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THE SYSTEM OF ENVIRONMENTAL DAMAGES AND THEIR ECONOMIC EFFECT ASSESSED BY WAY OF MATRIX STRUCTURE

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Abstract

One of today's most vigorous tasks is to tackle the challenges presented by climate change. In order to develop a better understanding of environmental damages caused by human activities, a new approach is necessary. Neither the usual comprehensive analytic tools encompassing the aggregate national economy as a whole, nor the indicators expressing details in an isolated way are capable of providing an answer to such problems

The paper proposes a new method for environmental impact assessment by enumerating cross-sectoral damages using a model similar to the crossindustry input-output approach. The proposed methodology would allow decision makers to assess national economy level decisions by exploring cross-sectoral relationships with environmental impacts.

Key Words: *environmental impact assessment, damage matrix, input-output method*

JEL Classification: C67, Q01, Q51, Q56

1. INTRODUCTION

In this article the generalised concept of the environmental damage matrix is described based on recent development in the field of environmental impact assessment (Keuning, 1992, Dasgupta et al, 2004).

In recent years there has been much progress in the analysis of environmental damage costs, thanks to several major projects. Concerning environmental indicators the endeavours within the framework of OECD should be primarily mentioned. Since the early 90's the OECD has published a number of recommendations in the field of environmental indicators (EC,2009).

To implement sustainable development as described earlier by the Brundtalnd Committee Report (Brundtland, 1987), a comprehensive program entitled "Tasks for the 21st Century (Agenda # 21) was adopted in 1992 at the UN Conference 'Environment and Progress' (UNCED, 1992). This was followed by specialised UN organisations, different international bodies and countries elaborating their own programs, taking into consideration the Agenda #21 UN-Program and the characteristic features of their respective organisation or country. OECD has also dealt with this subject in depth, including specific recommendations. The European Union adopted its own 'Sustainable Development Strategy' for the Community.

The exact approach of environmental damage assessment requires a consequent analysis stemming from the realisation that a complex economic phenomenon acts in a comprehensive system of economic relationships.

Neither the usual comprehensive analytic tools encompassing the aggregate national economy as a whole, nor the indicators expressing details in an isolated way are capable of providing an answer to such problems. To raise accurate questions directed at the core of the problem and to elaborate answers with adequate thoroughness the application of a methodology is necessary which takes the relationship among the factors involved into consideration.

This requirement can be met by a modelling technique based on the input-output approach. Consistently with this approach the environmental conditions are to be registered, and changes in these conditions are to be evaluated economically by treating the relations between the recipients of damages and their causes in their mutual interdependence in a succinct but clearly defined way using the approach of input/output balance (emission/reception).

If the statistical methods of environmental economics between the sectors causing and receiving damage are employed with the implied definite and specific indicators, the assessment of environmental damages using the matrix approach allows macro-level analyses to be performed for preparing environmental protection decisions at the national economy level by exploring cross-sectoral relationships (Fekete-Farkas, 2007).

2. MODELING CROSS-SECTORAL ENVIRONMENTAL IMPACTS

2.1 The logical structure of the cross-sectoral damage matrix

At the level of national economy the harmful impacts can be assessed and evaluated by the respective emitting and recipient sectors. Considering the fact that a cross-sectoral negative impact may also be regarded by the recipient sector as paying some sort of inevitable input cost (i.e. the damage recipient is obliged to its own expense to finance the productive activity of the emitting sector), in principle there is a possibility to adapt the method of cross-sectoral or input-output matrix in this area (Molnar, 1994).

In adapting the generally used input-output matrix models to the assessment of environmental damages, certain restrictions and accurate specifications should be introduced.

Keuning (1992) presents the national accounts in a matrix format to get a coherent, generally applicable system, where specific tables for each relevant substance can easily be related to aggregated ecological and economic flows. As a result, the whole system can be mirrored on a few sheets of paper. Additionally, the matrix format reveals which entities and which accounts are involved at both ends of each set of monetary and physical flows. This is particularly advantageous for the I-O modeling practice.

It is not the classical sectors of the national economy that are to be entered into the rows and columns of the damage matrix, but the areas where the roles of the parties 'causing' and 'suffering' the damage can be separated in a clear-cut way (i.e. where the damage caused can be monitored and so the necessary statistical data can also be collected).

One of the matrix schemes capable of representing or mapping and recording or analysing the changes in state in multiple forms is illustrated in Figure 1. In the column and row vectors respectively those emitting and receiving factors are shown at the macro-level where relationships are assumed or searched for. This matrix is called the simplified *damage matrix.*

Among the receptors, the Table also shows the *damage originators*, since they may also be afflicted by the harmful impacts. It is therefore necessary to set up a complete damage matrix, supplemented with a block representing the sectors of the economy.

In this approach the simplest damage matrix enumerating the entire damage balance is basically composed of two sub-matrices. The lower sub-matrix represents the direct damage data for the respective areas, whereas the upper sub-matrix contains the cross-links for the originators of the damage.

2.2. Contents of the damage matrix

The balance of environmental damages can be acquired using the damage data of the respective emitters and the methodology of the interindustry exchanges model.

For this the amount of damage per unit of production has to be calculated applying the appropriate statistical methods for the respective emitters and recipients (Debrecin, 2008)

This information basis establishes a relationship between the final damage recipients and the cross-sectoral impacts. (*The aim of the model is therefore to explore and reveal the relationship between direct and indirect environmental damage*.) The pattern is capable of expressing the environmental costs between the various economic sectors, connecting the emitters and recipients.

There are a number of approaches to define specific environmental impact factors for the emitter and recipient parties, leading to somewhat different modeling results.

For instance:

- Land surface usage per unit mined (mining sector – farming);
- Air pollution per unit of power produced (power sector– environment protection);
- Landscape deterioration per unit of timber produced (forestry – environment protection);
- Loss of cropland per unit of performance increment in transport and haulage (traffic – cropland).

For example, Goralczyk and Stauvemann (2007) show in their paper that the production of electricity in the Noord-Brabant region of Netherlands contributes only 0.42 % to employment, but it contributes 46.31 % to the total emission of CO2 and 39.32 % to the GHG theme.

Similar observations can be made for each industry to get its profile. With the help of such profiles it becomes clear that the aggregate environmental damage of a country or region does not only depends on the country's (region's) size and development stage, but also on the structure of economic activities. For example, a region with a relative less developed service sector and high shares of the manufacturing and agriculture sector will pollute the environment relatively more than a region where the share of the services sector is relatively high. Of course this is the case in Noord-Brabant, because the manufacturing sector is over proportionally big in relation to the whole Netherlands.

In the followings we generalise the concept of the damage balance outlined above.

3. GENERALISATION OF THE CONCEPT OF ENVIRONMENTAL DAMAGE BALANCE

3.1. The cross-sectoral damage matrix

The elements of the upper, $n * n$ size sub-matrix of the damage balance represent impact links related directly to production. Its characteristic element:

x_{ij}: Environmental impacts of the j^{th} sector by its production or service provisions on the i^{th} sector.

Further notations:
$\mathbf{x_j}$: Gross damage caused by the j^{th} sector.

x: Row vector of gross damage caused

3.2. Matrix of final direct environmental damage

y_{li}: damage caused by products or service provisions of the i^{th} sector to the l^{th} recipient
Further notations:
$\mathbf{y_l}$**:** The total and direct damage received by the l^{th} ultimate recipient

y: Row vector of direct, gross damage received

3.3. The damage matrix

The ratio

$a_{ij} = x_{ij}/\mathbf{x_j}$ (I, j = 1,…., n)

shows the contribution of sector '*i*' to a unit of gross damage caused by sector '*j*'.

The matrix containing the a_{ij}-s is the matrix of indirect damage factors ('*damage matrix'*). We denominate this matrix with $\mathbf{A=[}a_{ij}\mathbf{]}$.

3.4. The damage equation and the inverse of the damage matrix

Making use of these definitions, and in analogy to the input-output matrix, we take our starting point from the following fundamental relationship: the gross damage caused by a given sector is equal to the sum of damages caused by this sector to the other productive sectors and to the final damage recipient.

$$\mathbf{x*A+y=x}$$

From this:

$$\mathbf{x=y*(E-A)^{-1}}$$

The inverse of the damage matrix shows the original contribution of sector '*j*' to the gross damage caused by sector '*j*'.

(Note: Besides the above static model, one may also use a dynamical model , which focuses on added value in production.)

If we assume the invertibility of the damage matrix **A**, which is a relatively straightforward assumption based on the irreducibility of fundamental economic activities this implies the existence and invertibility of its Leontief-inverse. From this we get the very interesting conclusion that no economic activity is without direct environmental impact. This is because the lack of any environmental harmful impact would imply that there is at least one row in the inverse matrix with only zero elements, and this would contradict the first assumption on invertibility of matrix *A*.

4. POSSIBILITIES OF USING THE DAMAGE MATRIX AND FURTHER AREAS FOR RESEARCH

In exploring possible applications for the damage matrix we should focus our efforts on the following two main tasks to delegate further research.

4. 1. Using the model for purposes of decision support (refinement of the model);

By detailing and refining the damage matrix and damage equation as interpreted above, the mutual accounting of damages caused by the various (productive and non-productive) sectors becomes possible:

- by accounting for direct damage effects as cost factors;

- and by taking into account the indirect damage effects on the value-producing components (e.g. upon property assets) and other inputs.

4. 2. Interpretation of the damage coefficients and their determination.

Interpreting and establishing the damage coefficients may raise a number of further issues in contents and methodology for investigation:

- What are the indirect economic and production impacts of environmental pollution? In other words: how large can be the damage caused by i^{th} sector in the j^{th} sector in terms of output value (such as asset value reduction, loss of capital, etc)? How can these relationships be formalised?

- What statistical methods should be applied in determining the damage coefficients? Estimating the damage caused would in any way lead to serious difficulties, while the determination of aggregated, specific damage coefficients requires a statistical methodology that would result in at a fairly good estimation. (Fekete-Farkas, 2006) may be assumed that in some simpler instances the value of damage received can be enumerated in a concrete manner by a relatively exact technique (such as mineral resources, forest, water bodies), whereas in certain special cases value-estimating procedures based on specific, representative observations, procedures are to be employed (e.g. built-in surroundings). In other cases only the conceptual value is available for assessment (e.g. air, landscape, recreational potential);

- Is there a significant departure in methodology or in contents in damage-assessment methods for productive enterprises and the final damage recipients? (In other words: should we interpret elements in the different blocks of the damage matrix in a similar manner or not?)

Given these kinds of tables for specific periods, as is explained in De Haan & Keuning (1995), it is possible to decompose the changes in emissions by industry into several effects:

1. Demand composition shift effects
2. Output growth effects
3. Eco-efficiency change effects

5. CONCLUSIONS

The presented approach allows for a dedicated assessment of specific (environmental and other) impact and for modeling the mutual economic interdependencies of different enterprises or sectors.

This allows us

- to undertake an emission abatement impact assessment for specific emitters and sources under a given scheme of priorities
- to work out regulations based on the assessment of environmental damages which take into account abatement costs
- to consider environmental impacts affecting natural resources when preparing major investment programs/projects and to get a realistic picture of the net expected profit and income;
- to optimise the macro-level regional income with regard to the specific regional characteristics, such as the peculiar ecological/social features of the respective region;
- to develop the optimal production structure for transformation of the local production pattern or structure by prioritising damage effects and sectors,.

Figure 1: Balance scheme of crossindustry environmental damage (damage matrix)

Damage recipients	Pollution emitters (productive branches)					Total damage from productive activities
			I.			
Productive sectors			x_{ij}			**x**
			II.			
Final damage recipients			y_{li}			**y**

Source: own compilation

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