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A Study on Model Reference Adaptive Pollution Control (I)
—— in Enclosed Coastal Sea ——

Etuso YAMAMURA
Department of Regional Planning, Division of Environmental Planning, Graduate School of Environment Science, Hokkaido University, Sapporo 060, Japan

Abstract

As for the pollution control in enclosed coastal sea, it is necessary to clarify in more detail the structure between the economic activities on land and ecological activities in enclosed coastal sea.

This paper represents an attempt to examine in more detail the ecologic-economic activities with most of the emphasis of two fields such as the economic activities on land and ecological activities in enclosed coastal sea. Specifically, we are interested in the insights gained into the balance of inter-field repercussion by using Inverse Matrix Analysis which shows the total effects of inter-field propagation. Furthermore, for the achievement of model reference pollution reduction, we investigated a path which converges to the reference model and the adaptation processes of system and its stability by using Model Reference Adaptive Input-Output Method. This model is to clarify how the actual field activities would converge on the reference structure when the reference field structure is established.

Key words : Enclosed coastal sea, Inverse matrix analysis, Model reference adaptive theory.

1. Introduction.

Enclosed coastal seas which are mostly surrounded by land, and endowed with blessed natural environments, have been used for fishery and other human activities as well as for traffic and recreation, thereby having supported the life of people living along their coasts as well as fostering a wide variety of cultures. However, when people become overconfident of the seas in pursuing their activities, detrimental changes in the environment of enclosed coastal seas may deprive the benefits of people.

Recognizing that the environmental protection and an appropriate use of enclosed coastal seas are matters of urgent and global concern and given that their rich environments of enclosed coastal seas are in serious jeopardy in many parts of the world. The rich environment and great benefits of enclosed coastal seas must be passed on to future generations. All those concerned should seek to advance the use of these seas in a sustainable manner. Especially, land and sea resources and the environment are closely interrelated and land use, industrial resources and the environment are closely interrelated and land use, industrial activities, coastal reclamation and other activities effect the quality and availability of coastal land, coastal waters, the ecosystems, the natural landscape and the marine environment. It is needed a comprehensive, integrated approach to coastal zone management to ensure economic development as well as environmental protection of these areas.

A comprehensive approach would involve planning at regional and local levels, preventive policies and appropriate control of the inflow of heavy metals, hazardous chemicals, organic and other pollutants from catchment basin. In addition, conservation and preservation measures are needed to maintain the natural character of enclosed coastal areas.

2. General Interrelation Model

Our basic procedure for linking the economic activities on land and ecological activities in enclosed coastal sea is an extension of what is generally characterized as linear systems by applied input-output and model reference adaptive control methods.

The basic procedure in one of the many possible developments of the approaches that may be set down as follows:

(1) The investigator examines carefully all processes, whether the economic activities on land or ecological activities in enclosed coastal sea in order to identify those processes which, either as a whole or in large part, can be approximated in linear form.

(2) The use of linear systems analysis, with side computations for nonlinearitie makes a useful linkage of the economic activities on land and ecological activities in enclosed coastal sea possible, at least conceptually.

(3) All such processes are set down in a matrix in accordance with the Inverse Matrix Analysis and Model Reference Adaptive Input-Output Method.

(4) A description of processes in linear form, as of a given point in time, is useful in terms of the data. It makes available as well as the consistent classification system it imposes.

(5) A projection based on linear analysis, sound judgment, and perhaps a fewside computations for several key non-linear relations is, in many critical situations, as useful as a projection based on sound judgment alone.

This model has two systems which differ in their basic physical processes and structure such as the economic activities on land and ecological activities in enclosed coastal sea. Accordingly, the first major division of columns refers to the economic activities on land, and the second to ecological activities in enclosed coastal sea, while the first major division of row refers to commodities from land sources, and the second major division to commodities from enclosed coastal sea.

If we focus on just the two major divisions, land and enclosed coastal sea, there are four major sets of cells in the flow, or coefficient, table to be considered. Fox example, the coefficient table A is as follows :

$$A = \left[\begin{array}{c:c} A^{LL} & A^{LS} \\ \hdashline A^{SL} & A^{SS} \end{array}\right] \qquad (1)$$

where,

A^{LL} : the coefficients indicating the flows of commodities from land sources to meet the requirements of activities on land.

A^{LS} : the coefficients indicating the flows of commodities from land sources to meet the requirements of the activities in the enclosed coastal sea.

A^{SL} : the coefficients indicating the flows of commodities from the enclosed coastal sea sources to meet the requirements of activities on land.

A^{SS} : the coefficients indicating the flows of commodities from the enclosed coastal sea sources to meet the requirements of activities in the enclosed coastal sea.

The ecological activities in enclosed coastal sea are defined as the activities based on the materials for economic activities and the impact resources arising from the pollution of economic activities on land.

For the estimation of coefficients of ecological activities based on the materials for economic activities, we can use the interregional input-output tables. And also we can use the pollution input-output tables for the estimation of coefficients of ecological activities based on the impact resources.

3. Inverse Matrix Analysis

This chapter represents an attempt to examine in more detail the structure of interrelational repercussion between the economic activities on land and ecological activities in enclosed coastal sea. Specifically, we are interested in the insights gained into the balance of interrelatioal repercussion by using Inverse Matrix Analysis (Yamamura, 1973)

This matrix method is based on Inverse Matrix which shows the total effects of interrelational propagation.

Letting,

$$A=\begin{bmatrix} A^{LL} & \vdots & A^{LS} \\ \cdots & & \cdots \\ A^{SL} & \vdots & A^{SS} \end{bmatrix} \qquad (2)$$

We define the notations of partitioned matrices as follows :

$B^{L}=[I-A^{LL}]^{-1}$:total direct and indirect production coefficients on land.

$B^{S}=[I-A^{SS}]^{-1}$: total direct and indirect production coefficient in the enclosed coastal sea.

$$C^{SL}=A^{SL}\cdot B^{L} \qquad (3)$$

C^{SL} : total input coefficients from enclosed coastal sea sources to meet production of activities on land.

$$C^{LS}=A^{LS}\cdot B^{S} \qquad (4)$$

C^{LS} have a similar interpretation replacing the activities on land and the activities in the enclosed coastal sea as against each other.

$$D^{LS}=B^{L}\cdot A^{LS} \qquad (5)$$

D^{LS} : total production coefficient from land sources to meet the total requirements of activities in enclosed coastal sea.

$$D^{SL}=B^{S}\cdot A^{SL} \tag{6}$$

D^{SL} have a similar interpretation replacing the activities on land and the activities in the enclosed coastal sea.

$$G^{LS}=[I-D^{LS}\cdot D^{SL}]^{-1}\cdot B^{L} \tag{7}$$

$$G^{SL}=[I-D^{SL}\cdot D^{LS}]^{-1}\cdot B^{S} \tag{8}$$

G^{LS} : total effect coefficients on land.

G^{SL} : total effect coefficients in the enclosed coastal sea.

4. Model Reference Adaptive Pollution Control Model

For the achievement of model reference pollution reductions, we investigated a path which converges on the reference model and the adaptation processes of system and its stability by using Model Reference Adaptive Input-Output Method. (Yamamura, 1983–1989, Yamamura, 1985)

This model is to clarify how the actual field activities would converge on the reference structure when the reference field structure is established.

Model Reference Adaptive Input-Output method is composed of two models such as :

Reference Model

$$X_m(t+1)=B_m^{-1}(I-A_m+B_m)X_m(t)-B_m^{-1}H(t) \tag{9}$$

Adaptive model

$$X(t+1)=B^{-1}(t+1)(I-A(t)+B(t))X(t)-B^{-1}(t+1)H(t) \tag{10}$$

where,

X_m : n-dim, reference output vector to achieve the model reference pollution reduction

A_m : $n\times n$ reference input coefficient matrix to achieve the model reference pollution reduction

$H(t)$: n-dim, final demand vector to achieve the model reference pollution reduction

$X(t)$: n-dim, real output vector

$A(t)$: $n\times n$, real input coefficient matrix

$B(t)$: $n\times n$, real capital coefficient matrix

The reference model represents a reference growth model to achieve the model reference pollution reduction, and the adaptive model is a real model which converges asymptotically and stably to the reference output through technological changes whose initial condition is given.

(9) and (10) are transformed as reference model

$$X_m(t+1)=C_mX_m(t)+D_m(t+1)H(t) \tag{11}$$

Adaptive model

$$X(t+1)=C(t+1)X(t)+D(t+1)H(t) \tag{12}$$

where, $C_m=B_m^{-1}(I-A_m+B_m)$ (13)

$D_m=-B_m^{-1}$ (14)

$C(t+1)=B^{-1}(t+1)\ (I-A(t)+B(t))$ (15)

$D(t+1)=-B^{-1}(t+1)$ (16)

The adaptation that C(t) and D(t) are determined to make $\lim_{t\to\infty} \|X_m(t)-X(t)\|=0$ is equivalent the asymptotical stability of the error equation mentioned below.

$$\varepsilon(t+1)=C_m\varepsilon(t)+(C_m+C(t+1))X(t)+(D_m-D(t+1))H(t). \tag{17}$$

The adaptation laws are introduced from the next equations.

$$C(t+1)=C(t)+\varepsilon(t+1)X^T(t) \tag{18}$$

$$D(t+1)=D(t)+\varepsilon(t+1)H^T(t) \tag{19}$$

These equation may by written as

$$C(t+1)=C(0)+\sum_{i=0}^{t} E(i+1)X^T(i) \tag{20}$$

$$D(t+1)=D(0)+\sum_{i=0}^{t} E(i+1)H^T(i) \tag{21}$$

Namely, the adaptation laws of C(t) and D(t) are determined by the past trend of $\varepsilon(t)$.

However, (20) and (21) equations include E(t+1), therefore, let $\varepsilon(t+1)$ be transformed as follows ;

$$\varepsilon(t+1)=\frac{1}{K(t)}\hat{\varepsilon}(t+1) \tag{22}$$

where,

$$K(t)=1+\|X(t)\|^2+\|H(t)\|^2 \tag{23}$$

$$\hat{\varepsilon}(t+1)=X_m(t+1)-C(t)X(t)-D(t)H(t) \tag{24}$$

If K(t) is becoming sufficiently large as $t\to\infty$, then the below-stated adaptation laws of C(t), D(t) make the error equation asymptotically stable.

$$C(t+1)=C(t)+(I+\Gamma(t))^{-1}\,Kc\otimes\hat{\varepsilon}(t+1)H^T(t) \tag{25}$$

$$D(t+1)=D(t)+(I+\Gamma(t))^{-1}\,Kd\otimes\hat{\varepsilon}(t+1)H^T(t) \tag{26}$$

Where Kc and Kd are the matrices which have positive elements i,e, $Kc=(kc_{ij})$, $Kd=(kd_{ij})$, kc_{ij} and $kd_{ij}>0$,

$\otimes$ stands for a matrix operation as follow ;

$$\begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \otimes \begin{bmatrix} b_{11} & \cdots & b_{1n} \\ \vdots & & \vdots \\ b_{n1} & \cdots & b_{nn} \end{bmatrix} = \begin{bmatrix} a_{11}b_{11} & \cdots & a_{1n}b_{1n} \\ \vdots & & \vdots \\ a_{n1}b_{n1} & \cdots & a_{nn}b_{nn} \end{bmatrix} \tag{27}$$

And $\Gamma(t)$ represents the next $n\times n$ diagonal matrix.

$$\Gamma(t)\begin{bmatrix} \sum_{j=1}^{n}\{kc_{ij}X^2_j(t)kd_{ij}h^2_j(t)\} & \bigcirc \\ \bigcirc & \sum_{j=1}^{n}\{kc_{nj}X^2_j(t)+kd_{nj}h^2_j\} \end{bmatrix} \tag{28}$$

If the sequence $\{H(t)\}_{t=0}^{\infty}$ includes sufficient lineally independent vectors, then

$$\lim_{t\to\infty}\|A_m - A(t)\| = 0 \text{ and } \lim_{t\to\infty}\|B_m - B(t)\| = 0 \tag{29}$$

It is possible that Kc and Kd are variables. Now let variable Kc and Kd be noted as Kc(t) and Kd(t). These can be substituted into (25) and (26) as follows :

$$C(t+1) = \sum_{k=0}^{t}(I - \Gamma(k))^{-1}\ (Kc(k+1) \otimes \hat{\varepsilon}(k+1)H^T(k))$$

$$D(t+1) = \sum_{k=0}^{t}(I - \Gamma(k))^{-1}\ (Kc(k+1) \otimes \hat{\varepsilon}(k+1)H^T(k)) \tag{30}$$

5. Conclusion

We have investigated the Inverse Matrix Analysis and Model Reference Adaptive Pollution Control Model.

The Inverse Matrix Analysis is conceived to be useful analysis in specifying the total effects of inter-field propagation between the economic activities on land and ecological activities in enclosed coastal sea.

The Model Reference Adaptive Pollution Control Model is conceived to be a useful model in specifying the adaptive processes when the reference world is established.

For the estimation of the coefficients, we can use the interregional input-output tables and the pollution input-output tables published by the Ministry of International Trade and Industry of Japan.

In implementing researchs effectively, a comprehensive contribution from all fields of researches, including ecological, social and regional sciences is needed, in order to advance the use of enclosed coastal seas in a sustaninable manner.

References

(1) Yamamura, Etsuo (1973) : A Basic Study on the Balance of Interregional Trade, Proceedings of Japan Society of Civil Engineers, No.221, 109−116.

(2) Yamamura, Etsuo (1983−1989) : A Study on Model Reference Adaptive Control in Economic Development (I)−(8) : Environmental Science, Hokkaido University, Vol. 6, No. 2, 281−300, Vol. 7, No. 1, 1−13, Vol. 9, No. 1, 27−43, Vol. 9, No. 2, 151−161, Vol. 10, No. 1, 19−35, Vol. 10, No. 2, 145−165, Vol. 11, No. 1, 47−79, Vol. 11, No. 2, 141−184, Vol. 12, No. 2, 13−28.

(3) Yamamura, Etsuo (1985) : Optimal and Reference Adaptive Process for the Control of Regional Income Disparities : Papers of Regional Science Association, Vol. 56, 201−213.

(4) Yamamura, Ersuo (1989,a) : Model Reference Adaptive Theory on International Technology Transfer (I)−Transfer of coal mining Technology into Hokkaido−, Environmental Science, Hokkaido University, Vol. 12, No. 1, 17−25.

(5) Yamamura, Etsuo (1989,b) : Model Reference Adaptive Management Theory (I) Focus on Meiji Era of Japanese Management−, Environmental Science, Hokkaido University, Vol. 12, No. 2, 29−43.