, we did not develop specific technology measures for those sectors.

The assignment of countries to specific score-points on the technology scale must depend on detailed information and adjustment to local conditions. Ultimately, either a multiattribute scale or a qualitative scale must be developed that allows the assignment of country technology levels over time.

Environmental Investment

Environmental investments include investments in pollution restoration (cleanup) and investments in pollution control. Pollution cleanup investments, as Figure 3-1 shows, are applied directly to reduce levels of pollution. This activity is independent of simultaneous economic sector activity (except to the degree that continuing to produce pollution to replace that which is being cleaned up at great cost is counterproductive). Our model, therefore, treats such investment as a fully independent variable.

Pollution control investments are made for installing or maintaining devices that reduce existing pollutant outputs. Such devices do this with some level of efficiency based largely on the technology that is applied. That effort can be measured by the investment in pollution control as a proportion of the total industrial output. Pollution control investments are affected by regulatory levels; some external or government investment may be applied directly, but otherwise pollution control investment changes by producers will occur only as a result of changes in the regulatory picture. Our initial assessment of this relationship is based on changes in pollution control investments in the United States observed in conjunction with changing regulatory levels (as assessed subjectively). This relationship needs further study.

We assumed that only industry is required to make significant investments for pollution control. In reality, of course, this is hardly the case since the consumer usually ends up carrying the cost. Nevertheless, pollution control devices tend to be located physically at the industrial plant level, and certainly data are more readily available from those entities than from the consumer.

In addition, consumers pay other costs beyond production costs (higher waste disposal costs, for instance) that are not borne by manufacturers, especially when the item is manufactured elsewhere. However, in the consumer sector, some of these costs counterbalance: pollution-controlled cars may be more expensive, but they may also be more fuel efficient. There are also additional impacts that we do not address: these same cars, for instance may be less fuel-efficient than some of their predecessors, but that could be because they are carrying additional structural material mandated by safety considerations, which in turn became necessary because cheap fuel-efficient plastic cars were deemed unsafe. Because there are any number of unrelated explanations for these outcomes, we decided for now that the use of the industrial sector pollution control investment, which is relatively well quantified, would suffice to account for changing levels of pollution control (regulation and technology remaining constant).

Pollution control investments create a level of control efficiency that abates a proportion of the overall uncontrolled pollution. These controls have limited efficiency, and the limits are generally well known in the environmental community. The efficiency varies with the pollutant being controlled. Table 3-2 depicts the nominal levels of efficiency expected for various pollutants within the United States in 1994 using generally available technology.

Table 3-2.
Pollution Control Efficiencies

Pollutant	Percentage in air	Percentage in water
Particulates (PM-10)	80	–
Sulfur oxides (SO_x)	85	–
Nitrogen oxides (NO_x)	80	–
Volatile organic compounds (VOC)	90	90
Metals	95	95
Inorganics (nutrients)	–	80
Oxygen demand levels	–	95
Biological/microbial	–	99
Physical water character[a]	–	95
Sediment	–	99

[a] Includes pH, total suspended solids, color, and odor.

The achievement of pollution control efficiencies always displays diminishing returns. We assume that the control levels currently achieved in the United States represent the point of diminishing returns and that the curves have the same shape for all pollution control systems. The general equation then is as follows:

Pollution control efficiency = (system coefficient)(investment percentage) to the power of b {the coefficient that gives the curve its shape}.

This relationship is illustrated in Figure 3-2. We developed this curve by limiting the minimum and maximum range of efficiency to 0 and 1 (i.e., 100 percent) and establishing the current amount of pollution control expenditure and 85 percent efficiency as a known point. Equations for specific pollution control systems simply require adjustment of the formula coefficient to reflect current efficiency levels. Thus, a percentage change in pollution control investment results in the same percentage change in efficiency in all substances, even though the actual efficiency levels themselves are not the same. The standard for both levels of investment and for efficiency is assumed to be that of the United States.[4,5]

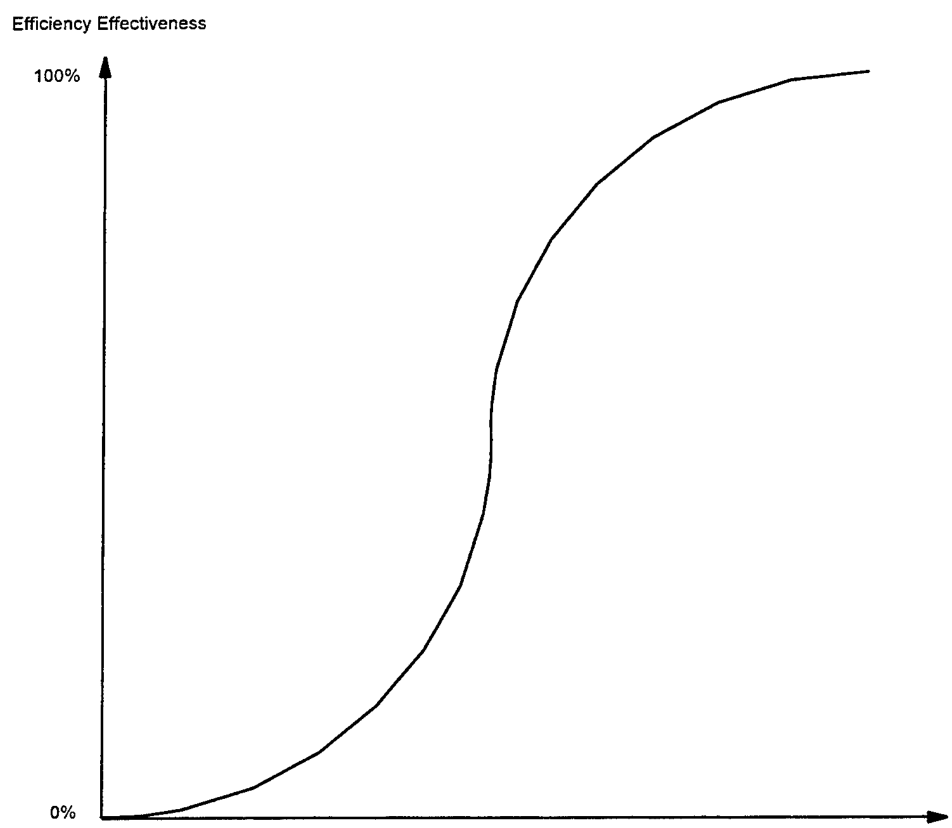

Figure 3-2.
Diminishing Returns of Pollution Control Investments

[4] The methodology we used, while different from that used by USEPA, had the same results. USEPA's model for national air pollution is based on selected key industries and applies an engineering approach to pollution output assigning case-by-case efficiency levels.

[5] U.S. Environmental Protection Agency, *National Air Pollutant Emission Trends,* Document No. 454, various years.

The relationship between pollution control efficiency and investment is subjectively determined and needs further research. Additionally, pollution control investments are a function of regulation, while the achievable pollution control efficiency is a function of the level of technology attained. A maximum control effort in 1940 could not have achieved the control levels possible today (although, since most control systems do not use very advanced technology, the difference is by no means as great as the differences between general levels of technology at the two times).

Regulations

During the initial phase of the research, the argument was advanced that pollution control technology is driven by, and inseparable from, regulatory levels. After extensive debate, we decided that, although related, these two concepts are distinct.

Although many technological innovations are implemented as a result of regulation, it is by no means true that such innovation is developed strictly as a result of regulation. In the absence of a strong regulatory structure, production technology could be advanced and yet pollution could be extensive (the situation in many recently industrialized countries, as well as that of the U.S. nuclear weapons production industry, proves this point).

To represent regulatory controls in our environmental sector model, we used a multiplicative approach that accounts for both the regulatory structure and the enforcement process. We used that approach because the presence of a regulatory structure is illusory if it is not accompanied by a credible enforcement process. Thus, a combination of high regulatory and enforcement standards was required to achieve a high net score; foot-dragging in either area reduces the value of the product. For the international case, where regulatory schema are expected to vary and financial measures lose their value when transferred across borders, we concluded that a subjectively determined categorical scale was the most appropriate measure for regulatory issues. We also determined arbitrarily that the scales would be developed on a 10-point basis (actually 0 to 9.9). As a means of defining the range of the scales, we decided to construct the scales such that the United States would fall generally in a range from 6.0 to 9.0 on most measures.

The effect of scale scoring has not been satisfactorily addressed in the regulatory literature. At present, only subjective assessments by an expert panel can be used to develop either the scale score of the relationship between regulatory effectiveness and emissions control. Much more research is needed in this area; ultimately, a formal subjective scale should be developed to allow consistent assignment of a case country to specific scale rankings. Development of such a scale depends on including a number of factors that address local conditions that do not apply in the United States. To provide a starting point for discussion, we used quantitative measures based on the investment in environmental regulation as a proportion of the state's total budget and on the size of the regulatory work force (normalized for the amount of industry to regulate) as measures of regulation and enforcement, respectively. Those initial assessments should be the subject of extensive follow-on study.

Regulation differs for different economic sectors. In the United States, for instance, direct regulation of households or of agriculture is seldom attempted. Thus, there could be different regulatory factors for each sector of the model, to the degree that data are available. We did not make this distinction in the initial model version.

Regulatory and enforcement capabilities are affected by investment. In Figure 3-1, we show the link between investments and the regulatory and enforcement level. That link exists in our model such that, over time, investments in these activities can result in increased capacities.

Regulation also interacts with pollution control investment: where regulation is aggressive we expect to see high levels of pollution control in place. However, aggressive regulation can also cause a total avoidance of the polluting activity.

OUTPUTS

The more detailed outputs of the environmental model are the resource quality measures. These measures are developed at three different levels. The most aggregate measure is an overall environmental quality index, used principally to demonstrate environmental issues on the multisector time charts that are found as progress reports in the Threshold-21 model.

Each of the resources has a quality index that accumulates pollutant-specific impacts; the indices should be constructed so that proportionate change in each of the contributing impacts creates a proportionate change in the overall index.[6] We took this approach because we believe that the general economic and political system reacts to overall quality issues (for example, smog, rivers catching fire, and dead fishing grounds) rather than to specific constituent issues (sulfur dioxide or sediment content levels). This political system effect is reflected in changes in the regulatory structure and in enforcement capacity. Thus, the composite indices affect the regulatory values and serve as general indicators of progress over time.

The resource indices are constructed from specific pollution impacts (in terms of total emissions of substances of concern, e.g., volatile organics) or specific resources that are impacted (e.g., wetland acreage). Table 3-3 shows the set of impacts that is included in the model. Each impact has a different way (if any) of affecting the economic sectors; thus, in the model, each of those links is established separately.

[6] At the time of publication, work continues on the development of a useful set of quality indices. We are attempting to match our indices to nationally accepted measures but have not yet located any such measures.

Table 3-3.
Outputs of the Environmental Sector Module

Constituent	Air quality	Water quality	Soil quality	Natural resources	External impact
Particulates (PM-10)	x	x			Smog, health, crops
Sulfur oxides (SO_x)	x				Smog, health, crops
Nitrogen oxides (NO_x)	x				Smog, health, crops
Volatile organic compounds (VOC)	x	x			Health, crops
Metals	x	x			Health
Inorganics (nutrients)		x			Aquatic life
Oxygen demand levels		x			Aquatic life
Biological/microbial		x			Health
Physical water character		x			Recreation
Sediment		x			Aquatic life
Soil quality			x		Crops
Soil contamination			x		Health
Water availability		x		x	Health, crops
Surface water condition		x		x	Health, recreation, aquatic life, fisheries
Coastal water condition		x		x	Health, recreation, fisheries
Wetland condition				x	Health, recreation, aquatic life
Land uses			x	x	Recreation, quality of life, potential health impact
Biodiversity				x	Recreation

SUMMARY

Our model of the environmental sector accounts for pollution pools or resource impacts that are created by activities within the economic sectors, investments that are applied directly or indirectly to reduce those impacts, and the regulatory structure.

To prevent the model from becoming incomprehensibly complex, we decided to model environmental processes only to the extent needed. Thus, our equation represents macro-level relationships matching the level of detail of the overall Threshold-21 model. However, in developing the relationships, we constructed much more detailed summations of the key activities occurring in the economic sectors (those summations are provided in the Appendix); if the model were to be expanded to address subnational issues, those additional levels of detail would need to be included. (Whether they could be supported with data is another matter.)

At present, our model does not address international issues such as global warming (greenhouse emissions or ozone depletion) or cross-border pollution. Although, the basic structure of the model allows for the calculation of such emissions, it cannot be done until the larger Millennium model is structured to integrate multiple country scenarios. Further, for the many cases where the general effect is accepted to be adverse but no specific effects can be identified (global warming being a key example), our model can display the accumulation of emissions but cannot translate those accumulations into meaningful economic or social impacts. Perhaps, in our economics-driven world, this is the reason that these issues do not receive the attention that some scientists believe they should; most policy processes are optimized at the self-centered level (national policies at the national level, for instance). One of the most important contributions of the Threshold-21 model will be to provide the vehicle for making decisions that include consideration of the effects of a policy when viewed from the international level.

CHAPTER 4

Next Steps

Up to this point, we have discussed our environmental sector model chiefly in terms of its elements and the linkages among them. We have displayed the most critical aspect of our module: the equation that represents all the economic activities and their resulting environmental impacts. We have also discussed the use of scales for inputs, such as the impact of technology and regulation. The next steps are to implement the model and then integrate it with the Millennium Institute's Threshold-21 model.

IMPLEMENTING THE ENVIRONMENTAL SECTOR MODEL

The basic equation in our model contains four interactive variables — economic activities, the technological level at which those activities occur, the coefficients representing pollution output without controls, and the efficiency of controls that are in place — and two additive variables — cleanup operations and the effect of regulation. To implement the model, we must assign coefficients that quantify the interrelationships of those variables. Assignment of coefficients requires empirical data on environmental causes and effects. Thus, in the second year of our study, we will be focusing on identifying, validating, and adapting the needed data.

Because technological levels, pollution control, and environmental regulations vary tremendously from country to country, we decided to use conditions in the United States as a baseline. Even within the intensely regulated United States, the amount of useful data on environmental causes and effects is limited. The science for assessing total pollution simply is not well developed; scientific or engineering equations are virtually nonexistent. Moreover, measurements of pollution levels (the dependent variable), which are needed to develop coefficients for the independent variables, also are not readily available — a surprise given the enormous amount of regulatory data collected.

To date, we have collected data from each of the 50 states. Since technological levels and pollution control capabilities are generally equal across the states, we can use those data to derive the basic emissions coefficients and regulatory impact coefficients. We can also derive technological change factors, pollution control efficiency factors, and factors quantifying the impact of regulation on pollution control. Where state data are not helpful, we have assembled historical data ranging back to 1960 (and in some cases to 1940) at the national level. That may prove useful in establishing the effect of evolving technology and regulation. We are addressing air pollution first because it offers the simplest dependent variable and because there is no requirement to account for cleanup investments. During FY96, we will continue our research to validate the coefficients and values we used to make the environmental module work with the Threshold-21 model.

Integrating the Environmental Sector Model

Some critical relationships in the environmental model need to be reflected in the Threshold-21 model. Since, in developing our model, we maintained a focus on the World Bank data sets that form the basis for much of the Threshold-21 model, all of the economic sector inputs that we need for the environmental sector module can be provided through the Threshold-21 model simply by including a few more data elements from the existing databases.

We welcome constructive criticism and, even better, offers of partnership to research specific issues and assumptions as we strive to improve the effectiveness, utility, and credibility of this complex modeling process.

We anticipate that, during FY96, LMI and the Millennium Institute will complete a fully functional version of the Threshold-21 model (including our environmental sector module) and apply it to several countries. In that process, we expect to gain additional validation for our subjective scale systems. We hope that the resultant model will serve as a useful decision tool both for international funding agencies and for internal government agencies when allocating budgets.

APPENDIX

Environmental Impacts from Economic Activities

All environmental impacts from economic sectors

Sector **Agriculture**

Sub-sector *CROP*

Activity	*Impact Action*	*Impact Mode*	*Media*	*Impact Type*	*Measurement*
AFTER-HARVEST	CLEAR BY BURNING	DEPOSIT, RUNOFF	WATER	PARTICLES	TONS/ACRE
AFTER-HARVEST	CLEAR BY BURNING	SMOKE	AIR	SMOKE PARTICLES	TONS/ACRE
CROP GROWING	IRRIGATION	DEPLETION (WETLAND)	BIO	HABITAT LOSS	ACRE-FEET/YR
CROP GROWING	PESTICIDES	BIO INCREASE	BIO	HABITAT GAIN	NUMBER SPECIES???
CROP GROWING	PESTICIDES	BIO DECREASE	BIO	HABITAT LOSS	NUMBER SPECIES???
CROP GROWING	IRRIGATION	WATER USE PATTERNS	WATER	RESOURCE DEPLETION	ACRE-FEET/YEAR
CROP GROWING	ROTATION	DEPLETION	SOIL	SOIL QUALITY	??
CROP GROWING	PESTICIDES	DEPOSITION	SOIL	??	TONS/ACRE
CROP GROWING	PESTICIDE SPRAY	DRIFT	AIR	TOXIN	TONS/ACRE
CROP GROWING	PESTICIDES	RUNOFF	WATER	TOXIN	TONS/ACRE
CROP GROWING	IRRIGATION	DEPOSITION	SOIL	??	ACRE-FEET/YEAR
CROP GROWING	IRRIGATION	RUNOFF	WATER	TOXIN	ACRE-FEET/YEAR
HARVESTING	MECHANICAL HARVESTING	SOIL DISTURBANCE	AIR	SOIL PARTICLES	TONS/ACRE
LAND PREP	CLEAR BY BURNING	DEPLETION	BIO	HABITAT LOSS	NUMBER SPECIES???
LAND PREP	FERTILIZING	COVER	BIO	HABITAT LOSS	NUMBER SPECIES???
LAND PREP	MECHANICAL CLEARING	DEPLETION	BIO	HABITAT LOSS	NUMBER SPECIES???

LAND PREP	FERTILIZING	DEPOSITION	SOIL	SOIL QUALITY	TONS/ACRE
LAND PREP	TILLING	EROSION	SOIL	SOIL QUALITY	TONS/ACRE
LAND PREP	TILLING	EROSION	WATER	SOIL PARTICLES	TONS/ACRE
LAND PREP	FERTILIZING	RUNOFF	WATER	??	TONS/ACRE
LAND PREP	TILLING	SOIL DISTURBANCE	AIR	SOIL PARTICLES	TONS/ACRE
LAND PREP	CLEAR BY BURNING	DEPOSIT, RUNOFF	WATER	PARTICLES	TONS/ACRE
LAND PREP	CLEAR BY BURNING	SMOKE	AIR	SMOKE PARTICLES	TONS/ACRE
LAND PREP	MECHANICAL CLEARING	SOIL DISTURBANCE	AIR	SOIL PARTICLES	TONS/ACRE

Sub-sector *LIVESTOCK*

Activity	*Impact Action*	*Impact Mode*	*Media*	*Impact Type*	*Measurement*
RAISING	WASTE GENERATION	EMISSION	AIR	METHANE	PPM??
RAISING	GRAZING	EROSION	SOIL	SOIL EROSION?	TONS/ACRE
RAISING	WASTE GENERATION	RUNOFF	WATER	SOIL	
RAISING	WASTE GENERATION	ODOR	AIR	AIR QUALITY	QUALITY INDEX?
RAISING	GRAZING	DEPLETION	BIO	HABITAT LOSS	NUMBER SPECIES???
RAISING	GRAZING	DEPLETION	SOIL		
RAISING	GRAZING	RUNOFF	WATER	SOIL QUALITY	ACRE-FEET/YEAR
RAISING	WASTE GENERATION	DIRECT DISCHARGE	WATER	SLUDGE/SOLIDS?	

Sector **ENERGY**

Sub-sector *COAL*

Activity	*Impact Action*	*Impact Mode*	*Media*	*Impact Type*	*Measurement*
EXTRACTION	MINING	RUNOFF	WATER	HEAVY METALS	TONS

POWER GEN	BURNING	EMISSION	AIR	SO2, NOX, PM-10	TONS

Sub-sector *FUEL OIL*

Activity	***Impact Action***	***Impact Mode***	***Media***	***Impact Type***	***Measurement***
ENGINE FUEL	INT'L COMBUSTION	EMISSION	AIR	SO2, NOX, PM-10	GALLONS
POWER PLANT	BURNING	EMISSION	AIR	SO2, NOX, PM-10	GALLONS

Sub-sector *HYDROPOWER*

Activity	***Impact Action***	***Impact Mode***	***Media***	***Impact Type***	***Measurement***
DAM CONSTRUCTIO	CONSTRUCTION	PHYSICAL BARRIER	BIO	HABITAT DISRUPTION	HECTARES

Sub-sector *NATR GAS*

Activity	***Impact Action***	***Impact Mode***	***Media***	***Impact Type***	***Measurement***
TRANSPORT	PIPELINE	PHYSICAL BARRIER	BIO	HABITAT DISRUPTION	HECTARES

Sub-sector *NUCLEAR*

Activity	***Impact Action***	***Impact Mode***	***Media***	***Impact Type***	***Measurement***
FUEL PROCESSING	BY-PRODUCT	WASTE DISPOSAL	SOIL	RADIOACTIVE	TONS
POWER GEN	EXCESS HEAT	COOLING	BIO	HABITAT DISRUPTION	TONS
POWER GEN	BY-PRODUCT	WASTE DISPOSAL	SOIL	RADIOACTIVE	TONS

Sub-sector *OIL PRODUCTION*

Activity	***Impact Action***	***Impact Mode***	***Media***	***Impact Type***	***Measurement***
EXPLORATION	CONSTRUCTION	SOIL DISTURBANCE	WATER	VOC, BTEX	GALLONS
EXPLORATION	CONSTRUCTION	PHYSICAL BARRIER	BIO	HABITAT DISRUPTION	HECTARES
EXPLORATION	CONSTRUCTION	OIL SPILL	WATER	VOC, BTEX	GALLONS

EXTRACTION	DRILLING	OIL SPILL	WATER	VOC	GALLONS
EXTRACTION	DRILLING	OIL SPILL	SOIL	VOC, BTEX	GALLONS

Sub-sector *OIL REFINERY*

Activity	*Impact Action*	*Impact Mode*	*Media*	*Impact Type*	*Measurement*
REFINERY	BY-PRODUCT	SPILL	WATER	VOC	GALLONS
REFINERY	DISTILLATION	EMISSION	AIR	VOC	GALLONS
REFINERY	BY-PRODUCT	SPILL	SOIL	VOC, CHEMICAL TOXIN	GALLONS

Sub-sector *OIL TRANSPORT*

Activity	*Impact Action*	*Impact Mode*	*Media*	*Impact Type*	*Measurement*
PIPELINE	RUNNING OIL	OIL SPILL	WATER	VOC, BTEX	GALLONS
PIPELINE	CONSTRUCTION	PHYSICAL BARRIER	BIO	HABITAT DISRUPTION	HECTARES
PIPELINE	RUNING OIL	OIL SPILL	SOIL	VOC, BTEX	GALLONS
PIPELINE	RUNING OIL	OIL SPILL	BIO	HABITAT DSIRUPTION	HECTARES
TANKER	SHIPPING	OIL SPILL	BIO	HABITAT DISRUPTION	HECTARES
TANKER	SHIPPING	OIL SPILL	WATER	VOC	GALLONS

Sub-sector *RENEWABLE*

Activity	*Impact Action*	*Impact Mode*	*Media*	*Impact Type*	*Measurement*
POWER GENERATI	CONSTRUCTION	PHYSICAL BARRIER	BIO	HABITAT DISRUPTION	HECTARES

Sector **Food/Nutrition**

Sub-sector *Meat/Poultry*

Activity	*Impact Action*	*Impact Mode*	*Media*	*Impact Type*	*Measurement*

Food Production	Packaging	Solid Waste Incineration.	Air	PM10.CO2,NOx,SOx,VO	KG/Ton (food produced)
Food Production	Cooling/Freezing	Coolant Emission	Air	CFCs	KG/Ton (food produced)
Food Production	Cooking	Solid Waste Landfilling	Water	OCs,OD,Micro,Phys,Nutri	KG/Ton (food produced)
Food Production	Packaging	Solid Waste Landfilling	Water	OCs,OD,Micro,Phys,Nutri	KG/Ton (food produced)
Food Production	Cooking	Solid Waste Landfilling	Soil	Land Use	KG/Ton (food produced)
Food Production	Packaging	Solid Waste Landfilling	Soil	Land Use	KG/Ton (food produced)
Food Production	Cooking	Fuel Burning	Air	PM10.CO2,NOx,SOx,VO	KG/Ton (food produced)
Food Production	Washing	Effluent discharge	Water	OCs,OD,Micro,Phys,Nutri	KG/Ton (food produced)
Food Production	Slaughter	Solid Waste Landfilling	Soil	Land Use	KG/Ton (food produced)
Food Production	Slaughter	Solid Waste Landfilling	Water	OCs,OD,Micro,Phys,Nutri	KG/Ton (food produced)
Food Production	Slaughter	Solid Waste Incineration.	Air	PM10.CO2,NOx,SOx,VO	KG/Ton (food produced)
Food Production	Slaughter	Effluent Discharge	Water	OCs,OD,Micro,Phys,Nutri	KG/Ton (food produced)
Food Production	Cooking	Solid Waste Incineration.	Air	PM10.CO2,NOx,SOx,VO	KG/Ton (food produced)
Transportation	Energy Use	Vehicle Emission	Air	PM10.CO2,NOx,SOx,VO	KG/Ton (food produced)

Sub-sector *Vegetable*

Activity	*Impact Action*	*Impact Mode*	*Media*	*Impact Type*	*Measurement*
Food Production	Packaging	Solid Waste Landfilling	Soil	Land Use	KG/Ton (food produced)
Food Production	Washing	Effluent discharge	Water	OCs,OD,Micro,Phys,Nutri	KG/Ton (food produced)
Food Production	Cooking	Fuel Burning	Air	PM10.CO2,NOx,SOx,VO	KG/Ton (food produced)
Food Production	Cooking	Solid Waste Incineration.	Air	PM10.CO2,NOx,SOx,VO	KG/Ton (food produced)
Food Production	Packaging	Solid Waste Incineration.	Air	PM10.CO2,NOx,SOx,VO	KG/Ton (food produced)
Food Production	Cooking	Solid Waste Landfilling	Soil	Land Use	KG/Ton (food produced)

Food Production	Packaging	Solid Waste Landfilling	Water	OCs,OD,Micro,Phys,Nutri	KG/Ton (food produced)
Food Production	Cooking	Solid Waste Landfilling	Water	OCs,OD,Micro,Phys,Nutri	KG/Ton (food produced)
Food Storage	Cooling/Freezing	Coolant Emission	Air	CFCs	KG/Ton (food produced)
Transportation	Energy Use	Vehicle Emission	Air	PM10.CO2,NOx,SOx,VO	KG/Ton (food produced)

Sector Goods

Sub-sector *Finished Goods*

Activity	*Impact Action*	*Impact Mode*	*Media*	*Impact Type*	*Measurement*
Allocation	Energy Use	Fuel burning	Air	PM10,NOx,SOx,CO2,VO	Mg/gal burned
Packaging	Solid Waste Production	Landfilling	Soil	VOC,OOC,Metals,Inorgs	Kg/Ton waste
Packaging	Solid Waste Production	Landfilling	Water	TOC,Metals,Inorg,TOD,P	Kg/Ton waste
Packaging	Solid Waste Production	Incineration	Air	PM10,NOx,SOx,CO2,VO	Kg/Ton waste
Processing	Water Use	Wastewater effluent	Soil	VOC,OOC,Metals,Inorgs	Mg/gal used
Processing	Hazardous Waste Production	Landfilling	Soil	VOC,OOC,Metals,Inorgs	Kg/Ton waste
Processing	Energy use	Fuel Burning	Air	PM10,NOx,SOx,CO2,VO	Mg/gal burned
Processing	Hazardous Waste Production	Incineration	Air	PM10,NOx,SOx,CO2,VO	Kg/Ton waste
Processing	Solid Waste Production	Landfilling	Soil	VOC,OOC,Metals,Inorgs	Kg/Ton waste
Processing	Solid Waste Production	Incineration	Air	PM10,NOx,SOx,CO2,VO	Kg/Ton waste
Processing	Water Use	Wastewater effluent	Water	TOC,Metals,Inorg,TOD,P	Mg/gal used
Processing	Solid Waste Production	Landfilling	Water	TOC,Metals,Inorg,TOD,P	Kg/Ton waste
Processing	Hazardous Waste Production	Landfilling	Water	TOC,Metals,Inorg,TOD,P	Kg/Ton waste
Storage	Cooling/refrigeration	Chemical leakage	Air	CFCs	Kg lost
Storage	Energy Use	Fuel burning	Air	PM10,NOx,SOx,CO2,VO	Mg/gal burned

Sub-sector *Raw Materials*

Activity	*Impact Action*	*Impact Mode*	*Media*	*Impact Type*	*Measurement*
Acquisition	Energy use	Fuel Burning	Air	PM10,NOx,SOx,CO2,VO	Mg/gallon burned
Acquisition	Water Use	Wastewater effluent	Water	TOC,Metals,Inorg,TOD,P	Mg/gal used
Acquisition	Water Use	Wastewater effluent	Soil	VOC,OOC,Metals,Inorgs	Mg/gal used
Acquisition	Hazardous Waste Production	Landfilling	Water	TOC,Metals,Inorg,TOD,P	Kg/Ton waste
Acquisition	Hazardous Waste Production	Incineration	Air	PM10,NOx,SOx,CO2,VO	Kg/Ton waste
Acquisition	Solid Waste Production	Landfilling	Soil	VOC,OOC,Metals,Inorgs	Kg/Ton waste
Acquisition	Solid Waste Production	Landfilling	Water	TOC,Metals,Inorg,TOD,P	Kg/Ton waste
Acquisition	Hazardous Waste Production	Landfilling	Soil	VOC,OOC,Metals,Inorgs	Kg/Ton waste
Acquisition	Land Clearing	Habitat loss	BIO	Species loss	Hectares habitat lost
Acquisition	Water Use	Consumption	BIO	Water Reserve Depletion	Gallons lost
Acquisition	Physical Land Preparation	Soil distubance	Air	PM10	Kg/Hectare
Acquisition	Solid Waste Production	Incineration	Air	PM10,NOx,SOx,CO2,VO	Kg/Ton waste
Processing	Solid Waste Production	Landfilling	Water	TOC,Metals,Inorg,TOD,P	Kg/Ton waste
Processing	Water Use	Wastewater effluent	Water	TOC,Metals,Inorg,TOD,P	Mg/gal used
Processing	Solid Waste Production	Incineration	Air	PM10,NOx,SOx,CO2,VO	Kg/Ton waste
Processing	Solid Waste Production	Landfilling	Soil	VOC,OOC,Metals,Inorgs	Kg/Ton waste
Processing	Hazardous Waste Production	Incineration	Air	PM10,NOx,SOx,CO2,VO	Kg/Ton waste
Processing	Hazardous Waste Production	Landfilling	Water	TOC,Metals,Inorg,TOD,P	Kg/Ton waste
Processing	Hazardous Waste Production	Landfilling	Soil	VOC,OOC,Metals,Inorgs	Kg/Ton waste
Processing	Energy use	Fuel Burning	Air	PM10,NOx,SOx,CO2,VO	Mg/gal burned

Processing	Cooling/refrigeration	Chemical leakage	Air	CFCs	Kg lost
Processing	Water Use	Wastewater effluent	Soil	VOC,OOC,Metals,Inorgs	Mg/gal used

Sub-sector *Transportation*

Activity	*Impact Action*	*Impact Mode*	*Media*	*Impact Type*	*Measurement*
Goods movement	Energy Use	Fuel burning	Air	PM10,NOx,SOx,CO2,VO	Mg/gal burned

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13. ABSTRACT ***(Maximum 200 words)***

The connection between the economy and the environment has generally remained unexplored. The Logistics Management Institute decided to investigate whether the indirect benefits of environmental investments could be identified and quantified, thus enabling the inclusion of environmental issues in traditional economics-oriented decision-making processes. We were unable to find any existing environmental assessment models or economic development models that we could use as a generally accepted framework for modeling the link between the economy and the environment. Consequently, we modeled the environmental sector as a module of the Threshold-21 simulation that is being constructed by the Millennium Institute to investigate sustainable development issues.

The general concept of our environmental model is that activity in the economic sectors creates associated pollutant emissions, which in turn affect the quality or quantity of the resource pool — air, water, soil, and natural resources. Those impacts are moderated by production technology and by investments in pollution control equipment; they are further modified by the levels of regulatory control and enforcement that are in place. We expressed those interrelationships in an equation.

This report on a work in progress is being published in order to engage a wider research community in addressing the many unknowns that continue to exist in this area.

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