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DYNAMIC SIMULATION MODEL FOR DEVELOPING MARINE INDUSTRY IN CONNECTION WITH NATIONAL ECONOMY

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ABSTRACT

The computer simulation model proposed in this study enables a policy planner to assess a contribution of marine industry to the national economy. The simulation model consists of the national economic cycle submodel(econo-submodel) and the marine industry technology submodel(techno-submodel). The econo-submodel which utilizes the Input-Output analysis can evaluate the multiplying effects of preferential investments in the marine industry on the national economy. The techno-submodel may be characterized as a production planning model. This submodel is also furnished with several functions such as 1) forecasting the demand of marine transportation, 2) planning the development of shipbuilding facility including ship repairing service, 3) planning the development of port facility, and 4) deciding on feasible investment scheme under several constraints. Two submodels include several parameters of economics and technology as exogenous variables and are mutually linked by trades and investments.

KEYWORDS

Dynamic simulation model; Econo-submodel and Techno-submodel; I-O table; Policy planner; Investment; Shipping, shipbuilding, ship-repairing, port & harbour, and fishery.

1. INTRODUCTION

The pressure for correcting the balance of international payments tends to originate in connection with a long range scheme for developing the national economy in the developing countries. The object of this study is to prepare a tool with which a policy planner can seize a clear view on the strategy for establishing a self supporting national economy. In this study, the development of marine industry is considered as one of the potential measures for industrialization.

In light of the new international economic order having been advocated since the 1970's in the United Nations with reference to the north-south gap, the south is putting in a claim for restoring their right of navigation as a new economic order at sea, followed by their shipping policies: national cargo reservation, participation in the shipping conference and etc. [1].

Investment in the national shipping industry can not only promote the national foreign trade but also motivate the enlargement of port & harbour facilities and domestic transportation. It may also stimulate other industries through the expansion of demand for shipbuilding, energy, construction, manufacturing and so on among which demand for shipbuilding has the biggest multiplying effect on the national economy. However, the developing path caused by an investment is not common for various developments on a variety of economic and social conditions in the respective countries. It is important to do research on how the preferential investment and introduction of advanced technologies to the marine industry will stimulate the development of the other industries and the national economy. To answer the above problem, an analysis of the industrial structure and social status of the country should be made first. In other words, the endowment of natural and social resources as well as many other factors such as geographical condtions , technological capacity, and industrial structure may influence the future economic development. Since there will be a wide range of political alternatives and specific investment possibilities, the policy planner needs some appropriate measures to evaluate how and which alternatives can contribute to the development of the national economy. Many mathematical models to represent the national economic cycle have been developed so far [2]. It seems, however, that those models fail to take due account of the above mentioned problems, especially of the effect of the introduction of new technology.

The originality of thus study is in the potentialities that the effect of introduction of new technology can be evaluated quantitatively by means of national economic indicators. The simulation model consists of 1) the national economic cycle submodel(econo-submodel) and the marine industry technology submodel(techno-submodel). The econo-submodel has functions to measure multiplying effects on the national economy induced by a preferential investment in the marine industry. On the other hand, the techno-submodel may be characterized as a production planning model. The national imports, exports, and products from the econo-submodel cause the techno-submodel to yield demand of investments. The demand of investments is input into the econo-submodel, which evaluate the multiplying effects of the investments. The results of this evaluation are exports, imports, and national products which are sequentially fed back to the techno-submodel.

2. REVIEW OF SIMULATION MODEL

Fig.1 shows the skeleton of the simulation model and displays the functional linkage between the econo-submodel and the techno-submodel. Two different phases of the national economic cycle are included in the model. One of them is an endogeneous economic cycle(Cycle A) which traces the multiplying effect of the demand of investment goods. Cycle A estimates (1)the demands for investment goods to be supplied by other domestic industries, and (2)the amounts of the additional imports of other industries. On the other hand, new or additional facilities necessiated in the marine industry are to be completed after the lapse of time τ, measuring from start of investment. And the productiviy of newly completed facilities will bring about additional products and may raise exports depending upon supply and demand for the products. The above process and the demand for importing capital goods in the cycle A vary the boundary conditions of the industrial structure, the I-O table. This can be considered as an indirect multiplying effect of the marine industry investment. Cycle B in Fig.1 shows the skeleton of process. By usung the RAS method[4], we can rewrite the coefficients of the initial input-output matrix, corresponding to the new boundary conditions. This implies that the multiplying effect defined by the cycle B bring forth a change of industrial structure.

Since no restrictions are imposed upon the productivity of each category of industries in every step of simulation, an excess of production is allocated to be exported, and a shortage of production is allocated to be imported. Accordingly, the international balance of payments can be maneuvered by a preferential investment policy.

3. ECONO-SUBMODEL

The Econo-submodel is in charge of economic equilibrium analysis. The model is constructed on Leontief's I-O analysis modified by the authors[5] to meet the objective of this research.

The balance of products is kept by the constraint

$$X_i = \sum_j W_{ij} + F_i + E_i - M_i \qquad (1)$$

while the balance of supply is kept by the constraint

$$X_j = \sum_i W_{ij} + V_j \qquad (2)$$

where

X_i: gross domestic product of i-th industry,

W_{ij}: intermediate trade from i-th to j-th industry,

F_i: final demand of i-th industry (consumption and investment),

E_i: exports of i-th industry,

M_i: imports of i-th industry, and

V_j: added value of j-th industry.

Gross national product(GNP) and balance of payment B are represented by F,E and M

$$GNP = F + E - M \qquad (3)$$

and

$$B=E-M \tag{4}$$

If A denotes the basic input coefficient matrix, intermediate trade W is rewritten as

$$W=AX \tag{5}$$

To simplify the model, F_i is assumed to be proportional to the national income Y. That is

$$F_i=d_iY \tag{6}$$

where

$$Y=\Sigma_j V_j \tag{7}$$

and d_i is a kind of consumption function. On the other hand

$$F_i=d_iv_jX_i \tag{8}$$

is another expression of Eq.(6), where v_j is the coefficient of added value shown by

$$v_j=V_j/X_j \tag{9}$$

The substitution of Eqs.(4),(5) and (8) into (1) yields

$$X=AX+dvX+B \tag{10}$$

Now suppose that A* is an enlarged basic input coefficient matrix with the supplementation of vector v and vector d to A, and new equilibrium equations

$$X=A^*X+B \tag{11}$$

enable us to obtain the simple equation of national economy instead of Eqs.(1) and (2),where "'" indicates a transposition of

matrix. In Eq.(11), vector X and B must be also enlarged in accordance with matrix A*.
Thus

$$X=(I-A^*)^{-1}B \tag{12}$$

and with a demand D, the new products including the increment is

$$X+\Delta X=(I-A^*)^{-1}(B+D) \tag{13}$$

The principle role of the econo-submodel is to keep the balance between B and X by the use of Eqs.(12) and (13).

4. TECHNO-SUBMODEL

4.1 Functions of Techno-Submodel

The econo-submodel outlined above, can only express an economic system necessary to insure a consistent relation between B, D and X. That is, econo-submodel is able to produce the new products X+ΔX by Eq.(13) only when B and D are given. However, the I-O analysis has no functions to estimate D. For example, the left side box in Fig.2 corresponds econo-submodel, it has no function to estimate the new domestic demand D. Therefore, we must have another submodel by presenting sufficient technological information in order to estimate D. We call this portion a techno-submodel. The techno-submodel will be supplied with production and import/export of the respective industries from the econo-submodel. It will compute the consequent demands for ocean shipping, inland transport, port service, and fishing.

Techno-submodel also estimate their present capacity, that is the quantity of supply in the near future. Thus, techno-submodel determine an optimal investment plan comparing between the demand and the supply.

4.2 Detailed description of techno-submodel

The techno-submodel is composed of 1)programs of assorting sea-born cargo(Converter), 2)marine transportation sector(MT), 3) shipbuilding sector(SB), 4)shiprepairing sector(R), 5)port & harbour sector(P), and 6)fishery sector(F). The submodel is constructed to:

1. receive the information on exports E, imports M and products X from the econo-submodel, and
2. forecast both
   a. the demand of investments of marine industries ΔK_i, and
   b. the products X_i, exports ΔE_i and imports ΔM_i by taking due account of the present technology levels of relevant industries. Where i indicates category of sector.

Parameters π_i's are built in the submodel for the purpose of giving national share of productions to total demand of products. The follwing are descriptions of the practical computational procedures whose flow charts correspond to Fig. 3.

4.2.1 Program of assorting sea-born cargo(Converter)

This program converts E, M and X in dollars from the econo-submodel into marine cargoes in tons. International marine transportation demands(ITD) are classified by the kinds of cargo and the routes. For this purpose, multi-regression analysis is employed, using a data base prepared by making use of U.N. trade statistics.

4.2.2 Marine transportation sector(MT)

The shortage of national tonnage for international trade is estimated based on the information from the converter and A-D table. The demand of investment to prepare national fleets is also appropriated. The computational procedures are listed as follows:

step 1: Mutiply ITD by π_{MT}, and then obtain the amount of cargo to be transported by national flag ships A.

step 2: Considering the idle time of capital formation, count the existing tonnage in A-D table

$$DW_i^1 = DW_{i-1}^1 + \Delta DW_{i-\alpha}^1$$

where DW_i^1, DW_{i-1}^1, $\Delta DW_{i-\alpha}^1$ and α are tonnage in the i-th term, tonnage in the (i-1)-th term, increment of tonnage in the (i-α)-th term, and period required for building new ship, respectively. A-D(Age-Dead Weight) table is a muti-dimensional data base by ship's age, dead weight, ship speed, and so on.

step 3: Caluculate the existing transport capacity B(supply of marine transportation) from A-D table.

step 4: If $A-B \leq 0$, go to step 6. If not, proceed to step 5.

step 5: Calculate $\Delta DW_I^1 = A-B$, and go to step 7. ΔDW_I^1 is the shortage of national tonnage for international service, where subscript I means the the abbreviation of the term "International".

step 6: Calculate the amount of exports of shipping service ΔE_{MT} by putting $\Delta DW_I^1 = 0$, and go to step 7.

step 7: Calculate the domestic marine transportation demand A' using the given regression equation

$$A' = f_2(X)$$

step 8: Calculate the existing transportation capacity for domestic service B' from A-D table.

step 9: If $A'-B'<0$, go to step 11. If not, proceed to step 10.

step 10: Calculate $\Delta DW_D^1 = A'-B'$ for domestic marine transportation, and go to step 12. Subscript D means the abbreviation of the term "Domestic".

step 11: Let $\Delta DW_D^1 = 0$, and go to step 12.

step 12: Calculate total replenishment tonnage of both international and domestic service

$$\Delta DW^1 = \Delta DW_I^1 + \Delta DW_D^1$$

step 13: Determine the investment ΔK_{MT} which is needed to prepare ΔDW^1.

step 14: Calculate the investment for importing tonnage $\Delta M'_{SB}$ by

$$\Delta M'_{SB} = (1-\pi_{SB}) \cdot \Delta K_{MT}$$

where π_{SB} is the national share of shipbuilding for ΔK_{MT}.

step 15: Add $\Delta M'_{SB}$ to $\Delta M''_{SB}$

$$\Delta M_{SB}=\Delta M'_{SB}+\Delta M''_{SB}$$

where $\Delta M''_{SB}$ is the import increment from step 5 in the shipbuilding sector.

step 16: Calculate ΔM_R and ΔM_P by using A-D table, where ΔM_R and ΔM_P are imports of shiprepairing and port & harbour sectors respectively. These quantities are expenditures of the national fleet at foreign ports.

4.2.3 Shipbuilding sector(SB)

The major function of this sector is to calculate the demand of investment for expanding shipbuilding facility ΔK_{SB} and the exportable tonnage $\Delta\dot{E}_{SB}$. The algorithm is enumerated in the following.

step 1: Calculate the replenishment tonnage to be built at home

$$\Delta DW^{1*}=\pi_{SB}\Delta DW^{1}$$

where ΔDW^1 is the total replenishment tonnage given in step 12 in 4.2.3.

step 2: Find the feasible replenishment tonnage $\Delta DW^{1'}$ with the aid of the SUBROUTINE CHARGE*).

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*) A permanent facility is assumed to be expanded by stages where an increement of facility is given in advance. SUBROUTINE CHARGE is a sub-program to take into account such a process. When the demand of increment $\Delta(.)$ is given, this program offers a feasible increment of facility $\Delta(.)'$. That is, $\Delta(.)'$ can be determined by the equation

$$\Delta'(.)=\begin{cases}(.) & \Delta(.)\geq C\\ 0 & \Delta(.)<C\end{cases}$$

where C is a threshold figure for expanding facility, and $(.)_C$ is an optimum amount of increment greater than $\Delta(.)$.

step 3: Count the existing shipbuilding capacity

$$DW_i^2=DW_{i-1}^2+\Delta DW_{i-\beta}^2$$

and replace $DW_i^{2'}$ with DW^2. β is a parameter for capital formation.

step 4: Calculate the available shipbuilding capacity for building new merchant ships ηDW^2, where η is a parameter of facility availability. $(1-\eta)DW^2$ is allocated to build fishing ships, one and off-shore constructions, and so on. If $\eta DW^2-DW^{1'}>0$, go to step 7 with $\Delta DW^{2'}=0$, go to step 15 in the marine transportation sector(4.2.2.) with $\Delta M''_{SB}=0$. Then, ΔE_{SB} is estimated. If $\eta DW^2-DW^{1'}\leqq 0$, go to step 5.

step 5: Calculate the necessary increment of facility

$$\Delta DW^2=DW^{1'}-\eta DW^2$$

and go to step 6 in this sector, go to step 15 in 4.2.2. after setting ΔDW^2 to $\Delta M''_{SB}$ where $\Delta M''_{SB}$ means the amount of ships to be imported immediately.

step 6: Count the feasible increment of shipbuilding facility $\Delta DW^{2'}$ using the SUBROUTINE CHARGE.

step 7: Calculate ΔK_{SB}, the demand of investment for expanding shipbuilding facility by $\Delta DW^{2'}$.

4.2.4 Shiprepairing sector(R)

The calculation procedures are as follows:

step 1: Calculate the demand of repair works of domestic service ships DD_R by using A-D table in 4.2.2.

step 2: Calculate the demand of repair works of international service ships including forign flag ships D_R

$$D_R=\xi_1|M_R|\frac{\pi_R}{1-\pi_R}+\xi_2|E_R|$$

where ξ_1 and ξ_2 are the factors to transfer dollars into tons and M_R and E_R are the amount of imports and exports. Since the π_R represents the national share to total demand of repairing, $|M_R|\{\pi_R/(1-\pi_R)\}$ shows the value of shiprepairing demand for the national facility because $|M_R|/(1-\pi_R)$ means the whole shiprepairing demand from the national fleet.

step 3: Count the existing shiprepairing facility

$$DW_i^3 = DW_{i-1}^3 + DW_{i-\gamma}^3$$

and replace DW_i^3 with DW^3. γ is a parameter for capital formation.

step 4: Calculate the utility of shiprepairing facility ζDW^3 where ζ is a parameter of facility utility. If $\zeta DW^3 - D_R \geq 0$, go to step 7 with $\Delta DW^{3'} = 0$, then calculate the exports of shiprepairing ΔE_R. If $\zeta DW^3 - D_R < 0$, go to step 5.

step 5: Calculate the necessary increment of facility

$$\Delta DW^3 = D_R - \zeta DW^3$$

step 6: Calculate the feasible increment of shiprepairing facility $\Delta DW^{3'}$ by using the SUBRPUTINE CHARGE.

step 7: Calculate ΔK_R, which is the demand of investment for expanding shiprepairing facility by $\Delta DW^{3'}$.

4.2.5 Fishery sector(F)

The computational procedures are as follows:

step 1: Calculate fishing catches A" using the given regression equation

$$A'' = f_3(X)$$

step 2: Calculate the capacity of existing fishing boats B" using the A-D table

step 3: The value of η in 4.2.3. is controlled, comparing A" with B".

step 4: Calculate the amount of investment for fishery sector ΔK_F.

4.2.6 Port & Harbour sector(P)

The Computational steps are shown in the following:

step 1: Calculate the international transit cargo(TC) by using the regression function

$$TC=f_1(X)$$

step 2: Calculate the cargo movement of the national ports D_P

$$D_P=ITD+TC+A'$$

where A' is the demand of domestic marine transportation from step 7 in 4.2.2.

step 3: Count the existing cargo handling capacity C_{P_i}

$$C_{P_i}=C_{P_{i-1}}+C_{P_{i-\theta}}$$

and replace C_{P_i} with C_P(capacity of port). θ represents a time interval for capital formation.

step 4: Calculate the imports of marine transportation ΔM_{MT} derived from the cargo transported by foreign vessels $(1-\pi_{MT})ITD$.

step 5: Estimate the number N and length L of forign ships calling on national ports per year using $(1-\pi_{MT})ITD$ and forecast the exports of port & harbour sector ΔE_P.

step 6: Calculate the number and length L of national ships calling on national ports per year by using A-D table.

step 7: Calculate the average demand of wharf length $\tilde{L}$ per day using the results of steps 5 and 6

$$\tilde{L}=\frac{\varepsilon}{365}\Sigma NL$$

where ε is a parameter for port utility.

step 8: Convert $\tilde{L}$ into an equivalent cargo handling capacity of port $\tilde{C}$

$$\tilde{C}=Pb\cdot\tilde{L}$$

where Pb is a technological parameter.

step 9: If $D_p - C_p \leq 0$, $\Delta C=0$, otherwise $\Delta C = D_p - C_p$.

step 10: If $\tilde{C} - C_p \leq 0$, let $\Delta\tilde{C}=0$, otherwise $\Delta\tilde{C} = \tilde{C} - C_p$.

step 11: Comparing all amounts of ΔC and $\Delta\tilde{C}$, select one of the increment schemes ΔC_p among the following alternatives

1) $\Delta C_p = 0$,
2) $\Delta C_p = \Delta C$, and
3) $\Delta C_p = \Delta\tilde{C}$.

step 12: Calculate the feasible increment of port facility $\Delta C_p'$ by using the SUBROUTINE CHARGE.

step 13: Calculate the demand of investment ΔK_p

$$\Delta K_p = EC \frac{\Delta C_p'}{\Delta 1}$$

where $\Delta 1$ is a unit increment and EC is a coefficient for capacity-cost conversion.

5. APPLICATION OF RAS METHOD

It is a complex problem to evaluate the changes of industrial structure which vary with exogeneous capital investment. To meet this problem, the RAS method by Stone [4] is applied to renew the basic input-output matrix as shown in Fig.4

6. DECISION MAKING AND POLICY PLANNER

The final purpose of this simulation study is to observe the effects of investment to marine industry including shipping on the industrial structure and the national development. Fig 5 synthesizes the author's concept, where the flow of informations in the model are illustrated.

Of many feasible investment schemes, the optimal one should be selected by policy planner taking into account the newly introduced industrial productivity, the international payments, and other national economic indices. The simulation can be performed in cooperation with a judgment box in which some criteria on development and appropriate informations are assumed to stored. The decisions on schemes of preferential investment are to be made by the policy planner with the aid of his consulting action on the outputs of that box.

Prior to the decision on preferential investments in marine industries, the share of the national production to the total production of each category of marine industry should be exogeneously selected by the policy planner through the box. In Fig.3 and Fig.5 π_i indicates this share, for example, π_{MT} in Fig.3 is the share of national cargo reservation. The techno-submodel yields the demand of investment $\Delta K_{i=M}$ according to the given goal $\pi_{i=M}$, where M indicates each category of marine industry listed in 4.2.

The endogeneous demand of investment goods for industries other than marine industry $I_{i\neq M}$ is obtained by multiplying $\Delta K_{i=M}$ by N_{ij}, a coefficient for investment goods. $\hat{I}_{i\neq M}=\pi_{i\neq M}\cdot I_{i\neq M}$ shows the domestic demand and $(1-\pi_{i\neq M})\cdot I_{i\neq M}$ indicates $\Delta M_{i\neq M}$, the increment of imports. All these results are supplied to the judgment box in Fig.5. When some sensitivity studies are carried out based on the combinations of π_i's fixed politically, the policy planner can decide on an optimal policy by selecting one of the combinations of π_i's.

7. CONCLUDING REMARKS

A simulation model is proposed as a basic idea to assess the introduction of advanced technology in connection with the development problem in the developing countries. Much emphasis is put on the marine industry as one of the potential triggering industries.

In the techno-submodel, a conventional procedure, SUBROUTIN CHARGE, is in charge of determing a feasible stepwise investment scheme, which, however, is not always optimal. This procedure would run counter to the intension of this study. To cover this drawback, a function for optimizing long term scheme of investment should be added to the above procedure. The authors consider that a computational method using DP is suitable one wherein, for example, NPV of investment can be used as a criterion of optimization. In the process, the future productivity of marine industry due to the introduction of advanced technology is taken into account. A wide variety of cargo, as well as a increment of quantity, can be seen with the development of industrial activity. In consequence, the marine transportation system is asked to introduce new technology to increase its efficiency.

The I-O table of developing countries are generally hard to obtain. In such a situation, we have to prepare an equivalent substitutional model instead of the I-O table. An analysis of a substitutional model has carried out using Econo-Techno Causal Chain Model developed by the authors [7], where the econo-submodel is formed by multi-regression equations.

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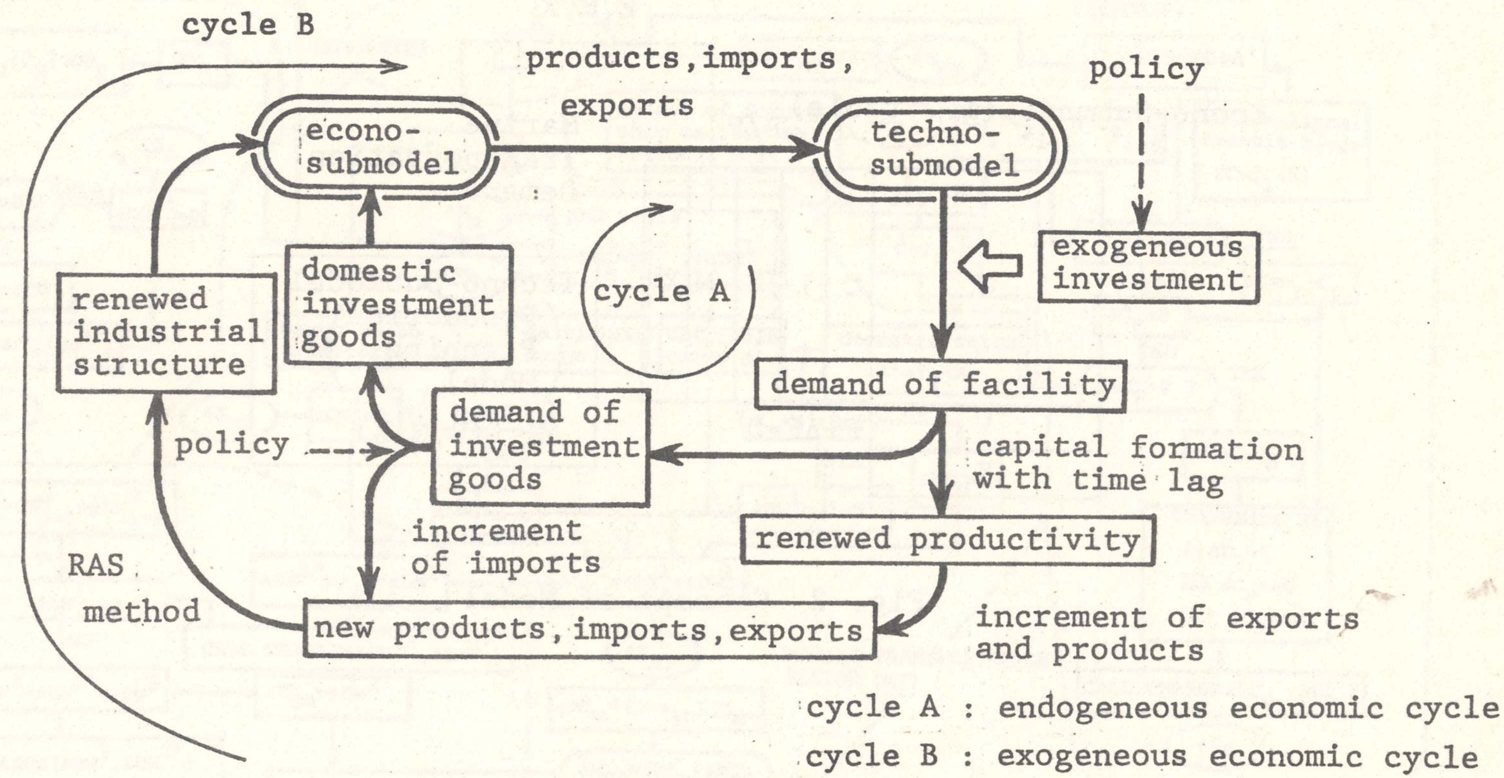


Fig.1 Skeleton of Simulation Model

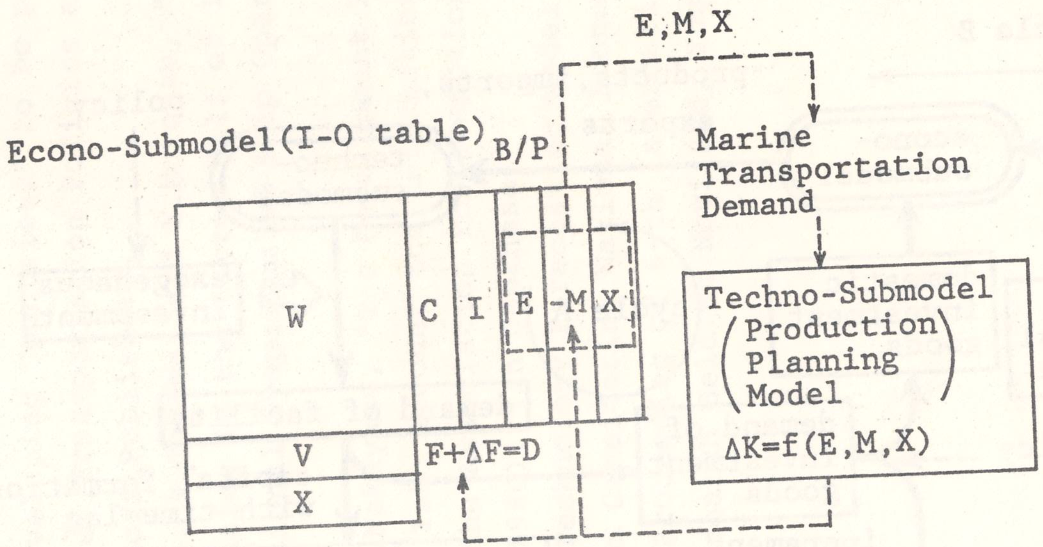
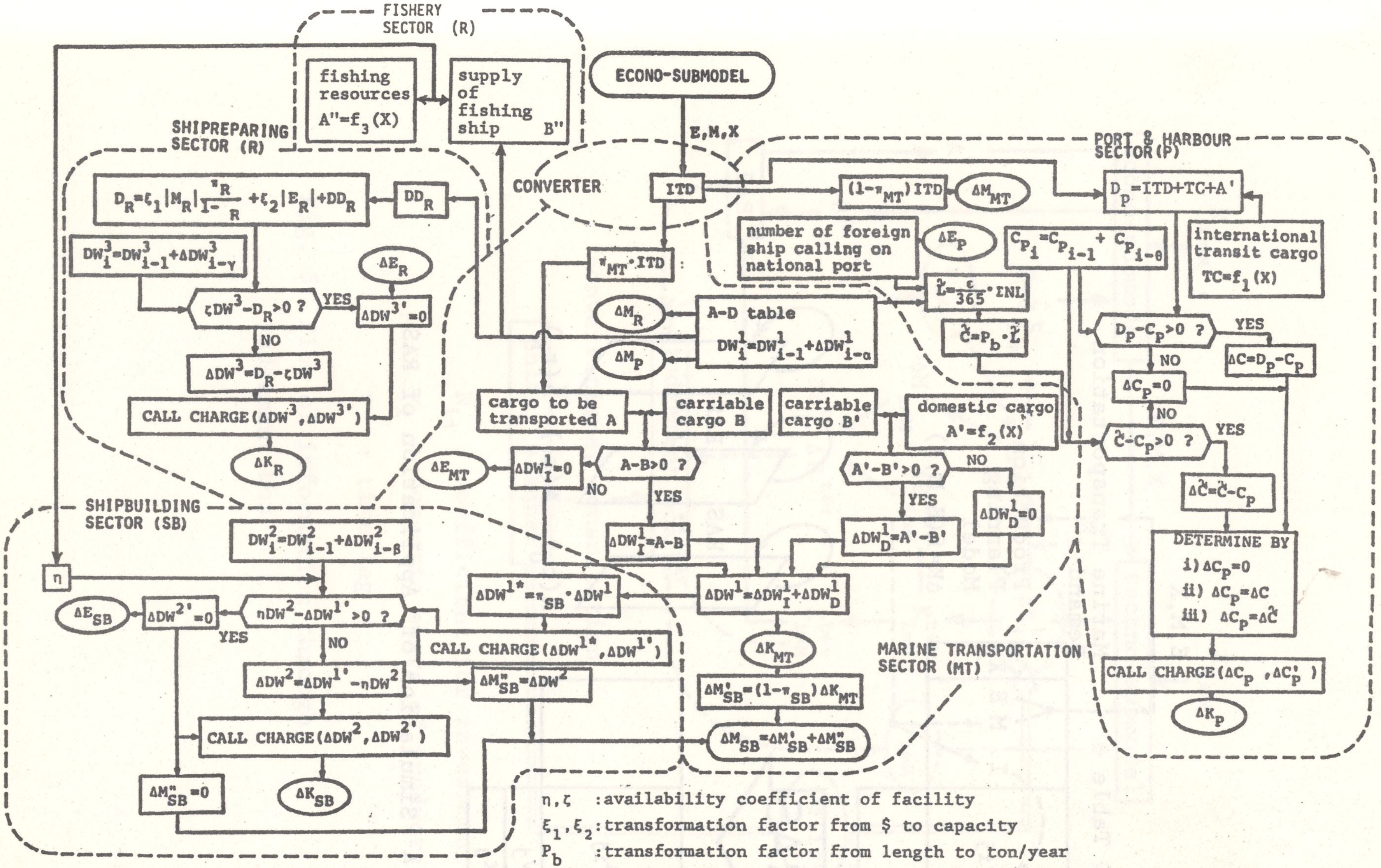


Fig. 2 Concept of Model



η, ζ :availability coefficient of facility

ξ_1, ξ_2:transformation factor from \$ to capacity

P_b :transformation factor from length to ton/year

Fig. 3 Flow chart of techno-submodel

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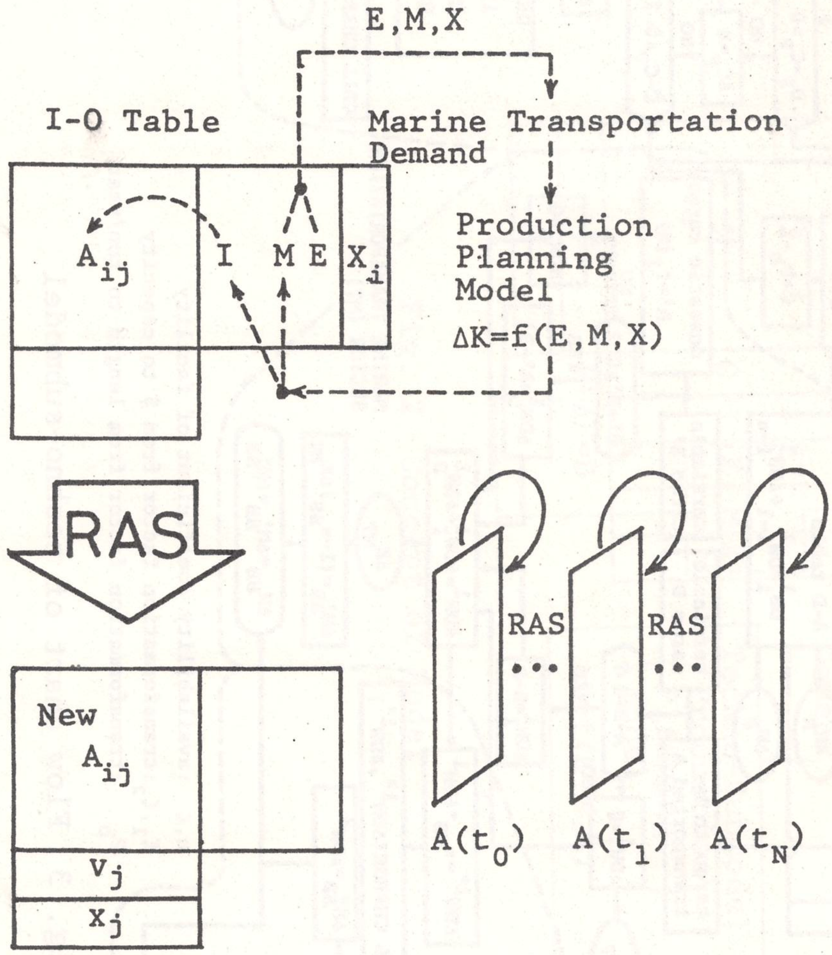
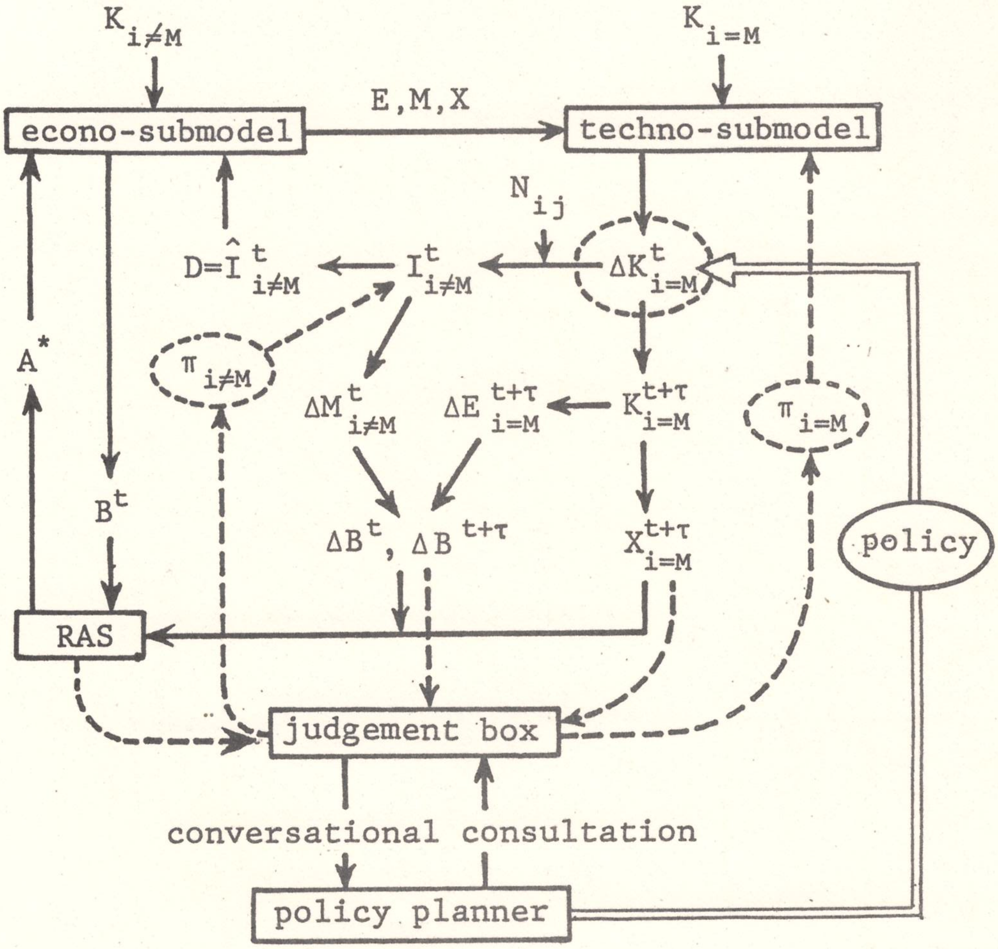


Fig. 4 Simulation of Application of RAS



N_{ij} : coefficient for investment

π_i : domestic share of products

τ : time lag

Fig. 5 Flow of information through judgement box