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A SIMPLE COMPUTER SIMULATION ON THE EFFECTS OF A DESIRABLE INDUSTRIAL ADJUSTMENT UNDER CONSTRAINT OF OIL SUPPLY : A CASE OF JAPAN

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Abstract Some of the results of a computer simulation on the effects of a desirable adjustment of the Japanese industrial structure are described. The simulation model is based on an LP calculation under certain constraints of energy consumption, using the abbreviated industrial input-output table for 1979. The objective function of this LP model, which the author refers to as a welfare function, is selected to be maximized by the output vector of domestic industries under some possible constraints.

1. Introduction

Present forecasting technology by model building seems to be proceeding along the two ways. One is the time series analysis approach (TS method) which focuses only on the statistical treatment of the phenomena concerned, mainly for short periods, and the other is the systems analysis approach (SA method) which seeks the dynamics of the focal phenomena, for both short and long periods. There are arguments as to which method is more accurate. Supporters of the TS method maintain that the SA method gives rise to many coefficients to be determined with some necessary inaccuracy, and thus the forecast results involving their accumulated errors might pose inherent unreliability. Contrarily proponents of the SA method assert that the time series method might be suitable for a very short term forecasting, but in general its results might not hold for a longer period because of lack of theoretical consideration of the system behavior. In addition, it seems to be very difficult to know the degree of accuracy of forecasts by TS methods in non-stationary system behavior. Examples of other forecasting problems concerning uncertain circumstances include that with a small size of available data and that of industrial forecasting. These cases are not suitable for the TS approach, and require the SA approach. Accordingly the two ways should be investigated more extensively in collaboration to forecast more accurately even for long periods.

An industry develops itself fundamentally by the nation-wide demand for its product. However, since the current industrial society is extremely intricate, the output level of each industrial sector at a given time cannot necessarily be determined simply by the final demand for it. For example, even when the capital investment for pollution prevention on the part of major polluters is strongly desired, no company is willing to make such investments because they would not yield any direct profit. Thus, in general, industrial forecasting seems to have more complex features.

The best way to forecast the future trends of industrial sectors may be to rely upon the activity equations of their dynamic system. However, these equations are too complex to build any useful models on. First, nation-wide demands for various products including services are uncertain and subject to change, especially over long periods. In addition, one can hardly forecast the technological developments and changes in any industrial sector. Secondly, some industrial policies, which the Japanese government is sometimes accused of, could influence the pace of industrial changes considerably. Generally speaking, any industry develops itself based on the pursuit of economic profit and on the industrial policy. Thus, when we attempt to build a model to forecast the behavior of an industrial sector or of an industrial system, it seems we will have to try systems analysis using econometric models which are based on economic assumptions, or the well-known Leontief's static and/or dynamic input-output model.

Readers can find the applications of the Leontief's IO model on such areas as forecasting, energy analysis and ecological/environmental analysis in [1] ∿ [3]. Also [4] and [5] are typical examples of the studies using the combination of Leontief's model and linear programming.

Another difficult problem in the industrial forecasting concerns exports and competing imports. These are dependent on the difference of the price-quality condition of various materials and goods existing in various countries in the world. Usually they are dealt with as exogenous in econometric models, but it is obvious that they will affect domestic industrial activities. For example, even when the demand for IC's (integrated circuits) can be determined, the effects of their competing imports on domestic productivity must be considered. Recently, disputes on this subject have been arising among industrialized countries but these problems should be examined separately as an approach to establish world-wide trade and socio-economic stability.

As another aspect of industrial forecast, sometimes we have to consider the problem of employment, which depends upon the education policy, especially that in the case of high-technology. It takes plenty of time to bring up competent engineers. All of these problems will bring about uncertainty in industrial forecasting. However, there are no alternatives but to rely on hypotheses or on judgement. This is the very reason that industrial forecasting is said to be at the same time an art and a science.

2. A Computer Simulation on the Desirable Trend of Japanese Industrial Structure Adjustment Observed through Energy Consumption.

Every industrial country experienced intensive economic difficulties posed by the two oil crises of 1973 — 1974 and of 1979. Although Japan is said to have tided them over well, there may well remain so many problems unsolved. So far the aspect of industrial energy supply has been investigated by the governmental agencies. Owing to price increases and the difficulties in securing necessary amounts of petroleum, the total energy supply plan was changed temporarily in the autumn of 1983. As for demand, there seems to be no detailed forecast on energy consumption by industrial sectors involving the change of industrial structure. Of course, such forecasts would involve many difficult problems. Often we hopefully refer to the terms like "the production structure for high value added", "high-technological structure", or "the economically soft structure with domination of the service sector". All of them might well be the dream of us living in the industrial society. Thus it is of current necessity that we grope for the desirable trends of industrial structure adjustment under various constraints, especially of energy consumption.

Until now, research on energy problems in our country have been concerned mainly with the acquisition of crude oil, whereas its relationship to the industrial structure has been discussed by only a few authors ([4], [5]). Readers are referred to [6] for various energy models developed in Japan.

The purpose of this paper is to look into the possible adjustment of Japanese industrial system which will enable more effective use of energy without deteriorating the standard of living. Another purpose is to simulate the effect of oil supply reduction upon Japanese economy by way of the combination of Leontief's static model and linear programming using a microcomputer system.

2.1. A Simple Simulation Model

As is well-known, the Leontief's static equation in a reference year can be described as follows:

$$AX + Y + E = X + M \qquad (1)$$

The left-hand side of this equation corresponds to the various demands and the right-hand side to the supply in that year, where A is the input coefficients matrix concerned, X is the domestic production vector, E and M are vectors of exports and of competing imports, and Y is the final domestic demand vector needed in the household sector. The i-th element of AX which is called the intermediate demand vector takes the following form: $(AX)_i = a_{i1}X_1 + a_{i2}X_2 + \cdots\cdots + a_{in}X_n$, where a_{ij} is an input coefficient and $a_{ij}X_j$ represents the material inputs (e.g. steel plates) from the i-th industrial sector (e.g. the iron-steel industry) required by the j-th sector (e.g. the automobil industry) to produce the amount X_j.

Usually we use the equation (1) to obtain the value of X in the near future, giving some values forecasted exogenously to $(Y+E)$, where Y is considered positive generally and M is assumed to be proportional to X.

If E and M can be assumed to be some linear functions of M, then eq. (1) can be treated as the constraint equation in the linear programming version. In that case, Y will become a slack variable vector to be determined endogenously. And if we put $Y = Y^o + Y'$ and especially consider Y^o to be the vector composed of the acceptable lower limits of our domestic consumption in each sector, we can plan our desirable living standard in an optimization scheme, giving some values to Y^o beforehand. At that time $Y' \geqq 0$ will mean a margin vector of available products. And if Y' takes too great value in some sectors, the optimal solution of X would not be realistic. Hereto we shall have to apply our intuitive judgment to the feasibility.

As stated above, even in the case when we deal with X vector, E and M vectors as variables respectively in any particular i-th industry, we can impose the following inequality for every period:

$$(AX)_i + Y_i^o + E_i \leqq X_i + M_i \qquad (2)$$

We must also take into consideration the cases of special industries in which the domestic production will not be attempted to increase in spite of the future possibility of a considerable increase of its final demand. That will be done by replacing the competing imports M_i by a bigger value M^* which is independent of the domestic production level X_i. These measures must be taken in the cases of the stock breeding industry, the coal industry etc., because Japan has insufficient pasture land and coal beds which permit easy mining. In any case, we can allow for the condition that the lower limit of the domestic final demand level should be maintained at its present value by setting Y_i° as such.

As for competing imports, it is said that the coefficient of imports is not a plausible assumption, that is, we cannot assume that the ratio of each competing import to the domestic product is constant. But in developed countries this assumption $M_i = m_i X_i$, m_i = const, might be considered valid without loss of generality. Concerning exports, we might adopt the same assumption that $E_i = e_i X_i$, e_i = const, in order to make the simulation easier.

In certain industries, however, we might have to assume E_i and M_i to be constant or of given values. For example, we shall have to take the import volume of oil as fixed or as decreased when we take into consideration the situation during an oil crisis. In those cases, we can exogenously assign the values of E_i and M_i in formula (2). Usually the imports of petroleum is included in the mining industry sector in the input-output table. Each industry which needs petroleum gets it from the mining industry as a matter of formality. If we designate the imports of the mining industry as M_k, then M_k will consist of $M_{k1} = m_{k1} X_k$, which is the imports other than petroleum and natural gas, and M_{k2}, which is the part of crude oil and natural gas that is to be fixed at the assigned value. M_{k2} will then be distributed into the oil refining industry and others (for example, the gas and electric power industries). Each of the distributed values can be considered to be $\beta_r X_r$ for the r-th sector, where β_r is a temporary constant and may be changed after the calculation, considering the consistency of substitution effects between crude oil and natural gas. In any case, we shall have to investigate the substitution effects by assuming various price conditions and considering environmental problems.

Under the above-mentioned conditions, we can constitute a part of the constraints for the linear programming version of the static Leontief's model (1), in addition to some other specific conditions for particular sectors which are to be considered later.

Now we can introduce an objective function on the assumption that the domestic production vector X is variable. In the present article, we shall be concerned with the conservation of oil. However, if the economic activity shrinks as a result, it is disfunctional. In order to promote the welfare of the nation we shall have to consider not only the growth of the Gross National Product but also the improvement of employment opportunities so as to maintain peace and order in the society.

$$Z = \text{(Welfare function)} = \sum_j \{\alpha v_j + k(1-\alpha)e_{mj}\}X_j \tag{3}$$

where α is a weighted average index, v_j is a coefficient of value added, e_{mj} is a coefficient of employment, and X_j is the domestic production level in the j-th sector. The units of X_j and e_{mj} are ¥ billion and 1000 persons per ¥ billion respectively. The coefficient k is a constant to make ke_{mj} non-dimensional (so that k has a dimension of yen per head such as labor productivity or labor wage rate) and to make the orders of v_j and ke_{mj} balanced and here k=4. This means that we assume, for example, the overall average labor productivity in Japan to be four million yen per-capita annually.

The inequalities with a large M^* in place of the competing imports M_j remain to be the inequalities for an optimal solution vector X obtained, and hence the corresponding slack variables for those industries are determined to be large positive values as to absorb the possible large final demands. This fact implies that any consumption beyond domestic production could be made possible by competing imports which are expressed by the following equation:

$$M_j = (AX)_j + Y_j + E_j - X_j \tag{4}$$

where $(AX)_j$ is the j-th element of the intermediate demand vector which means the sum of material inputs to be supplied from the j-th industrial sector to every industrial sector, Y_j is the desirable consumption demand in the j-th sector which may become larger than the domestic production due to various constraints, and $E_j = e_j X_j$ is the export demand in j-th sector.

Summarizing the above remarks,

(1) We can make the following inequality in general:

$$(AX)_i + e_i X_i \leqq m_i X_i + X_i,$$

(2) As for a specific k-th industry, in order to ensure the lower limit of domestic consumption, for instance the level of its final demand Y_k° in the reference year, we can set the inequality

$$(AX)_k + Y_k^\circ + e_k X_k \leqq m_k X_k + X_k,$$

where figures written in the Y° column in Table 1 are examples of this procedure;

(3) As for some industries whose domestic production is considered insufficient, competing imports would be available freely and then we can set

$$(AX)_j + e_j X_j < X_j + M^*$$

where M^* is large. After the unknown X vector has been determined, the required imports for those industries are to be determined by Eq. (4); and

(4) In ordinary sectors we assume the exports and competing imports to be proportional to the domestic production level, but in special sectors they may have fixed values.

2.2. Other constraints and data adjustment

This simulation study aims to seek, from the supply side, the industries to be strengthened in order to increase the welfare of nation under various restrictions of oil consumption. Accordingly, if the actual national demands did not behave in the manner assumed by the calculated final demands, the results might be considered irrelevant. From another viewpoint, however, it seems to be of interest that we consider the feasibility of the derived production vector, or that of corresponding final demands and intermediate production processes obtained through each simulation under various conditions, especially under restriction of oil consumption, keeping the coefficients of input and value added unchanged. A part of the conditions has been described in the preceding section and we shall have to take into consideration the following conditions under which the results obtained will give more realistic figures:

(1) that crude oil consumption is to be restricted at or less than the current amount (1979 value);

(2) that the production levels X_k's of certain industries are restricted at or less than the current values, because those current production levels are considered satisfactory enough. These industries include the agricultural and forestry industry, the domestic coal industry, the food industry, and other industries which are considered appropriate to be fixed from the standpoint of national demand. (In Table 1, the X_k^o column shows the 1979 values of production levels of k-th industry in units of ¥billion);

(3) that the difference between total exports and total imports is made changeable to examine its effects upon the rate of economic growth;

(4) that in order to keep the national work motivation vigorous, the level of energy consumption used in the people's livelihood must be kept at least at the current value. For this reason, the sum of final demands for electricity, gas, and oil refinery sectors is fixed at the current value;

(5) that the sum of final demands in the transportation sector is fixed at the current value because development works in Japan are considered to be satisfactory at this value; and

Table 1. An Example of Calculation, showing the Corresponding Constraints of Sectors.

*** Case (101) *** (Unit: ¥billion)

	Industrial Sector	AX +	E +	(Y^o +	Y')	Left sum	= M +	X	Right sum
1	Elec-POWER	5696.6	2.0	1371.0	0.0	7069.6	0.0	7069.6	7069.6
2	GAS	1553.8	5.0	0.0	1898.0	3456.8	10.0	3446.8	3456.8
3	ROAD	12880.0	138.4	7890.0	0.0	20908.4	79.2	20829.2	20908.4
4	RAIL-Road	2096.9	22.7	0.0	1684.8	3804.4	46.4	3758.0	3804.4
5	Air-TRANS	593.9	220.5	837.0	0.0	1651.4	365.8	1285.6	1651.4
6	Ships-TRANS	2457.9	2225.0	0.0	229.1	4912.0	1100.0	3812.0	4912.0
7	Other-TRANS	1193.9	74.0	0.0	285.1	1553.0	23.0	1530.0	1553.0
8	AGRI & Forest	12761.4	45.0	3438.0	0.0	16244.4	3026.4	13218.0	16244.4
9	FISHERY	2078.8	13.6	0.0	0.0	2092.4	187.3	1905.1	2092.4
10	MINING	11155.1	18.0	0.0	0.0	11173.1	9328.1	1845.0	11173.1
11	CONSTRUCTION	5463.3	0.0	48746.0	0.0	54209.3	0.0	54209.3	54209.3
12	FOODSTUFFS	7669.5	232.0	0.0	19528.5	27430.0	2488.0	24942.0	27430.0
13	TEXTILE	5938.9	787.0	6525.0	0.0	13250.9	1054.9	12196.0	13250.9
14	PAPER-Pulp	6021.7	154.3	128.0	0.0	6304.0	235.3	6068.7	6304.0
15	CHEMICAL	15091.5	1679.6	2555.0	0.0	19326.1	1305.2	18020.9	19326.1
16	Oil-Refining	10668.8	219.9	932.0	0.0	11820.7	1568.1	10252.6	11820.7
17	COAL	3064.1	32.0	3.0	0.0	3099.1	656.1	2443.0	3099.1
18	CERAMIC	7288.3	375.8	225.0	0.0	7889.0	79.2	7809.9	7889.0
19	IRON-Steel	22071.7	2736.0	0.0	0.0	24807.7	280.6	24527.0	24807.7
20	Nonfer METAL	5202.7	372.0	0.0	0.0	5574.7	988.1	4586.6	5574.7
21	Metal MACHINE	34915.3	12188.4	0.0	19520.6	66624.3	1902.5	64721.8	66624.3
22	Other MANUFAC	15009.7	376.8	0.0	0.0	15386.6	640.1	14746.5	15386.6
23	COMMERCE	42605.5	1745.4	0.0	75674.7	120025.7	497.7	119527.9	120025.7
24	SERVICES	19778.1	160.3	63496.0	0.0	83434.4	697.9	82736.5	83434.4
25	OTHER	6929.9	1147.0	0.0	0.0	8077.0	907.0	7170.0	8077.0

		(x_k)		(x^o_k)				
26	PRDCT-Agricl	13218.0	<=	13218.0	*	1	=	13218.0
27	PRDCT-Mining	1845.0	=	1845.0	*	1	=	1845.0
28	LIMIT-Oil	(Power): 527.7 + (Oil Ref.): 6672.7 = 7200.4≤(Consumption Limit): 7300.0						
29	PRDCT-Coal	2443.0	=	2443.0	*	1	=	2443.0
30	PRDCT-Ship TR	3812.0	=	3812.0	*	1	=	3812.0
31	PRDCT-Othr TR	1530.0	=	1530.0	*	1	=	1530.0
32	PRDCT-Food	24942.0	=	24942.0	*	1	=	24942.0
33	PRDCT-Air TR	1285.6	<=	1285.6	*	2	=	1285.0
34	PRDCT-Fish	1905.1	<=	2950.0	*	2	=	2950.0
35	PRDCT-Textil	12196.0	<=	12196.0	*	1	=	12196.0
36	BLNC-Imp/Exp	IMPORTS TOTAL (27466.9) - EXPORTS TOTAL (24970.9) = 2496.0(=T°)						
37	PCE-Energy	SIGMA ENERGY PCE: 4201.0>= 4201.0						
38	PCE-Tranship	SIGMA TRANSP PCE: 10926.0>= 10926.0						
39	PRDCT-COMMRC	119527.9	<=	85737.0	*	2	=	171474.0
40	PRDCT-GAS	3446.8	<=	3437.0	*	2	=	6874.0

Table 2. An Example of Calculation, showing the Growth Rates of GNP and Employment.

*** Case (101) ***

Ind. No.	X	Share	1979	v_i	VA	Share	1979	e_{mi}	EMP	Share	1979	$\Delta X/X^o$
1	7069.6	1.4	7154	.456	3225.5	1.3	3264	.025	177.9	.3	180	-1.2
2	3446.8	.7	3437	.688	2371.8	.9	2365	.047	160.5	.3	160	.3
3	20829.2	4.1	20766	.352	7328.2	2.9	7306	.083	1735.3	2.9	1730	.3
4	3758.0	.7	3643	.538	2021.9	.8	1960	.143	536.4	.9	520	3.2
5	1285.6	.3	1265	.473	607.7	.2	598	.040	50.8	.1	50	1.6
6	3812.0	.7	3812	.373	1421.0	.6	1421	.045	170.0	.3	170	.0
7	1530.0	.3	1530	.478	732.0	.3	732	.261	400.0	.7	400	-.0
8	13218.0	2.6	13218	.591	7817.0	3.1	7817	.424	5600.0	9.4	5600	0.0
9	1905.1	.4	2950	.719	1369.7	.5	2121	.156	297.1	.5	460	-35.4
10	1845.0	.4	1845	.769	1419.0	.6	1419	.060	110.0	.2	110	-.0
11	54209.3	10.6	52992	.413	22413.3	8.9	21910	.101	5483.1	9.2	5360	2.3
12	24942.0	4.9	24942	.283	7064.0	2.8	7064	.047	1160.0	2.0	1160	.0
13	12196.0	2.4	12196	.294	3584.0	1.4	3584	.153	1860.0	3.1	1860	-.0
14	6068.7	1.2	6370	.264	1602.4	.6	1682	.052	314.4	.5	330	-4.7
15	18020.9	3.5	19109	.283	5093.5	2.0	5401	.049	877.0	1.5	930	-5.7
16	10252.6	2.0	10396	.218	2238.7	.9	2270	.004	39.4	.1	40	-1.4
17	2443.0	.5	2443	.319	780.0	.3	780	.008	20.0	.0	20	-.0
18	7809.9	1.5	7794	.377	2945.0	1.2	2939	.078	611.2	1.0	610	.2
19	24527.0	4.8	26481	.208	5101.6	2.0	5508	.018	435.3	.7	470	-7.4
20	4586.6	.9	5018	.262	1201.0	.5	1314	.042	191.9	.3	210	-8.6
21	64721.8	12.6	73821	.355	22995.1	9.1	26228	.071	4620.4	7.8	5270	-12.3
22	14746.5	2.9	19998	.357	5258.4	2.1	7131	.112	1644.4	2.8	2230	-26.3
23	119527.9	23.3	85737	.742	88634.2	35.1	63577	.145	17315.0	29.2	12420	39.4
24	82736.5	16.1	81565	.656	54314.0	21.5	53545	.187	15458.9	26.0	15240	1.4
25	7170.0	1.4	7526	.130	931.7	.4	978	.016	114.3	.2	120	-4.7
(Total)	512648.0	100.0	496008		252470.8	100.0	232914		59383.4	100.0	55650	
(Growth)	3.4%				8.4%				6.7%			

(6) any arbitrary restrictions, such as that commercial activity, air transportation, and fishing should not exceed some designed limit in order to avoid international economic frictions, or that the primary, the secondary, and the tertiary industries should have some desirable ratios between their respective production.

After we have obtained the results of simulation, we must evaluate them in regard to their feasibility. If we obtain some feasible solutions, we can suppose that they might predict possible trends of future industrial structure. However, as often occurs in LP calculations, some slack variables which correspond to the domestic consumption Y^o+Y' (illustrated in Table 1) except for the sectors with a large number M^*, might become zero. Although such solutions seem to be irrelevant, we can sometimes adopt them as reasonable solutions by taking into consideration the actual circumstances of Japanese industries if necessary. In order to avoid this kind of trouble, we might have to assign Y^o some value (such as an actual value).

Table 3. An Example of Calculation, showing Changes of Exports and Competing Imports.

*** Case (101) ***

Ind. No.	$Y=Y^o+Y'$	Share	1979	Growth (%)	e_i	E	Share	1979	m_i	M	Share	1979
1	1371.0	.5	1371	0.0	.000	2.0	.0	2	0.000	0.0	0.0	0
2	1898.0	.7	1898	.0	.001	5.0	.0	5	.003	10.0	.0	10
3	7890.0	3.1	7890	0.0	.007	138.4	.6	138	.004	79.2	.3	79
4	1684.8	.7	1714	-1.7	.006	22.7	.1	22	.012	46.4	.2	45
5	837.0	.3	837	0.0	.172	220.5	.9	217	.285	365.8	1.3	360
6	229.1	.1	194	18.1	.584	2225.0	8.9	2225	.289	1100.0	4.0	1100
7	285.1	.1	291	-2.0	.048	74.0	.3	74	.015	23.0	.1	23
8	3438.0	1.3	3438	0.0	.003	45.0	.2	45	.229	3026.4	11.0	3613
9	0.0	0.0	1110	-100.0	.007	13.6	.1	21	.098	187.3	.7	290
10	0.0	0.0	92	-100.0	.010	18.0	.1	18	5.056	9328.1	34.0	9629
11	48746.0	19.1	48746	0.0	0.000	0.0	.0	0	0.000	0.0	0.0	0
12	19528.5	7.7	19508	.1	.009	232.0	.9	232	.100	2488.0	9.1	2488
13	6525.0	2.6	6525	0.0	.065	787.0	3.2	787	.086	1054.9	3.8	1110
14	128.0	.1	128	0.0	.025	154.3	.6	162	.039	235.3	.9	247
15	2555.0	1.0	2555	0.0	.093	1679.6	6.7	1781	.072	1305.2	4.8	1384
16	932.0	.4	932	0.0	.021	219.9	.9	223	.153	1568.1	5.7	1590
17	3.0	.0	3	0.0	.013	32.0	.1	32	.269	656.1	2.4	777
18	225.0	.1	225	0.0	.048	375.8	1.5	375	.010	79.2	.3	79
19	0.0	0.0	-132	-100.0	.112	2736.0	11.0	2954	.011	280.6	1.0	303
20	0.0	0.0	-52	-100.0	.081	372.0	1.5	407	.215	988.1	3.6	1081
21	19520.6	7.7	24778	-21.2	.188	12188.4	48.8	13902	.029	1902.5	6.9	2170
22	0.0	0.0	4651	-100.0	.026	376.8	1.5	511	.043	640.1	2.3	868
23	75674.7	29.7	44283	70.9	.015	1745.4	7.0	1252	.004	497.7	1.8	357
24	63496.0	24.9	63496	0.0	.002	160.3	.6	158	.008	697.9	2.5	688
25	0.0	0.0	458	-100.0	.160	1147.0	4.6	1204	.126	907.0	3.3	952
(Total)	254966.8	100.0	234939			24970.9	100.0	26747		27466.9	100.0	29243
(Growth)	8.5%					-6.6%				-6.1%		

The data used in this simulation study were compiled from the 1979 input-output table made by the Japanese Ministry of Trade and Industry. We decreased the number of sectors to 25 as shown in Table 1 in order to use a microcomputer and to examine specifically the circumstances of transportation in somewhat detail.

3. Examples of Simulation Results and their Interpretation.

The concept of welfare is so difficult to define that we cannot formulate it in a simple form. In our case, the results were independent of the value of α. When α is unity, the objective function means only the value of GNP, and when $\alpha=0$, the objective function is identical with the employment. Obviously, both cases have a different significance in the objective function. Accordingly, the fact that one obtains the same output vector for various values of α might imply that, in general, under adopted constraints the increase of the GNP value will also increase the employment and vice versa.

The simple correlation coefficient between the coefficients of value added and of employment, however, is below 0.5. Consequently, they are not too similar in nature. Thus, only the case of α=0.5 are illustrated in Table 1. For α=0.5, we can also calculate for different types of cases: to maximize employment with constant GNP, and to maximize GNP with constant employment.

A case which seems most feasible from the viewpoint of the current industrial circumstances is illustrated in Table 1, 2 and 3. This is based on the additional constraints that the trade balance $T=\tilde{M}-\tilde{E}$, where $\tilde{M}$ is the total sum of imports and $\tilde{E}$ is the total sum of exports, and the final domestic demand of the oil refining sector (16) should not be less than their current values, that is $T \geqq T^{\circ}$ and $Y_{16} \geqq Y^{\circ}_{16}$ (Subscript indicates the industrial sector or the constraint concerned).

As shown in Table 2, we can obtain a moderate increase of GNP and employment by about 8.4% and 6.7%, respectively, compared with the actual values of 1979, despite a moderate decrease in petroleum consumption by 1.4% as a result of maximizing the welfare function. In the same table we also find the fact that the growth rate of production level would have to increase in the commerce sector and to decrease in the fishery, the metal-machine and the other manufacturing sectors very intensively in order to meet these constraints. This tendency appears in almost all cases of our simulations, because various constraints have been imposed to secure the current standard of living.

Thus Table 2 seems represent a potentiality that, even if the majority of manufacturing industries decreased their production lebels in some degree and accordingly their exports decreased, Japanese economy would have still the growing ability as a whole, despite the reduction of oil consumption by rather small percentage, by increasing the production level in the commercial sector.

In Table 2 and 3, the coefficients of value added, employment, exports and imports are shown. Especially the decreased amounts of imports are remarkable in the agriculture-forestry (which include the stock-breeding), crude oil (mining), the fishery and the other manufacturing sectors, and contrarily the increased amounts of exports are shown in the commerce sector.

The decrease of imports in the agriculture-forestry seems mainly due to the decrease of the intermediate demands from the other manufacturing industries which include the industries concerned with lumbering and wooden manufactures. If the demands for lumber products and fishery sectors increase, we can provide them through the commerce sector from abroad.

If the constraint $Y_{16} \geqq Y^{\circ}_{16}$ were removed, both the GNP and employment values would increase about twice as much as the above values, and conversely the petroleum requirement would decrease by about 6.1%. In this case, however we could not secure the actual amount of oil Y°_{16} to maintain the present standard of living, and therefore we would have to supplement it by natural gas or coal, which would be unrealistic when considering the difficulties in securing the necessary amount or the possible pollutions. Table 4 shows the composition ratio of the primary (I), secondary (II), and tertiary (III) industries for the GNP and employment in regard to the case of Table 1 and the actual figures for 1979. Thus the case in Table 1 (Exp. No.101) seems highly feasible.

Table 4. Composition Rate of GNP and Employment (%).

Group of Industries	I	II	III
GNP	3.6 (3.9)	32.4 (34.6)	63.6 (53.4)
Empl.	9.9 (10.9)	29.2 (33.4)	60.6 (55.5)

(Note). Figures in parentheses refer to 1979. As for the classification of industry groups I, II and III, we define them as follows: (written by the industry number illustrated in Table 1), I: 8,9, II: 10,11, 12,13,14,15,16,17,18,19,20,21,22, III: 1,2,3,4,5,6, 7,23,24.

If $T=\tilde{M}-\tilde{E}$ becomes zero, we cannot find a feasible solution unless the size of the economy is reduced from the present size. The optimization scheme would lose its meaning in that kind of situation. In fact, we have a feasible solution of GNP down 5.7%, employment down 4.8%, and the total amount of trade down 10.4% by removing the constraint $Y_{16}\geqq Y^{\circ}_{16}$ which leads to a decrease in the crude oil requirement to about 74% of current consumption.

Contrarily the values of GNP and employment show a very rapid increase with a growing excess of imports over exports. This fact means that more extensive domestic production will cause more imports, that is, the GNP elasticity of imports will be positive in the Japanese current economy. We are fairly certain of this tendency because it was supported not only by the data of 1979 when the trade balance was unfavorable or negative but also by the data in 1977 with a favorable trade balance.

This trend is illustrated in Figs. 1 and 2. All the results for $T>T^{\circ}$ have been calculated under the constraint of $Y_{16}\geqq Y^{\circ}_{16}$ which is not so important for a growing economy. The increase in the trade deficit does not always mean

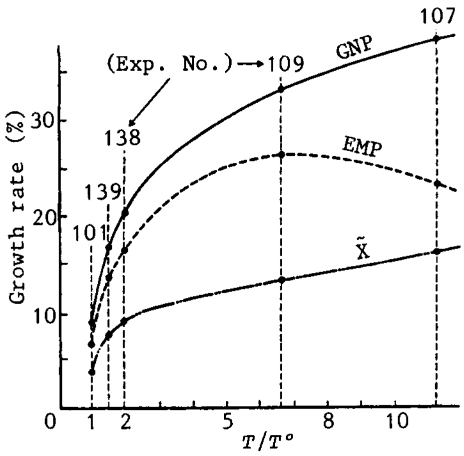

Figure 1. Effect of Trade Balance Upon the GNP, Employment and Total Production

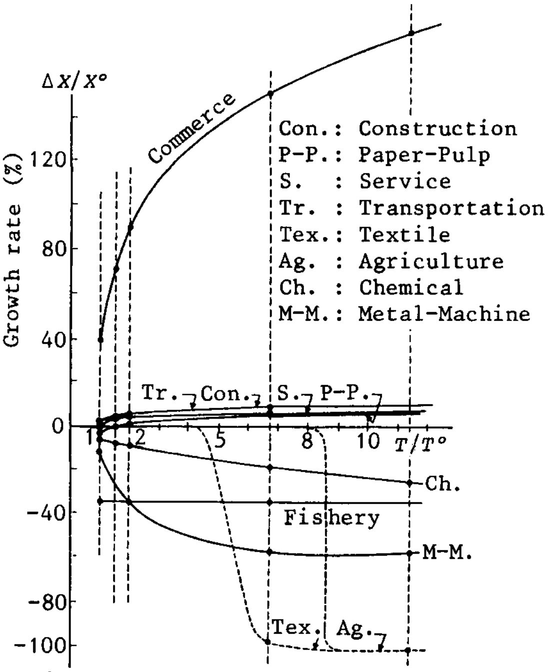

Figure 2. Effect of Trade Balance Upon the Domestic Production Levels

that the sum of imports amounts becomes larger than the present value. There are cases where both imports and exports decrease from their present values but their balance remains unfavorable. In our country, it has been considered natural that Japan exports many products in order to pay for imports of necessary materials and goods. Now, however, Japan manufactures too much products and the economic friction has arisen from exports of them. Then the decrease of crude oil imports would have an effect of reducing the exportation pressure of miscellaneous products, so that the economic friction might be reduced and also the environmental pollution will be mitigated. Therefore we shall have to investigate the practical feasibility of the resulting output vector to realize such circumstances in the future. Here we also must note that, in each case, the standard of living will not decline from the present status.

As seen in Fig. 2, it is a common feature that, in general, the commerce sector increases its growth rate of production remarkably and those of manufacturing sectors decrease to some limiting values with a growing trade deficit. Also the fishery sector shows relatively constant percentage reduction in almost all cases. Further, the transportation sector and some other industries increase their growth rate to a similar ceiling, probably due to the constraints given. The most difficult problem will be concerned with how to make the best use of a surplus production capacity arising from the production adjustment. Perhaps the scenario like the case of Table 2 will not be welcomed by the Japanese industries. However, the author thinks this would be a natural way for us to step forward in the future, because of the so-called Petty's law. And the industrial structure with larger tertiary industries and smaller secondary industries does not always exclude the possibility of the manufacturing industries with high value added and low energy consumption to be developed. Therefore we must investigate how we can pave the way for such a production adjustment without lowering our current standard of living. One way of resolution of this problem may be to consider the global situation of production in the world, especially concerning the economic development of the Third World.

Recently Prof. Moriguti has proposed a very instructive direction using microelectronics for the development of the Third World ([7]). He has developed a new paradigm of economic development that much more rapid development of the world as a whole is possible, if the advanced countries help the Third World by investing about over 30% of their production surplus to improve the infrastructures in the Third World.

Table 5 shows the various figures of growth rates for miscellaneous items concerned, where T is trade balance, $\tilde{E}$ is the total sum of exports, $\tilde{M}$ is the total sum of imports, G is GNP, E_m is total employment, $\tilde{X}$ is total domestic production, D is crude oil requirement, and the value with (°) mark, such as D°, indicates 1979 values. The growth rates of only three items among these items are plotted in Fig. 1 against the change rate of trade balance. Further, the corresponding growth rates of domestic production of various industries

Table 5. The Growth Rates for Miscellaneous Items (%) in the Optimization Schemes.

Exp.No.	$\frac{\Delta T}{T^\circ}$	$\frac{\Delta\tilde{E}}{\tilde{E}^\circ}$	$\frac{\Delta\tilde{M}}{\tilde{M}^\circ}$	$\frac{\Delta(\tilde{E}+\tilde{M})}{(\tilde{E}+\tilde{M})^\circ}$	$\frac{\Delta G}{G^\circ}$	$\frac{\Delta E_m}{E_m^\circ}$	$\frac{\Delta\tilde{X}}{\tilde{X}^\circ}$	$\frac{\Delta D}{D^\circ}$
101	0%	-6.6	-6.1	-6.3	8.4	6.7	3.4	-1.40
142	10	-6.9	-5.5	-6.2	12.2	9.9	5.7	-0.39
140	25	-8.4	-5.6	-7.6	14.6	11.9	7.0	0
139	50	-11.6	-6.3	-8.8	16.6	13.7	7.7	0
138	100	-17.8	-7.8	-12.5	20.6	17.1	9.0	0
109	570	-31.6	+11.4	-9.2	33.5	26.1	13.5	0
107	1040	-30.4	+52.7	+13.0	38.5	23.0	16.3	0

are protted in Fig. 2. Figures show the fact that the effect of trade balance upon the various items is rather strong near the current value $T/T^o=1$ or $\Delta T/T^o=0$ in the optimization scheme.

4. A Plausible Scenario for an Oil Supply Reduction

So far we have considered mainly the cases when the oil supply is set within the neighborhood of the current amount D^o, and have found that the change in crude oil input upon industrial productions will affect much stronger in the tertiary industries than in the secondary industries. This may be a general feature of our current national economy because the rate of change of production of the tertiary industries is generally larger than that of the secondary industries in our optimization scheme, as shown in the example of Table 6.

Table 6. The change rate of production (%)

Exp. No.	Group of Industries			Rate of change of Oil Supply
	I	II	III	
101	-6.46	-6.47	+16.80	-1.4%
S	-6.49	-5.90	+10.0	+1.4%
Weighted mean of coefficient of value added	v_I=0.61	v_{II}=0.33	v_{III}=0.65	

This fact also may be considered to correspond with the Petty's Law because the weighted mean of coefficients of value added in the tertiary industries is larger than that in the secondary industries. An example of the weighted averages of coefficients of value added in the primary, secondary, and tertiary industries is shown in Table 6 in regard to the case 101.

However, one of the interesting problems is the critical cases when the oil supply is reduced to some limit value. This problem is very difficult to solve because of the possibility of many unseen economic constraints. Therefore, we selected three stages to study the possibility of our living standard keeping the trade balance at the current value. The first stage is to examine the amount by which the oil supply can be reduced while maintaining the present economic status. As the second stage, we examine the critical condition of oil supply by means of reducing the household demands for energy, transportation and others, while keeping the current trade balance. Finally, we remove the constraint of trade balance to obtain a mathematically possible solution.

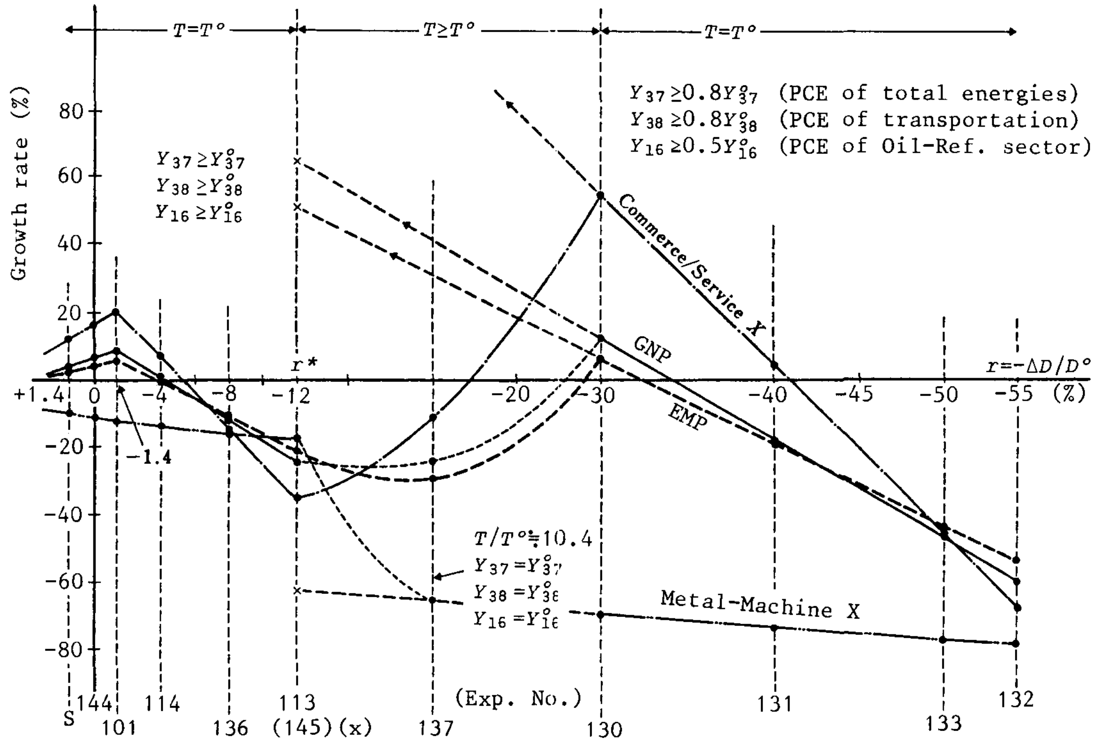

Figure 3. Effect of Petroleum Reduction Upon the GNP, Employment and Some Production Levels

The results are shown in Figure 3. The origin corresponds to the actual position in 1979 and, departing from it, each curve reaches the points obtained by maximizing the welfare function subject to the constraints, keeping the trade balance $T=T^o$. First, we can see that the most optimal solution is not obtained at $r=0$, but at $r=-1.4\%$. As the reduction rate of the oil supply $|r|$ becomes larger than this value, the growth rate of every item decreases linearly to the limit value at $r=r^*(=-0.12)$, beyond which we could not obtain a mathematically feasible solution unless some of the constraints were changed, Secondly, we can see that the increase in the oil supply may be unnecessary if we are to maintain the current standard of living. Since the conservation of crude oil is an urgent issue, it seems more sensible that we confine ourselves to the analysis of the cases of oil supply reduction.

The fact that we have a limit at $r^*=-0.12$ implies that our current standard of living could be kept materially until the reduction rate of oil supply reaches $r*$, apart from the monetary problem based on an unfavorable trade balance. However the situation of industrial activity would be so miserable that we would have to rely on considerable imports and the unemployment problem would become very grave. In this limit case, GNP and employment would decrease by about 24% and 20.5%, respectively.

If the Private Consumption Expenditure (PCE) of total energy and transportation were reduced to 80% of current values and the requirement of oil in the household sector decreased to a half of the current value, we could also obtain a feasible optimal solution with the additional conditions $Y_{11}=0.5\ Y^{\circ}_{11}$ and $X_{23}<2X^{\circ}_{23}$ under the same trade balance $T=T^{\circ}$. Exp.No.130, 131, 132 and 133 in Fig. 3 are those examples.

Of course, we could obtain other feasible optimal solutions at the limiting rate $r*$ by giving such constraints as those mentioned above, but it would probably show an unbelievable increase in growth rates of GNP and commercial production which seem never practically possible. And, in this vein, Exp.No. 145 shows not a practical possibility but a mathematical feasibility. If we want to link the two corresponding points for Exp.No.113 and 130, we must adopt both of two measures, namely the reduction of the standard of living and the increase in an unfavorable trade balance, which results in the change in industrial structure.

It seems we would be better off by adopting the latter way, because the reduction in standard of living may hinder the vigorous motivation for work and increase in the GNP. Thus, as shown in Fig. 3, it will be reasonable to link the corresponding points between Exp.No.113 and No.130 that seems rather practical, by the dotted lines via the points calculated for Exp.No.137, etc.

As illustrated in Fig. 3, the mere reduction of the oil supply by only 4% would prohibits the Japanese economy from developing beyond the current position even if its industrial structure were changed most favorably.

If that were the case, energy would still remain one of the most crucial issues for Japan. We think it is very important for Japan to seek, in the future, an industrial structure based on mutual cooperation with various countries in the world.

5. Conclusions

In this paper, assuming that exports and competitive imports are proportional to domestic production, the input coefficient matrix derived from the industrial input-output table for 1979 does not change and the price change also does not occur in our economic system, some simulations by a special use of the Leontief's static model and linear programming method were carried out to forecast the effects of a Japanese industrial adjustment desirable from the viewpoint of an effective use of oil and especially increasing the employment opportunity.

It is well-known that the input coefficients from the oil-refinery sector to other sectors have decreased their values gradually in recent years since the first oil shock in our country. And hence we might be anxious about not changing the input coefficients for 1979 in this study, but the author believes that this will not have so serious effect on the LP solutions in this study, because of an experience of the previous experiment [8], in which, though these input coefficients were changed in proportion to the oil price to somewhat remarkable extent, the LP solutions were too robust to change.

Though these results of this study are not accurate enough to enable a quantitative forecast of effects of industrial adjustment as a result of the above-mentioned assumptions, the adopted method will be better than visionary or intuitive methods in that it gives at least a quantitative approximation of system behavior as a whole.

The results of simulation could be summarized as follows:

1. More emphasis should be put on the service sector of the economy to improve welfare. Consequently, the tertiary industries will grow while the manufacturing industries will contract. In planning such a production adjustment, we might find one way of the best use of the production surplus to help the Third World to develop themselves, so that we will be able to enjoy a possible future profit as a result.
2. Oil will play a crucial role in the above effort. Even with the assumption of optimum usage of oil under present technology, a decrease in oil imports by 10% would tremendously affect the activities of industries. It would not only hinder the enhancement of the service sector of the economy, but would also require the increase of product imports (to offset the decrease of oil imports and to keep the current trade balance), if Japan were to maintain the present standard of living in face of the resulting contraction of economy.

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