REGIONAL SOCIO – ECOLOGY – ECONOMIC MODELS

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Keywords: regional sustainable development, pressure-state-response modeling, generalized dynamic input-output models, social development index, Newly Independent States, technological state, welfare indicators, sustainability indicators, policy analysis and determination, simulation, optimization, Pereslavl region

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Summary

A general framework for analyzing regional sustainable development from a policy-oriented perspective is presented: The use of a general state-pressure-response model for describing the economic-environmental system, together with an inter-temporal welfare function for assessing the desirability and sustainability of alternative policies. The specific formal structure suggested is presented, together with a discussion of the way an empirically estimated model is to be used in practice. A practical application is given: A case study of the region of Pereslavl in Russia. Conclusions about the scope for sustainable development in the region are drawn, and fundations for policy-analysis established.

1. Introduction

In the recent past, attention has often been devoted to global environmental issues in which policy-making is made either at the international level, through multi-country agreements on emission control, nuclear weapon use and testing ban, etc., or at the national level, when environmental policies are designed to control domestic pollution. Nevertheless, many environmental problems have a local or regional dimension. Even when their consequences are global, relevant decisions, such as the adoption of energy saving utilities, are taken at the regional level. The design of appropriate policies for sustainability has necessarily to take into account the mutual interaction over time of economical, social, and ecological factors, as well as local conditions to explore the short and long term consequences of these interactions, and to offer a practical platform for policy analysis and determination. To reflect properly on the complexity of the dynamic interactions considered, empirical models should be constructed. The underlying modeling philosophy is the use of a state-pressure-response framework for describing the economic-environmental system, together with an inter-temporal welfare function for assessing the desirability and sustainability of alternative policies. Its effective use along the lines suggested necessitates recourse to numerical approaches. The development and utilization of appropriate and efficient user interfaces, for generating scenarios as well as for organizing the results, are of basic importance.

2. Sustainable development and regional sustainable development

The concept of sustainable development has recently taken a pivotal position both in the public awareness and in the policy-making discussion. It’s most popular interpretation is doubtlessly the one suggested in the famed Bruntland report, that is, "a pattern of development that meets the needs of present generations without jeopardizing the ability of future generations to meet their own needs". The Bruntland definition, however, is much too vague to provide an operational basis for policy analysis and recommendation (see *Future Outlook for Environment and Sustainable Development*).

While there remains a substantial debate about what sustainable development practically entails, a wide consensus has emerged that sustainability considerations should transcend purely economic aspects. Ideally, they ought to comprehensively take into consideration the diverse economic, environmental, and social underpinnings of human activity. Furthermore, and contrary to what a narrow lecture of the Bruntland definition may suggest, it is nowadays widely acknowledged that sustainable development does not have only an intergenerational dimension. It also has a clear spatial scope. On the one hand, it would be difficult to justify placing attention on inter- without paying regard to intra-generational and thus, inter-regional equity. This implies that regional pollution and hazards from the chemical or nuclear industry, the local provision with health and educational services, the extinction of area-specific species, and similar small-scale phenomena, are to be taken into consideration. On the other, large-scale phenomena that are considered crucial for sustainability, such as global warming, destruction of the ozone layer, or deforestation, most often result from the many decisions taken at a much lower, regional level. Thus, serious attention must be given to the analysis of local processes, and appropriate information and guidelines for "good" regional governance must be developed. This is all the more true, as from a management and policy point of view a local scale is generally deemed more suitable for policy control and transformation than a global one.

Broadly speaking, any analysis of sustainable development should include the definition of a set of criteria for sustainability, and suggest operational guidelines about the policy measures to be taken for meeting these criteria (see *Dimensions of Sustainable Development*). This is true at the global as at the regional level. A local sustainability consideration differs from a global one on three main respects.

- The decision-making process, and in particular the decisions about the provision of public goods, are under regional authority. The importance of this aspect leads us to typically define the concept of a region in administrative rather than in, say, geographic terms. In that sense, a "region" can loosely be defined as any organized social unit with some coherent rules of governance.
- The possibility of averaging or compensating favorable against unfavorable elements is limited due to the relatively small size and high homogeneity of a region.
- Neighboring regions are not independent of one another. There are spillovers across the socioeconomic boundaries such as pollution of air or watershed, human migration, and economic spillovers, that typically do not appear explicitly in a global analysis.

These three points would by themselves suffice to justify the existing interest in local analyses, and the development of specific approaches and methodologies thereof. An important additional justification is that a local analysis and policy planning may lead to much more manageable, realistic, and efficient recommendations than a larger scale one. All these elements should be considered explicitly in a bottom-up approach, where sustainable development at a large scale is addressed as resulting expressly from the many policy decisions and interactions at the regional level.

Typically, developing a regional sustainable development strategy requires an integrated approach to (a) insure a satisfactory level of welfare for all living persons; (b) bequeath a social and environmental state of affairs providing a sound basis for a likewise satisfactory level of welfare for all members of all future generations; and (c) insure that sustainability at the local level does not conflict with sustainability at upper levels. In that context, welfare is assumed to depend upon two interdependent elements: (i) the consumption of human-made goods and services (including education and employment possibilities, access to health services, public safety, etc.); and (ii) the consumption of environmental amenities. Ideally, one would aim at a policy that increases or at least keeps welfare constant at all points of space and time, i.e., for all inhabitants of the region, present and future. To do so, one must minimize the different conflicts between the needs of different present and future inhabitants. Importantly, one must exploit to the largest possible extent potential "virtuous cycles", in which measures that improve the welfare of one group at a moment of time set the basis for improving the position of another group, possibly at another time. Such positive synergies are common in the context of sustainable development – a better educated population, e.g., may be able to use existing resources more efficiently and in a less destructive way, thus paving the way for a higher future welfare.

Recommendations for regional development strategy may take very diverse forms, from analytical-theoretical to descriptive-empirical or to prescriptive guidelines. Likewise, the measures and instruments that can be used to achieve regional sustainable development are most diverse. Strongly advocated in much of the Western literature is the establishment of well-defined property rights and of a functioning market economy – which implies an efficient and honest administration as a prerequisite. Other main instruments are the design and the implementation of appropriate technologies, an adequate provision of the population with public goods such as health and educational services or public transportation, and quantitative/qualitative steering through quotas, prohibitions, and regulations, and redistribution measures, mechanisms and administrative structures.

3. A framework for analysis

The "pressure-state-response" framework advocated by the Organization for Economic Cooperation and Development (OECD) is arguably the most practicable setting for analyzing regional sustainability from an applied perspective. Within this framework, the current "state of the world" is described, as comprehensively as possible, by the values taken by a set of variables, the *state vector*. The elements of the state vector, that is, the *state variables*, may be understood as generalized stock variables: They describe the quantity and quality of human-made goods, information, human capital, and institutions, as well as the quantity and quality of natural resources, pollution, and so forth, existing at any given point of time. Somewhat simplifying, the state variables can be classified into three categories: Those describing the condition of the *economic sphere*, those describing the condition of the *natural sphere*, and those describing the condition of the *social sphere*. For short, the latter two will be called the *environmental sphere*. The first category includes, among others, the quantities of built capital of all kinds; the state of technological knowledge; the level of human capital. The second typically comprise the size and quality of the different stocks of natural resources, renewable or non-renewable; the quality of the environment and in particular, its degree of pollution. The third one, finally, may represent the size and the health of the population; its level of education; the performance of human institutions in meeting human needs; etc., etc. The level of disaggregation, that is, the number of state variables, can and should possibly be as large as practically feasible and meaningful.

The state variables evolve over time according to their own dynamics in the absence of human action. The capital stocks, for example, decay over time if no investment is made. Forests and other renewable resources change over time in size and composition. The level of education of the population may deteriorate if no resources are devoted to schooling.

The dynamics can be also influenced by direct feedback from one sphere to the other. For example, a clean natural environment may favor a good state of health of the population. Moreover, and most importantly, the evolution of the state variables over time depends also on the *pressures* exerted by human activity. Some of those are potentially detrimental, like the release of pollutants.

Others are inherently state-improving, like investment in environmental restoration, health, and education. Others, finally, are ambiguous. The depletion of the stock of some natural resource may, for example, be desirable or undesirable depending on the pace of depletion, the stock's own dynamics, the use made of the resource.

Notice that, in this terminology, the main difference between own dynamics, feedback, and pressures, is that only the later directly results from human decisions and thus can potentially be used as policy instruments (see *Systems Dynamics Models*).

The diverse feedback phenomena and pressures induce *responses* of the different state variables, that combine, possibly in a non-linear way, with the variables own dynamics to define the evolution over time of the overall economy-nature-society system.

The state-pressure-response framework thus draws the attention to the way the state variables (stocks) describing human society and its environment change as a function of their own interrelated dynamics and of human decisions. A crucial point here is the fact that the framework takes into account the pressure-response relationships not pairwise, but simultaneously, in their full mutual interaction.

The different variables taken into account into such a framework are hardly directly commensurable. Indeed, it is commonly, but not unanimously, argued that there is no natural common scalar index into which one can express, say, the state of health of a population and the environmental pollution level.

In any event, a monetary evaluation will often be difficult or impossible. In order to overcome this difficulty, it may be necessary to construct appropriate composite indices or welfare functions.

Figure 1 captures the essential relationships in a regional state-pressure-response model. The regional system, represented within the dotted frame, is subjected to feedback and pressures from the outside world, such as imports of consumption and capital goods, inflows of pollution, human migration, and the like.

At the same time, it places pressures on other regions, through exports of the same type. These pressures from and to the outside of the region are represented in the Figure by continuous thin lines. The regional economic, natural, and social spheres are described by rectangular boxes. The dashed lines symbolize the corresponding feedback and own dynamics and the plain ones anthropogenic pressures.

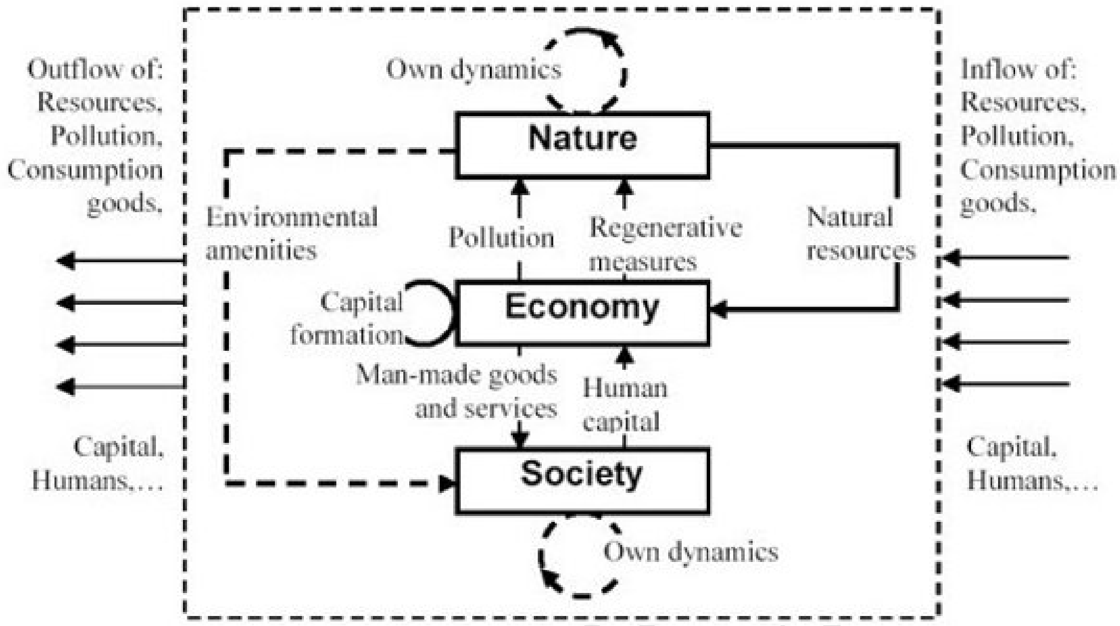

Figure 1. A regional state-response-pressure model

4. Formalization

Applying the general framework presented above to a concrete situation implies a proper formalization of the different state-pressure-response relationships. This formalization must be able to fully reflect the main peculiarities of the area of study, and to capture the underlying dynamic links and decision-making processes. Most importantly, in order to lead to precise policy recommendations, it must be amenable to quantitative estimation in the concrete application cases of interest. In that sense, it cannot be chosen independently from the obtainable data.

The dynamic Input-Output-based structure presented in the following is comprehensive and flexible enough to potentially describe any specific regional economy, and to capture the dynamic interactions among and between ν_1 productive activities, a ν_2-dimensional state of the natural and social environment, and ν_3 policy variables, where ν_1, ν_2, and ν_3 are context-dependant numbers that can differ from region to region (see *Input – Output Models*).

The modeling framework encompasses the following main elements:

- a generalized input-output core that describes the prevailing short-term relationships, i.e.: the current possibility production frontier and flows among and between sectors of human activity and the natural and social environment;
- dynamic relationships describing the evolution over time of the capital stocks and of the environmental and social spheres as a function of the past human activity (consumption, investment, etc., disaggregated in different types of goods and

services), of depreciation and obsolescence, and of the nature's own dynamics, assuming constant input-output coefficients;

- dynamic relationships describing the variation over time of the *technological state* of the economy, as a function of specific policy measures such as investment in new technologies.

The current technological state, denoted as x, is defined as the set of input-output coefficients and other important parameters of interest at the given moment of time. It is not assumed constant but may vary over time, either exogenously or as the result of planned actions.

The relationships describing the dynamics of x allow us to include in the analysis policy efforts aiming at modifying the existing technology in an environmentally beneficial sense, that is, at changing the prevailing input-output coefficients in the direction of lower emissions, lower material consumption, and the like.

These efforts will be termed *technology-improving measures.* They are to be understood in a very broad sense. Technology-improving measures are not only aimed at producing the same goods and services in a more environmentally friendly way; but may also consist in a fundamental re-orientation of the productive activities, such as a switch from heavy industry towards information technologies, from manufacturing towards tourism, and the like.

4.1. The Input-Output Core

Within the Input-Output core of the model, a distinction is made between two different types of productive sectors. The first one is the traditional production sector. This sector produces all investment and consumption goods except those pertaining directly to the improvement and/or preservation of the natural and social spheres. The gross output vector of the traditional sector is denoted as y .

The second one is the environmental production sector. This sector produces goods and services used directly for the improvement and/or preservation of the natural and social spheres, using as input part of the output of the traditional sector. The output vector of the environmental sector (which is also its net output) is denoted as z .

The traditional goods y can either be consumed or used as inputs in the production of any kind of other goods (consumption goods, traditional or environmental capital, etc.) The output of the environmental sector, on the other hand, does not enter directly into the production of traditional goods.

This output, that consists, for example, not only of abatement equipment, of nature-restoring actions, but also of medical equipment and of investment in education, serves only to improve the natural and social environment, i.e., the environment. However, over time, it contributes to a higher traditional production, through a more healthy environment.

At any time t the regional economy can thus be described by y and z together with the following vectors:

i^c the investment in traditional capital k^c;
i^n the investment in environmental capital k^n;
i^d the investment in innovative capital k^d;
c the real consumption of traditional goods;
d the vector of technology-improving measures;
ex^y, im^y the exports respectively imports of traditional consumption goods

In the more basic version of the model, the flows of exports and imports are treated as exogenous. The Leontieff-type relationship linking the current traditional output with its final use is defined as:

$$c = y - A^y y - A^n i^n - A^z z - A^c i^c - A_1^d d - A_2^d i^d + im^y - ex^y \qquad (1)$$

(see *Input – Output Models*).

In this equation, A^y, A^n, etc., are matrices of technological coefficients. In the matrix $A^y = \left(a_{ij}^y\right)$ for example, the coefficient $a_{ij}^y \geq 0$ indicates the quantity of the traditional good j necessary to produce one unit of good i and $A^y y$ is the part of the current output y that is used in the production of y. Thus, $y - A^y y$ is the net output. Similarly, $A^n i^n$ is the amount of output needed to produce the vector of environmental investment i^n. The expressions $A_1^d d$ and $A_2^d i^d$ capture the parts of output y used in technology-improving measures. The final consumption c is the difference between total outputs, plus imports minus exports, minus all productive uses of this output. All variables and coefficients may, and typically do, vary over time. For the sake of simplicity, however, this and other time-dependencies are not reflected in the notation.

Equation (1) describes the different flows between sectors and activities. However, it does not give any indication on the current production possibility set for traditional or environmental goods. The outputs of the traditional, of the environmental and of the innovative sectors *(y*, *z* and *d)* are assumed to be constrained by the available traditional and environmental capital stocks, k^c, k^n and k^d, the quantity and quality of labor available, the technological state *x*, and the state of the natural and social spheres, *n*, according to some possibly time-varying production functions. Typically,

$$y \leq \gamma^c k^c, \quad z \leq \gamma^z k^z, \quad d \leq \gamma^d k^d, \quad L_{\min}^{\text{dem}} \leq l^y y + l^z z + l^d d \leq L_{\max}^{\text{dem}},$$

where l^y, l^z and l^d are labor input row-vectors, $L_{\min}^{\text{dem}}$ is the lower bound for the employment, and $L_{\max}^{\text{dem}}$ is the labor available.

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Biographical Sketches

Christophe Deissenberg is Professor of Economics at the University of Aix-Marseilles, France. He holds a Ph.D. from the University of Frankfurt am Main and the Habilitation and Venia Legendi from the University of Konstanz, Germany. He previously occupied visiting or permanent positions at Princeton

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