Capital Accumulation and Structural Change in Japan [*]

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1 Introduction

Objective of our analysis is to evaluate quantitatively the impacts of the structural changes on the Japanese economic growth during the last half of 20th century. The structural changes in an economy could be observed in both sides of supply and demand as changes of the structural parameters. Here, we intend to focus on the structural changes of the supply side on an economy from the viewpoints of the Input-Output analysis. Structural changes of the supply side on the Input-Output analysis are described as changes of structural parameters such as intermediate inputs coefficients, labor and capital coefficients, where the properties of the production technology in each commodity and the features of the production linkages among commodities are realized. According to the decomposition of sources of the economic growth in Japan during the period 1960-90, we can conclude that the Japanese economy during three decades since 1960 fairly well-behaved with regard to resource allocations along with the changes of relative prices. Changes of relative prices among inputs seem to have accelerated smoothly changes in input structure of every commodity production. Introducing extended concepts of total factor productivity, we can evaluate impacts of the input structural changes on the efficiency in the economy. The measure of the growth rate of total factor productivity in each commodity production could be ordinarily defined by the difference between the growth rate of output and the growth rate of inputs, which is measured by weighted sum of the growth rates of various inputs. The changes of input structure in each commodity production might be able to be evaluated as improvement of the production efficiency by the growth of the total factor productivity. On the other hand, technology in each commodity production is mutually interdependent through the intermediate transactions as well as factor markets. Structural changes in some commodity productions would have spillover effects on the structure in the other commodity production and might induce changes of the production efficiency in the related other commodities. Therefore, the efficiency in some commodity productions should be evaluated totally as impacts on all of related commodities through the interdependency of the commodity linkage. We try to define measures by which we can evaluate the total improvement of the efficiency in the economy through the spillover effect by the structural changes.

We begin with some findings concerning properties of the structural changes in the supply side of the Japanese economy in section 2. Japan has ample experiences for estimating Input-Output Tables and giving policy suggestions induced from results of Input-Output Analysis. The first Japanese Input-Output table was officially estimated in 1951, when the country still had been in utter chaos in the aftermath of the World War II. Estimated table could explicitly show the existence of various bottlenecks and imbalances in the Japanese economy. The table made an important role in the governmental decision-makings of the allocation of the limited resource keeping interrelationships among sectors in mind. In every five years after 1955, so-called “Basic Input-Output Tables" were published as a governmental official project work collaborated with statistical divisions of the related

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Ministries. The most recent, 1995 table was published in 1999 and the estimation of the 2000 table is now started.

Our first observation is concerning the structural linkages among intermediate inputs, which are observed by the Basic Input-Output Tables since 1955. Our second observation is related to changes on the production efficiency, which is defined by the changes of total factor productivity in the specific commodity production as well as in the aggregated level. Thirdly, we try to show some findings of the structural changes on the labor and capital coefficients. In order to observe changes of labor and capital coefficients in the Input-Output framework, we estimated labor and capital coefficient matrices consistently with the 43 industrial classification during the period 1960-92. Reader can see detail explanation for the estimation of capital stock matrices in Appendix.

In section 3, we try to connect above three observations concerning the structural changes with the Input-Output framework. We will propose concepts of "static unit TFP" and "dynamic unit TFP", in order to evaluate the impacts of the structural changes on the efficiency of the economy. Our concept of the measurement of the total factor productivity(TFP) is an extension of the concept of the ordinary TFP measures by the specific commodity production, from the viewpoints of technological properties of commodity production and spillover effect of the technology as a system. We will evaluate the structural changes of the Japanese economy by our proposed concept of measurements of the changes of the production efficiency in section 4. It is assuming that TFP growth as technological change in certain commodity production is related to the structural changes of inputs coefficients of intermediate inputs and factor inputs like labor and capital, which are realized by the installation of the new technology. Changes of structural parameters, which are realized by the new technologies, might have sizable impacts on the framework of the linkage among various economic sectors. We can point out that these changes of the input coefficients by new technologies could realize the extension of the spillover effect of the TFP growth.

Finally they contribute to the increase of the efficiency in the economy, even if the ordinary measures of the TFP growth in each commodity production were relatively lower. Our analytical framework is based upon the "Dynamic Inverse" approach of the input-output analysis. In the dynamic inverse approach, a structure of the economy is composed of linear equations described by input coefficients of intermediate and labor as well as capital inputs as structural parameters. We assume here that the development of new technologies could be embodied on changes of capital input coefficients as structural parameters and it would have the spillover effect on the whole economy through the productivity growth. The development of new technologies assume to be realized by the changes of composition among capital goods in capital formation and observed by the changes of the capital coefficients in capital stock by sector. We begin with the development of the measures of capital input in current and constant prices for each of the 43 industrial sectors in Japan for the period 1955-1992. We estimate capital formation in terms of flow and stock in order to evaluate the impact of the structural changes in capital coefficients on the economy, where new technologies have been expected to be embodied. The spillover effect of the structural changes on productivity can be measured not only by the static interdependent relationship among sectors through the transactions of their intermediate goods, but also by the dynamic inter-relationship among sectors through the capital accumulation process. We assume here that the development of new technologies could be embodied in changes of capital stock through new investment, and that this would have a spillover effect on the whole economy through productivity growth. These approaches to the static and dynamic measures of the spillover effect provide us the extended concepts of the measurement of total factor productivity.

2 Structural Change in the Commodity Production

Changes in the input structure for a specific commodity production are realized by the technical progress. We can observe these changes as changes in intermediate input coefficients, labor and capital coefficients in the Input-Output framework. In other words, observed changes in every input coefficient should represent the changes in the production efficiency through the technical progress. In order to characterize patterns of the structural changes as shifts of the production efficiency, we would like to focus on the following two aspects. One is a static property and the other is a dynamic property. The structural linkage of the technology characterizes the static property, where the linkage is depicted by the interdependency of intermediate input transactions among industries shown in the input-output table at the specific period. Second, the static structural linkage at the specific period is based upon the capital structure, in which the production technology when the capital stock has been accumulated in the past was embodied. The production technology embodied in the accumulated capital stock is characterized by the efficiency of the production. In order to represent the changes of the efficiency of the technology, we try to introduce the measurements of rates of the technical progress in each commodity production. The impacts of the technical progress in certain commodity production have been observed in other technically related sectors through the static structural linkages and the dynamic capital accumulation processes.

2.1 Static Structural Linkage of the Technology

As we mentioned above, the first Japanese input-output table compiled in 1955 for the 1951 table, which made an important role to introduce the economic planning such as so-called "Priority Production Systems" during the economic recovery periods after the War. Since 1955 the Japanese government has continued to compile the input-output table in every five years. We can rearrange these tables to be comparable in the definition and concept with around 350 commodities.[1] In each table commodities are rearranged in the triangular order from the end-use products to the primary use products. This triangularity designates the hierarchical structure of the intermediate inputs among commodities, where the inter-block hierarchy among certain commodity groups and the intra-block hierarchy within certain commodity group characterize it. From the viewpoints of inter and intra-block hierarchy among commodity we can finally aggregate to 50 industrial sectors as shown in Table 1, in which commodities are arranged in the hierarchical order. Fifty industrial sectors can be sub-aggregated into twelve hierarchical blocks from (A) to (L) as shown in Table 1. Construction, which is designated as the top tier industry, is mostly a supplier to the final use products and a demander to almost all products of the less ordered industries as its intermediate inputs, especially products of block (C), (D) and (F). The block (B) includes almost all of machinery products, which are also, suppliers to the end use products as the investment goods and have hierarchical relationships to the block (D), primary metal products. In block (G) various manufacturing products which are used partly as intermediate inputs and partly as end use products are classified. Commodities classified in the hierarchical orders more than the block (G) have the closely related dependency to one of the specific raw materials, which are included in the block (H). We refer these relationships to "material ordering" in the technology linkage. Finally, commodities included in block (I), (J), (K) and (L) are basic commodities as intermediate inputs such as energy, auxiliary, repairs and services. From the viewpoint of these hierarchical structure of the technology, structure of the intermediate inputs among commodities shows a strong similarity in comparisons with the time-series of the input-output tables during the period 1960-95. We try to show two tables in 1960 and 1985 as Figure 1 and Figure 2, in which input coefficients in each transaction are plotted in the triangular order. We can recognize the inter-block hierarchy and intra-block hierarchy and the similarity of the relationships between the two tables.

[1] Precisely speaking, four tables in 1960, 1965, 1970 and 1975 were rearranged in the size of 301 commodity classification and five table in 1975,1980,1985,1990 and 1995 were classified into the size of 349 commodities. Both size of tables are linked in 1975.

Table 1: Industry Classiåcation and its Abbreviation

Block	Ind.No.	Industry Name	Abbreviation
A.Construction			
	(1)	Construction	Const.
B.Machinery			
b1	(2)	Transportation Equipment except Motor	Trasp.Eq.exp.Motor
b2	(3)	Motor Vehicle	Motor
b3	(4)	General Machinery	Machinery
b4	(5)	Electric Machinery	Elec.Mach.
b5	(6)	Electric Computer and Related	Computer
b6	(7)	Precision Instruments	Prec. Inst.
C.Other Final Manufacturing Products			
c1	(8)	Miscellaneous Manufacturing Products	Misc.Mng. Prod.
c2	(9)	Plywood	Plywood
c3	(10)	Electric Equipment for Industrial and Home Use	Elec. Equip.
D.Primary Metal Products			
d1	(11)	Steel Products	Steel
d2	(12)	Crude Steel	Clude Steel
d3	(13)	Pig Iron	Pig Iron
d4	(14)	Ferro Alloy	Ferro Alloy
d5	(15)	Nonferrous Metal Products	Nonferrous
E.Foods Products			
	(16)	Foods and Kindred Products	Foods
F.Stone and Clay			
	(17)	Stone and Clay Products	Stone Clay
G.Manufactring Products			
g1	(18)	Apparel Products	Apparel
g2	(19)	Textile Products(Natural Fiber)	Natural Fiber
g3	(20)	Textile products(Synthetic Fiber)	Synthetic Fiber
g4	(21)	Rubber and Leather	Rubber & Leather
g5	(22)	Paper and Pulp Products	Paper & Pulp
g6	(23)	Dissolving Pulp and Related Products	Dissolving Pulp
g7	(24)	Miscellaneous Mng. Products	Misc. Mng. Prod.
g8	(25)	Synthetic Resins for Fiber	Synthetic Resins
g9	(26)	Tar Chemicals	Tar Chemicals
g10	(27)	Petroleum Basic Products	Pet. Basic Prod.
g11	(28)	Inorganic Industrial Chemicals	Inorganic Chemic.
g12	(29)	Manures	Manures
g13	(30)	Coal Dry Distillation Products	Coal Dry Prod.
g14	(31)	Other Chemical Products	Other Chemic. Prod.
H.Raw Materials			
h1	(32)	Ore Mining	Ore mining
h2	(33)	Materials for Ceramics	Mat. for Ceramics
h3	(34)	Agricultural Products	Agric. Prod.
h4	(35)	Fisheries Products	Fisheris
h5	(36)	Livestock Products	Livestock Prod.
h6	(37)	Materials for Natural Textile	Mat. for Natiral Tex.
h7	(38)	Materials for Woods Products	Mat. for Woods Prod.
h8	(39)	Coal Mining	Coal Mining
h9	(40)	Crude Petroleum and Natural Gas	Crude Pet.
I.Secondary Energy			
i1	(41)	Electricity and Gas	Electric.& Gas
i2	(42)	Petroleum Reånery Products	Pet. Reånery
J.Auxialiary			
	(43)	Auxialiary	Auxialiary
K.Repairs			
	(44)	Repairs	Repairs
L.Services			
l1	(45)	Whole Sale and Retail	Trade
l2	(46)	Finance and Insurance	Finance
l3	(47)	Real Estate	Real Estate
l4	(48)	Transportation	Transportation
l5	(49)	Communication	Communication
l6	(50)	Other Miscellaneous Service	Misc. Service

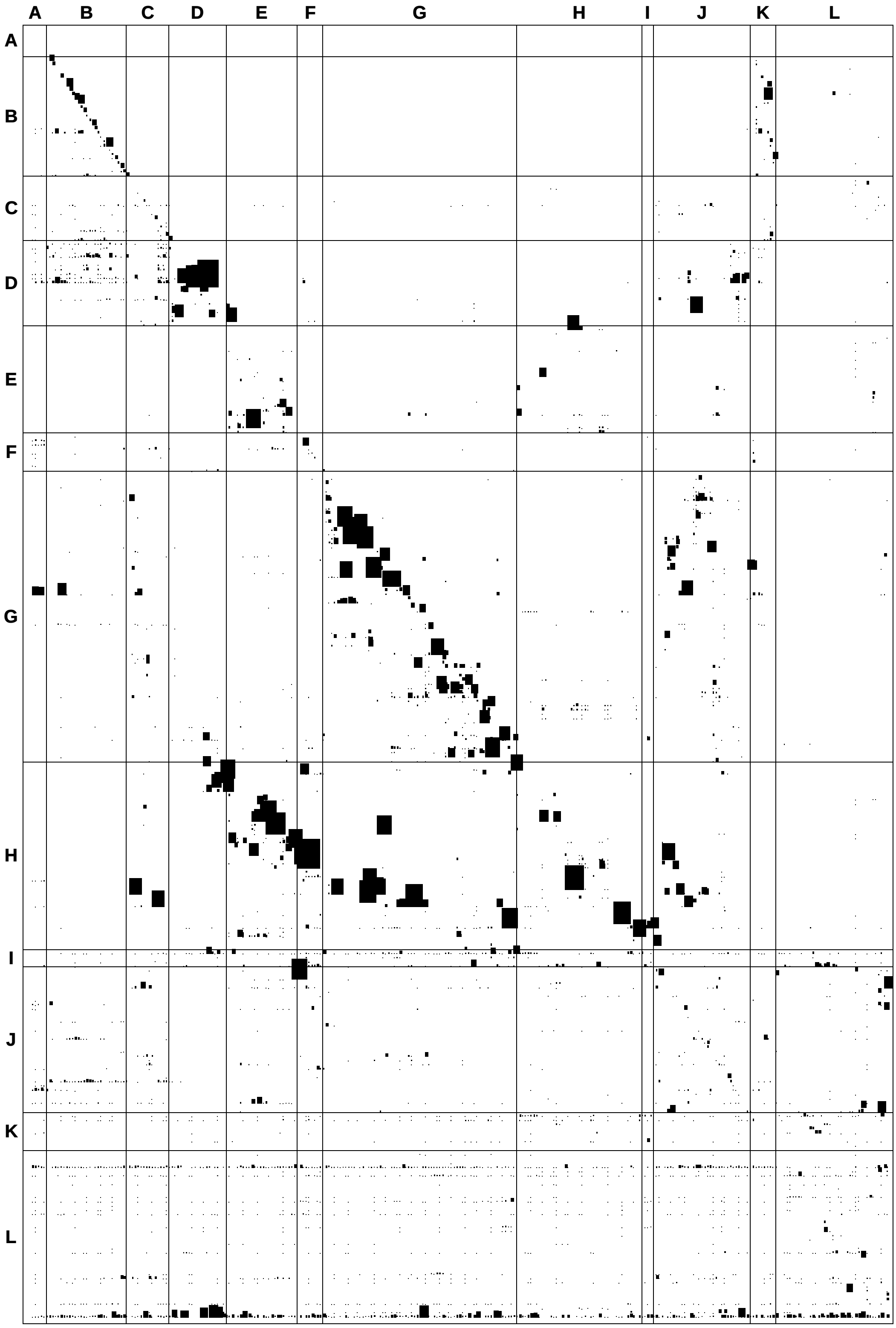

Figure 1: Input Coeécient in 1960 (301 commodities)

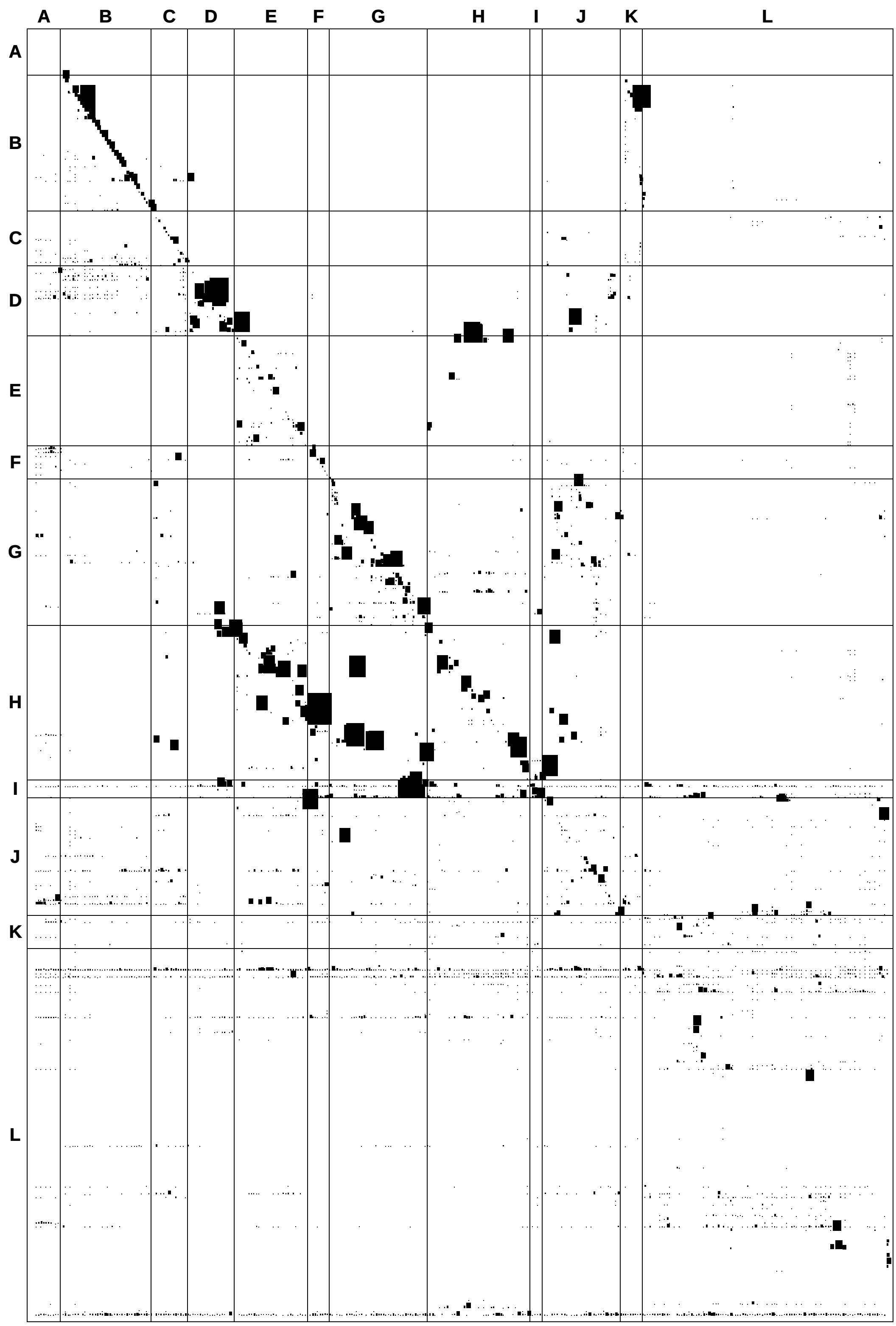

Figure 2: Input Coeécient in 1985 (349 commodities)

This stable pattern in the interdependency among intermediate input transaction could be reformulated by the stability of the following unit structure of a commodity. We will begin with the definition of "Static Unit Structure". In the static input-output framework, the system of production can be described in terms of input coefficient matrix, A_t, vector of final demand, F_t, vector of output, Z_t, vector of value added, V_t and unit vector, i as follows:

$$A_t Z_t + F_t = Z_t; \tag{1}$$

$$i' V_t = F_t i \tag{2}$$

If A_t is a non-singular matrix, we obtain the following equation system.

$$Z_t = (I - A_t)^{-1} F_t = B_t F_t \tag{3}$$

We will call the following equation the "Unit System" of the j_{th} commodity.

$$A_t \hat{B}_j i + f_j^* = B_j; \tag{4}$$

$$i' v^* = f_j^* i; \tag{5}$$

where $\hat{B}_j$ represents a diagonal matrix with the j_{th} column vector of inverse matrix $(I - A_t)^{-1}$ as elements, f_j^* stands for the final demand vector with unity as j_{th} element and zero as other elements and v^* is a row vector of the unit value added. In the system of the equation (4), the following matrix,

$$U^{(j)} = u_{ik}^{(j)} = A_t \hat{B}_j \tag{6}$$

is referred to as the "Static Unit Structure" peculiar to the j_{th} commodity. The technology of the economy is described by the compound system of the "Unit Structure" of the various commodities. Each unit structure of the j_{th} commodity represents the characteristics of the technology of the production. We can define the vectors of labor and capital inputs corresponding to the unit structure L_t and K_t, which represent the direct and indirect input requirements of labor and capital by sectors in the production of the final demand f_j^*.

2.2 Decomposition of Sources of Economic Growth

By using the framework in the growth accounting, we can decompose sources of the economic growth in Japan. Table 2 presents a summary of the sources of Japanese economic growth during the period 1960-92.

Table 2 shows the average annual rate of growth of output, inputs and productivity at the aggregated level as sources of the economic growth for the economy. Values in parentheses in the Table represent the ratio of the contribution to economic growth as sources. The first column represents the average annual rate of net aggregate output. It should be noted that while the average rate per year over the whole period 1960-92 reached more than 6.3%, it was remarkably higher (10.4%) during the period of high economic growth, 1960-72, compared with 3.9% per year after the period of the first oil crisis: 1972-92. According to the breakdown of the sources, contributions of labor, capital and productivity are shared out on average into 21%, 63% and 16%, respectively, during the whole period. One can see, however, that this average trend of the contribution of growth is completely different between the periods before and after the oil crisis. Before the oil crisis, it was one of the interesting features of the economy that the contribution of productivity growth was higher than 25%, while the contribution of productivity growth was negligible after 1972. Even during the period 1960-72, the contribution of productivity growth reached to 26% on average. During the same period, the contributions of capital and labor inputs were 56% and 18%, respectively. On the other hand, after the oil crisis, the contribution of capital inputs increased rapidly by 73%, and that of productivity decreased by about 20%. During the period before the oil crisis, the growth rates of labor and capital inputs were 3.37% and 12.55% annually, while that of output was 10.43%. This means that the partial productivity of labor increased rapidly during the high growth period at the cost of the partial productivity of capital. After the oil crisis, the growth rate of capital input was also higher than the growth rate of output, while the growth rate of labor input was even lower than that. In other words, we can say that the characteristics of the factor substitution between labor and capital have been dominant in Japan since 1960s. It is not necessarily a specific characteristic of recent technology. The contribution of productivity as a source of growth, however, declined to around 16% from 26% before the oil crisis. In particular, after 1990, the growth rate of labor input turned out to be negative, and that of capital input still continued to be higher than that of output. It is impressive that the substitution between labor and capital was rapidly encouraged during the recent period of the Japanese economy. The growth rate of total factor productivity was 1.04% per annum, on average, during the period 1960-92. Before the oil crisis, it was more than 2.78% annually, while after that it rapidly declined to an average negative rate each year.

Table 2: Sources of Economic Growth (annual growth rate(%))

	value added	labor		capital		TFP
		input	contribution	input	contribution	
	;$\frac{\dot{V}}{V}$	;$\frac{\dot{L}}{L}$	;$S_L \frac{\dot{L}}{L}$	;$\frac{\dot{K}}{K}$	;$S_K \frac{\dot{K}}{K}$	;v_T
1960-65	10.126	3.343	1.819	12.523	5.688	2.619
	(100)		(18)		(56)	(26)
1965-70	11.790	3.660	1.956	11.102	5.260	4.575
	(100)		(17)		(44)	(39)
1970-75	5.009	1.305	0.687	14.456	6.402	-2.080
	(100)		(14)		(128)	(-42)
1975-80	4.277	2.878	1.780	6.582	2.516	-0.019
	(100)		(42)		(59)	(-1)
1980-85	3.795	1.850	1.130	5.060	1.975	0.690
	(100)		(30)		(52)	(18)
1985-90	4.629	2.225	1.311	5.859	2.409	0.909
	(100)		(28)		(52)	(20)
1990-92	2.349	-0.554	-0.326	6.896	2.842	-0.167
	(100)		(-14)		(121)	(-7)
1960-72	10.425	3.372	1.814	12.553	5.829	2.781
	(100)		(18)		(56)	(26)
1972-92	3.887	1.737	1.050	7.053	2.849	-0.012
	(100)		(27)		(73)	(-0)
1960-92	6.339	2.350	1.336	9.116	3.967	1.036
	(100)		(21)		(63)	(16)

Table 3 represents the results of the breakdown of the sources of economic growth at the aggregate level. Concerning the growth rate of value-added, there were sizable contributions made by the allocational changes among the industrial sectors. The positive biases of the output allocation indicate that the efficiency of the economy would be improved by resource allocation. During the period before the oil crisis, almost one-third of the total growth of output was attributed to increases of the efficiency of the allocation. In particular during the period 1960-65, the contribution was fairly high. After the 1972 the weight of the contribution declined to a level of less than 15%. Especially, during the period 1985-90, it was seen to be negative. It would be expected that there were distortions, which disturbed the efficient allocation of the resources.

From the fourth column to the seventh in Table, we can see the results of the breakdowns of labor input: $\frac{\dot{L}^E}{L^E}$ represents the growth rate of the total man-hour labor force. $\frac{\dot{Q}_L}{Q_L}$, $\frac{\dot{A}_L}{A_L}$ and $\frac{\dot{I}_{LQA}}{I_{LQA}}$ represents the rate of qualitative change, the rate of allocational changes and the rate of their interactive effect respectively. The rate of qualitative changes of labor input was fairly stable and it had a positive effect of 0.7-0.8% annually. It meant that the qualitative change of labor input contributed an improvement

Table 3: Breakdown of the Sources of Economic Growth (annual growth rate)

	value added		labor input				capital input			
	$\frac{\dot{V}}{V}$	$\frac{\dot{A}_V}{A_V}$	$\frac{\dot{L}}{L}$	$\frac{\dot{Q}_L}{Q_L}$	$\frac{\dot{A}_L}{A_L}$	$\frac{\dot{I}_{LQA}}{I_{LQA}}$	$\frac{\dot{K}}{K}$	$\frac{\dot{Q}_K}{Q_K}$	$\frac{\dot{A}_K}{A_K}$	$\frac{\dot{I}_{KQA}}{I_{KQA}}$
1960-65	4.435	5.691	1.763	0.277	-0.192	1.495	6.502	0.726	-1.682	6.976
1965-70	9.957	1.833	2.613	0.885	-0.161	0.324	9.258	0.765	-1.432	2.511
1970-75	4.820	0.188	-0.431	1.176	-0.125	0.685	12.792	1.039	-2.153	2.778
1975-80	3.434	0.844	1.715	0.812	-0.013	0.364	6.318	0.063	-0.478	0.679
1980-85	3.572	0.224	0.529	1.056	0.019	0.247	4.964	-0.031	-1.237	1.364
1985-90	4.981	-0.352	1.591	0.463	-0.002	0.173	6.017	0.125	-1.199	0.917
1990-92	2.215	0.134	-1.250	0.661	0.007	0.028	7.179	0.103	-1.562	1.176
1960-72	7.387	3.038	1.954	0.722	-0.194	0.890	8.862	0.817	-1.643	4.517
1972-92	3.589	0.297	0.648	0.800	-0.002	0.291	6.863	0.192	-1.215	1.213
1960-92	5.013	1.325	1.137	0.771	-0.074	0.515	7.613	0.426	-1.376	2.452

in marginal productivity at a constant annual rate of 0.7-0.8%. On the other hand, the rate of change of the allocation of labor input among industries was mostly negative. As mentioned above, the negative changes of the allocational biases in labor input suggests that labor be shifted from industries with expensive labor costs to industries with less expensive labor costs. Consequently, this improved the total efficiency of resource allocation in the economy as a whole. We can observe the breakdown of the sources of capital input from the eighth column to the last in Table. The qualitative change of capital input was positive, but it was not constant like that of labor input. The rate of allocational changes of capital input among industries was seen to be negative. This means that the allocational changes of capital inputs contributed to an improvement in the efficiency of capital input in the economy as a whole. Specifically, qualitative change and allocational bias of capital input have gradually increased recently. Also, the interactive effect of qualitative change and allocational bias of capital input are sizable during the whole period.

Finally, we can conclude that in the process of the structural changes in Japan, partial labor productivity increased rapidly at the cost of increases in partial capital productivity as a result of the substitution between labor and capital. Consequently, since the increases of the labor productivity are cancelled out by the decreases of the capital productivity, efficiency increases by the measure of total factor productivity would be moderate.

2.3 Changes of Capital Coefficients

Our second observation comes from the time-series input-output tables of 43 sectors during the period 1960-92, which is based upon above official basic tables in every five years. Furthermore, we tried to estimate labor and capital inputs consistently with the 43 sector's input-output table. Especially, in order to describe the properties of the dynamic structural changes, we tried to estimate the capital stock matrices consistent with the 43 sector's input-output table during the period 1960-92. Here, we intend to focus on the dynamic changes of capital coefficients. We assume that all of the new technologies are originally embodied in the new investment, and changes of composition of capital stock might have an impact on the substitution of factor inputs and TFP growth. In order to analyze quantitatively the impact of new technologies embodied in capital formation on TFP growth, we should begin with the estimation of capital flow and stock matrices. Our estimated capital flow and stock matrices are divided into private and government owned enterprises; capital classified by industry; and social overhead capital unclassified by industry. Both private and government enterprises are classified by 43 industrial sectors, as shown in Table 4. On the other hand, capital formation in each industrial sector is classified by 78 types of capital goods as types of assets; which correspond to the

Table 4: Industry Classification

No.of Sector	Industry Name	No.of Sector	Industry Name
1	Agri.Forestry and Fishery	2	Coal Mining
3	Other Mining	4	Construction
5	Food Manufacturing	6	Textile
7	Apparel	8	Woods and Related Products
9	Furniture and Fixture	10	Paper and Pulp
11	Publishing and Printing	12	Chemical Products
13	Petroleum and Refinery	14	Coal Products
15	Rubber Products	16	Leather Products
17	Stone and Clay	18	Iron and Steel
19	Non-ferrous Metal	20	Metal Products
21	Machinery	22	Electric Machinery
23	Motor Vehicle	24	Other Trasp. Machinery
25	Precision Instruments	26	Other Manufacturing
27	Railroad Transp.	28	Road Transp.
29	Water Transp.	30	Air Transp.
31	Storage Facility Service	32	Communication
33	Electricity	34	Gas Supply
35	Water Supply	36	Wholesale and Retail
37	Finance and Insurance	38	Real Estate
39	Education	40	Research
41	Medical Care	42	Other Service
43	Public Services		

commodity classification in the input-output table.[2] We estimated capital stock matrix that to be consistent with the flow matrices of capital formation.

Let us summarize the findings in the trends of the capital formation in Japan during the period 1955-92. Table 13 represents average annual rates of growth in capital stock of private enterprises by industry during the period 1955-90, where the period is divided into the following seven sub-periods; 1955-60, 1960-65, 1965 70, 1970-75, 1975-80, 1980-85, and 1985-90, in order to clarify features of the capital accumulation in the Japanese economy. According to the results in these Tables, growth rates of the private capital accumulation in all sectors (except water supply) since 1975 clearly slowed down in comparison with the rapid growth up to 1975, while those in 1980s gradually recovered in some sectors, such as electrical machinery, motor vehicle, precision instrument, communication, and education. Annual growth rates of capital stock during the three sub-periods since 1960 were significantly higher than those of labor input by sector in the same periods.[3] In particular, during the second sub-period 1960-65, twenty-eight sectors out of 43 sectors accomplished high growth of capital stock at more than 10% annually. These trends continued during the next two terms until 1975. After the oil crisis almost all industries (except electricity, gas, medical and other services) experienced a dramatic slowing down of growth in terms of capital stock.[4] During the fifth sub-period, 1975-80 growth rates of capital stock deteriorated by less than half of the growth rate in the previous sub-periods by sectors. During the period 1955-75 capital input by sector grew rapidly, showing a higher growth rate more than the historical standard of the Japanese economy. After 1980, capital formation by sector gradually recovered. Annual growth rate of capital stock increased in sixteen industries during the period 1980-85 and in twenty-six industries after 1985. It is one of the

[2] Commodity classification of capital goods corresponds to the commodity in the Basic Japanese Input-Output Table classified by 541 commodities and capital goods are divided into 78 commodities in the table.

[3] See Table 3.

[4] In Japan where more than 90 % of the energy sources are imported, the impact of the oil crisis was unexpectedly serious. Trends of capital formation in almost all of industries were shifted downward. The few exceptions such as electricity, gas, medical and other service were due to the investment promotion policy in utility sectors, supported by government, in order to avoid a serious deterioration of the economy.

interesting characteristics of the economy that the capital formations in the specific industries such as electrical machinery, precision machinery and communications increased rapidly after 1985.[5]

Capital stock matrices at 1985 constant prices are estimated for every year during the period 1955-92. The matrix consists of 43 commodities in column, and 43 industries in row. 43 commodities are aggregated into twelve types of asset: 1.Animal and plants, 2.Construction, 3.Apparel, 4.Woods products, 5.Furniture, 6.Metal products, 7.Machinery, 8.Electric machinery, 9.Motor vehicle, 10.Other transportation equipment, 11.Precision instruments, and 12.Miscellaneous products. Capital coefficients are defined as follows:

$$b_{ij} = K_{ij}/Z_j; \quad (i = 1; \ldots; 12; j = 1; \ldots; 43). \tag{7}$$

We can recognize structural changes from trends of capital coefficients by industry. The volume of coefficients designates the degree of capital intensity in industry, and the trend or change of coefficients during the periods represents the patterns of the structural changes, in terms of capital intensity, or capital productivity. We assume properties of recent new technologies are embodied in the new capital formation and accumulated in the capital stock. Properties embodied in capital should be reflected in changes of capital coefficients as structural parameters. We can investigate the changes of capital coefficients preliminary. Figure 3 represents change of capital coefficients at the macro level during the period 1955-92, where the poll in figure stands for the level of capital coefficient and number in each poll corresponds to the asset types classified into twelve categories. We can observe that capital coefficients at the macro level increased from 1.5 in 1955 to 2.5 in 1992 and, moreover, compositions of machinery and electrical machinery among assets have gradually increased, instead of building and construction. The figures also show the relationship between real value added and volume of capital stock by a solid line (*) during the period 1960-92. This also represents a rapid increase in capital-output ratio in terms of value-added base.

When it comes to the development of technologies, we should focus on observations at the industry level instead of macro level. We can detect certain typical changes of coefficients by industries: 1.agriculture, 4.construction, 6.textile, 18.iron, 21.machinery, 22.electric machinery, and 23.motor vehicle. Capital coefficients in agriculture increased rapidly from 0.3 in 1960 to 3.0 in 1992 in terms of the sum of coefficients, which suggests that capital productivity has been declining historically. Growth rates slightly decreased during the first half of the 1980s, but recovered during the last half of the 1980s. Although the capital coefficient of machinery has been increasing rapidly, more than 70% of assets are shared by construction. We have to note in the agricultural sector that capital accumulation, especially for construction, owed mainly to that in government enterprises. Capital productivity in the construction sector has also been declining gradually, and the assets mostly consist of own products. In the textile industry changes of coefficients were more characteristics, where they were fairly stable in the 1960s and shifted higher in the 1970s and then continued to increase gradually in the 1980s. Volume of coefficients changes from 0.2 in 1960 to 0.7 in 1992. Recently we can observe rapid increases of capital coefficient in machinery and electrical machinery in the textile industry. In the iron and steel industry, capital coefficients increased from 0.2 in 1960 to 1.0 in 1992, where the rate of increase slowed down, especially after 1985. Here again, the shares of machinery and electrical machinery in assets have increased, while the share of construction has been declining recently. In machinery, the level of capital coefficients in total capital stock shifted after the oil shock from 0.3 to 0.5, where decreases of capital coefficients for construction instead of increases of those in electrical machinery after 1975 are one of the specific characteristics. Electrical machinery is an exceptional example where the capital coefficients showed a decreasing trend from the beginning of the 1960s. This means that in the electrical machinery sector capital productivity increased rapidly. After 1975, capital coefficients of input for construction in electrical machinery sector were decreasing gradually,

[5] Japan National Railway and National Telecommunication Company were privatized in 1987 and 1985 respectively. Growth rates of both industries in Table 13 include their impacts.

while those from electrical machinery were increasing rapidly. Capital coeécients of motor vehicles were relatively stable, although after 1975 they indicate a gradually declining trend. While total volume of capital coeécient in motor vehicle were stable, the composition of capital coeécient has been changed remarkably, where coeécient of construction has been decreasing and coeécients of machinery and electric machinery increased rapidly in the recent years.

Capital coeécients for private and government capital including social overhead capital have been changing since 1960. In particular, capital asset shares of machinery and electrical machinery instead of those of construction have been increasing rapidly in almost all sectors recently. Simultaneously, we must note that capital productivity in machinery and electrical machinery sectors have improved historically, and that such trends of capital productivity in these sectors were really rare exceptions among 43 industries. It seems to be one of the important characteristics of the recent movement of capital formation. In the economy, changes of capital coeécients have an impact on the changes of input coeécients in intermediate and labor inputs as a system of the economy, and, ånally, the production eéciency in terms of TFP growth measure.

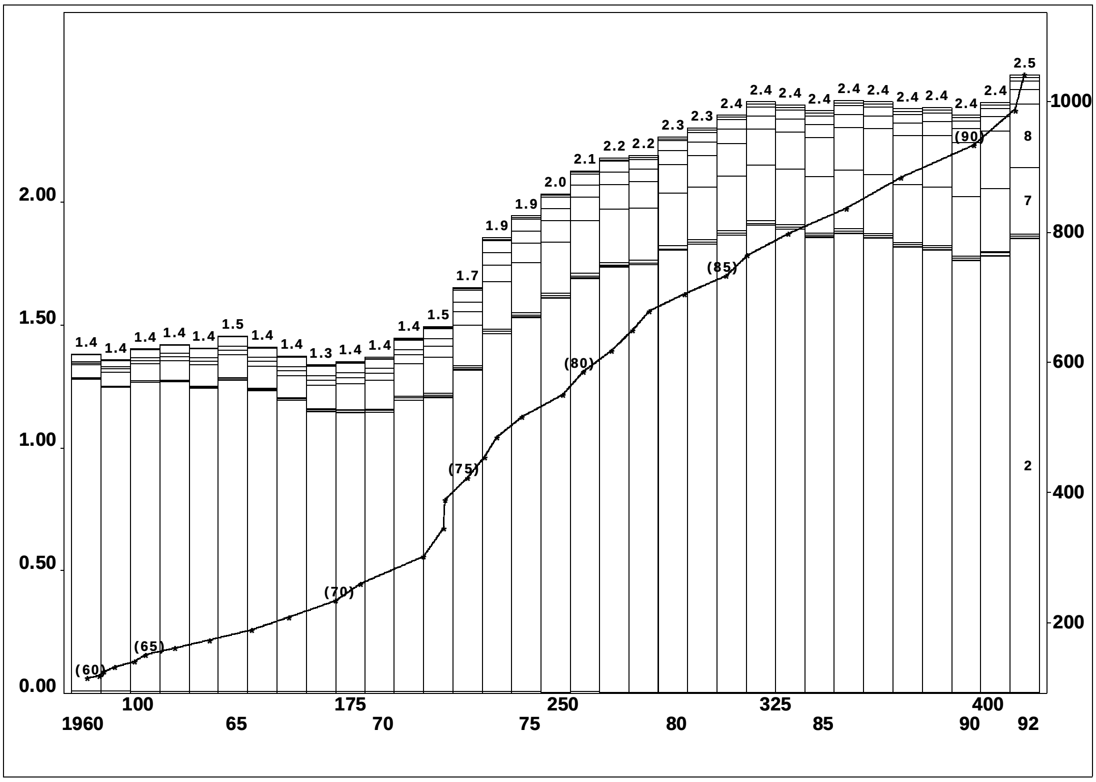

Figure 3: Trends of Capital Coefficients and Changes of Capital Composition

Note:

1)Dotted line:Plots in time-series of real value-added(x-axis) and capital stock(y-axis), where x-axis is measured by the upper scale in the bottom with the unit of trillion yen at 1985 constant price and y-axis is measured by the scale in the right-hand side with the unit of trillion yen at 1985 constant price.

2)Poll figure:Trend of capital coefficients in the time-sereis during the period 1960-92, where x-axis represents the year in the lower scale of the bottom and y-axis is measured by the scale of the capital coefficeints by the left-hand side. Numbers in the poll figure represent the number of capital assets, where the capital assets are classified into twelve capital goods; 1.Animals/Plants; 2.Building & Construction; 3.Apparel; 4.Wood Products; 5.Furniture; 6.Metal Products; 7.General Machinery; 8.Electric Machinery; 9.Motor Vehicles; 10.Other Tansport Equipment; 11.Precision Machinery; 12.Miscellaneous Products.

3 Unit Structure and Dynamic Spillover

According to our findings in the previous section, the composition of general and electrical machinery, as assets in capital formation and stock, increased rapidly in almost all sectors. Furthermore, the partial productivity of labor and capital, and probably the total factor productivity in general and electrical machinery sectors, by themselves improved significantly. It is to be easily expected that the basic knowledge of the new technologies might be embodied in the capital goods, such as general and electrical machinery. Other sectors used to install the capital goods as part of their investment. New knowledge of recent technologies is diffused among sectors through their investment. Therefore, when it comes to evaluating the impacts of new technologies on productivity in each industrial sector, we have to evaluate direct and indirect impacts of productivity growth in the sectors, in which are embodied the new technologies, such as general and electrical machinery sectors, on productivity growth in other sectors. New technologies are expected to be embodied in commodities produced in general and electrical machinery sectors, and the new technologies are installed in other sectors through the investment of machinery, such as computer and information facilities. In other words, it suggests to us that we should consider the spillover effect on productivity measurement among sectors especially, and beyond the time periods dynamically.

We will return to our definition of the growth rate of total factor productivity at the macro level and begin to clarify the meanings of the definition of this measure from the viewpoint of the spillover effect of changes in productivity. By using the input-output framework of the economy, we can obtain the following relationship as a definition of the growth rate of TFP in an aggregated measure:

$$
\begin{aligned}
v_T^t &= \sum_j \frac{p_I^{jt} Z_I^{jt}}{p_V^t V^t} v_T^{jt} \\
&= \sum_i \frac{p_i^t f_i^t}{p_V^t V^t}\left(\frac{\dot{f}_i}{f_i}\right)^t - \sum_j \sum_l \frac{p_{Ll}^{jt} L_l^{jt}}{p_V^t V^t}\left(\frac{\dot{L}_l^j}{L_l^j}\right)^t - \sum_j \sum_k \frac{p_{Kk}^{jt} K_k^{jt}}{p_V^t V^t}\left(\frac{\dot{K}_k^j}{K_k^j}\right)^t \\
&= \sum_i \frac{p_i^t f_i^t}{p_V^t V^t}\left(\frac{\dot{f}_i}{f_i}\right)^t - s_L\left(\frac{\dot{L}}{L}\right)^t - s_K\left(\frac{\dot{K}}{K}\right)^t . \qquad (8)
\end{aligned}
$$

This is a measure of the growth rate of TFP at the macro level as defined in section 2. The right-hand side of the second equation indicates that the measure of growth rate of TFP at the macro level is simultaneously explained as a difference between the aggregate measure of the growth rate of final demand and that of factor inputs including labor and capital. The aggregate measure of the growth rate of final demand is defined by a divisia growth rate index of final demand components weighted by nominal shares of each component in the nominal GDP. In order to clarify the meanings of the aggregate measure from viewpoints of the spillover effect of productivity changes, we should connect a concept of "unit structure" in section 2 with TFP. By using this concept, we can clarify the inter-dependent relationships among commodities as characteristics of the specific commodity production technology(Ozaki[1984]). A unit structure of the specific commodity represents the internal linkages among production directly and indirectly, which are described by intermediate input coefficients, A_t and factor input coefficients such as labor and capital, l_t and k_t. In this concept, we can define the static measure of the production efficiency for a specific commodity, where the measure defined here is closely related to the traditional measure of "Total Factor Productivity".

The technology of the economy is described by the compound system of the 'unit structure' of the various commodities. Each unit structure of j-th commodity represents the characteristics of the technology involved in production. If we can give factor input coefficients such as labor and capital, l_t and k_t, we can define the vectors of labor and capital inputs corresponding to the unit structure L_t and K_t. These represent the direct and indirect input requirements of labor and capital by sectors in the production of the final demand f_j^{*}. We understand that a 'unit structure' for j-th commodity represents the direct and indirect input requirements in terms of intermediate inputs, labor and capital inputs which are needed to supply one unit of final demand of j-th commodity. We can define a measure of the production efficiency of any $k_{th}(k = 1; \ldots; n)$ sector in the production system based upon `unit structure' for j-th commodity production as follows:

$$v^{jt}_{Tk} = \left(\frac{\dot{Z}^j_{Ik}}{Z^j_{Ik}}\right)^t - \sum_i s^{jt}_{xik}\left(\frac{\dot{X}^j_{ik}}{X^j_{ik}}\right)^t - s^{jt}_{Lk}\left(\frac{\dot{L}^j_k}{L^j_k}\right)^t - s^{jt}_{Kk}\left(\frac{\dot{K}^j_k}{K^j_k}\right)^t; \tag{9}$$

where Z^j_{Ik}, X^j_{ik}, L^j_k, K^j_k represent output, intermediate inputs, labor and capital inputs of k-th commodity which are needed to supply one unit of j-th final demand, directly and indirectly, and s^j_{xik}, s^j_{Lk}, s^j_{Kk} stand for the cost share of each input respectively. We should note that the TFP measure defined by equation (9) exactly corresponds to an ordinary measure of sectoral TFP. Furthermore, we can define an aggregate measure of the production efficiency in the framework of unit structure as follows:

$$\begin{aligned} v^t_{Tj} &= \sum_k \frac{p^{kt}_I Z^{kt}_I}{p^t_V V^t} v^{jt}_{Tk} \\ &= \left(\frac{\dot{f}^*_j}{f^*_j}\right)^t - \sum_k \frac{L^{jt}_k p^t_{Lk}}{p^t_V V^t}\left(\frac{\dot{L}_k}{L_k}\right)^t - \sum_k \frac{K^{jt}_k p^t_{Kk}}{p^t_V V^t}\left(\frac{\dot{K}_k}{K_k}\right)^t; \end{aligned} \tag{10}$$

where p^{kt}_I represents output price of k-th commodity and $p^t_V V^t$ stands for aggregate nominal value-added, which is defined by the sum of sectoral labor and capital compensations, $\sum_k L^{jt}_k p^t_{Lk}$ and $\sum_k K^t_k p^t_{Kk}$. v^t_{Tj} is an aggregate measure of the production efficiency in term of the unit structure of j-th commodity. This measure designates the production efficiency of j-th commodity production, where the production efficiency is evaluated as a measure of the total factor productivity and as a system, which is needed to supply one unit of j-th commodity as final demand. Aggregate measure of TFP growth has to be distinguished from growth rate of TFP in the ordinary measure at the macro level. The measure defined here corresponds to an aggregate measure of production efficiency in terms of the unit structure of j-th commodity. We will refer to this measure, v^t_{Tj}, as a `static unit TFP on j-th commodity as its unit structure.

In the framework of static unit TFP, we can give a final demand vector, f instead of f^*_j. Here, f stands for a final demand vector which corresponds to the composition of final demand such as consumption, fixed capital formation, exports, etc. We can define the aggregate measure corresponding to (10), which suggests a `static unit TFP on a specific final demand components as a vector'. In particular, if we give total final demand vector as corresponding to GDP as f, the definition of the aggregate measure (10)is back to the definition of the growth rate of TFP defined in (8).

The above concept of `unit structure' and `static unit TFP' aims to measure the production efficiency of j-th commodity in the specific time period t. The production of j-th commodity at the year t is restricted by the technology that is embodied in the capital stock at the beginning of the period. Capital stock in the production has already been accumulated over past period as a result of the investment. Each investment at a certain time in the past period used to embody the knowledge of the technology at that time. Therefore, the productivity at a certain time for the production of j-th commodity is presumably a result in which all of the knowledge in the past is accumulated through a series of investments. Focussing on the historical perspective of the capital accumulation, we can define a dynamic concept of the spillover effect of productivity change. We try to formulate a dynamic measure of the growth rate of TFP embodied in the dynamic production process to realize one unit of the final demand, f^{t*}_j.

We will turn again to the basic definition of an aggregate measure of the growth rate of TFP, (8). In this definition, a term, $\left(\frac{\dot{K}}{K}\right)^t$ represents a divisia growth rate of capital service input at the macro level. We assume that the volume of capital service is proportional to the amount of aggregate capital stock at the beginning of the year t. Aggregate capital stock has been accumulated by the capital formation in the past years. The capital formation in each time period of the past was characterized by the technological structure at that time. If there is some installation of facilities embodied within new technologies, it could be influenced by the capital service flow induced from the accumulated capital stock, and the efficiency through input of the capital service in the production process.

We assume a proportional relationship between quantity of capital service at the year t and capital stock at the beginning of the year t at the macro level. Also, we assume the following relationship between capital stock at the beginning of the year t and t-1 and capital formation, I^{t-1} at the year t-1:

$$S^t = (1-\delta)S^{t-1} + I^{t-1}. \tag{11}$$

Differentiating (11) logarithmically with respect to the time t,

$$\left(\frac{\dot{K}}{K}\right)^t = \left(\frac{\dot{S}}{S}\right)^t = (1-\delta)\frac{S^{t-1}}{S^t}\left(\frac{\dot{S}}{S}\right)^{t-1} + \frac{I^{t-1}}{S^t}\left(\frac{\dot{I}}{I}\right)^{t-1}; \tag{12}$$

where δ stands for the rate of depreciation.

On the other hand, we can define the similar relationship of the growth rate of TFP in the previous year t-1 as (8) as follows:

$$\begin{aligned} v_T^{t-1} &= \sum_j \frac{p_i^{j\,t-1} Z_i^{j\,t-1}}{p_V^{t-1} V^{t-1}} v_T^{j\,t-1} \\ &= \sum_i \frac{p_i^{t-1} f_i^{t-1}}{p_V^{t-1} V^{t-1}}\left(\frac{\dot{f}_i}{f_i}\right)^{t-1} - \sum_j\sum_l \frac{p_{Ll}^{j\,t-1} L_{Ll}^{j\,t-1}}{p_V^{t-1} V^{t-1}}\left(\frac{\dot{L}_{Ll}^j}{L_{Ll}^j}\right)^{t-1} - \sum_j\sum_k \frac{p_{Kk}^{j\,t-1} K_{Kk}^{j\,t-1}}{p_V^{t-1} V^{t-1}}\left(\frac{\dot{K}_{Kk}^j}{K_{Kk}^j}\right)^{t-1}. \end{aligned}$$

When we consider the dynamic production process needed to satisfy a unit of final demand at the year t, f_j^{t*}, real volume of the final demand at the year t-1 should be equal to real capital formation at the year t-1 enough to satisfy the capital service demand at the year t. Then we assume the following equation:

$$\left(\frac{\dot{I}}{I}\right)^{t-1} = \sum_i \frac{p_i^{t-1} f_i^{t-1}}{p_V^{t-1} V^{t-1}}\left(\frac{\dot{f}_i}{f_i}\right)^{t-1}. \tag{13}$$

Rearranging the definition of the growth rate of capital service at the macro level by using (13) and (12),

$$\begin{aligned} &\sum_j\sum_k \frac{p_{Kk}^{jt} K_{Kk}^{jt}}{p_V^t V^t}\left(\frac{\dot{K}_{Kk}^j}{K_{Kk}^j}\right)^t \\ &= \frac{p_K^t K^t}{p_V^t V^t}\left[(1-\delta)\frac{S^{t-1}}{S^t}\left(\frac{\dot{S}}{S}\right)^{t-1} + \frac{I^{t-1}}{S^t}\left\{v_T^{t-1} + \frac{p_L^{t-1}L^{t-1}}{p_V^{t-1}V^{t-1}}\left(\frac{\dot{L}}{L}\right)^{t-1} + \frac{p_K^{t-1}K^{t-1}}{p_V^{t-1}V^{t-1}}\left(\frac{\dot{K}}{K}\right)^{t-1}\right\}\right] \\ &= \frac{p_K^t K^t}{p_V^t V^t}\frac{I^{t-1}}{S^t} v_T^{t-1} + \frac{p_K^t K^t}{p_V^t V^t}\frac{I^{t-1}}{S^t}\frac{p_L^{t-1}L^{t-1}}{p_V^{t-1}V^{t-1}}\left(\frac{\dot{L}}{L}\right)^{t-1} \\ &\quad + \frac{p_K^t K^t}{p_V^t V^t}\left\{(1-\delta)\frac{S^{t-1}}{S^t} + \frac{I^{t-1}}{S^t}\frac{p_K^{t-1}K^{t-1}}{p_V^{t-1}V^{t-1}}\right\}\left(\frac{\dot{S}}{S}\right)^{t-1}. \end{aligned} \tag{14}$$

Capital stock at the beginning of the year t-1 can be formulated similarly as (12),

$$\left(\frac{\dot K}{K}\right)^{t-1} = \left(\frac{\dot S}{S}\right)^{t-1} = (1-\delta)\frac{S^{t-2}}{S^{t-1}}\left(\frac{\dot S}{S}\right)^{t-2} + \frac{I^{t-2}}{S^{t-1}}\left(\frac{\dot I}{I}\right)^{t-2}. \tag{15}$$

On the other hand, we can define a static measure of growth rate of TFP at the year t-2 by definition of (13) as follows:

$$\begin{aligned} v_T^{t-2} &= \sum_j \frac{p_I^{j\,t-2} Z_I^{j\,t-2}}{p_V^{t-2} V^{t-2}} v_T^{j\,t-2} \\ &= \sum_i \frac{p_i^{t-2} f_i^{t-2}}{p_V^{t-2} V^{t-2}}\left(\frac{\dot f_i}{f_i}\right)^{t-2} - \sum_j\sum_l \frac{p_{Ll}^{j\,t-2} L_l^{j\,t-2}}{p_V^{t-2} V^{t-2}}\left(\frac{\dot L_l^j}{L_l^j}\right)^{t-2} - \sum_j\sum_k \frac{p_{Kk}^{j\,t-2} K_k^{j\,t-2}}{p_V^{t-2} V^{t-2}}\left(\frac{\dot K_k^j}{K_k^j}\right)^{t-2}. \end{aligned}$$

Therefore if we can assume the equality between real volume of the final demand and the capital formation at the year t-2, we can deduce the following equation as for the third item of the second equation in (14):

$$\begin{aligned} &\frac{p_K^t K^t}{p_V^t V^t}\left\{(1-\delta)\frac{S^{t-1}}{S^t} + \frac{I^{t-1}}{S^t}\frac{p_K^{t-1}K^{t-1}}{p_V^{t-1}V^{t-1}}\right\}\left(\frac{\dot S}{S}\right)^{t-1} \\ &= \frac{p_K^t K^t}{p_V^t V^t}\rho^{t-2} \\ &\quad \left[(1-\delta)\frac{S^{t-2}}{S^{t-1}}\left(\frac{\dot S}{S}\right)^{t-2} + \frac{I^{t-2}}{S^{t-1}}\left\{v_T^{t-2} + \frac{p_L^{t-2}L^{t-2}}{p_V^{t-2}V^{t-2}}\left(\frac{\dot L}{L}\right)^{t-2} + \frac{p_K^{t-2}K^{t-2}}{p_V^{t-2}V^{t-2}}\left(\frac{\dot K}{K}\right)^{t-2}\right\}\right] \\ &= \frac{p_K^t K^t}{p_V^t V^t}\rho^{t-2}\frac{I^{t-2}}{S^{t-1}}v_T^{t-2} + \frac{p_K^t K^t}{p_V^t V^t}\rho^{t-2}\frac{I^{t-2}}{S^{t-1}}\frac{p_L^{t-2}L^{t-2}}{p_V^{t-2}V^{t-2}}\left(\frac{\dot L}{L}\right)^{t-2} \\ &\quad + \frac{p_K^t K^t}{p_V^t V^t}\rho^{t-2}\left\{(1-\delta)\frac{S^{t-2}}{S^{t-1}} + \frac{I^{t-2}}{S^{t-1}}\frac{p_K^{t-2}K^{t-2}}{p_V^{t-2}V^{t-2}}\right\}\left(\frac{\dot S}{S}\right)^{t-2}, \end{aligned} \tag{16}$$

where

$$\rho^{t-2} = (1-\delta)\frac{S^{t-1}}{S^t} + \frac{I^{t-1}}{S^t}\frac{p_K^{t-1}K^{t-1}}{p_V^{t-1}V^{t-1}}. \tag{17}$$

Finally, we can trace backward the process of capital accumulations which is required to satisfy the unit of final demand in year t. Since the capital formation invested in the year $\tau(\tau = t-1, \ldots, -\infty)$ is assumed to embody the technology at that time, we can evaluate, dynamically, the impact of the growth of efficiency improvement brought about by the installation of new technology by the aggregate measure of static TFP in the following formulation:

$$\begin{aligned} \left(\frac{\dot T}{T}\right)^t &= v_T^t + \frac{p_K^t K^t}{p_V^t V^t}\sum_{\tau=t-1}^{-\infty}\rho^\tau\frac{I^\tau}{S^{\tau+1}}v_T^\tau \\ &= \sum_i \frac{p_i^t f_i^t}{p_V^t V^t}\left(\frac{\dot f_i}{f_i}\right)^t - \frac{p_K^t K^t}{p_V^t V^t}\sum_{\tau=t-1}^{-\infty}\rho^\tau\frac{I^\tau}{S^{\tau+1}}\frac{p_L^\tau L^\tau}{p_V^\tau V^\tau}\left(\frac{\dot L}{L}\right)^\tau, \end{aligned} \tag{18}$$

where

$$\rho^\tau = \begin{cases} 1 & (\tau = t-1) \\ \rho^{\tau+1}\left\{(1-\delta)\frac{S^{\tau+1}}{S^{\tau+2}} + \frac{I^{\tau+1}}{S^{\tau+2}}\frac{K^{\tau+1}p_K^{\tau+1}}{p_V^{\tau+1}V^{\tau+1}}\right\} & (\tau = t-2, \cdots, -\infty) \end{cases} \tag{19}$$

We refer to this measure $\left(\frac{\dot{T}}{T}\right)_t$ as growth rate of `dynamic unit TFP'. By using the concept of `dynamic unit TFP', we can recognize the impact of structural changes in the intermediate input, labor and capital inputs on certain specific commodity production as a production system, as a whole, in the economy. As mentioned above, the recent trend of capital coefficients indicates that the share of machinery and electrical machinery has increased rapidly. Productivity changes in industries which could implement the newly developed technology are expected to have an impact on the productivity changes in all of other sectors, directly and indirectly through the dynamic process of the capital formation in each sector.

4 Structural Change and Trends of Efficiency in Japan

We begin with a comparison between ordinary measures of growth rate of sectoral TFP and the growth rate of static unit TFP as unit structure of j-th commodity as shown in Tables 5 and 6, respectively. Ordinary measures of sectoral TFP, represent the efficiency of j-th commodity production of its own. On the other hand, static unit TFP, based upon unit structure, indicates the total efficiency in j-th commodity production, where we can evaluate the efficiency of direct and indirect linkages of the technology as a system of j-th commodity production. According to the results shown in Table 5, high growth of TFP in the 1960s rapidly deteriorated during the first half of the 1970s in almost all industries. After a slight recovery during the second half of the 1970s was observed in some sectors, growth of TFP turned out to be lower again during the second half of the 1980s. It should be noted, however, that there were some exceptional sectors such as chemical, rubber products, metal products, machinery, electrical machinery, precision instruments, communication and trade, where TFP grew at a stable rate during these periods. On the other hand, according to the results shown in Table 6, efficiency based upon unit structure seems to be exaggerated by the interdependency of the production linkages. During the first half of the 1970s, when TFP growth in almost all of sectors deteriorated, growth rates of `static unit TFP' worsened in comparison with those of ordinary TFP in almost all industries except rubber products. Conversely, in the 1980s, growth rates of static unit TFP indicated a smooth recovery of production efficiency in many sectors. This suggests that efficiency gains in the sectors in which the efficiency of their own technology has improved could compensate for efficiency loss in the sectors in which they're own efficiency has deteriorated. Especially, it might be expected that there were some leading sectors where the production efficiency increased rapidly in recent years. For example, in the agricultural sector, its growth rates of static unit TFP have been compensated by the technology linkages to other sector during these periods, except the first half of the 1970s; while its own efficiency has deteriorated during the whole period; except the period 1980-85. In machinery and electrical machinery, the efficiency gain increased in the unit measures rather than in its own measure during the whole periods.

Let us turn to the dynamic approach. By using the framework of the dynamic inverse, we can estimate sectoral output requirements in the past which are needed to supply a certain amount of final demand in the reference year. Dynamic output requirements for the final demand of one dollar's worth of all commodities in the past have diminished until the last eight to ten years. The value of the dynamic multiplier in investment goods such as construction, chemical, stone, iron, metal, machinery, electrical machinery and vehicles, and services, continues to remain fairly high. We can estimate a measure of dynamic unit TFP defined in equation (18), in which we can evaluate, dynamically, the total efficiency of the production which is directly, and indirectly, required to supply one unit of j-th commodity final demand at the year t. Table 7 shows the results. Since dynamic impacts of production chains for one unit of production of j-th commodity of final demand seem to diminish until the past ten years past; and, as mentioned above, our estimates of dynamic aggregate TFP can be evaluated after the period 1970. In Table 7 we can show the annual growth rate of this measure for every five years since 1970 in each sector.

The results are shown in Table 7. Each value in the table represents the average annual growth rate of dynamic unit TFP as a measure of the impact of structural change during each sub-period. The growth rate is evaluated by the difference per year between the dynamic unit TFP corresponding to the structure of the beginning year, and that of the ending year in each sub-period. Then, each value in the table indicates the degree of the annual impact by the structural changes during each sub-period. According to our results, the impact of structural changes was fairly high in every sector. We try to focus upon the recent impacts of new technologies on TFP growth during the period 1985-90. As mentioned above, the values of capital coefficients of machinery and electrical machinery have rapidly increased in almost all of sectors, in which these changes of composition in capital coefficients are expected to embody recent new development of technologies in production. In spite of this hypothesis, it is quite difficult to detect the impact on productivity growth in the results of ordinary measures of TFP growth, as shown in the last column of Table 5. In 23 out of 43 sectors, annual growth rates of TFP in the ordinary measures deteriorated during the period 1985-90 rather than in the previous sub-period. It might suggest that there are initial intuitive questions regarding the so-called `productivity paradox' in recent years. When it comes to focussing upon the measures defined by the static unit TFP (as shown in Table 6), the number of industries showing a deterioration of TFP growth during the period 1985-90 decreased from twenty-three in the ordinary measures to twenty in the static unit TFP measures. On the other hand, if we try to measure TFP growth in the dynamic unit TFP concept (as shown in Table 7), the deterioration of TFP growth can be observed only in eleven of 43 sectors. In comparison with the static unit TFP, the dynamic unit TFP represents an improvement of production efficiency in almost all sectors, except coal mining, coal products and real estate. We can conclude that there was fairly dominant impact of new technologies on TFP growth even in these sectors. This can be verified by changes of capital coefficients, especially capital coefficients of machinery and electric machinery in which is expected to be embodied new technologies in recent years.

Finally, we can evaluate the impact of new technology development on the productivity growth at the macro level by using the framework of static and dynamic TFP measures. In order to evaluate these impacts at the aggregate level, we can estimate measures of static and dynamic TFP growth rates by giving one unit of final demand along with observed weights of commodities in a specific final demand instead of one unit of a special commodity as a final demand. As weights of commodities in final demand, we can select alternative weights on consumption, investment, export and total domestic final demand as final demand, respectively. By using the formulations, (10) and (18) separately, we can estimate TFP growth rates at the macro level, in terms of the static and dynamic TFP measures, in order to realize one unit of the specific final demands such as consumption, investment, export and total domestic final demand. Table 8 represents the results. The first row in Table 8 represents the growth rates of the ordinary TFP measure at the macro level. We can confirm, from result of the trend of the ordinary TFP measures, that the growth rate of TFP declined at the beginning of the 1970s, and continued at a lower stable level after 1975; even if a slight recovery could be observed after 1985. In the ordinary measure of TFP, we cannot identify the impact of new technology on the productivity growth at the macro level. It is because the deterioration of TFP growth needed to realize one unit of consumption contributed sharply to the decline of the TFP growth, in terms of total final demand. On the other hand, if we try to evaluate the TFP growth by dynamic measure at the macro level, we can observe a drastic recovery of TFP growth after 1975, especially after 1985. After 1975, the growth rate of TFP by the dynamic measure along with total final demand as weights increased continuously at annual average growth rates of 0.52%, 1.60% and 2.20% during the periods, 1975-80, 1980-85 and 1985-90 respectively. In the dynamic measure, TFP growth in terms of consumption as weights recovered gradually after 1975. Also, we can see that the TFP growth in terms of investment and export as weights completely recovered after 1975. It might be concluded that the impact of new technology on productivity growth should be evaluated to be sizable in terms of investments and exports, especially after 1975.

Table 5: Ordinary TFP (annual growth rate)

	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90	1970-90
1.Agriculture	-1.549	-4.079	-4.488	-3.077	1.263	-0.315	-1.654
2.Coal Mining	6.490	2.607	2.541	-2.115	0.717	-1.369	-0.056
3.Other Mining	4.013	8.934	-4.068	4.967	-2.450	2.512	0.240
4.Build.&Const.	-1.222	1.044	-0.639	-1.930	0.205	0.813	-0.388
5.Foods	-0.350	0.364	-1.394	1.851	0.247	-1.268	-0.141
6.Textile	0.885	1.305	0.756	1.429	0.937	1.515	1.159
7.Apparel	0.641	1.417	0.731	1.380	-0.137	-0.654	0.330
8.Woods	1.632	1.222	1.890	-3.298	4.409	-1.225	0.444
9.Furniture	-0.862	1.250	0.217	1.126	0.834	0.439	0.654
10.Paper&Pulp	2.144	2.463	-1.457	0.441	1.259	2.216	0.615
11.Publishing	-4.456	-3.501	-2.241	-0.216	0.066	0.832	-0.390
12.Chemical	2.672	4.712	-1.630	1.062	2.319	1.341	0.773
13.Petroleum	4.867	0.764	-5.757	-1.423	0.044	7.570	0.108
14.Coal Prod.	0.004	2.139	-5.109	-7.431	-0.010	2.018	-2.633
15.Rubber Prod.	3.282	3.534	-3.538	-0.600	2.860	3.045	0.442
16.Leather Prod.	3.212	-0.674	2.921	-2.232	1.550	-0.926	0.328
17.Stone&Clay	2.455	1.150	-2.122	0.682	0.971	1.038	0.142
18.Iron&Steel	0.218	1.991	0.035	0.828	-0.428	0.166	0.150
19.Non-ferrous	-0.402	1.035	2.951	2.224	2.007	0.260	1.861
20.Metal Prod.	2.171	3.634	-1.893	1.582	0.794	1.425	0.477
21.Machinery	-0.993	3.415	-1.624	3.105	1.413	0.456	0.838
22.Elec.Mach.	2.861	6.300	1.396	5.430	1.895	3.034	2.939
23.Vehicle	1.409	4.816	2.098	3.326	0.558	0.629	1.653
24.Oth.Trans.Mach.	4.577	1.189	-5.089	0.678	1.479	1.987	-0.236
25.Precision Inst.	3.027	4.960	0.186	6.220	1.527	-0.356	1.894
26.Misc.Mng.Prod.	2.511	3.960	-2.237	1.440	0.797	0.755	0.189
27.Railway	1.913	-2.511	3.900	-11.994	2.232	-2.088	-1.988
28.Road Trans.	2.731	4.781	-6.400	1.939	-2.365	0.091	-1.684
29.Water Trans.	-0.566	7.234	2.090	-2.196	4.152	-3.668	0.095
30.Air Trans.	4.061	9.564	8.874	-0.869	2.060	0.828	2.723
31.Storage	1.433	3.474	-5.768	8.065	0.601	0.009	0.727
32.Communication	1.814	2.139	0.937	2.138	5.679	2.808	2.891
33.Electricity	4.389	5.526	-3.162	-1.639	2.018	1.449	-0.334
34.Gas	3.549	1.178	0.673	-0.326	1.118	3.036	1.125
35.Water	-2.742	-3.143	-2.968	-5.937	0.061	-1.621	-2.616
36.Trade	5.571	5.524	-0.181	2.314	-0.296	3.454	1.323
37.Finance	5.465	1.270	-0.620	-0.677	3.671	0.839	0.803
38.Real Estate	5.596	-0.204	-2.993	-0.461	0.719	-0.433	-0.792
39.Education	0.867	3.563	0.994	-5.014	-3.558	-1.481	-2.265
40.Research	5.950	2.695	-2.707	4.041	-2.108	-0.236	-0.253
41.Medical Serv.	1.628	-0.592	5.186	-1.912	-1.262	-3.715	-0.426
42.Other Serv.	-5.507	1.719	-3.803	0.252	-0.776	-2.372	-1.675
43.Public Adm.	4.087	2.480	6.916	-4.955	-0.843	0.451	0.392

Table 6: Static Unit TFP (annual growth rate)

	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90	1970-90
1.Agriculture	-1.243	-3.888	-6.360	-3.241	2.082	0.072	-1.862
2.Coal Mining	7.135	4.615	0.514	-2.368	1.406	-1.024	-0.368
3.Other Mining	5.327	10.454	-5.503	5.447	-1.826	3.680	0.449
4.Build.&Const.	1.023	5.157	-2.623	-1.230	1.077	1.651	-0.281
5.Foods	-0.500	-0.364	-5.146	1.046	1.321	-1.014	-0.948
6.Textile	2.731	4.459	-1.120	2.404	2.769	3.284	1.834
7.Apparel	3.138	5.126	-0.589	2.656	1.179	1.095	1.085
8.Woods	1.689	0.269	-1.606	-5.074	6.337	-0.878	-0.305
9.Furniture	1.176	4.161	-1.525	0.731	2.725	1.093	0.756
10.Paper&Pulp	4.507	5.833	-4.524	0.205	3.282	4.150	0.778
11.Publishing	-3.017	-1.174	-4.458	-0.007	1.259	1.990	-0.304
12.Chemical	5.724	9.352	-4.811	1.777	4.266	2.806	1.010
13.Petroleum	5.056	1.094	-6.473	-1.417	0.272	8.168	0.138
14.Coal Prod.	3.187	5.328	-6.531	-8.716	0.650	2.474	-3.031
15.Rubber Prod.	5.544	7.420	-5.582	0.037	4.486	4.387	0.832
16.Leather Prod.	7.497	1.639	2.839	-2.525	3.134	-0.520	0.732
17.Stone&Clay	4.768	5.448	-4.899	1.663	1.438	2.277	0.120
18.Iron&Steel	2.314	7.936	-1.974	0.507	-0.051	1.071	-0.112
19.Non-ferrous	3.141	9.548	1.717	5.120	3.974	1.495	3.076
20.Metal Prod.	3.722	7.670	-3.200	2.226	1.353	2.141	0.630
21.Machinery	0.283	8.520	-3.196	5.639	2.768	1.404	1.654
22.Elec.Mach.	5.221	12.347	0.574	8.207	3.475	5.041	4.324
23.Vehicle	3.800	10.786	1.506	6.176	1.906	2.205	2.948
24.Oth.Trans.Mach.	6.874	5.901	-7.290	2.158	2.841	3.332	0.260
25.Precision Inst.	4.986	9.355	-0.556	8.395	2.873	0.391	2.776
26.Misc.Mng.Prod.	4.981	8.107	-4.854	2.135	2.663	2.020	0.491
27.Railway	3.608	-0.773	1.675	-11.552	2.910	-1.924	-2.223
28.Road Trans.	3.822	6.436	-7.188	2.281	-2.016	0.665	-1.564
29.Water Trans.	0.411	10.121	2.473	-3.215	6.572	-3.793	0.509
30.Air Trans.	5.997	12.093	7.662	-0.949	3.172	1.894	2.945
31.Storage	1.796	4.571	-7.609	8.018	1.154	-0.122	0.360
32.Communication	1.984	2.655	0.250	2.305	5.695	2.822	2.768
33.Electricity	5.199	6.380	-4.926	-2.146	2.276	1.905	-0.723
34.Gas	4.518	2.484	-0.051	2.660	1.177	3.173	1.740
35.Water	-2.330	-2.060	-5.024	-6.487	1.017	-1.117	-2.903
36.Trade	6.539	6.946	-1.234	2.400	0.279	3.677	1.280
37.Finance	5.252	2.111	-1.709	-0.600	4.143	0.623	0.614
38.Real Estate	5.758	0.413	-3.360	-0.585	0.961	-0.422	-0.852
39.Education	0.607	4.487	0.511	-5.066	-3.403	-1.387	-2.336
40.Research	5.426	3.734	-3.938	4.046	-1.877	-0.181	-0.488
41.Medical Serv.	3.127	1.899	3.515	-1.480	-0.251	-2.903	-0.280
42.Other Serv.	-4.381	3.691	-5.600	0.451	-0.029	-1.876	-1.763
43.Public Adm.	4.971	3.769	5.889	-4.919	-0.514	0.641	0.274

Table 7: Dynamic Unit TFP (annual growth rate)

	1970-75	1975-80	1980-85	1985-90	1970-90
1.Agriculture	-5.730	-3.401	2.560	1.507	-1.266
2.Coal Mining	1.847	-1.952	2.406	0.108	0.602
3.Other Mining	-3.748	6.313	-0.475	5.215	1.826
4.Build.&Const.	-1.321	-0.762	1.861	2.943	0.680
5.Foods	-4.742	1.031	2.087	0.351	-0.318
6.Textile	-0.297	2.777	3.397	4.148	2.506
7.Apparel	0.310	2.955	1.750	2.050	1.766
8.Woods	-0.957	-5.043	6.890	0.305	0.299
9.Furniture	-0.525	0.938	3.358	2.352	1.531
10.Paper&Pulp	-3.255	0.947	4.337	5.649	1.919
11.Publishing	-3.410	0.511	2.119	3.142	0.590
12.Chemical	-3.485	2.438	5.212	4.476	2.160
13.Petroleum	-5.350	-1.120	0.621	9.331	0.871
14.Coal Prod.	-5.206	-9.425	2.017	4.406	-2.052
15.Rubber Prod.	-4.518	0.662	5.378	5.686	1.802
16.Leather Prod.	3.915	-2.242	3.839	0.662	1.543
17.Stone&Clay	-3.298	1.962	2.195	3.559	1.105
18.Iron&Steel	-0.450	1.244	1.062	2.806	1.165
19.Non-ferrous	3.626	5.448	4.933	2.998	4.251
20.Metal Prod.	-1.853	2.540	2.025	3.428	1.535
21.Machinery	-1.821	6.321	3.923	2.949	2.843
22.Elec.Mach.	2.427	8.843	4.398	6.658	5.582
23.Vehicle	2.716	6.941	2.970	3.453	4.020
24.Oth.Trans.Mach.	-5.673	2.624	3.669	4.484	1.276
25.Precision Inst.	0.738	9.082	3.867	1.664	3.838
26.Misc.Mng.Prod.	-3.717	2.639	3.548	3.443	1.478
27.Railway	2.441	-11.593	3.182	-0.747	-1.679
28.Road Trans.	-6.603	2.253	-1.802	1.572	-1.145
29.Water Trans.	5.115	-3.854	7.205	-2.409	1.514
30.Air Trans.	10.510	-1.258	4.060	3.474	4.197
31.Storage	-6.623	8.574	2.090	1.305	1.337
32.Communication	1.906	2.868	6.545	4.665	3.996
33.Electricity	-2.510	-1.588	3.291	4.364	0.889
34.Gas	1.402	3.484	1.796	4.534	2.804
35.Water	-3.906	-6.149	1.540	0.490	-2.006
36.Trade	0.281	2.810	0.953	4.931	2.244
37.Finance	-0.188	-0.049	4.965	2.183	1.728
38.Real Estate	-2.021	-0.435	1.837	2.355	0.434
39.Education	0.837	-4.953	-3.175	-0.893	-2.046
40.Research	-3.365	4.322	-1.437	0.624	0.036
41.Medical Serv.	5.103	-0.951	0.513	-1.592	0.769
42.Other Serv.	-4.029	1.117	0.970	-0.430	-0.593
43.Public Adm.	6.750	-4.692	-0.126	1.189	0.780

Table 8: Comparison of Alternative Measures of TFP at aggregated level(annual growth rate)

	Demand Item	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90
Ordinary TFP		2.360	4.831	-1.999	0.499	1.074	0.921
Static-	Consumption	2.146	2.850	-3.022	0.540	0.972	0.352
Unit-	Investment	1.841	6.436	-2.166	0.911	1.587	2.159
TFP	Export	2.947	7.601	-1.990	3.034	2.644	2.322
	Domestic F.D.	2.104	4.227	-2.141	0.172	0.902	0.824
Dynamic-	Consumption	—	—	-1.711	0.795	1.657	1.883
Unit-	Investment	—	—	-0.802	1.453	2.399	3.478
TFP	Export	—	—	-0.379	3.330	3.478	3.715
	Domestic F.D.	—	—	-0.814	0.523	1.601	2.200

5 Conclusion

In this paper we try to depict features of the structural changes in the Japanese economic growth during the last half of 20th century and clarify the characteristics of the technical progress from the viewpoints of the structural change. According to our decomposition of the sources of the economic growth, we can conclude that the Japanese economy fairly well-behaved regarding resource allocation along with the changes of relative prices. It implies that the economic structure was smoothly adjusted in Japan. We prepared two analytical framework: One is a concept of "material ordering" based upon the trianguralized input-output structure. Trianguralizing intermediate transations in input-output table, we can confirm that there exist clear linkages of the technology among commodities. Another is a concept as concerning characteristics of the technology such as total factor productivity and their spillover effect along with the technological linkage among commodities.

1. Each technology linkage is characterized by "material ordering", where every upper stream commodities are characterized by their specific raw materials from viewpoints of technology. We can observe significant differences of the rate of technical progress between growing commodities groups and declining commodities groups.

2. Structural adjustment was a process of the substitution of commodities groups in the economy. It supported certain specific commodity group in order to encourage its activity as a set of commodity groups along with material ordering.Also, it contributed to adjust declining industries without any frictions as possible. Industrial characteristics concerning growing or declining is highly correlated to the growth rate of technical progress in each commodity group. In the devepoling process in the Japanese economy, industrial policy supported to the growing industries including their commodity group with high growth rate of the technical progress such as metal products and machinery block. On the other hand, industrial policy also supported to the declining industries with low rate of the technical progress such as agricultural products, natural textile and wood material block. These policies promoted smoothly resource allocations among commodity groups.

3. When we tried to carefully measure qualitative changes of inputs and allocational biases of output and inputs, we could observe that the partial productivity of labor increased rapidly, while that of capital has deteriorated gradually since the 1960s in Japan. Furthermore, these trends

have been exaggerated recently. In particular, the growth rate of labor input turned out to be negative instead of a positive growth of capital input. We can conclude there are significant substitutions between labor and capital in the new development of technology.

4. We can assume that such new technology might be embodied in the new investment, and that changes in composition by assets in capital stock, along with new investment, should have an impact on the TFP growth. We try to measure the changes in compositions of assets in capital stock caused by new technology as distinct from changes of trends in capital coefficients in each industrial sector. We can observe remarkable changes in the capital coefficients, where the capital coefficients of machinery and electrical machinery as capital goods in each sectors have increased rapidly, instead of the decreases of construction as capital goods in almost all sectors recently.

5. In order to clarify the implications of observed substitutions between labor and capital and evaluate the impacts of the changes of the composition in capital coefficients, we proposed a new concept of measures of TFP growth. In this case, TFP growth in specific commodity production is evaluated by a unit system, in which spillover effect of the productivity is taken into accounts directly and indirectly. It is an extension of ordinary TFP growth measures. New measurement of TFP growth is divided into two concepts, `static unit TFP' and `dynamic unit TFP'. While in the measure of static unit TFP direct and indirect spillover effects of TFP growth among sectors are taken into accounts in the static input-output framework, dynamic unit TFP growth measures try to evaluate direct and indirect spillover effects of TFP growth dynamically.

6. In the aggregated level in terms of static TFP, the contributions of the sources in the economic growth are devided into 21%, 57% and 22% for TFP, capital and labor inputs respectively during the period 1975-90. On the other hand, we can divide the contribution of capital input in the static framework into the contributions of TFP and labor input dynamically. Result shows that the contribution of catital input in the static framework,57% is attributed into 15% of TFP and 42% of labor input respectively. Consequently, it implies that the sources of the economic growth during the period 1975-90 are divied into the contributions of 36% of TFP and 64% of labor input.

A Capital Input and Capital Stock

Capital flow and stock matrices used here are estimated in the following framework. We choose the perpetual inventory method as the methodological framework to estimate the stocks of depreciable capital assets. Let I^j_m be the quantity of gross investment made in the m-th asset in the j-th industry, and ρ^j_m the rate of replacement of the m-th asset utilized in the j-th industry ($0 < \rho^j_m < 1$). The method relates changes in the level of capital stock to current acquisitions of capital goods and replacement requirements; or, to put it in a different perspective, it links current level of capital stock to past acquisitions of capital goods as follows:

$$\begin{aligned} A^j_m(T) &= I^j_m(T) + (1 - \rho^j_m)A^j_m(T-1) \\ &= \sum_{S=1} (1-\rho^j_m)^{T-S} I^j_m(S) \\ &\quad + (1-\rho^j_m)^T A^j_m(0); \qquad (m = 1; \ldots M; j = 1; \ldots J); \end{aligned} \tag{20}$$

where $A^j_m(0)$ is the benchmark capital stock for the j-th industry's m-th asset. It is the second formulation in (20) that becomes operational in the estimation of capital stock.

The key assumption in the formulation (20) is that the rate of replacement, i.e., the proportion of a stock replaced in each period incorporating the replacement of the initial investment as well as the following replacements in each succeeding replacement, is a constant and independent of the time path of past net investments for a given asset and an industry. The analytical foundation for this assumption lies in the fundamental result of the economic theory of replacement summarized by Jorgenson (1973). In short, the result establishes that under certain assumptions a sequence of time - dependent replacement rates generated by retirement or loss of efficiency of a capital asset tends asymptotically to a constant regardless (in most cases) of the manner in which the relative efficiency of a capital good declines over time.

The above result in replacement theory suggests alternative methods for the imputation of replacement rates. One is to assume, directly, that economic depreciation of an asset approaches a form of geometric distribution in the limit, thus resulting in a constant rate as an approximation to the true rate of replacement. In particular, the double declining balances form is commonly chosen as the specific form of the geometric distribution. The rate of replacement is then approximated as $\rho^j_m = [\frac{2}{N^j_m}]$, where N^j_m is the average economic life (as distinguished from tax life) of the m-th asset in the j-th industry.[6]

This study chooses a method that utilizes the second formulation of (20), and carries out the estimation numerically to arrive at the implicit rate of replacement. We begin by noting that (20) can be rewritten as real polynomial $P(x)$ of the T-th degree:

$$P(x) = \sum_{S=0} a_S x^S = 0; \tag{21}$$

where

$$\begin{aligned} x &= 1 - \rho^j_m; \\ a_0 &= I^j_m(T) - A^j_m(T); \\ a_S &= I^j_m(T-S); \quad (0 < S < T); \\ a_T &= A^j_m(0); \end{aligned}$$

so that it is possible to compute ρ^j_m as $1 - x$ where x is the zero of the polynomial $P(x)$. (The industry superscripts and asset type subscripts are omitted from the polynomial expression for brevity.) First, in order to compute the replacement rate from a zero of $P(x)$, all elements that compose the sequence of polynomial coefficients $\{a_S\}$ must be observable. In particular, this requires that we observe both the initial and the terminal benchmark capital stocks $A^j_m(0)$ and $A^j_m(T)$. All components of $\{a_S\}$ are observable in our database.

We are now ready to discuss the selection of data and computational details of the measurement of capital stocks by asset types for private and government enterprises by industries, and social overhead capital. The classification of industries is shown in Table 4. Capital formation except social overhead capital is divided into

6 Refer to Hulten and Wykoff (1981a) and (1981c) and Hulten(1990).

the formation by private and government enterprises. Both private and government enterprises are classified by 43 industrial sectors as shown in Table 4. Social overhead capital is not classified into sectors and they are divided into broad seven categories, which are subdivided into 52 categories in detail, as shown in Table 9. On the other hand, capital formation is classified by 78 types of capital goods as types of assets, which are corresponding to the commodity classification in the input-output table. We can show the framework of our capital formation matrices in Figure 4.

Table 9: Classification of Social Overhead Capital

2-digit Code	3-digit Code		2-digit Code	3-digit Code	
440.		Housing		522.	Wooded Area Protection
450.		Railway Construction		523.	Sewage Disposal
460.		Toll Road		524.	Sewage Disposal Facility
	461.	High Way	530.		Land Protection
	462.	Toll Road(National/Local)		531.	Forestry Protection
470.		Road		532.	Rivers
	471.	Road(National)		533.	Erosion Control
	472.	Road(Main Local)		534.	Seashore
	473.	Road(Prefecture)	540.		Land Development
	474.	Road(City)	550.		Natural Disaster Relief
	475.	Road(others)		5501.	Toll Road
480.		Street		5502.	Road(National)
	481.	Street(National)		5503.	Road(Main Local)
	482.	Street(Main Local)		5504.	Road(Prefecture)
	483.	Street(Prefecture)		5505.	Road(City)
	484.	Street(City)		5506.	Street
490.		Bridge		5507.	Bridge(National Road)
	491.	Bridge(National Road)		5508.	Bridge(Main Local Road)
	492.	Bridge(Main Local Road)		5509.	Bridge(Prefecture))
	493.	Bridge(Prefecture)		5510.	Bridge(City)
	494.	Bridge(City)		5511.	Harbor Construction
	495.	Bridge(others)		5512.	Park Construction
	496.	Bridge(Street/National)		5513.	Sewage Disposal
	497.	Bridge(Street/Main Local)		5514.	Sewage Disposal Facility
	498.	Bridge(Street/Prefecture)		5515.	Forestry Protection Facility
	499.	Bridge(Street/City)		5516.	Rivers
500.		Harbor Construction		5517.	Erosion Control
510.		Airport Construction		5518.	Seashore
520.		Environment Protection	560.		Mining disruption Relief
	521.	Park			

We begin with the estimation of the capital formation matrices both by private and government enterprises, which are categorized by 43 industrial sectors and 78 commodities during the period 1955-92. Next, we try to estimate the rate of replacement by asset types in each industry for the perpetual inventory method. After we obtained the rate of replacement by each commodity types in each industrial sectors, we can estimate the series of the capital stock by assets during the period 1955-92 by extending the benchmark capital stock in 1970 with the series of gross investment and the estimated rate of replacement. The first step for the perpetual inventory method is to select benchmark capital stocks in 1955 and 1970. The Economic Planning Agency's National Wealth Survey(NWS) conducted for 1955, 1960, 1965 and 1970 makes available, by assets and industry, the stock levels for private and government enterprise separately. Unfortunately, the 1960 and 1965 surveys are meager in scale and quality compared to the other years, and must therefore be disregarded.

The deflators for producer's durable, total and by commodities are obtained from sources of input-output table. The 1955 stock values are then inflated using the price indexes at the base year price of 1985. The second step is to obtain investment series by commodities in constant prices. The gross investment series for private enterprises are available by sector, but not by commodity, in the Economic Planning Agency's Gross Capital Stock of Private Firms (CSPF). Unfortunately the classification of manufacturing sectors in CSPF is less precise than ours. Disaggregation of investment series into our classification is made by using

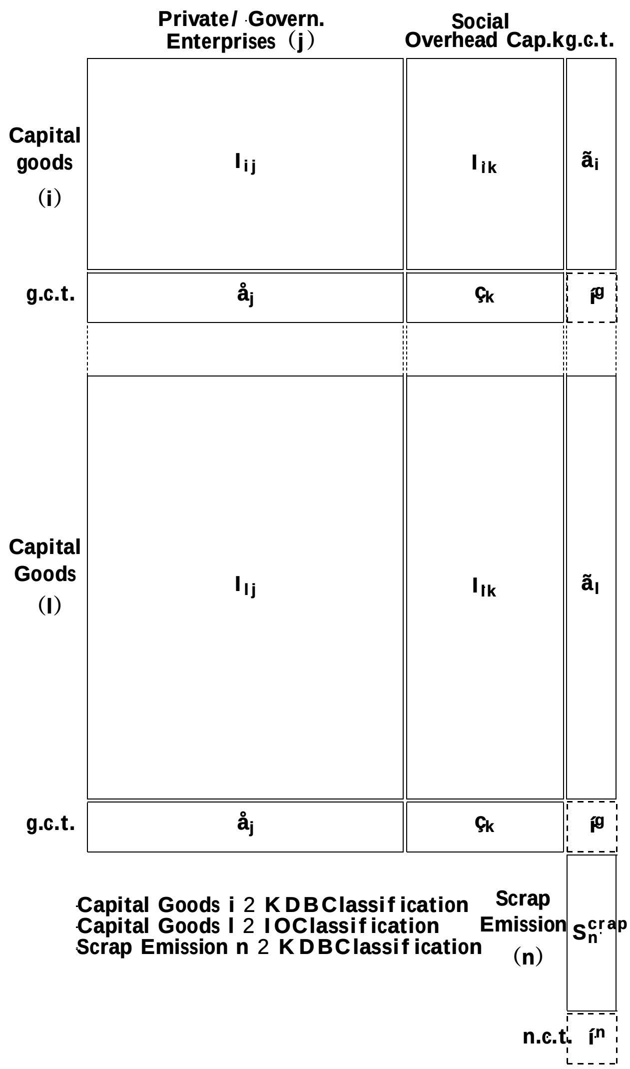

Figure 4: Framework of KDB-FCFM

the deflated gross investment in Census of Manufacturing, Reported by Industry (CMRI) for manufacturing sectors and other sources for service sectors. Total investment as a sum of the investments is consistent with the aggregated value of investment in the System of National Accounts(SNA). On the other hand, we can obtain the information of value shares of commodities of capital formation vector from series of input-output tables in every five years since 1960. By using this these information, we can estimate series of capital formation vectors, separately by private and government enterprises, by commodities, where total amounts of investment by commodity in private and government enterprises are consistent with aggregated investment in SNA. Finally, we estimated capital formation matrices classified by commodities and sectors during the period 1955-92, where row and column total of matrix is consistent with above estimated vector by sectors and commodities respectively. Here, we use KEO-RAS method (Kuroda[1988]) with a benchmark from the Capital Formation Matrix of Input–Output Table, 1975. Gross investments in government enterprises are separately estimated by balance sheet reported by each government enterprises. Gross investment of each government enterprise is estimated from the increment of the relevant asset items in the balance sheet and list of property of closing accounts, and deflated by the investment price indexes. Government enterprises are bridged to industrial sectors consistently with the definition of SNA. Total amount of investment of government enterprises is also consistent with the value of SNA. We can estimate capital formation matrices by commodity and sector for government enterprises by using the same interpolation method as the private sector during the period 1955-92.

The last set of data required by our perpetual inventory method is the rate of replacement. With the two benchmark capital stocks in NWS, and the investment series during the period 1955 - 1970, the "polynomial method" discussed above is applied to impute the economic rate of replacement. After 1970, we tried to estimate the rate of replacement by alternative methods, where we can use other information for estimation of rate of replacement from prices in rental market and prices in used commodities. It is because the rate of replacement after 1970 is expected to change from the previous estimation. Table 10 and Table 11 is a summary of the results of the "polynomial method" for imputation of the economic rates of replacement classified by commodities and sectors in private and government enterprises. Finally, we decided the volumes of rate of replacement by commodity in private and government enterprises after 1970 as shown in Table 14. The changes of the volumes of rate of replacement since 1970 might reflect the changes of structure of new technologies, where rapidly increasing new development of technology in the recent years might have an incentive to promote higher replacement in investment behavior.

Given the estimates of capital formation matrices in 1985 prices, the 1970 benchmark stocks and the rates of replacement discussed above, the perpetual inventory method of the form (20) generates the estimates of capital stocks matrices in 1985 prices for commodities in private and government enterprises in 43 industrial sectors :

$$A^j_m(T) = \sum_{s=1} (1 - \delta^j_m)_{T-S} I^j_m(S) + (1 - \delta^j_m)_T A^j_m(1955): \qquad (22)$$

Table 13 represents average annual rates of growth in capital stock of private enterprises by industry during the period 1955 - 1990, where the period is divided into the following seven sub-periods; 1955-60, 1960 - 65, 1965 - 70, 1970 - 75, 1975 - 80, 1980 - 85, and 1985-90, in order to clarify the features on the capital accumulation in the Japanese economy. According to results in these Table, growth rates of the private capital accumulation in all sectors except water supply since 1975 were clearly slowed down in comparison with the rapid growth until 1975, while those in 1980's were gradually recovered in some sectors such as electric machinery. motor vehicle, precision instrument, communication and education. Annual growth rates of capital stock during the three sub-periods since 1960 were significantly higher than those of labor input by sector in the same periods. Especially, during the second sub-period, 1960 - 1965 twenty-eight sectors of 43 sectors accomplished high growth of capital stock at more than 10 percent annually. These trend continued during the next two terms until 1975. After the oil crisis almost all industries except electricity, gas medical and other service experienced dramatic slow down of the growth in terms of capital stock. During the fifth sub-period, 1975 - 1980 growth rate of capital stock deteriorated by less than half of the growth rate in the previous sub-periods by sectors. During the period 1955-75 capital input by sector has grown rapidly in the high growth rate more than the historical standard of the Japanese economy. It is also an interesting feature that growth rates in capital input were significantly higher than the growth rates in labor input. After the oil crisis, growth rates of capital input have been declined due to the slowdown of capital accumulation.

Table 15 represents series of estimated capital stock by government enterprises. Annual growth rates of capital accumulation in government enterprise show constantly rapid growth such as 6.00%, 10.90%, 9.77%, 13.37%, 8.18%, 4.55%, 2.28% during the every five years since 1955 respectively. We have to note that values after 1989 in Table are not adjusted by the trends of privatization of government enterprises.

Trends of social overhead capital are shown in Table 16. Capital accumulation of social overhead capital was accumulated almost stable since 1955,although its growth rate was slightly less than that of private and government capital accumulation. Since 1965, growth rate of the accumulation in toll road, road, airport, park and sewage increased rapidly. The Term of maximum growth rate of each social overhead capital is different: Road(1960-65), Harbor(1970-75), Airport(1965-70), Park(1985-90), Sewage(1970-75), Forestry(1970-75), Rivers(1975-80),Erosion(1965-70) and Seashore(1960-65). We also have to note that the share of toll road to general road increased rapidly from 0.09% in 1965 to 23.14% in 1990.

Table 10: Estimated Rate of Replacement by Industry/Assets: Private Enterprises

		Animals/Plants	Build/Const	Textile	Woods	Furniture	Metal Prod.
1	Agri.	0.10650	0.14243	0.48951	|	0.47664	0.39948
2	Coal Mining	|	0.14345	N.A.b	|	N.A.b	N.A.b
3	Other Mining	0.39843	0.14448	0.39698	|	0.31744	0.25505
4	Construction	0.34788	0.04169	0.57266	|	0.47590	|
5	Foods	0.20465	0.07748	0.78896	|	0.68297	0.59107
6	Textile	0.38115	0.08309	0.37034	|	0.28818	0.23120
7	Apparel	|	0.04851	N.A.a	|	N.A.a	N.A.a
8	Woods	0.37864	0.12834	0.42161	|	0.35747	|
9	Furniture	0.18011	0.18802	0.05333	|	N.A.a	|
10	Paper&Pulp	N.A.a	0.22904	|	|	0.56363	0.50288
11	Publishing	|	0.12844	0.53914	|	0.47369	0.38260
12	Chemical	|	0.23865	0.65735	|	0.56973	0.48427
13	Petroluem	|	N.A.a	0.79151	|	0.86855	0.71691
14	Coal Prod.	|	N.A.a	0.74622	|	0.78634	0.64326
15	Rubber Prod.	|	N.A.a	N.A.b	|	0.96660	|
16	Leather Prod.	|	N.A.a	|	|	|	|
17	Stone&Clay	0.33666	0.15821	0.32156	|	0.23739	0.18564
18	Iron&Steel	|	0.28125	0.33480	|	0.24385	0.19256
19	Non-ferrous	|	0.36039	0.31160	|	0.22718	|
20	Metal Prod.	0.28625	0.49151	N.A.a	|	N.A.a	|
21	Machinery	0.21714	0.43092	0.43944	|	0.33480	0.27437
22	Elec.Mach.	|	0.27155	0.76785	0.94778	0.61974	0.53531
23	Motor Vehicle	|	0.34205	0.60871	|	0.52465	0.46217
24	Other Trasp. Mach.	|	0.29845	0.66448	|	0.55881	0.45898
25	Precision Mach.	|	N.A.b	N.A.b	|	0.92449	0.89265
26	Other Mfg,	0.18011	0.32870	0.47312	|	0.37926	|
27	Railroad Trans.	N.A.a	0.20027	0.94636	|	N.A.b	0.73226
28	Road Trans.	0.14924	0.10082	N.A.b	|	N.A.b	N.A.b
29	Water Trans.	N.A.a	0.00088	N.A.b	|	N.A.b	N.A.b
30	Air Trans.	|	N.A.a	N.A.b	|	N.A.b	N.A.b
31	Storage	0.34645	0.02018	N.A.b	|	N.A.b	N.A.b
32	Comminucation	|	N.A.b	|	|	N.A.b	|
33	Electricity	|	0.14263	0.55729	|	0.53649	0.45989
34	Gas	|	0.34173	0.09634	|	0.03221	|
35	Water	|	N.A.b	0.01988	|	|	|
36	Trade	0.49842	0.01058	0.19337	|	0.15362	|
37	Finance	0.30124	N.A.a	0.84099	|	0.93139	|
38	Real Estate	0.18011	0.20659	N.A.a	|	0.01403	|
39	Education	|	0.11718	0.15574	|	0.08426	0.04809
40	Research	|	0.11173	0.13226	|	0.09178	0.05816
41	Medical	N.A.a	0.34245	N.A.b	|	N.A.b	N.A.b
42	Other Service	N.A.b	0.05675	N.A.b	|	N.A.b	N.A.b
	Total	0.11124	0.13211	0.50108	0.94778	0.43388	N.A.b

N.A.a means rate of replacement will be estimated by negative value

N.A.b means rate of replacement will be estimated by more than unity.

Table 10:Continued

		Machinery	Elec.Mach.	Vehicle	Oth.Tras.	Precision	Others
1	Agri.	0.25840	0.27982	0.26087	N.A.a	0.50143	0.30995
2	Coal Mining	0.63524	0.90886	N.A.b	N.A.b	N.A.b	0.98938
3	Other Mining	0.17338	0.15660	N.A.b	N.A.b	0.33422	0.18564
4	Construction	0.35645	0.29640	0.57417	0.40045	0.50689	0.31358
5	Foods	0.35473	0.40138	0.89806	N.A.a	0.73024	|
6	Textile	0.16279	0.13807	N.A.b	0.06506	0.30331	|
7	Apparel	N.A.a	N.A.a	N.A.a	N.A.a	N.A.a	|
8	Woods	0.20141	0.18228	0.89199	N.A.b	0.35633	|
9	Furniture	N.A.a	N.A.a	0.37891	0.90031	0.02212	|
10	Paper&Pulp	0.31348	0.31242	0.77704	0.57244	0.47270	|
11	Publishing	0.25575	0.26835	N.A.b	N.A.b	0.48343	|
12	Chemical	0.33593	0.37155	N.A.b	0.57780	0.58414	|
13	Petroleum	0.54102	0.57227	0.65669	N.A.a	0.83907	|
14	Coal Prod.	0.57614	0.51327	0.66002	N.A.a	0.76937	|
15	Rubber Prod.	0.56099	0.62332	0.63876	0.38267	0.86202	|
16	Leather Prod.	0.06171	0.02534	N.A.b	0.18841	0.14891	|
17	Stone&Clay	0.11771	0.10099	N.A.b	0.77007	0.25226	|
18	Iron&Steel	0.12291	0.09903	N.A.b	0.50855	0.25837	|
19	Non-ferrous	0.10808	0.08933	N.A.b	N.A.b	0.24614	|
20	Metal Prod.	N.A.a	N.A.a	0.55919	N.A.b	N.A.a	|
21	Machinery	0.19021	0.16472	N.A.b	N.A.b	0.35963	|
22	Elec.Mach.	0.34981	0.43517	0.92464	N.A.b	0.67865	|
23	Motor Vehicle	0.33356	0.34089	0.52585	N.A.b	0.59086	|
24	Other Trasp.Mach.	0.35144	0.33302	0.56646	N.A.b	0.59798	0.35261
25	Precision Mach.	0.67827	0.71724	N.A.b	N.A.b	N.A.b	|
26	Other Mfg.	0.23782	0.21815	0.65476	0.47790	0.38974	|
27	Railroad Trans.	0.58361	0.46309	N.A.a	0.47641	N.A.b	0.73239
28	Road Trans.	N.A.b	N.A.b	N.A.b	0.16434	N.A.b	N.A.b
29	Water Trans.	N.A.b	N.A.b	0.31948	0.13582	|	N.A.b
30	Air Trans.	N.A.b	N.A.b	0.40443	0.13364	|	N.A.b
31	Storage	N.A.b	N.A.b	0.33052	0.12951	|	N.A.b
32	Comminication	N.A.b	N.A.b	N.A.b	N.A.a	|	|
33	Electricity	0.27038	0.27497	N.A.b	0.86674	0.56183	|
34	Gas	0.01461	N.A.a	N.A.b	N.A.b	0.01446	|
35	Water	|	N.A.a	|	|	|	|
36	Trade	0.05269	0.04421	N.A.b	N.A.a	|	0.01853
37	Finance	0.79940	0.83187	0.99818	N.A.a	|	|
38	Real Estate	N.A.a	N.A.a	N.A.b	N.A.a	|	|
39	Education	N.A.a	N.A.a	N.A.b	0.13583	0.09675	N.A.a
40	Research	0.00469	N.A.a	N.A.b	|	0.09264	|
41	Medical	N.A.b	N.A.b	0.05666	N.A.a	N.A.b	|
42	Other Service	N.A.b	N.A.b	N.A.b	0.30931	N.A.b	N.A.b
	Total	0.24981	0.37106	0.88327	0.12882	0.59970	0.13369

N.A.a means rate of replacement will be estimated by negative value.
N.A.b means rate of replacement will be estimated by more than unity.

Table 11: Estimated Rate of Replacement by Industry/Assets: Government Enterprises

		Animal/Plants	Build/Const	Textile	Woods	Furniture	Metal Prod.
1	Agri.	|	0.12806	|	|	|	|
3	Other Mining	|	N.A.b	0.29271	0.35130	|	|
4	Construction	|	0.11560	|	|	0.29052	|
5	Foods	|	0.12132			|	|
11	Publishing	|	0.09065	|	|	0.28439	|
12	Chemical	|	0.11788	|	|	|	|
20	Metal Prod.	|	|	|	|	|	|
27	Railroad Trans.	|	0.07813	0.26818	|	0.28857	0.21286
28	Road Trans.	|	0.11625	0.26522	|	|	0.21599
29	Water Trans.	|	0.13121	0.26693	|	|	|
30	Air Trans.	|	0.14709	0.27786	|	|	N.A.b
32	Comminication	|	0.12475	0.26881	0.33771	0.30065	|
33	Electricity	|	0.10252	|	0.32616	0.28900	|
34	Gas	|	0.11563	|	|	0.29062	|
35	Water	|	0.13324	|	|	|	0.21537
36	Trade	|	0.14899	|	|	0.29378	|
37	Finance	|	0.12827	|	|	0.29404	|
38	Real Estate	|	0.14110	|	|	|	|
39	Education	|	0.12248	|	|	0.29648	|
40	Research	|	0.10302	|	|	0.29731	|
41	Medical	|	0.17045	|	|	0.30031	|
42	Other Serv.	|	0.13719	|	|	0.30072	|
43	Public Adm.	|	0.12754	0.26823	|	0.30300	|
	Total	|	0.12505	0.26856	0.33686	0.30098	0.21362

		Machinery	Elec.Mach.	Vehicle	Oth.Trans.	Precision	Others
1	Agri.	0.14045	|	0.76838	0.25620	|	|
3	Other Mining	0.17402	0.15173	|	N.A.b	0.32092	|
4	Constructiuon	0.13788	0.13450	0.77586	0.23646	0.28367	|
5	Foods	0.15893	|	0.83814	|	|	|
11	Publishing	0.13554	0.11994	0.80919	|	|	|
12	Chemical	0.13581	0.13263	N.A.b	|	|	|
20	Metal Prod.	0.13978	|	|	|	0.27600	|
27	Railroad Trans.	0.13709	0.11824	0.66382	0.27441	0.28212	0.13839
28	Road Trans.	0.13745	0.11793	0.71553	|	|	|
29	Water Trans.	0.13937	0.13861	0.92020	0.23593	|	|
30	Air Trans.	0.14713	0.12861	N.A.b	0.27047	|	|
32	Comminication	0.15317	0.13009	N.A.b	0.22960	0.29503	|
33	Electricity	0.13301	0.12397	0.59208	|	|	|
34	Gas	0.13648	0.12315	0.67914	|	|	|
35	Water	0.14101	0.12058	0.75317	|	|	|
36	Trade	|	|	|	|	|	|
37	Finance	0.13993	0.12537	N.A.b	|	|	|
38	Real Estate	0.38691	0.36740	N.A.b	|	|	|
39	Education	0.14130	0.12679	N.A.b	|	0.28382	0.14126
40	Research	0.14087	0.13639	N.A.b	0.27513	0.28262	0.14342
41	Medical	0.13921	0.12262	N.A.b	|	0.28720	0.14573
42	Other Serv.	0.16403	0.12660	N.A.b	|	0.28767	0.14314
43	Public Adm.	0.13936	0.12429	N.A.b	0.22061	0.28366	0.14417
	Total	0.14181	0.12628	N.A.b	0.23036	0.28531	0.14309

N.A.a means rate of replacement will be estimated by negative value.
N.A.b means rate of replacement will be estimated by more than unity.

Table 12: Trends of Private Capital Stock by Industry

(Unit: 1 billion yen at 1985 price)

	1955	1960	1965	1970	1975	1980	1985	1990
1.Agri.	3274	3325	4744	9505	17950	22804	24896	27127
2.Coal Mining	449	329	340	318	522	713	760	703
3.Other Mining	186	198	380	619	1050	1048	1073	1141
4.Construction	236	377	1225	3039	8072	11911	14715	19954
5.Foods	617	687	1616	3038	6264	8327	10796	14186
6.Textile	1231	1213	1632	2567	3896	3898	4306	5077
7.Apparel	54	82	192	442	722	907	1074	1399
8.Woods	289	225	390	688	1399	1409	1323	1496
9.Furniture	97	81	190	396	814	951	1003	1282
10.Paper&Pulp	252	524	882	1678	4254	5571	6598	8612
11.Publishing	111	162	460	969	1830	2442	3467	5261
12.Chemical	839	1658	3448	6317	12739	16093	19839	25499
13.Petroleum	220	261	528	1316	3024	3778	4564	5255
14.Coal Prod.	36	63	178	489	994	1231	1216	1344
15.Rubber Prod.	56	82	164	384	937	1240	1703	2344
16.Leather Prod.	18	24	38	63	90	109	129	169
17.Stone&Clay	273	532	1172	2317	4776	5677	7262	9237
18.Iron&Steel	902	1991	3451	7500	15081	19820	22300	24673
19.Non-ferrous	275	322	630	1477	2901	3482	4585	6152
20.Metal Prod.	95	234	575	1741	4392	6247	8759	12209
21.Machinery	225	516	1287	3543	7935	9858	13461	18583
22.Elec.Mach.	310	1094	1642	3355	6404	8798	15133	25819
23.Motor Vehicle	193	566	1475	3355	7035	9125	13750	20382
24.Other Tras.Mach.	206	237	400	870	2797	2516	2487	2563
25.Precision Mach.	55	82	170	470	1320	1505	2591	4054
26.Other Mfg.	53	135	436	1012	2707	3458	4984	7455
27.Railroad Trans.	575	1036	1406	1682	3071	3507	4035	8912
28.Road Trans.	146	1202	1283	1910	4586	7112	10194	12203
29.Water Trans.	762	1189	1613	2727	3972	4151	5006	5275
30.Air Trans.	38	296	866	1795	3256	3824	4646	5958
31.Storage	121	162	224	350	610	707	795	1288
32.Comminucation	48	58	137	169	532	736	2293	11796
33.Electricity	3496	5167	6440	9012	18277	29519	38465	46661
34.Gas	174	296	415	776	1657	2815	3508	3852
35.Water	21	10	21	41	74	170	308	666
36.Trade	3317	3888	6884	11252	22687	33609	40945	55073
37.Finance	728	1359	2890	4673	6651	7931	9736	15251
38.Real Estate	226	269	946	2048	5573	7600	10196	17654
39.Education	943	702	994	1326	1928	2561	3236	4055
40.Research	33	33	32	37	76	94	221	354
41.Medical	552	150	281	568	2319	5544	9620	15204
42.Other Service	3274	3088	3879	5083	9727	16839	32546	61168
Total	25005	33907	55953	100919	204903	279638	368525	517344
Private Housing	66604	50364	51380	74590	117121	147579	155612	185847

Table 13: Annual Growth Rate of Private Capital Stock

(unit : %)

	1955-60	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90
1.Agri.	0.31	7.11	13.90	12.72	4.79	1.76	1.72
2.Coal Mining	-6.21	0.62	-1.31	9.89	6.24	1.27	-1.55
3.Other Mining	1.24	13.01	9.75	10.57	-0.04	0.48	1.23
4.Construction	9.40	23.56	18.18	19.54	7.78	4.23	6.09
5.Foods	2.15	17.11	12.62	14.48	5.69	5.19	5.46
6.Textile	-0.29	5.93	9.06	8.34	0.01	1.99	3.30
7.Apparel	8.55	16.92	16.67	9.81	4.58	3.38	5.29
8.Woods	-4.99	10.94	11.38	14.18	0.15	-1.26	2.46
9.Furniture	-3.58	17.17	14.67	14.39	3.11	1.06	4.91
10.Paper&Pulp	14.60	10.41	12.88	18.60	5.39	3.39	5.33
11.Publishing	7.57	20.80	14.90	12.73	5.77	7.01	8.34
12.Chemical	13.64	14.64	12.11	14.03	4.68	4.18	5.02
13.Petroleum	3.47	14.06	18.29	16.63	4.45	3.78	2.82
14.Coal Prod.	11.31	20.66	20.20	14.18	4.26	-0.24	2.01
15.Rubber Prod.	7.58	13.97	17.03	17.82	5.61	6.35	6.38
16.Leather Prod.	5.15	9.59	10.17	6.96	3.92	3.32	5.42
17.Stone&Clay	13.34	15.79	13.63	14.47	3.46	4.92	4.81
18.Iron&Steel	15.84	11.00	15.52	13.97	5.47	2.36	2.02
19.Non-ferrous	3.13	13.41	17.06	13.50	3.65	5.50	5.88
20.Metal Prod.	18.09	17.95	22.18	18.50	7.05	6.76	6.64
21.Machinery	16.63	18.26	20.25	16.13	4.34	6.23	6.45
22.Elec.Mach.	25.20	8.12	14.29	12.93	6.35	10.85	10.68
23.Motor Vehicle	21.58	19.15	16.44	14.81	5.20	8.20	7.87
24.Other Transp.Mach.	2.78	10.48	15.56	23.35	-2.12	-0.23	0.61
25.Precision Mach.	7.90	14.59	20.27	20.67	2.63	10.86	8.96
26.Other Mfg.	18.89	23.39	16.83	19.68	4.90	7.31	8.05
27.Railroad Trans.	11.79	6.11	3.58	12.04	2.66	2.80	15.85
28.Road Transp.	42.11	1.30	7.96	17.52	8.78	7.20	3.60
29.Water Transp.	8.90	6.10	10.51	7.52	0.88	3.75	1.05
30.Air Transp.	40.93	21.51	14.57	11.91	3.22	3.90	4.97
31.Storage	5.91	6.40	8.99	11.11	2.92	2.36	9.65
32.Communication	3.72	17.24	4.27	22.89	6.50	22.74	32.76
33.Electricity	7.81	4.41	6.72	14.14	9.59	5.29	3.86
34.Gas	10.66	6.77	12.50	15.18	10.60	4.40	1.87
35.Water	-14.18	14.05	13.11	12.15	16.54	11.84	15.44
36.Trade	3.18	11.42	9.83	14.02	7.86	3.95	5.93
37.Finance	12.49	15.09	9.61	7.06	3.52	4.10	8.98
38.Real Estate	3.47	25.13	15.46	20.02	6.20	5.88	10.98
39.Education	-5.90	6.95	5.77	7.49	5.68	4.68	4.51
40.Research	-0.17	-0.54	2.94	14.50	4.18	17.22	9.38
41.Medical	-26.07	12.58	14.07	28.13	17.43	11.02	9.15
42.Other Services	-1.17	4.56	5.41	12.98	10.98	13.18	12.62
Total	6.09	10.02	11.80	14.16	6.22	5.52	6.78

Table 14: Estimated Rate of Replacement by Assets:1970-92

	Assets	Private	Public	Method and Sources
1	Animal/Plants	0.11124	|	Table10
2	Build/Const	0.04783	0.04783	Price Approach
3	Textile	0.50108	0.26856	Table10、Table11
4	Woods	0.33686	0.33686	Table11
5	Furniture	0.43388	0.30098	Table10、Table11
6	Metal Prod.	0.21362	0.21362	Table11
7	Machinery	0.12250	0.12250	Hulten-Wykoã Method
8	Elec. Mach.	0.11790	0.11790	Hulten-Wykoã Method
9	Motor Vehicle	0.25116	0.25116	Age-Price Proåle Approach
10	Other Trasp.	0.12882	0.12882	Table10
11	Precision	0.27290	0.27290	Hulten-Wykoã Method
12	Others	0.13369	0.14309	Table10、Table11

Table 15: Estimated Capital Stock : Government Enterprises

(unit:1 billion yen at 1985 price)

	1955	1960	1965	1970	1975	1980	1985	1990
1.Agri.	730	1246	2231	3979	8392	13921	19406	24860
3.Other Mining	0	0	0	6	9	8	6	10
4.Construction	90	127	226	358	486	490	499	506
5.Foods	176	96	129	145	215	276	218	154
11.Publishing	2	3	27	27	25	26	31	38
12.Chemical	1	1	1	3	4	5	10	13
20.Metal Prod.	0	1	5	7	8	8	8	9
27.Railroad Trans.	153	189	421	703	1192	1704	1699	1505
28.Road Trans.	1	14	92	196	398	490	645	742
29.Water Trans.	4	13	35	67	130	158	200	322
30.Air Trans.	0	0	1	6	19	30	34	59
32.Communication	891	1572	3541	6531	12751	17094	18285	13881
33.Electricity	1087	1467	1491	1159	1172	1350	1507	1273
34.Gas	6	9	15	18	46	77	111	147
35.Water	0	451	1286	2757	6359	9599	12070	14548
36.Trade	5	18	50	123	403	570	629	717
37.Finance	18	19	46	54	75	204	204	522
38.Real Estate	1	0	1	2	25	60	148	207
39.Education	1178	1630	2850	4411	8448	13597	16926	19758
40.Research	27	110	191	324	747	1169	1466	1956
41.Medical	94	225	585	1463	3105	4848	6670	8484
42.Other Service	16	59	269	601	1690	2742	3566	4627
43.Public Adm.	2906	2726	3710	5095	9017	13941	19071	21560
Total	7388	9975	17204	28036	54716	82366	103410	115898

Table 16: Social Overhead Capital by Asset Categories

(upper) 1 billion yen at 1985 price (lower) annual growth rate:%

	Housing	Railway	Toll Road	Road	Harbor	Airport	Park
1955	1143	7340	42	4687	1939	16	620
1960	1559	7316	208	6452	1961	24	523
1965	2585	8822	1036	11649	2497	63	509
1970	4778	11496	2756	20017	3411	181	676
1975	8438	14947	5683	30281	4777	421	1055
1980	10633	18778	8670	39763	6146	528	1716
1985	11107	20230	12176	47878	7295	548	2691
1990	11121	18782	18120	60206	8813	846	4754
1955-60	6.21	-0.07	31.95	6.39	0.23	8.92	-3.39
1960-65	10.11	3.75	32.16	11.82	4.83	19.05	-0.56
1965-70	12.29	5.29	19.56	10.83	6.24	20.98	5.69
1970-75	11.37	5.25	14.48	8.28	6.74	16.89	8.89
1975-80	4.62	4.56	8.45	5.45	5.04	4.50	9.74
1980-85	0.87	1.49	6.79	3.71	3.43	0.76	9.00
1985-90	0.03	-1.49	7.95	4.58	3.78	8.67	11.38

	Sewage	Forestry	Rivers	Erosion	Seashore	Land Imp.	Total
1955	1302	652	3465	332	423	6	21967
1960	1070	705	3539	485	496	150	24488
1965	1444	884	4260	764	747	1056	36317
1970	2843	1188	5694	1228	934	2879	58080
1975	6315	1662	7938	1915	1204	5878	90513
1980	11443	2278	11125	2860	1536	7966	123442
1985	16055	2728	14266	3740	1835	9694	150244
1990	22039	3356	18146	4748	2235	11282	184450
1955-60	-3.93	1.56	0.42	7.62	3.17	63.16	2.17
1960-65	6.00	4.51	3.71	9.08	8.22	39.07	7.88
1965-70	13.55	5.91	5.80	9.48	4.47	20.06	9.39
1970-75	15.96	6.73	6.65	8.89	5.08	14.27	8.87
1975-80	11.89	6.30	6.75	8.03	4.87	6.08	6.21
1980-85	6.77	3.61	4.97	5.36	3.55	3.93	3.93
1985-90	6.34	4.15	4.81	4.77	3.95	3.03	4.10

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