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The Potential Contributions of Mutually Consistent, Sectorally Disaggregated Economic Models to Analyses of National Environmental Policies and Global Environmental Interdependence

Dresch, S.P.

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Stephen P. Dresch

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This paper has been prepared for the Input-Output Modeling Task Force Meeting, IIASA, Laxenburg, Austria, 4-6 October 1984. The author is a IIASA research scholar and chairman of the Institute for Demographic and Economic Studies, New Haven, Connecticut, U. S. A.

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
2361 Laxenburg, Austria

FORWARD

Although ultimately addressing the question of possible substantive applications of the "family" of national input-output models developed and maintained by members of the IIASA-INFORUM network, this paper is effectively concerned more generally with the issue of appropriate and scientifically effective approaches to the analysis of questions of social significance. Now, when the subject of the future configuration of the IIASA research program, generally and in economics specifically, is the focus of attention and of prospective decision, the paper should be of particular interest.

In formulating his critique of certain aspects of the current research program and his suggestions for future programmatic reoirentation the author has benefited from discussions which we have had over the past year within the project on Comparative Analysis of Economic Structure and Growth [members of which, in addition to the author and myself, included Professor Ernö Zalai (Karl Marx University of Economics, Hungary) and Professor Mitsuo Saito (Kobe University, Japan)] and visitors to the project, especially including Professor Yuri Yaremenko (Central Economic-Mathematical Institute, U.S.S.R.), Dr. Seppo Leppänen (Economic Planning Center, Finland), Professor Merton J. Peck (Yale University, U.S.A.), Professor Osmo Forssell (University of Oulu, Finland), and Professor F. Girard Adams (University of Pennsylvania, U.S.A.).

With reference to the IIASA-INFORM family of input-output models, the author proposes an examination of environment-economy interactions which could be initiated very quickly and at low cost, both to IIASA and to the various national participants. In addition to exploiting the capabilities developed by members of the network over the last several years,

the proposed collaborative study would also constitute a potential bridge between the (heretofore quite separate and unrelated) IIASA economics and environmental programs, contributing to the achievement of an integration of IIASA research (through what the author characterizes as "cross-fertilization rather than permanent cohabitation") which has been repeatedly proclaimed as an objective but toward the achievement of which little progress can be identified.

The author and I would both welcome any reactions to the ideas expressed in this paper.

Anatoli Smyshlyaev
Project Leader
Comparative Analysis of Economic Structure and Growth

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Stephen P. Dresch

1. Overview of the Issue

Much of the contemporary concern for "structural change" in advanced economies has its origins in the significant changes in patterns of international trade which have occurred over the last two decades. While these changes in trade patterns are the joint consequences of developments in a number of interrelated dimensions (e.g., differentials in rates of technological innovation and diffusion and differential changes in relative factor prices, in rates of savings and capital formation, in the vintage of the capital stock and in primary materials and energy prices and availabilities), a growing emphasis in a number of countries on the environmental consequences of productive activities has constituted an important contributing factor, serving to discourage apparently "environmentally-adverse" ("pollution-intensive") production in some countries and to encourage the transfer of that production to countries in which environmental concerns are less intense (or impinge less severely on productive activity).

If "open economies" enjoyed "closed (natural) environments," then international trade would represent an effective means by which to "purchase" environmental amenities. In those societies in which these amenities were valued more highly, higher "prices" would be placed on "environmental services" as factors of production (either *de jure* or, through regulation, *de facto*). Other economies, placing lesser value on environmental services and amenities, would enjoy a comparative advantage with reference to commodities the production of which was environmentally "intensive." In consequence, patterns of trade would evolve exhibiting relative specialization, either in environmentally-adverse or

in environmentally-neutral production. Those countries more highly valuing environmental amenities would experience an apparent deterioration in terms of trade, compensated by simultaneous increases in the consumption of environmental amenities relative to the consumption of other commodities. In the absence of barriers to international migration, individuals would distribute themselves over countries (characterized, *inter alia*, by closed environmental systems and open economies) so as to maximize welfare.[1] On the assumption that environmental services were efficiently priced in each country, i.e., that any given level of environmental quality (consumption of environmental amenities) in any country could not be achieved at lesser cost (higher real income and output in that country), it would follow that the the global distributions of population, production and environmental quality would be Pareto optimal.[2]

In fact, of course, virtually all of the assumptions (explicit or implicit above), necessary for the conclusion that independently-taken national decisions concerning the explicit or implicit pricing of environmental services will lead to a globally Pareto-optimal solution, can be expected to be violated. Thus:

- Individual countries are not characterized by open economies and closed (natural) environments.
  - Because of less than "complete" environmental closure, the transfer of production from one country to another may be offset to a greater or lesser extent by trans-border environmental impacts of production, i.e., consequences of production in any one country on the environments of other countries.
  - Because of less than "complete" economic openness, the anticipated benefits of national actions designed to raise the effective prices of environmental services may not materialize or may be inefficientiy achieved. For example, adverse changes in international competitiveness of industries engaged in environmentally intensive production may lead to the imposition of import tariffs and quotas and to other trade interventions which preclude to some extent the efficient global reallocation of productive activity, erode the intended improvement in environmental quality in the initiating country and raise the effective economic cost of such environmental improvement as is achieved in that country. Similarly, restrictions on international capital movements may well prevent full adaptation of the global economy.

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[1] What is required here is freedom of movement of individuals both as consumers (of environmental amenities) and as factors of production (labor). The absence of barriers to international movements of capital as a factor of production is implicit in the assumption of a perfectly "open" economy, and corresponding stipulations concerning knowledge and technology are also implicit.

[2] The general ssystem, as just described, would be in the class described by James Buchanan's "economic theory of clubs" and Charles Tiebout's "pure theory of local government" (analysis of local governmental expenditure and taxation).

- Constraints on international migration preclude the conclusion that the market-determined global allocation of productive activity would be Pareto optimal even if individual countries were characterized by open economies and closed environments and if national environmental policies were efficient. Even in the absence of perfect mobility, constrained optimality could be achieved if political decisions in each country fulfilled the compensation criterion that beneficiaries of the policy be able to fully compensate victims, although this is also unlikely.
- It is apparent that national environmental policies are not even internally efficient, i.e., that given levels of environmental quality and amenity could generally be achieved even if prices of environmental services confronted by producers were reduced (or, conversely, that given levels of nonenvironmental output and income could be achieved at lesser cost in terms of the sacrifice of environmental amenities).[3]

In short, the net benefits/costs (not to mention optimality/efficiency) of environmental policies are unclear, not only globally but even at the level of the national economy.

2. Toward an Analytical Framework for the Analysis of National Policies and Global Environmental-*cum*-Economic Interdependence, With Particular Reference to the IIASA Research Program

A complete portrayal of global economic and environmental interdependence would require a fully articulated specification of both the global economy and the global environment. It would be necessary that this system capture all significant interdependencies between economic activity and the environment in the spatial dimension, with economic activity at any point in space influencing the environment at all other points, and *vice versa*.[4] Attempted construction of such a fully articulated portrayal of the economic-*cum*-environmental systems would, obviously, be a preposterous undertaking, given the current states of our understanding of both the economy and the environment. However, a selfconscious recognition of the environmental implications of economic activity and of the economic implications of environmental actions would clearly be beneficial to the substantive interpretation of the

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[3]This problem would also be mitigated by free international migration, in that population (and capital) would leave jurisdictions pursuing inefficient environmental policies.

[4]In fact, it would also be necessary to incorporate the time dimension, in that current productive activity will have implications for the global environment at subsequent points in time, and *vice versa*. Differently stated, optimality must be considered not only with reference to persons currently alive but also with reference to those who will be alive in the future. If all environmental externalities could be internalized, then this would not require a qualification of the above suggestion that market outcomes would constitute a global optimum, as discussed in the related context of exhaustible resources in Stephen P. Dresch, "Myopia, Emmetropia of Hypermetropia? Competitive Markets and Intertemporal Efficiency in the Utilization of Exhaustible Resources" [IIASA Working Paper, WP-84-48, June 1984 (revised September 1984)], forthcoming (in Russian translation) in J. Gvishiani and A. Wierzbicki, eds., *Soviet Yearbook on Systems Research* (Moscow: USSR Academy of Sciences and The State Committee on Science and Technology, 1985).

conclusions of economic *and* environmental analyses and might well contribute also to the further development of capabilities in each dimension.

Unfortunately, most current economic and (exhibiting an economist's bias, especially) environmental analyses are not notably selfconscious with reference to implications in the other domain. Overstating, perhaps, but not radically, environmental analyses pay lip service to economic implications but procede as though environmental amenities were virtually "unlimited goods" (the value of which is invariant with respect to the amount "produced" and almost invariably greater than the value of the alternatives sacrificed for their attainment), while economic analyses, until quite recently, have virtually ignored the issues of the environmental implications of productive activity and of the evaluation of these implications.

Substantively, there appear to be several interdependent but separately identifiable issues warranting explicit economic and/or environmental analysis:

- *Representation of the environment as a factor of production (environmental services as productive inputs).* While characterization of environmental consequences of productive activity as simply *negative externalities* (negatively valued byproducts) is formally equivalent to the characterization of environmental services as factor inputs, comprehension of the issue may well be clarified by election of the latter representation. The issue is then one of the role of environmental services in production functions, substitution possibilities between environmental services and other inputs, etc. An important subsidiary issue here concerns the probable environmental *nonneutrality* of technological change, both as it affects production processes of existing products and as it eventuates in new products and thus alters the composition of output. Involving a major technological, engineering component, this subject is clearly within the purview of both economics and the environmental sciences.
- *Behavioral determinants of the choice of technology (and thus the relative utilization of environmental services in production).* This issue is obviously related to but is also distinct from the foregoing. The production function provides a menu of possibilities involving differential utilization of different factors of production. The issue here is the selection of one production technology over others, focusing on the implications of alternative mechanisms by which to allocate and ration environmental services (prices versus regulation), substitutions between direct consumption *versus* factor input utilization of environmental services, etc.
- *Environmental consequences of specific environmental service flows.* The significant but often ignored issue here concerns the nonabsolute nature of the environmental implications of productive activity, i.e., the dependence of environmental consequences on the specific characteristics of the environment (e.g., its absorbtive or regenerative capacities, capacities which are probably not invariant either spatially or over time). This issue is significant in the international context because it indicates that, even holding the global

level and composition of output constant, redistributions of productive activity in space may well not constitute environmentally zero-sum games.

- *Spatial transmission of the environmental consequences of productive activity (international externalities).* Explicit recognition of the openness of national environments is necessary not only with reference to the issue of internalizing international environmental externalities (alternative *supra*national mechanisms of pricing or otherwise rationing foreign environmental inputs into any country's domestic production activities) but also for purposes of evaluating any individual country's own environmental policies, in that the environmental effects of a national policy (e.g., increased prices of environmental services) may be more or less offset by transnational externalities. Thus, a shift of certain production activities out of a country may not eliminate the environmental consequences of those production activities if there are significant externalities of foreign production (for export to the policy-initiating country).

Significant initiatives have, of course, been undertaken in these and related areas. With reference only to current IIASA activities, the acid rain project is explicitly concerned with transnational environmental externalities, as is the regional water policy project and the much more ambitious "biosphere" proposal currently under discussion. In each of these, however, it would appear that the economic dimension, although perhaps recognized, is considered secondary (implicitly if not explicitly); economic activities may be perceived as a source of the problem, but economic analysis is not considered essential either to the understanding of the problem or to its solution (whatever the problem is thought to be).

Operationally, the important question concerns the way in which the economic aspects of these issues are to be illuminated and the way in which economic intelligence is to be brought to bear. It is certainly appropriate that studies such as the foregoing be framed to explicitly include consideration of economic aspects and issues and, hence, that the scientific groups undertaking these studies include economists. However, the general approach of undertaking large, avowedly comprehensive studies may well be inefficient and, even, counterproductive. When true comprehensiveness may be impossible to achieve, the pretention of comprehensiveness may well lead to a pseudoscientism the biases and excesses of which may well negate the value of the entire activity. This is particularly likely because economists associated with such efforts may become "captives" of an effort dominated by others and are may also not be of especially high caliber.

These considerations suggest that the most productive approach under current circumstances may involve a loose, informal interaction between environmental and economic studies, in which the environmental aspects of economic activities are explored as a byproduct of other economic analyses, and *vise versa*. Under this approach major reliance would be placed on cross-fertilization rather than permanent cohabitation. I would suggest that current circumstances are especially favorable for such an approach:

- The analytical excesses and effective pseudoscientism of large, ostensibly comprehensive studies of significant constellations of issues are increasingly being publically recognized, as reflected in the decline in credibility accorded to studies such as *Limits to Growth*, the *Global 2000 Report* and *Energy in a Finite World*.[5]
- Current budgetary realities (especially at IIASA but also in most countries as well) are such that highly ambitious, comprehensive (probably ultimately pseudoscientific) undertakings will be precluded, even if they were still thought to be of value.
- Also because of these budgetary circumstances, specific research efforts in economics and in other fields are being subjected to ever more jaundiced examination, motivating *rentier* "scientists" to search for at least apparent justifications for their continued existence and financial sustenance.
- A number of specific studies in economics and environmental sciences, originally undertaken for possibly quite unrelated purposes, are now at a stage at which they might contribute to and benefit from extension and cross-fertilization.

The last three of these considerations are especially relevant with reference to current IIASA efforts in the economics and environmental areas. Analytical excesses are being increasingly perceived in both areas (as reflected in the progressively more skeptical attitude toward ostensible forecasting capabilities), while at least limited capabilities amenable to application to subjects deemed to be of social significance, but not requiring major financial infusions, have been developed. Here attention will be focused on a possible application of the capabilities developed by the IIASA/INFORUM-centered group of national input-output modelling efforts.

3. Multinational Analyses of Secular Change in the Pollution Intensity of International Trade Flows

It seems readily apparent that any meaningful analysis of the environmental implications of international trade must be undertaken at a reasonably high degree of sectoral disaggregation. A "single-commodity" characterization of the global economy would effectively assume away the substance of the issue, i.e., differential pollution-intensities in production and thus the capacity to separate the spatial distribution of pollution generation from the spatial distribution of product utilization. Thus, sectorally-disaggregated input-output models are obvious candidates as the analytical basis for initiating analyses of the environmental implications of international trade. The IIASA/INFORUM models are

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[5] A substantial part of the blame for the earlier popular regard for these studies must, of course, be placed on members of the scientific community, who perceived benefits in the popular perception that scientific analysis could reach dramatic conclusions of immediate, practical import. Similarly, much of the credit for the declining popular appreciation of these efforts must be accorded to those members of the scientific community (most notably, Julian Simon and Herman Kahn) who refused to be "coopted" by the short-term benefits associated with these analytical excesses.

especially well placed for this role because of the degree of cross-model consistency which they have achieved, specifically the capacity to bridge into a common commodity classification. The following describes a very simple preliminary analysis which could be undertaken on the basis of these models. The objective of this initial modest effort would be simply to document the degree to which changes in patterns of international trade have served to redistribute pollution-intensive production across national economies over the recent past.

In this preliminary phase the focus of the study would be entirely descriptive. That is, it would attempt to identify significant changes over time in patterns of net importation/exportation of pollution-intensive products, but it would not attempt to establish the degree to which pollution-intensity has acted as a *cause* of changes in patterns of trade. Furthermore, because of the qualifications necessarily associated with the data which would be employed, the study would not provide firm evidence concerning, e.g., identities of net importers/exporters of pollution-intensive products; rather, it would attempt to identify significant changes over time in relative importation/exportation of these commodities. In other words, it is concerned with differential trends in the global pattern of pollution-intensive production, as revealed by trends in net importation/exportation of pollution-intensive products.

The analysis of changes over time in directions of international trade in pollution-intensive products will be very simply formulated. For each country (or regional group of countries) vectors of product imports and exports (dimension n *by* 1) are observed over time (t). These are designated y_{mt} and y_{et}, respectively. Exports can be represented as produced subject to a linear Leontief production technology. Thus,

$$x_{et} = (I-A)^{-1}y_{et}$$

where x_{et} represents the vector of outputs required to produce the observed vector of exports, and A is a matrix (dimension n *by* n) of direct requirements from each sector (row) per unit of output of each sector (column).

Sectoral production can be represented as having quantifiable environmental impacts in some finite number of dimensions (q). These can be represented by the effluent matrix F (dimension q *by* n), in which columns represent sectors and rows represent environmental impacts per unit of sectoral output. Thus, the quantitative environmental impacts, u_{et} (dimension q *by* 1), of the production of the vector of exports are be given by

$$u_{et} = Fx_{et} = F(I-A)^{-1}y_{et}.$$

Ignoring transborder flows of pollutants, imports effectively constitute a means by which to avoid the environmental impacts of production. Thus, from the vantage point of the individual economy, the vector of imports is associated with "environmental-impact savings" of

$$u_{mt} = Fx_{mt} = F(I-A)^{-1}y_{mt}.$$

The net environmental effect of international trade, for the individual economy, is, then, $u_{bi} = u_{mi} - u_{ei}$. If this quantity (i.e., any element 1,...,q of the vector u_{bi}) is positive, then the environmental impacts avoided through imports exceed the environmental impacts associated with exports, and *vice versa*. More important, for purposes of this study, would be the direction and rate of change over time of this net "environmental balance of trade" for any economy relative to others. Policies which increase the "prices" of "environmental services" in one economy relative to those in others should be reflected in an improvement in its environmental balance of trade as pollution-intensive production is shifted to other economies in which the prices of environmental services are relatively lower.

In the absence of environmental impact matrices for individual countries over time, and on the assumption that lower impacts per unit of output of any commodity (across countries at a point in time, or over time for an individual country) are purchased at a price (higher capital and/or labor inputs per unit of output), a single environmental impact matrix (F) can be employed for indicative purposes. On the basis of U.S. data for 1967,[6] fourteen categories of environmental impacts, measured in physical units (pounds, gallons), can be identified. These are indicated in Table 1. For most purposes these can be grouped into four major categories: (1) air pollutants (pounds), (2) solid waste (pounds), (3) waste water (gallons), and (4) water pollutants (pounds). Thus, a reasonably comprehensive set of indicative indicators of secular change in the "first-round" envionmental implications of international trade could be obtained. In association with other groups, e.g., the IIASA project on transborder flows of pollutants, subsequent "rounds" of this process could then be explored.

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[6]International Research and Technology Corporation (IRTC). *Effects of Technological Change on, and Environmental Implications of, an Input-Output Analysis for the United States, 1967-2020* (Washington, D.C.: IRTC, 1970).

Table 1.
Environmental Impacts (Effluents)

Code	Effluent	Symbol	Unit
	Air Pollutants		
1	Particulates	P	Billions of Pounds
2	Hydrocarbons	HC	
3	Sulfur Oxides	SOX	
4	Carbon Monoxide	CO	
5	Nitrogen Oxides	NOX	
6	Solid Waste	SW	Trillion Pounds
	Water Pollutants		
7	Waste Water	WW	Trillion Gallons
8	Chemical Oxygen Demand	COD	Billions of Pounds
9	Biological Oxygen Demand	BOD	
10	Refractory Organics	RO	
11	Suspended Solids	SS	
12	Dissolved Solids	DS	
13	Nitrogen	N	
14	Posphate Compounds	PH	