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Industrial Ecology (IE) is an emerging field that deals with conserving and recycling energy and other materials in the production process. IE faces two challenges. First, practical methods must be identified for reducing and recycling wastes in a wide range of situations. While some changes may be profitable in the short run and therefore adopted voluntarily, these may not be the most important ones from a system-wide or long-term perspective. Secondly, IE should provide a framework both for evaluating the long-term advantages and disadvantages of different patterns of industrial change, and for identifying the short-term bottlenecks that may be associated with these changes. These studies will assist in both public discussions and private calculations. This paper discusses how Structural Economics and an input-output model can assist in the development of the IE framework.

STRUCTURAL ECONOMICS

Structural Economics attempts to provide a detailed, disaggregated description of an entire economy in terms of its concrete and observable constituent parts and the interrelationships between them. The constituent parts include natural objects, technologies and social institutions. The analysis is carried out using both mathematical input-output models and qualitative analysis for those issues that are difficult to formalize. The qualitative aspects of the analysis help in the formulation of questions and the evaluation of results. Of particular interest to the structural economist are the dynamics of long-term structural changes under different assumptions, rather than analysis of static or equilibrium states. Unlike mainstream economic models that are used to arrive at unique solutions to optimization problems, structural economics models are used to arrive at a set of possible solutions. In addition, Structural Economics considers changes in input structure in terms of both process changes that may originate outside of the system, and substitutions of sets of inputs rather than of individual inputs. The input-output model is central to the formalism of structural economics models.

INPUT-OUTPUT MODELS[1]

The input-output model is based on the interdependence of the productive sectors of an economy, where every sector's output is an input to every other sector and to itself. The input-output framework relates output, prices, deliveries to final users, and factor costs per unit of output in matrix form through a set of equations. There is no attempt to discover an optimal strategy because issues may not be purely economic. Rather, the effects on all sectors of the

economy of a range of technically feasible scenarios can be examined, as well as the implications of different policies.

The simple static input-output model has been extended to consider dynamic issues. This dynamic input-output model can be used to describe and analyze changes in the economy over historical time. The simple model has also been extended to include an optimization framework used to identify the least-cost technological options faced by different sectors. This optimization framework can distinguish between those cases where the application of formal optimization is appropriate and those where it is misleading. A third extension is the development of a model of the world economy that incorporates international resource flows and can be used to investigate strategies for environmentally sound economic development.

IMPLICATIONS FOR INDUSTRIAL ECOLOGY

A program to reduce the input of raw materials and to recycle wastes often gives rise to questions about the *costs* and *benefits* of undertaking the program and the policies that will lead to the *optimal* level of recycling. While these questions are relevant and need to be raised, the first question that should be asked is, *how* can this source reduction and recycling be achieved? This question of *how* has been largely ignored by economists because of their conviction that, given the right incentives, firms will always seek to minimize costs, and thus will know *how* to do things. This may be true in situations where the changes in the economic environment have been small. However, when significant changes are called for, analysis of alternative techniques is necessary to explore the possible paths. Undertaking this task of analyzing the outcomes resulting from different techniques requires cooperation among economists, engineers and natural scientists. Once plausible and acceptable scenarios are identified, further analysis can reveal the extent of incentives, disincentives, and regulations that might be needed to encourage their adoption.

Notes

1. The paper includes an example showing input-output computations that has been omitted in this summary.