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An Approach to Economics-Environmental Relations from Expanding the Input-Output System

Trinh Bui*, Thai Nguyen Quang

Vietnam Development Research Institute, Hanoi, Vietnam
Email: *buitrinhcan@gmail.com, thai.nguyenquang@gmail.com

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Abstract

In the last few decades, the relationship between economy and environment has become the concern of many scholars, there have been many studies linking economic development and environmental pollution. Even the United Nations has introduced an economic-environmental linkage framework such as System of Environmental-Economics Accounts (SEEA) that is compatible with the System of National Accounts (SNA). This study attempts to provide a theoretical framework based on Miyazawa's ideas on interregional model and demographic-economic model in order to improve the integration between economy and waste.

Keywords

Economic, Environmental, Input-Output, Matrix, Multipliers

1. Introduction

For decades, scholars have attempted to propose models of the linkage between the economy and the environment through Leontief (1970)'s input-output model. It was he who first came up with the idea of combining economics and environment in a scientific activity (seminal paper). Leontief and a number of later scholars such as McNicoll & Blackmore (1993) and McGregor et al. (2001) used a direct production waste coefficient matrix to do empirical studies applying such an approach to modeling air pollution in Scotland. This type of work quantifies the impact of economy to the environment, in terms of emissions. However, these studies do not track further environmental responses to the economy, regarding the activity generated in environmental cleanup. The input-output model can be extended to study this problem with pollution reduction activities.

This research tries an attempt, a more detailed introduction to the literature related to the linkage between the economy and the environment through Leontief's input-output model.

There are some applications of Leontief's environmental input-output model to study the impact of economic activities on the environment through air pollutions in Vietnam such as studies of Trinh & Phong (2013), Trinh & Hoa (2017), Hung & Trinh (2019).

Studies around Leontief's input-output model include Flick (1974); Steenge (1978); Lowe (1979); Qayum (1991); Arrous (1994) and Luptacik & Böhm (1999). Allan, Hanley, McGregor, Swales, & Turner (2004). These studies extend and applying the Leontief system pollution model in both sides: Emission economy and waste treatment.

The using of input-output system to combine economic and environment is also given in "System of Environmental-Economic Accounting (SEEA)" by United Nation. This issue is also mentioned in "Handbook of input-output table compilation and analysis" by United Nation.

However, these extensions do not yet have the perfect combination of environmental and economics by "inter-environmental-economics" type. This study tries an attempt to extend Leontief's input-output model according to type of Miyazawa's (1976) inter-regional and demographic-economic models in order to linkage between environmental and economics in a more uniform way

2. Approach

Miyazawa's concept of the income multipliers was designed to analyze the structure of income distribution by opening columns by consumption type and corresponding income streams in the standard Leontief model. These ideas are also incorporated in the familiar social matrix accounting systems developed by Stone (1961), Pyatt and Roe (1977), and in the parallel development of the demographic-economic model. Relating to Batey and Madden (1981). In a sense, Miyazawa's system is perhaps the most complex in terms of how it extends the familiar input-output formula. In this study substitute the variables of consumptions and incomes are the amount of cost that the sectors in economy have to buy products (at rows) of waste reduction activity (at columns)

Leontief's input-output system is expanded with A_{11} is an endogenous direct input coefficient matrix; A_{21} is the coefficient matrix for the industries to pay for environmental cleaning, A_{12} is the cost coefficient matrix. waste treatment activities use products as input costs, A_{22} is the cost coefficient matrix when waste treatment activities also pay for environmental cleaning (because in the process of disposing of one type of waste it is possible to release another type of waste); X_1 and X_2 are production value vectors for the manufacturing and waste treatment industries. Calling E_1 the direct waste from production, E_2 being the waste generated in the waste treatment process, E_3 being the waste from final consumption and from other sources, Y_1 and Y_2 are the final demand vector of the products of economy and environmental protection costs, V_1 and V_2 are the value added of the manufacturing sectors and waste disposal operations sectors. So, the input-output expansion has structure below (Table 1):

Approach model **1:**

From the structure of the expanded input-output table above, we have:

$$A_{11}X_1 + A_{12}X_2 + Y_1 = X_1 \quad (1)$$

$$A_{21}X_1 + A_{22}X_2 + Y_2 = X_2 \quad (2)$$

Suppose to treat a unit of waste requires δ dollar, in the total waste E need to treat the amount of waste is αE ($\alpha < 1$), so production value of $X_2 = \delta \cdot \alpha \cdot E$ for abating required amount of waste disposal. Relation (1) and (2) we have:

$$\begin{aligned}(\sum Y_1 + \sum Y_2) = (\sum X_1 + \sum X_2) - \big[(\sum A_{11}X_1 + \sum A_{12}X_2) \\ + (\sum A_{21}X_1 + \sum A_{22}X_2)\big]\end{aligned} \quad (3)$$

Notice that:

$$(\sum X_1 + \sum X_2) - (\sum A_{11}X_1 + \sum A_{21}X_1) = \text{GDP}$$

So:

$$\sum Y_1 = \text{GDP} - (\sum A_{12}X_2 + \sum A_{22}X_2) - \sum Y_2 \quad (4)$$

where: $\sum Y_1$ can call "Green GDP" after subtracting the cost of cleaning the environment of both production and final consumption or can be considered as an "environmental tax".

Rewrite relations (1) and (2) as the matrix form we have:

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \cdot \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} \quad (5)$$

Put:

$$B = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}$$

$$X = \begin{bmatrix} X_1 \\ X_2 \end{bmatrix}$$

Table 1. The input-output table expands for the linking between economy and environment.

	Intermediate cónumption		Final demand	Gross output
Intermediate input	$A_{11}X_1$	$A_{12}X_2$	Y_1	X_1
	$A_{21}X_1$	$A_{22}X_2$	Y_2	X_2
Value added	V_1	V_2	Gross value added (GVA)	
Gross input	X_1	X_2		
Residuals	E_1	E_2	E_2	E

$$Y = \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix}$$

Relation (5) returns to the standard Leontief relation

$$X = (I - B)^{-1} \cdot Y \tag{6}$$

Put:

$$U = (I - B)^{-1}$$

The U matrix can include sub-matricies as follow:

$$U = \begin{bmatrix} U_{11} & U_{12} \\ U_{21} & U_{22} \end{bmatrix}$$

where: U_{11} and U_{22} are enlarge Leontief inverse matricies, So U_{11} and U_{22} include:

- Direct effects: A_{11}, A_{22}
- Indirect effects: $\left[(I - A_{11})^{-1} - A_{11}\right]$ and $\left[(I - A_{22})^{-1} - A_{22}\right]$
- Induced effects by waste treatment activities: $\left[U_{11} - (I - A_{11})^{-1}\right]$ and $\left[U_{22} - (I - A_{22})^{-1}\right]$

U_{21} is seen as a matrix of charges (taxes) to be paid per unit increase of the final products in order to reduce the required amount of waste. U_{12} represents the cost induced by the increase in waste resulting from a changing on the end product.

***Approach model* 2:**

Call: $E_1 = (e_{1ij})_{(k\times n)}$ With: $e_{1ij} = E_{1ij} \cdot X_{1j}$,

where: k is number of residuals and n is number of sectors in economy

And:

$$E_2 = (e_{2ij})_{(k\times m)} \quad \text{With} \quad e_{2ij} = X_{2j},$$

Where: m is number residual treamnet activities

On the other hand notice that:

$A_{12} \cdot X_2 = X_{12}$ presents intermediate input matrix of residual treatment activities

Put: $h_{ij} = X_{12ij} / E$

From the structure of the model we have:

$$A_{11} \cdot X_1 + h \cdot E + Y_1 = X_1 \tag{7}$$

$$e_1 \cdot X_2 + e_2 \cdot X_2 + E_3 = E \tag{8}$$

Write the system of Equations (7) and (8) as matrix form we have:

$$\begin{bmatrix} X_1 \\ E \end{bmatrix} = \begin{bmatrix} A_{11} & h \\ e_1 & e_2 \end{bmatrix} \cdot \begin{bmatrix} X_1 \\ E \end{bmatrix} + \begin{bmatrix} Y_1 \\ E^3 \end{bmatrix} \tag{9}$$

To implement the above relationship according to the Schur-Miyazawa formula (Miyazawa, 1976) and Sonis & Hewings (1993), we have:

$$\left[1-\begin{bmatrix} A_{11} & h \\ e_1 & e_2 \end{bmatrix}\right]^{-1} = \begin{bmatrix} \Delta_1 & \Delta_1 \cdot h \cdot (I-e_2)^{-1} \\ \Delta_2 \cdot e_1 \cdot (I-A_{11})^{-1} & \Delta_2 \end{bmatrix} \quad (10)$$

In relation (10) Δ_1 and Δ_2 include direct, indirect and diffuse effects. According to the Miyazawa definition Δ_1 and Δ_2 are the combination of an inner factor and an external factor.

Inrternal multipliers for economics: $(I-A_{11})^{-1}$.

Inrternal multipliers for environmentalchất thải: $(I-e_2)^{-1}$.

External multipliers: $\left[I-(I-A_{11})^{-1} \cdot h \cdot (I-e_2)^{-1} \cdot e_1\right]^{-1}$ are considered as the spillover by waste treatment activities to the output of other sectors of the economy.

$\left[I-(I-e_2)^{-1} \cdot e_1 \cdot (I-A_{11})^{-1} \cdot h\right]^{-1}$ are the waste spillover effects of the economy stimulated by the input to waste disposal activities.

$\Delta_2 \cdot e_1 \cdot (I-A_{11})^{-1}$ are residuals that induced by a unit increase of final demand

$\Delta_1 \cdot h \cdot (I-e_2)^{-1}$ are increased waste disposal to accommodate an increased unit of waste.

3. Discussion

Due to no data for making empirical study, so, the paper provides a theoretical framework that offers a new way for studying the relationship between the economy and the environment.

This study expands the basic relationship of the traditional input-output model with the notions of internal and external factors by Miyazawa to create the relationship between emissions generated by the economy and waste disposal activities. In this study, we attempt to determine the role of the waste multiplier in relation to the sensitivity analysis and the aggregate interactions between waste and waste disposal.

The theoretical framework developments provided here may set the stage for some important empirical analysis. Furthermore, the structure of an economy as revealed by many standard macroeconomic models is often conceal important differences in the nature of internal and external interdependence. For example, Waste reduction activities not only induce to the output of other sectors of the economy but also generate other wastes. The U_{21} matrix can also allow to determine the costs that industries have to pay for each industry and each type of waste. Moreover, in the approarch model 2 allows to know how amounts residuals increase when a unit final demand increases.

However, limit of this research to be there is no data for making empirical study, so, this research is hoping to get some attention to get the data needed for a later experimental work.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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