A Study on Model Reference Adaptive Pollution Control in Enclosed Coastal Sea

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This paper represents an attempt to present a model of the ecologic-economic analysis on land and ecological activities in an enclosed coastal sea. Specifically, we are interested in the insights gained into the balance of inter-field repercussion by using Hermite 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 to the reference structure when the reference field structure is looked over.

For the pollution control in an enclosed coastal sea, it is necessary to investigate the structure between the economic activities on land and ecological activities in the enclosed coastal sea.

General Interrelation Model

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

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 the enclosed coastal sea. Accordingly, the first major division of columns refers to the economic activities on land, and the second to ecological activities in the enclosed coastal sea, while the first major division of rows refers to commodities from land sources, and the second major division to commodities from the 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.

Hermits Inverse Matrix Analysis

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

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

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Letting,

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

A can be written by using Hermite Matrix as follows:

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

$$= \left[\begin{array}{c:c} A^{LL}+A'^{LL} & A^{LS}+A'^{LS} \\ \hdashline A^{SL}+A'^{SL} & A^{SS}+A'^{SS} \end{array}\right] \qquad (2)$$

where

$$A^{LL} = (A^{LL}+A'^{LL})/2 \qquad A'^{LL} = (A^{LL}-A'^{LL})/2$$
$$A^{LS} = (A^{LS}+A'^{SL})/2 \qquad A'^{LS} = (A^{LS}-A'^{SL})/2 \qquad (3)$$

A^{SS} and A'^{SS} have a similar interpretation for the enclosed coastal sea. Also, A^{SL} and A'^{SL} indicate shipments in the opposite direction.

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.

$$C^{SL}=A^{SL}\cdot B^L=(A^{SL}+A'^{SL})\cdot B^L=A^{SL}\cdot B^L+A'^{SL}\cdot B^L \qquad (4)$$

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

$C^{SL}=A^{SL}\cdot B^L$:total average input coefficients from the enclosed coastal sea sources to meet production of activities on land.

$C'^{SL}=A'^{SL}\cdot B^L$:total input variation coefficients from the enclosed coastal sea sources to meet production of activities on land.

$$C^{LS}=A^{LS}\cdot B^S=(A^{LS}+A'^{LS})\cdot B^S=A^{LS}\cdot B^S+A'^{LS}\cdot B^S$$
$$C^{LS}=A^{LS}\cdot B^S,\ C'^{LS}=A'^{LS}\cdot B^S \qquad (5)$$

C^{LS}, C^{LS} and C'^{LS} have a similar interpretation replacing the activities on land and the activities in the enclosed coastal.

$$D^{LS}=B^L\cdot A^{LS}=B^L(A^{LS}+A'^{LS})=B^L\cdot A^{LS}+B^L\cdot A'^{LS} \qquad (6)$$

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

$D^{LS}=B^L\cdot A^{LS}$:total average production coefficients from land sources to meet requirements of activities in the enclosed coastal sea.

$D'^{LS}=B^L\cdot A'^{LS}$:total production variation coefficient from land sources to meet requirements of activities in the enclosed coastal sea.

$$D^{SL}=B^S\cdot A^{SL}=B^S\cdot(A^{SL}+A'^{SL})=B^S\cdot A^{SL}+B^S\cdot A'^{SL} \qquad (7)$$
$$D^{SL}=B^S\cdot A^{SL},\ D'^{SL}=B^S\cdot A'^{SL}$$

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

$$G^{LS}=[I-{}^{LS}\cdot{}^{SL}]^{-1}\cdot{}^{L} \qquad (8)$$

$$G^{SL}=[I-{}^{SL}\cdot{}^{SL}]^{-1}\cdot{}^{S} \qquad (9)$$

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

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

Model Reference Adaptive Pollution Control Model

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

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

$$X_m(t+1)=C_m X_m(t)+D_m(t+1)H(t) \qquad (10)$$

Adaptive model

$$X(t+1)=C(t+1)X(t)+D(t+1)H(t) \qquad (11)$$

where, $C_m=B_m^{-1}(I-A_m+B_m)$ (12)

$$D_m=-B_m^{-1} \qquad (13)$$

$$C(t+1)=B^{-1}(t+1)\,(I-A(t)+B(t)) \qquad (14)$$

$$D(t+1)=-B^{-1}(t+1) \qquad (15)$$

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

$$\varepsilon(t+1)=C_m\varepsilon(t)+(C_m-C(t+1)X(t))+(D_m-D(t+1))H(t). \qquad (16)$$

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

$$C(t+1)=C(t)+(I+\Gamma(t))^{-1}Kc\otimes\hat{\varepsilon}(t+1)H^T(t) \qquad (17)$$

$$D(t+1)=D(t)+(I+\Gamma(t))^{-1}Kd\otimes\hat{\varepsilon}(t+1)H^T(t) \qquad (18)$$

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;

$$\begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \otimes \begin{bmatrix} b_{11} & \cdots & b_{1n} \\ \vdots & & \vdots \\ b_{n1} & \cdots & b_{nn} \end{bmatrix} = \begin{bmatrix} a_{11}b_{11} & \cdots & a_{1n}b_{1n} \\ \vdots & & \vdots \\ a_{n1}b_{n1} & \cdots & a_{nn}b_{nn} \end{bmatrix} \qquad (19)$$

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

$$\Gamma(t)=\begin{bmatrix} \sum_{j=1}^{n}\{kc_{1j}x_j^2(t)+kd_{1j}h_j^2(t)\} & O \\ O & \sum_{j=1}^{n}\{kc_{nj}x_j^2(t)+kd_{nj}h_j^2(t)\} \end{bmatrix} \qquad (20)$$

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

$$\lim_{t\to\infty}\|A_m-A(t)\|=0 \text{ and } \lim_{t\to\infty}\|B_m-B(t)\|=0 \qquad (21)$$

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 (17) and (18) as follows:

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

$$D(t+1)=\sum_{k=0}^{t} (I+\Gamma (k))^{-1} (Kd(k+1)\otimes \hat{\varepsilon} (k+1)H^{T}(k)) . \quad (22)$$

where,

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

A_m:n x 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 x n, real input coefficient matrix

B(t):n x n, real capital coefficient matrix

A is as follows:

$$A=\left[\begin{array}{c|c} A^{LL} & A^{LS} \\ \hline A^{SL} & A^{SS} \end{array}\right] \quad (23)$$

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 enclosed coastal sea sources to meet the requirements of activities on land.

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

For the estimation of the coefficients, we can use the interregional input-output tables and the pollution input-output tables published by the Ministy of International Trade and Industry of Japan. With respect to the detail computation of Model, the reader may refer to the papers (Yamamura, 1973, Iwasa, Yamamura and Ohta 1985).

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