KEO DISCUSSION PAPER

CALAMVS GLADIO FORTIOR

KEIO ECONOMIC OBSERVATORY
SANGYO KENKYUJO

KEIO UNIVERSITY

MITA MINATO-KU
TOKYO JAPAN

№ 68

Technological Change and Capital Accumulation in Japan

Masahiro Kuroda
and
Koji Nomura

Keio University
October 2001

Technological Change and Capital Accumulation in Japan

Masahiro Kuroda
and
Koji Nomura

Keio University

October 2001

Abstract

Objective of our analysis is to evaluate quantitatively the characteristics of the technical progress from the viewpoint of the static and dynamic production linkages. We try to define measures by which we can evaluate the total improvement of the efficiency through the spillover effect by the structural changes in all of the related commodities. Our idea will be condensed into two concepts of "Static Unit TFP" and "Dynamic Unit TFP". Our concept of the measurement of TFP is an extension of the concept of the TFP measures by the specific activity, from the viewpoints of the spillover effect of the characteristics of technical progress as a production system.

Keyword

Capital Stock Matrices, Total Factor Productivity (TFP),
Unit-Structure, Dynamic Inverse, Static Spillover,
Dynamic Spillover, Unit-TFP, Dynamic Unit-TFP

1. Introduction

Objective of our analysis is to evaluate quantitatively the characteristics of the technical progress from the viewpoint of the static and dynamic production linkages.

Technical progress in the production activity for a specific commodity seems to have an impact on the improvement of the efficiency through the changes of various input structure. Introducing concepts of total factor productivity (TFP) as a measurement of technical progress, we can evaluate impacts of the input structural changes on the efficiency in the economy. The measure of the growth rate of TFP in each activity[1] 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 (KLEM). Here, changes of input structure in each activity might be able to be connected with the improvement of the production efficiency by the growth of TFP.

On the other hand, technology in each activity is mutually interdependent through the market transactions of intermediate inputs. It implies that production of one commodity has a linkage through intermediate transactions of various related commodities directly as well as indirectly. Since the direct and indirect linkages among commodities are characterized by properties of the current technology, changes of the efficiency in the production technology for one specific commodity should be evaluated totally as a consolidated measure of impacts of efficiency on all of related commodities. In our analysis, we try to define measures by which we can evaluate the total improvement of the efficiency through the spillover effect by the structural changes in all of the related commodities. It could be referred as "Static Spillover" of productivity.

The spillover effect of 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. The production efficiency in each activity at the current period depends on the market transactions of the primary factors such as labor and capital as well as intermediate inputs. Capital input in the activity of production is served from the capital stock, which was accumulated in past as

[1] In this paper, we assume that the production technology for one commodity corresponds to one specific activity for the production. It means that a term of "activity" expresses the direct input structure for the commodity production, such as an input vector in input-output framework. Relating to this expression, we represent that the agent of the activity is expressed by a term, "sector", which is the agent of production and investment behavior.

investment. The past series of investment is characterized by properties of the past technology at the period when the capital goods were produced and invested. It implies that technical progress embodied in the capital goods at the past period would have an impact on the present production efficiency. Although it is measured as not TFP growth but capital contribution in ordinary growth accounting framework, it might be interesting to decompose the capital contribution in the ordinary measure into the effect of the past technical progress in the accumulated capital goods in order to identify the dynamic linkages of the technical progress in the commodity production. It could be referred as "Dynamic Spillover" of productivity.

These approaches to the static and dynamic measures of the spillover effect provide us the extended concepts of the measurement of TFP. Our idea will be condensed into two concepts of "Static Unit TFP" and "Dynamic Unit TFP". Our concept of the measurement of TFP is an extension of the concept of the TFP measures by the specific activity, from the viewpoints of the spillover effect of the characteristics of technical progress as a production system.

Our accounting framework for measuring the spillover effects of the technical progress through the static and dynamic production linkages is based upon "Unit Structure" approach proposed by Ozaki (1980) and "Dynamic Inverse" approach proposed by Leontief (1972). In section 3, we introduce our estimated results of "Dynamic Inverse" in Japan after the short explanation for two approaches.

In the framework of input-output analysis, structure of the economy is depicted by the static and dynamic interdependency of the commodity productions, in which the technologies are characterized by intermediate input coefficients as well as labor and capital coefficients. Especially, in Dynamic Inverse approach, capital coefficients are related to the capital stock matrices. We tried to estimate capital stock matrices in Japan during the period 1955-92 annually. It represents that there have been observed the clear structural changes in the period, which were presumably reflected by the technical progress. In the next section, we will give some findings of the structural change by estimated capital stock matrices after we try to summarize our concept of technology and our database for the measurement.

We will propose the methodological formulations of "Static Unit TFP" and "Dynamic Unit TFP" in section 4. These formulations are based upon the accounting balance in the static and dynamic production linkages, proposed in section 3. In section 5, we will decompose empirically the sources of the Japanese economic growth by using our proposed concept of indices of the changes of the production efficiency. It is important to emphasize that recent TFP growth as technological change in the production linkage has been contributing to the economic growth statically and dynamically. Finally we try to summarize the implication of our analytical framework from the viewpoint of the structural change as a concluding remark.

2.Technology and Its Measurement

2.1 Technology and Capital Accumulation

In order to evaluate quantitatively the characteristics of the technical progress from the viewpoint of the static and dynamic production linkages, we would like to clarify our concept of technical progress in this paper. Rate of technical progress in an activity for a specific commodity is defined as a difference between the growth rate of gross output and the growth rate of input which is measured by the weighted average of the growth rate of various inputs including intermediate, labor and capital inputs. The measure is referred to the growth rate of Total Factor Productivity (TFP). In other words, the growth rate of TFP is defined as a weighted average of the growth rates of partial productivities of various inputs, where the weights are measured by the cost share of inputs.

Here, the growth rate of TFP represents the change of the production efficiency in an activity for a specific commodity production as a technology. It should be emphasized that the measurement of TFP growth rate completely depends upon the measurements of the growth rates of gross output and various inputs by definition. It means that if and only if we could measure the growth rates of output and inputs exactly, the measurement of the growth rate of TFP is meaningful as a measure of the production efficiency in an activity. Precisely speaking, it is our starting point for evaluating the properties of the technology in each activity that the gross output and inputs including intermediate, labor and capital have to be measured by the homogenous unit in their quality.[2] In other words, if there have changes in quality of output and inputs, the changes of the quality have to be adjusted in the measurement of each output and input indices. Then the impact of the quality changes in "inputs" might be removed in the measurement of TFP as residuals, while the impact of the quality changes in "outputs" might be absorbed.

We often use the expression like "capital embodied technology" in the production. It vaguely implies that the technical progress is promoted by the quality change of

[2] We have to note that there are two possibilities to identify the quality change in the measurement of output and input: One is the quality change occurred in the well-defined homogenous commodity by the technical progress and the other is defined by the changes of compositions of disaggregated items in certain compound commodity. The former is a really quality change in the narrow concept, while the latter is observed in the measurement at certain aggregated level even if there are no

capital input. However, in our sense, although the technical progress might be measured in an activity that capital goods with quality improvement by the embodied technology are produced as output, it might not be measured in the production activity that the capital goods with quality improvement are used in the production process as input.[3] Although the technical progress embodied in the production process of the capital goods might not have any direct improvement in the efficiency of the activities in which the assets are used as capital stock, it should be important to take accounts of the dynamic impacts through the capital accumulation. In other words, it implies that it is highly important to measure the "capital input" consistently with the theoretical concept, in order to observe the dynamic relationships between technology and capital accumulation.

2.2 Measurements of Output and Inputs

As we pointed out, the measurement of the growth rate of TFP in an activity for a specific commodity production completely depends upon the measurements of output and inputs. We have to prepare for the measuring framework, in which the measures of output and inputs satisfy the required conditions for the measurements as possible as we can.

Our framework of the database is based upon the time-series input-output tables of 43 sectors, as shown in Table 1, during the period 1960-92, which are consistent with official basic tables in every five years in Japan. Furthermore, we tried to estimate labor and capital inputs consistently with the 43 sector's input-output table. Labor input consists of man, hour and wage per hour, each of which is cross classified into the categories of industry (43), sex (2), age (11), employment status of workers (3) and education (4).[4]

Especially as capital inputs, in order to describe the properties of the dynamic structural changes, we tried to estimate the time-series capital stock matrices during the period 1955-92. Our estimated capital flow and stock matrices are divided into private and government owned enterprises classified by industry and social overhead capital unclassified by industry. Both private and government enterprises are classified by 43 sectors in column. On the other hand, fixed capital formation matrix are classified by 78 types of capital goods in row as types of capital assets, which

---

quality changes in the narrow sense.

[3] In the case which there are certain improvement of the efficiency of intermediate inputs by using capital goods with new technology, we might measure the improvement of TFP.

[4] Number of workers includes self-employed and unpaid family workers as well as employees, in which the total numbers of workers are consistent with the numbers in Census. Also, labor compensation in input-output table is adjusted consistently with the definition of workers.

correspond to the commodity classification in the official basic input-output table.[5] Please refer to Kuroda et al. (1997) for the detail description of the database concerning input-output tables and related KLEM.

(Table 1: Industry Classification)

2.3 Trends of Capital Stock

Let us summarize the findings in the trends of the capital stock in Japan during the period 1955-92. According to results of average annual rates of growth in capital stock by industry during the period 1955-92, annual growth rates of capital stock since 1960 were significantly higher than those of labor input by sector in the same periods. In particular, during the period 1960-65, 28 sectors out of 43 sectors accomplished high growth of capital stock at more than 10% annually. These trends continued during the next decade until 1975. After the oil crisis almost all industries (except 33.electricity, 34.gas, 41.medical and 42.other services) experienced a dramatic slowing down of growth in terms of capital stock. During the period, 1975-80 growth rates of capital stock deteriorated by less than half of the growth rate in the previous periods by sectors. It is one of the interesting characteristics of the economy after 1985 that the capital formations in the specific industries such as 22.electrical machinery, 25.precision machinery and 32.communications increased rapidly after 1985.

Capital stock matrices at 1985 constant prices consist of 43 industries in column, and 43 commodities in row corresponding to input-output table. Commodities as capital goods are classified into 12 types of asset: 1.animal and plants, 2.building & construction, 3.apparel (e.g. fish net), 4.woods products, 5.furniture, 6.metal products, 7.general machinery, 8.electric machinery, 9.motor vehicle, 10.other transportation equipment (e.g. ship, train, plain and so on), 11.precision instruments, and 12.miscellaneous products.

Capital coefficients are defined by the ratio of capital stock of asset type by sector to gross output. 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. Let us begin to investigate the changes of capital coefficients preliminary. Figure 1 represents change of capital coefficients at the aggregate level and five specific sectors

[5] Our measurement of capital stock includes tangible assets as productive capital stock, inventory assets and land assets. For the measurement at the constant price, we try to take account of quality adjustment in capital goods. The series of capital stock for tangible assets is estimated by the double benchmark years method based upon the 1955 and 1970 National Wealth Survey, where age-efficiency profile is estimated from the observations from statistics in the markets like used car,

during the period 1960-92, where height of the poll in figure stands for the level of capital coefficient and each poll represents the decomposition by the asset types classified into 12 categories. We can observe that capital coefficients at the aggregate level, which is defined by the ratio of capital stock to real value added, increased from 1.4 in 1960 to 2.5 in 1992 and, moreover, compositions of general machinery and electrical machinery among assets have gradually increased, instead of building & construction.

(Figure 1: Trends of Capital Coefficients-Aggregated level and by Industry)

Next, we should focus on observations at the industry level. We can detect certain typical changes of coefficients by industries: 1.agriculture, forestry and fishery, 21.general machinery, 22.electric machinery, 23.motor vehicle, and 27.road transportation. Capital coefficients in 1.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 asset share of general machinery in agriculture has been increasing rapidly, more than 70% of assets are shared by construction. In 21.general machinery, the level of capital coefficients in total capital stock shifted after the oil shock from 0.1 to 0.2, where decreases of capital coefficients for building & construction instead of increases of those in electric machinery after 1975 are increasing rapidly. Trend of capital coefficient in 22.electric machinery is an exceptional example where the capital coefficients showed a decreasing trend from the beginning of the 1960s. This means that in the electric machinery sector capital productivity increased rapidly. After 1975, capital coefficients for building & construction as asset in 22.electric machinery sector were decreasing gradually, while those of electric machinery as asset were increasing rapidly. Capital coefficients of 23.motor vehicle were relatively stable, although after 1975 they indicate a gradually declining trend. While trend of capital coefficient in 23.motor vehicle were stable, the composition of capital coefficient by asset has been changed remarkably, where coefficient of building & construction has been decreasing and coefficients of general machinery and electric machinery increased rapidly in the recent years. Finally, capital coefficient in 27.road transportation represents rapid upper trend historically with increasing share of motor vehicle as asset.

In the economy, changes of capital coefficients might have presumably impacts on the changes of input coefficients in intermediate and labor inputs as a system of the economy, and, finally, the production efficiency in terms of TFP growth measure. In

---

rental housing and so on.

order to describe the spillover effect of TFP through the capital accumulation, we will formulate the interdependency among sectors by input-output framework in the next section.

3. Static and Dynamic Unit Structure

3.1 Static Unit Structure

Let us begin with the definition of "Unit Structure". In the static input-output framework, the system of production can be described in terms of input coefficient matrix, column vector of final demand $\mathbf{y}_t$, output $\mathbf{x}_t$, value added $\mathbf{v}_t$ and unit column vector $\mathbf{i}$, as follows:

$$\mathbf{A}_t\mathbf{x}_t + \mathbf{y}_t = \mathbf{x}_t, \quad \mathbf{i}'\mathbf{v}_t = \mathbf{f}_t'\mathbf{i}$$

If $\mathbf{A}_t$ is a non-singular matrix, we obtain the following equation system,

$$\mathbf{x}_t = (\mathbf{I} - \mathbf{A}_t)^{-1}\mathbf{y}_t = \mathbf{L}_t\mathbf{y}_t$$

where $\mathbf{I}$ is the identity matrix. We will call the following equation the "Static Unit System" of the k_{th} commodity.

$$\mathbf{A}_t\hat{\mathbf{L}}_t^*\mathbf{i} + \mathbf{y}_t^* = \mathbf{L}_t^*, \quad \mathbf{i}'\mathbf{v}_t^* = \mathbf{y}_t^{*'}\mathbf{i} \tag{1}$$

where $\mathbf{L}_t^*$ represents the k_{th} column vector of Leontief inverse matrix $\mathbf{L}_t$, $\mathbf{y}_t^*$ stands for the final demand vector with unity as k_{th} element and zero as other elements and $\mathbf{v}_t^*$ is a vector of the induced value added. Here, we attached the suffix "*" for coefficients and variables related to the k_{th} commodity. In the system of the equation (1), the following matrix,

$$\mathbf{U}_t^* = u_{ij,t}^* = \mathbf{A}_t\hat{\mathbf{L}}_t^* \tag{2}$$

is referred to as the "Static Unit Structure" or "Unit Structure" peculiar to the k_{th} commodity. Static Unit Structure means the required intermediate inputs matrix in order to produce one unit of final demand of the k_{th} commodity directly and indirectly. It can be interpreted as an expression of a self-sufficient production module for the production of one unit of certain "commodity". It would be characterized by the properties of static linkages among activities for the k_{th} commodity production. The form of the Unit Structure of the specific commodity as a module shows a strong similarity in the time-series comparison of input-output tables (see e.g. Ozaki, 1980), though the inputs values would change because of the substitution by the change of the relative prices, the scale economy, technological change and so on. It means that we can observe stably the characteristics of the static linkage among activities for one specific commodity by the Static Unit Structure. The technological system of one whole economy could be described by the compound system of the "Unit Structure" of the various commodities. We can also define the vectors of labor and capital inputs corresponding to the unit structure, which represent the direct and indirect input requirements of labor and capital by sectors in the production of the final demand $\mathbf{y}_t^*$.

3.2 Dynamic Inverse and Dynamic Unit Structure

Above concept of "Static Unit Structure" corresponds to a measure of the production system as a module in the specific time period t. In the production of the k_{th} commodity at year t, capital stock in the production has been already accumulated in the past period as results of the investment in every sector. When we focus on the historical perspective of the capital accumulation, we can define another concept of "Dynamic Unit Structure" in order to evaluate the production linkage of the k_{th} commodity production at the year t as results of a dynamic process including the capital accumulation. Leontief (1972) proposed an idea of "Dynamic Inverse"' in order to evaluate the dynamic property of the technology in the commodity production. Here we should begin with the explanation of Dynamic Inverse corresponding to our accounting framework. Assuming the following commodity balance equations.

$$\mathbf{A}_t\mathbf{x}_t + \mathbf{I}_t^P\mathbf{i} + \mathbf{I}_t^G\mathbf{i} + \mathbf{c}_t = \mathbf{x}_t \tag{3}$$

where $\mathbf{I}_t^P$ is the capital formation matrix of private and government enterprises, $\mathbf{I}_t^G$ the infrastructure formation matrix and $\mathbf{c}_t$ the other final demand. We assume that $\mathbf{I}_t^P$ is defined by perpetual inventory method using a column vector of constant replacement rate δ^P and capital stock matrix $\mathbf{S}_t^P$,

$$\mathbf{I}_t^P = \mathbf{S}_{t+1}^P - (\mathbf{I} - \hat{\delta}^P)\mathbf{S}_t^P = \mathbf{B}_{t+1}^P\mathbf{x}_{t+1} - (\mathbf{I} - \hat{\delta}^P)\mathbf{B}_{t+1}^P\mathbf{x}_t \tag{4}$$

And the infrastructure formation matrix is defined similarly,

$$\mathbf{I}_t^G = \mathbf{S}_{t+1}^G\mathbf{F} - (\mathbf{I} - \hat{\delta}^G)\mathbf{S}_t^G\mathbf{F} = \mathbf{B}_{t+1}^G\mathbf{x}_{t+1} - (\mathbf{I} - \hat{\delta}^G)\mathbf{B}_t^G\mathbf{x}_t \tag{5}$$

where the scale of $\mathbf{S}_t^G$ is the n(commodity) $\times$ m(infrastructure) matrix and the converter matrix from one infrastructure to one industry is defined by $\mathbf{F}\,(\mathrm{m}\times\mathrm{n})$.[6] We assume that some infrastructure services are imputed by only one particular industry and that some more general infrastructure (e.g. park, sewage and so on), are ignored and treated as the other final demand $\mathbf{c}_t$. Substituting (4) and (5) into (3), we can obtain the following equation using capital coefficient $\mathbf{B}_t^P$ and $\mathbf{B}_t^G$,

$$(\mathbf{I}-\mathbf{G}_t)\mathbf{x}_t-\mathbf{B}_{t+1}\mathbf{x}_{t+1}=\mathbf{c}_t \tag{6}$$

where

$$\mathbf{G}_t=\mathbf{A}_t-(\mathbf{I}-\hat{\delta}^P)\mathbf{B}_t^P-(\mathbf{I}-\hat{\delta}^G)\mathbf{B}_t^G \tag{7}$$

$$\mathbf{B}_t=\mathbf{B}_t^P+\mathbf{B}_t^G \tag{8}$$

These equations are called "Dynamic Inverse" approach expressed by linear difference equations (6), (7) and (8). We should note in particular that the stability of capital coefficients is not assumed here. Capital coefficients might be variable, as we could observe in section 2. When we could look back on the past from the present base year t, commodity balance equations in the past different years are also written as follows,

$$\mathbf{x}=(\mathbf{I}-\mathbf{D})^{-1}\mathbf{c}=\mathbf{M}\mathbf{c} \tag{9}$$

where

$$\mathbf{D}=\begin{pmatrix} \mathbf{G}_{t-T} & \mathbf{B}_{t-T} & & & \\ & \ddots & \ddots & & \\ & & \mathbf{G}_{t-2} & \mathbf{B}_{t-2} & \\ & & & \mathbf{G}_{t-1} & \mathbf{B}_{t-1} \\ & & & & \mathbf{G}_t \end{pmatrix},\ \mathbf{x}=\begin{pmatrix} \mathbf{x}_{t-T} \\ \vdots \\ \mathbf{x}_{t-2} \\ \mathbf{x}_{t-1} \\ \mathbf{x}_t \end{pmatrix},\ \mathbf{c}=\begin{pmatrix} \mathbf{c}_{t-T} \\ \vdots \\ \mathbf{c}_{t-2} \\ \mathbf{c}_{t-1} \\ \mathbf{c}_t \end{pmatrix}$$

where $\mathbf{G}_t$ is $\mathbf{A}_t$. Assuming that elements in final demand are given exogenously, equations (9) give us a series of production which are need to satisfy with the given level of the final demand, directly and indirectly in the static and dynamic process. The required series of production formulated in equations (9) is consistent with the required demands for the direct and indirect transactions in the static and dynamic linkages, where the capital stock must have been produced in the previous year or the more past. Furthermore, we should say that the system formulated in equations (9) is

[6] General road and highway are classified in the sector, 28.road transportation and harbor and airport are classified in the sectors, 29.water transportation and 30.air transportation respectively. Infrastructure for conservation of national land in forestry, mountain, river, erosion and seashore is classified in the sector, 1.agriculture, while land improvement is classified in the sector, 38.real estate.

satisfied with the technological conditions of supply sides identified with capital coefficients. The long continuative production chain can make it possible that the present consumption could be realized. We can call the following equation the "Dynamic Unit System" of the k_{th} commodity.

$$\mathbf{D}\hat{\mathbf{M}}^{*}\mathbf{i}+\mathbf{c}^{*}=\mathbf{M}^{*} \tag{10}$$

where $\mathbf{M}^{*}$ represents the $(T\times n+k)_{th}$ column vector of $\mathbf{M}$. $\mathbf{c}^{*}$ stands for the final demand vector with unity as k_{th} element and zero as other elements in the base year t, and $\mathbf{c}_{t-\tau}(\tau=1,\cdots,T)=0$. In the dynamic system of the equation (10), the following matrix,

$$\mathbf{U}^{*}_{(D)}=u^{*}_{ijt(D)}=\mathbf{D}\hat{\mathbf{M}}^{*} \tag{11}$$

is referred to as the "Dynamic Unit Structure", which corresponds to the concept of "Static Unit Structure", as mentioned above.

3.3 Dynamic Unit Structure

By using our estimated time-series intermediate input coefficient matrices and time-series capital coefficient matrices during 1960-92 in Japan, we can describe Dynamic Unit Structure expressed in the equations (11). Table 2 and Table 3 represent Dynamic Unit Structures of motor vehicle in the base years 1980 and 1992, where the volume of consumption of motor vehicle in both years are given by 1 million yen at 1985 constant price respectively. Each table is composed by a set of sub-tables, which describe the linkage of dynamic spillover effects year by year backwardly from the base year. A sub-table of a set represents the linkage among sectors within the certain period of the dynamic linkage. In each sub-table column "x" represents a vector of gross output by sector as results of the direct and indirect spillover, while column "c" stands for a given vector of 100 million yen of motor vehicle demand at the base year. Columns "Ip" and "Ig" in sub-tables represent vectors of required investment in private and government sectors. Other parts of sub-tables stand for the linkage of intermediate transaction in each stage of the dynamic spillover.

Top sub-table in Table 2 and Table 3 corresponds to the Static Unit Structure formulated in equation (2). According to our results, the volume of the production of electric machinery required as intermediate input becomes bigger from 8 in the 1980 Unit Structure to 18 in the 1992 Unit Structure. On the other hand, the volume of the production of general machinery and iron & steel required as intermediate inputs decreases from 1980 to 1992 in the static Unit Structure. It implies that the impact of the efficiency change in electric machinery on the production of motor vehicle has been gradually increasing, while that in general machinery and iron & steel has been diminishing.

The story of the dynamic linkage is slightly different from the static one. Required investment of general machinery as well as electric machinery in the past have been increasing from 1980 to 1992, as we can see the series of sub-tables in the past years in Table 2 and 3. Also, it is consistent with the trend of capital coefficients in the sector, 23.motor vehicle in Figure 1. It implies that the spillover effect of the changes of efficiency in general machinery and electric machinery has been increasing in the production of motor vehicle through the investment of the required capital goods. The spillover effects of the dynamic linkage through the required investment are gradually diminishing in the past and can be ignored around 10 years ago.

(Table 2: Dynamic Unit Structure for Motor Vehicle (Base Year=1980))

(Table 3: Dynamic Unit Structure for Motor Vehicle (Base Year=1992))

In Figure 2 we can show the results of the dynamic spillover effect in gross output by sectors in the past, where the impacts are estimated as the backward effects from the 100 million final demand of motor vehicle (at the 1985 constant price) in the base year. According to the results, the term of the spillover effect in the dynamic linkage of the production has been gradually longer in 1992 in comparison with the effect in 1970. However, it is interesting that in the intermediate energy input such as petroleum the spillover effect in the production on motor vehicle has been diminishing recently. It might be understood that the increase of energy efficiency in the production such as energy conservation and substitution contributes to save the energy input like petroleum. It should be noted that the spillover effect of electric machinery is increasing as a transaction of intermediate inputs as well as a required investment goods. On the other hand, that of general machinery is declining as a transaction of intermediate goods, while that is increasing as an impact of required investment goods.

(Figure 2: Output Requirement for Motor Vehicle)

4 Unit TFP and Dynamic Unit TFP

4.1 TFP and Unit TFP

Let us propose the methodological framework of "Static Unit TFP" and "Dynamic Unit TFP". In order to construct the formulations, we should begin with the growth rate of sectoral TFP and the aggregate measure of sectoral TFP. If production function is assumed to be constant return to scale, the rate of TFP growth in j-sector can be formulated under the assumption of perfect competition as follows:

$$\left(\frac{\dot{T}_j}{T_j}\right)_t = \left(\frac{\dot{Z}_j}{Z_j}\right)_t - \sum_i s^X_{ij,t}\left(\frac{\dot{X}_{ij}}{X_{ij}}\right)_t - \sum_l s^L_{lj,t}\left(\frac{\dot{L}_{lj}}{L_{lj}}\right)_t - \sum_k s^K_{kj,t}\left(\frac{\dot{K}_{kj}}{K_{kj}}\right)_t \tag{12}$$

where Z_j represents real output, and X_{ij} , L_{lj} and K_{kj} stand for intermediate inputs, labor input. The nominal income shares of each input, say s^X_{ij} , s^L_{lj} and s^K_{kj} , sum to unity. By using 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:

$$\begin{aligned}\left(\frac{\dot{T}}{T}\right)_t &= \sum_j \frac{p_{j,t}Z_{j,t}}{p^V_t V_t}\left(\frac{\dot{T}_j}{T_j}\right)_t \\ &= \sum_i \frac{p_{i,t}f_{i,t}}{p^V_t V_t}\left(\frac{\dot{f}_i}{f_i}\right)_t - \sum_j\sum_l \frac{p^L_{lj,t}L_{lj,t}}{p^V_t V_t}\left(\frac{\dot{L}_{lj}}{L_{lj}}\right)_t - \sum_j\sum_k \frac{p^K_{kj}K_{kj,t}}{p^V_t V_t}\left(\frac{\dot{K}_{kj}}{K_{kj}}\right)_t \end{aligned} \tag{13}$$

where $p_{j,t}$, $p^L_{lj,t}$,and $p^K_{kj,t}$ represent the price of output, labor and capital service input respectively, and $p^V_t V_t$ stands for the aggregated nominal value added. The first equation in (13) represents the aggregate growth rate of TFP measured by the weighted average of the rate of sectoral TFP growth, in which the weight is defined by the proportion of the nominal gross output of j-sector to the total nominal value added. The sum of the weight among sectors is necessarily more than unity. It is important that the aggregated growth rate of TFP necessarily differs from the simple average of the rate of sectoral TFP.

The second equation in equation (13) indicates that the measure of growth rate of TFP at the aggregate level is simultaneously explained as a difference between the aggregate measure of the growth rate of final demand and that of factor inputs decomposed into 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 GDE.

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 3.1 with TFP. As we mentioned before, Unit Structure for a specific commodity represents a linkage among the direct and indirect input requirements in terms of intermediate inputs, labor and capital inputs which are needed to supply one unit of a specific commodity as final demand.

An aggregate measure of the production efficiency in the framework of Unit Structure for a specific commodity can be defined as follows:

$$\begin{aligned}\left(\frac{\dot{T}}{T}\right)_t^U &= \sum_j \frac{p_{j,t} Z^*_{j,t}}{p_t^V V_t^*}\left(\frac{\dot{T}_j}{T_j}\right)_t \\ &= \sum_i \frac{p_{i,t} f^*_{i,t}}{p_t^V V_t^*}\left(\frac{\dot{f}_i^*}{f_i^*}\right)_t - \sum_j \sum_l \frac{p^L_{lj,t} L^*_{lj,t}}{p_t^V V_t^*}\left(\frac{\dot{L}^*_{lj}}{L^*_{lj}}\right)_t - \sum_j \sum_k \frac{p^K_{kj,t} K^*_{kj,t}}{p_t^V V_t^*}\left(\frac{\dot{K}^*_{kj}}{K^*_{kj}}\right)_t \end{aligned} \tag{14}$$

where $p_t^V V_t^*$ stands for aggregate nominal value-added defined by the sum of sectoral labor and capital compensations in an Unit Structure of a specific commodity. We should note by definition that the aggregate nominal value added is equal to the nominal value of given final demand of the commodity. If we try to focus on an Unit Structure of a specific i-commodity, the first term of the last equation in (14) could be rewritten by $\left(\dot{f}_i^* / f_i^*\right)_t$. It is because that all of other components except i-commodity in the final demand vector are zero and $p_t^V V_t^*$ should be equal to $p_{i,t} f^*_{i,t}$.[7] This measure designates the total production efficiency of a specific commodity, where the production efficiency is evaluated as a measure of the total factor productivity in terms of not a specific activity, but a specific commodity as final demand. The measure is defined by an aggregate measure of the production efficiency in all of directly and indirectly induced activities, which are needed to supply a specific commodity as final demand. Here, we should take a note that growth rate of each sectoral TFP in (14) is defined the same as that in (12) in each activity.

This aggregate measure in (14) has to be distinguished from the growth rate of TFP at the aggregate level in (13), though both formulations seem to be the same. As we mentioned above, the measure defined in (14) corresponds to an aggregate measure of production efficiency in terms of the Unit Structure of a specific commodity, where the Unit Structure represents the direct and indirect linkage of intermediate and factor

[7] If we try to give the same amount of final demand in the base period and the reference period in comparison in (14), the first term of the right-hand side of the last equation becomes to be zero. It implies that the growth rate of "total" factor productivity in the case is defined by the weighted average of the growth rates of "partial" productivities of inputs.

input transactions which are needed to supply an unit of a specific commodity as final demand. The Unit Structure represents a set of activities as a module, which is required to supply one unit of commodity as final demand. As we expressed in the previous section, we designates all of the related variables to Unit Structure for a specific commodity with the suffix "*". We will refer to this measure $\left(\dot{T}/T\right)_t^U$, as a "Static Unit TFP" on a specific commodity based on its Unit Structure, or "Unit TFP" simply.

In the framework of Unit TFP, we can extend the concept as a measure of the production efficiency for any final demand vectors corresponding to the composition of final demand such as consumption, fixed capital formation, exports and so on. The measure designates a TFP growth rate of the compound commodities, which are directly and indirectly needed to supply a set of commodities as a vector of final demand. The measure of Unit TFP corresponding to a specific final demand "vector" could be defined also in (14). Especially we can refer to this measure as a "Compound Unit TFP".

In particular, if we give total final demand vector as corresponding to GDE, the definition of the aggregate measure (14) is back to the definition of the growth rate of TFP defined in (13). It implies that the TFP growth rate as an aggregate measure corresponds to the growth rate of the production efficiency, which is defined by the compound Unit TFP for GDE components as final demand.

4.2 Dynamic Unit TFP

The above concept of "Unit Structure" and "Static Unit TFP" aims to measure the production efficiency change for a specific commodity only in the specific time period t. We should say that the production at the period t is restricted by the technology that is embodied in the capital stock at the beginning of the period. Capital stock in the production at the beginning of the period is composed by the accumulated capital goods over the past periods as results of investment. The capital formation in each time period of the past was characterized by the technological properties at that time. Focusing 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 in order to realize one unit of a specific commodity as final demand. For simplicity to formulate "Dynamic Unit TFP", we try to define the growth rate of Divisia aggregate inputs for capital and labor services as follows:

$$\left(\frac{\dot{K}}{K}\right)_t = \sum_j \sum_k \frac{p^K_{kj,t} K_{kj,t}}{p^K_t K_t} \left(\frac{\dot{K}_{kj}}{K_{kj}}\right)_t, \quad \left(\frac{\dot{L}}{L}\right)_t = \sum_j \sum_l \frac{p^K_{lj,t} L_{lj,t}}{p^L_t L_t} \left(\frac{\dot{L}_{lj}}{L_{lj}}\right)_t \tag{15}$$

We assume a proportional relationship at the aggregate level between quantity of capital service K_t at the year t and capital stock S_t at the beginning of the year t, where aggregate capital stock at the beginning of the period is related to the stock and investment at the previous period in the perpetual inventory formulation similar to the equations (4) and (5). Differentiating it logarithmically with respect to the time t, we can obtain the following relationship;

$$\left(\frac{\dot{K}}{K}\right)_t = \left(\frac{\dot{S}}{S}\right)_t = (1-\delta)\frac{S_{t-1}}{S_t}\left(\frac{\dot{S}}{S}\right)_{t-1} + \frac{I_{t-1}}{S_t}\left(\frac{\dot{I}}{I}\right)_{t-1} \tag{16}$$

where δ stands for the rate of replacement defined at the aggregated level of capital.

Now, let us discuss the dynamic formulation of the production process in which one unit of a specific commodity will be supplied at the period t. We should consider that the production for one unit of a specific commodity not only has a linkage among intermediate inputs and labor input at the period, but also has a dynamic linkage through the accumulation process of the capital stock. In order to clarify the relationship, let us turn to the discussion for the formulation of Unit TFP again. We can define the growth rate of Compound Unit TFP in the previous year $t-1$ as (14) as follows:

$$\begin{aligned}\left(\frac{\dot{T}}{T}\right)^U_{t-1} &= \sum_j \frac{p_{j,t-1} Z^*_{j,t-1}}{p^V_{t-1} V^*_{t-1}} \left(\frac{\dot{T}_j}{T_j}\right)_{t-1} \\ &= \sum_i \frac{p_{i,t-1} f^*_{i,t-1}}{p^V_{t-1} V^*_{t-1}} \left(\frac{\dot{f}^*_i}{f^*_i}\right)_{t-1} - \sum_j \sum_l \frac{p^L_{lj,t-1} L^*_{lj,t-1}}{p^V_{t-1} V^*_{t-1}} \left(\frac{\dot{L}^*_{lj}}{L^*_{lj}}\right)_{t-1} - \sum_j \sum_k \frac{p^K_{kj,t-1} K^*_{kj,t-1}}{p^V_{t-1} V^*_{t-1}} \left(\frac{\dot{K}^*_{kj}}{K^*_{kj}}\right)_{t-1}\end{aligned} \tag{17}$$

When we consider the dynamic production process needed to satisfy one unit of a specific commodity as final demand at the period t, $f^*_{i,t}$, real volume of the final demand at the year $t-1$ in (17) should be equal to real capital formation at the year $t-1$ enough to satisfy the capital service demand at the year t and year $t-1$. Then we assume here the following equation:

$$\left(\frac{\dot{I}^*}{I^*}\right)_{t-1} = \sum_i \frac{p_{i,t-1} f^*_{i,t-1}}{p^V_{t-1} V^*_{t-1}} \left(\frac{\dot{f}^*_i}{f^*_i}\right)_{t-1} \tag{18}$$

It implies that aggregate growth rate of investment at the previous period to be required to satisfy one unit supply of a specific commodity at the period t is assumed to be equal to the Divisia aggregate growth rate of each capital goods which composed the aggregate investment. We should note that the sum of weights in (18) is equal to unity. Rewriting the third term of the last formulation in equation (14) by substituting equations (15), (16), (17) and (18), we can obtain the following formulation. It implies that the growth rate of the capital service input needed to supply one unit of a specific commodity as final demand at the period t is able to decompose into the dynamic process of the capital accumulation in the past.

$$\sum_j \sum_k \frac{p_{kj,t}^K K_{kj,t}^*}{p_t^V V_t}\left(\frac{\dot{K}_{kj}^*}{K_{kj}^*}\right)_t$$

$$= \frac{p_t^K K_t^*}{p_t^V V_t^*}\left[(1-\delta)\frac{S_{t-1}^*}{S_t^*}\left(\frac{\dot{S}^*}{S^*}\right)_{t-1} + \frac{I_{t-1}^*}{S_t^*}\left\{\left(\frac{\dot{T}}{T}\right)_{t-1}^U + \frac{p_{t-1}^L L_{t-1}^*}{p_{t-1}^V V_{t-1}^*}\left(\frac{\dot{L}^*}{L^*}\right)_{t-1} + \frac{p_{t-1}^K K_{t-1}^*}{p_{t-1}^V V_{t-1}^*}\left(\frac{\dot{K}^*}{K^*}\right)_{t-1}\right\}\right]$$

$$= \frac{p_t^K K_t^*}{p_t^V V_t^*}\frac{I_{t-1}^*}{S_t^*}\left(\frac{\dot{T}}{T}\right)_{t-1}^U + \frac{p_t^K K_t^*}{p_t^V V_t^*}\frac{I_{t-1}^*}{S_t^*}\frac{p_{t-1}^L L_{t-1}^*}{p_{t-1}^V V_{t-1}^*}\left(\frac{\dot{L}^*}{L^*}\right)_{t-1}$$

$$+ \frac{p_t^K K_t^*}{p_t^V V_t^*}\left\{(1-\delta)\frac{S_{t-1}^*}{S_t^*} + \frac{I_{t-1}^*}{S_t^*}\frac{p_{t-1}^K K_{t-1}^*}{p_{t-1}^V V_{t-1}^*}\right\}\left(\frac{\dot{S}^*}{S^*}\right)_{t-1} \qquad (19)$$

The right-hand side of the second equal sign designates that the growth rate of capital service input at the period t is able to decompose into the contribution of three parts. The first term represents the Compound Unit TFP growth, which is required to satisfy the investment demand at the previous period, $t-1$. The second implies the contribution of labor service input in the production of the investment goods at the period $t-1$. The third term represents the contribution of capital service input at the period $t-1$, which is able to decompose into the contribution of the capital accumulation in the past again. If we can assume the equations (16), (17) and (18) in the previous period, respectively, we can deduce the following equation as for the third item of the second equation in (19):

$$\frac{p_t^K K_t^*}{p_t^V V_t^*}\left\{(1-\delta)\frac{S_{t-1}^*}{S_t^*}+\frac{I_{t-1}^*}{S_t^*}\frac{p_{t-1}^K K_{t-1}^*}{p_{t-1}^V V_{t-1}^*}\right\}\left(\frac{\dot{S}^*}{S^*}\right)_{t-1}$$

$$=\frac{p_t^K K_t^*}{p_t^V V_t^*}\Phi_{t-2}^*\left[(1-\delta)\frac{S_{t-2}^*}{S_{t-1}^*}\left(\frac{\dot{S}^*}{S^*}\right)_{t-2}+\frac{I_{t-2}^*}{S_{t-1}^*}\left\{\left(\frac{\dot{T}}{T}\right)_{t-2}^U+\frac{p_{t-2}^L L_{t-2}^*}{p_{t-2}^V V_{t-2}^*}\left(\frac{\dot{L}^*}{L^*}\right)_{t-2}+\frac{p_{t-2}^K K_{t-2}^*}{p_{t-2}^V V_{t-2}^*}\left(\frac{\dot{K}^*}{K^*}\right)_{t-2}\right\}\right]$$

$$=\frac{p_t^K K_t^*}{p_t^V V_t^*}\Phi_{t-2}^*\frac{I_{t-2}^*}{S_{t-1}^*}\left(\frac{\dot{T}}{T}\right)_{t-2}^U+\frac{p_t^K K_t^*}{p_t^V V_t^*}\Phi_{t-2}^*\frac{I_{t-2}^*}{S_{t-1}^*}\frac{p_{t-2}^L L_{t-2}^*}{p_{t-2}^V V_{t-2}^*}\left(\frac{\dot{L}^*}{L^*}\right)^{t-2}$$

$$+\frac{p_t^K K_t^*}{p_t^V V_t^*}\Phi_{t-2}^*\left\{(1-\delta)\frac{S_{t-2}^*}{S_{t-1}^*}+\frac{I_{t-2}^*}{S_{t-1}^*}\frac{p_{t-2}^K K_{t-2}^*}{p_{t-2}^V V_{t-2}^*}\right\}\left(\frac{\dot{S}^*}{S^*}\right)_{t-2},$$

where

$$\Phi_{t-2}^*=(1-\delta)\frac{S_{t-1}^*}{S_t^*}+\frac{I_{t-1}^*}{S_t^*}\frac{p_{t-1}^K K_{t-1}^*}{p_{t-1}^V V_{t-1}^*}$$

We can decompose the contribution of the capital service input at the period $t-1$ into the contributions of three components at the period $t-2$, similar to the equation (19).

Finally, repeating the same procedure, we can trace backward the process of dynamic production linkage, which is required to satisfy the unit of final demand at the period t. Since the capital formation invested in the year $\tau(\tau=t-1,\dots,t-\infty)$ is assumed to embody properties of 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 in the following formulation:

$$\left(\frac{\dot{\mathrm{T}}}{\mathrm{T}}\right)_t^D=\left(\frac{\dot{\mathrm{T}}}{\mathrm{T}}\right)_t^U+\frac{p_t^K K_t^*}{p_t^V V_t^*}\sum_{\tau=t-1}^{t-\infty}\Phi_\tau^*\frac{I_\tau^*}{S_{\tau+1}^*}\left(\frac{\dot{\mathrm{T}}}{\mathrm{T}}\right)_\tau^U$$

$$=\sum_i\frac{p_{i,t}f_{i,t}^*}{p_t^V V_t^*}\left(\frac{\dot{f}_i^*}{f_i^*}\right)_t-\frac{p_t^L L_t^*}{p_t^V V_t^*}\left(\frac{\dot{L}^*}{L^*}\right)_t-\frac{p_t^K K_t^*}{p_t^V V_t^*}\sum_{\tau=t-1}^{t-\infty}\Phi_\tau^*\frac{I_\tau^*}{S_{\tau+1}^*}\frac{p_\tau^L L_\tau^*}{p_\tau^V V_\tau^*}\left(\frac{\dot{L}^*}{L^*}\right)_\tau, \quad (20)$$

where

$$\Phi_\tau^*=\begin{cases}1 & (\tau=t-1)\\ \Phi_{\tau+1}^*\left\{(1-\delta)\frac{S_{\tau+1}^*}{S_{\tau+2}^*}+\frac{I_{\tau+1}^*}{S_{\tau+2}^*}\frac{p_{\tau+1}^K K_{\tau+1}^*}{p_{\tau+1}^V V_{\tau+1}^*}\right\} & (\tau=t-2,\dots,-\infty)\end{cases}$$

We refer to this measure $\left(\dot{T}/T\right)_t^D$ as growth rate of Dynamic Unit TFP. We can deduce the measure by two ways: One is the formulation of the first equation in (20), where the measure is defined as the weighted sum of the Static Unit TFP at the period t and the Compound Unit TFP at the past period. Here, it should be noted that the Compound Unit TFP includes all of the linkages of TFP through the production for capital goods and intermediate goods for direct and indirect requirement. The other is the formulation of the second equation in (20), where the measure is defined as the difference between the aggregate growth rate of final demand at the period t and all of the contributions of the growth of the labor input in the past. In the formulation of Dynamic Unit TFP, we can evaluate all of the impacts of the technical properties for the production of one unit of a specific commodity at the period t, through the accumulated capital as investments embodied all of the changes of the technology in the past.

5 Technological Change and Spillover in Japan

5.1 Static Evaluation

We will begin with a decomposition of economic growth in the aggregate level. Figure 3 shows the average annual growth rate of real GDE and the contributions of labor and capital inputs and TFP as sources of the economic growth during the period 1960-90. In Figure 3 the pole in every five-year's sub-period during 1960-90 represents the average annual growth rate of real GDE, where the average annual growth rate in each sub-period is decomposed into contributions of labor and capital inputs and TFP respectively.[8] Share of contribution is designated by the number (%) along each pole. During the rapid economic growth period in the 1960s, average annual growth rate of real GDE reached more than 10%, while the annual TFP growth rates were 2.1% and 4.6% during the periods 1960-65 and 1965-70 respectively. At that period, the contribution of TFP growth reached 22% and 40% respectively.

High growth rates of real GDE and TFP in the 1960s rapidly deteriorated during the first half of the 1970s. Average annual growth rate of TFP during the period

[8] Here, labor input is defined by the Divisia aggregate of the man-hour inputs, which is cross classified into 11,352 categories of industry (43), sex (2), age (11), employment status of workers (3) and education (4), while capital input is defined by the Divisia aggregate of capital service inputs, which is cross-classified into 516 categories of industry (43) and asset (12). We should note that in this paper we exclude inventory and land from the capital input in each sector. For the Divisia aggregate of the capital service inputs, we need to estimate the capital service prices by capital assets in each industrial sector. We try to measure the series of the capital service prices by imputation, taking accounts of the detail tax system including corporate tax, enterprise tax, property tax and acquisition tax with the institutions of various types of allowance and reservations. See Nomura (1998).

In our estimation of the growth rate of TFP, we try to evaluate the quality changes in each input as changes of the composition of various categories of inputs as detail as possible. Then estimated results of TFP growth is carefully evaluated by changes of input measures both in quantity and quality.

1970-75 was -1.8%. It mainly came from -6.0% annual growth rate of TFP in the period of the first oil shock, 1973-74. However, when we focus on the growth rate during the period 1970-71 and 1971-72 before the oil shock, we can observe the clear slowdown of the TFP growth we could never observe in the 1960s. It should be noted that there have been already observed some sort of changes in the growth pattern of the Japanese economy at the beginning of the 1970s before the first oil shock. Since the last half of the 1970s, the real growth rate of GDE slightly recovered by 3-4% annually; although the level were lower than that in the 1960s. However, it should be noted that the TFP growth rates slightly recovered by 0.3%, 0.8% and 0.7% annually during the periods 1975-80, 1980-85 and 1985-90 and they contributed to the real GDE growth by 8%, 21% and 16% respectively.

(Figure 3: Decomposition of Economic Growth in Japan)

Concerning the contribution of capital input, results show the stable contribution of capital input around 50-60% during all of every five-year's sub-periods except 1970-75. Annual growth rate of capital input reached around 12% annually in 1960-75, while it decreased stably by 6% during the period 1975-90. By our framework of the dynamic concept mentioned in the previous section, we try to decompose this contribution of capital input during certain period into the contributions of labor input and TFP growth in the past. Before the decomposition by the dynamic concept, we would like to focus on our results in sectoral TFP growth and static spillover effect by Static Unit TFP.

Table 4 shows average annual growth rate of sectoral TFP. Although the trends of sectoral TFP growth seems to represent the same pattern as the aggregate trend roughly, there are sizable differences in the patterns of the sectoral trends, if we try to look carefully. It should be noted in particular that there were some exceptional sectors such as 22.electric machinery, 23.motor vehicle and 32.communication, where TFP grew at a stably high rate during these periods, while the TFP growth rates in 1.agriculture, 14.coal products, 35.water supply and 42.other service were mostly negative. Although it is interesting to analyze the reasons why TFP growth rates were high in some industries and low in the other industries even if there were not so much differences in the patterns of the relative factor prices, we will not focus on the subject. In this paper, we assume that TFP growth rates in sectors were exogenously given as a condition of technology. And we would like to focus on the evaluation of the spillover effect of the exogenously given technology through static and dynamic linkages among sectors.

In order to consider the interdependency among sectors from the viewpoint of a static spillover of sectoral TFP, we would like to compare sectoral TFP with Static Unit TFP as shown in Table 4 and 5. Sectoral TFP by definition represents the efficiency of a specific activity in production. On the other hand, Static Unit TFP, which is based upon Unit Structure defined in section 3.1, indicates the total efficiency in a linkage of a specific commodity production, where we can evaluate the efficiency of direct and indirect linkages of the technology as a system of the commodity production.

When we focus on the difference between Static Unit TFP and sectoral TFP as shown in the column "-TFP" of Table 5, we can see the interesting characteristics of the spillover effect through the commodity linkage of intermediate transactions. For example, the growth rates of Static Unit TFP in 5.foods products and 8.woods products during the period 1960-75 were largely deteriorating by 1.4% and 1.6% rather than the growth rates of each sectoral TFP during the same period respectively. It is because the sectoral TFP growth rate in 1.agriculture, forestry and fishery, in which the products in this sector were mainly supplied to the sectors 5 and 8 as intermediate inputs, were deteriorating by 3.3% annually during this period. The deterioration of the efficiency in the 8.woods products might have an impact on the efficiency in 9.furniture through the transaction of the intermediate input. However, according to results, annual Unit TFP growth in the sector 9 during the period 1960-75 was higher by 1.0% than the growth rate of sectoral TFP in the sector 9. It is because the production efficiency of other main intermediate input like 20.metal products increased by 2.5% as a measure of Unit TFP and compensated the deterioration of the efficiency in the sector 8. It is highly interesting that in spite of the efficiency increase in the sectoral TFP of the sector 8, the Unit TFP of this sector deteriorated because of the indirect impact of the decline of the efficiency in intermediate inputs. As results of the deterioration in the efficiency of woods products as the Static Unit TFP and the improvement in the efficiency of metal products as the Static Unit TFP, we can observe trends of the input substitutions from woods products to metal products as intermediate inputs in many sectors.

On the other hand, we can observe the case in which the technical linkage had a positive spillover effect in the production efficiency. We try to focus on the linkage between 22.electric machinery and 23.motor vehicle. Difference of the growth rate between the Static Unit TFP and sectoral TFP in 23.motor vehicle shows positive effect of the spillover effect by 2.4% in 1960-75 and 1.9% in 1975-90. We can identify the specific sector in which the spillover effects were dominant. According to the results, 13.7% and 18.7% of total positive spillover effects in 23.motor vehicle during the period 1960-75 and 1975-90 were due to the impact from the efficiency improvement in 22.electric machinery. It is because the growth rates of Unit TFP in 22.electric machinery during the period 1960-75 and 1975-90 reached by more than 5% and the direct and indirect input requirement of intermediate goods from 22.electric machinery to 23.motor vehicle was gradually increasing during these periods.

We can translate the meaning of the spillover effect in Unit TFP into the framework of the commodity linkage in intermediate input transactions, in which the commodity orders in input-output table are triangularized. The higher hierarchical commodities, which mean the end-use commodities, might have bigger impacts of the spillover effect. It is because the production of the end-use commodity requires relatively various commodities as intermediate inputs. On the other hand, the lower hierarchical commodities have the properties in which the efficiency change in the commodities might have serious impacts on other commodities as spillover effect, while the impact from the efficiency changes in other commodities might not have impacts seriously on the efficiency of the lower hierarchical commodity. We can see the typical example in the sector, 32.communication. In 32.communication there was small difference of the growth rate between Unit TFP and sectoral TFP, while the efficiency change in this sector had sizable impacts on the efficiency in the other various sectors.

(Table 4:Sectoral TFP)

(Table 5:Static Unit TFP)

5.2 Dynamic Evaluation

Let us turn to the evaluation of the results in our dynamic approach. We can estimate a measure of Dynamic Unit TFP defined in equation (20), in which we can evaluate, dynamically, the total efficiency of the production which is directly, and indirectly, required to supply one unit of a specific commodity as final demand at the base year. As we explained in the previous section, the intertemporal accounting balance for Dynamic Unit TFP is given by the framework of Dynamic Unit Structure in section 3.2. Since it could be measured that dynamic impacts of production linkages diminish until the almost ten years past as we could show the case of Dynamic Unit Structure in 23.motor vehicle in Figure 2 and Table 2-3 as an example, we can evaluate our measures of Dynamic Unit TFP after the period 1970 in our experimental period 1960-90.

The results are shown in Table 6. Each value in the table represents the average annual growth rate of Dynamic Unit TFP and the differences between Dynamic Unit

TFP and Static Unit TFP are shown in the column expressed as "-UTFP" in the table. As shown in section 3.2, Dynamic Unit TFP is a measurement in which we try to evaluate the TFP growth embodied in the accumulated capital stock in the past. In the formulation, after the contribution of capital input in Static Unit TFP are decomposed into the contributions of labor input and TFP in the past, the part of the contribution of TFP in the past is added to the measurement of that of Static Unit TFP. Therefore, Dynamic Unit TFP would be greater than the Static Unit TFP, as shown by the positive sign of the column "-UTFP" in Table 6.

According to results in Table 6, differences between Dynamic Unit TFP and Static Unit TFP during the period 1975-90 represent more than 1% in the sectors, 18.iron & steel, 21.general machinery, 22.electric machinery, 23.motor vehicle, and 32.communication. The growth rate of Dynamic Unit TFP of the sectors, in which the capital were accumulated smoothly and the capital intensity were higher, might be evaluated higher. Even in the sectors that the difference of the growth rate between Static Unit TFP and sectoral TFP were relatively smaller like 32.communication, if the capital intensity in the sector were high, the growth rate of Dynamic Unit TFP could be evaluated higher.

As we mentioned in section 2, the values of capital coefficients of general machinery and electric machinery as capital goods have rapidly increased in almost all sectors. Growth rates of sectoral TFP as well as Unit TFP in 21.general machinery and 22.electric machinery recorded fairly high during the period 1960-90. As results due to above two reasons, growth rates of Dynamic Unit TFP have been gradually increasing in almost all sectors during the every five-year's sub-periods since 1975. For example, in the sector 23.motor vehicle, the differences of growth rates between Dynamic Unit TFP and Static Unit TFP represent 0.26%, 0.61% and 0.86% in each five-year's sub-periods, 1975-80, 1980-85 and 1985-90 respectively. In almost all sectors Dynamic Unit TFP has been improved by the capital accumulation.

(Table 6: Dynamic Unit TFP)

We try to pick up several sectors in Figure 4, in order to clarify the differences of three indices of the productivity measurement we proposed in the paper. In Figure 4, each measurement of TFP is represented by the index, which is defined as the value in the base year, 1970 is unity. It should be noted that Dynamic Unit TFP is able to measure only in the periods after 1970. In the sectors, 21.general machinery, 22.electric machinery and 23.motor vehicle, the index of Dynamic Unit TFP represents the highest growth rate, while the index of sectoral TFP represents the lowest growth rate. The level of the growth rate is the highest in 22.electric machinery.

In the sector, 1.agriculture, forestry and fishery, all of indices have been gradually declining until the last half of the 1970s and stabilizing in the 1980s. Especially, the index of Dynamic Unit TFP in this sector turned to the upward trend after 1985.[9] In the sectors, 28.road transportation and 32.communication, the indices of Static Unit TFP and sectoral TFP have been moving in the similar pattern by the specific properties in the commodity linkage as service, while the index of Dynamic Unit TFP in these sectors have been rapidly increasing after 1985. It is because the capital coefficients of motor vehicle as an asset in 28.road transportation and that of communication equipment in 32.communication have been increasing clearly and the Unit TFP growth rates in motor vehicle and communication equipment could be higher after 1985.

(Figure 4: Comparison of TFP Index)

We try to evaluate Dynamic Unit TFP at the aggregate level from the viewpoints of the decomposition of the sources of the economic growth, as we mentioned in Figure 3. Figure 5 represents the results of the decomposition of the contribution of capital input into two sources; one is the contribution of the labor input in the past and the other is the contribution of the TFP growth in the past. Then in Figure 5, the average annual growth rate of real GDE during every five year's sub-periods is decomposed into four components of sources of growth; the contribution of labor input at the base year (t=0), the contribution of labor input in the past ($t=-1,\cdots,-\infty$), the contribution of TFP at the base year, and the contribution of TFP in the past. In Figure 5 the share of contribution of each source are represented along the pole as measures of the annual growth rate of GDE in each sub-period. It should be noted that by definition the sum of the contributions of labor input and TFP in the past is equal to the contribution of capital input in Figure 3.[10]

(Figure 5: Dynamic Decomposition of Economic Growth in Japan)

The contribution of Dynamic Unit TFP is defined by the weighted sum of the contribution of TFP at the base period and the contribution of all of TFP growth in the

[9] It should be noted that we include the social overhead capital such as agricultural land reform, forestry road and fishing harbor in capital stock in 1.agriculture, forestry and fishery. Therefore, the trend of the decline in the capital productivity in this sector might be emphasized.

[10] As we defined in equation (20) previously, one of the measures of Dynamic Unit TFP is defined as the weighted sum of the Unit TFP at the period t and the compound Unit TFP at the past period. The other is understood in the measure defined as the difference between the aggregate growth rate of final demand at the period t and all of the contributions of the growth of the labor input in the past. Here, we estimated the contribution of TFP growth in the past at first and defined the contribution of the labor input in the past as differences between the contribution of capital input and contribution of TFP growth in the past.

past[11]. The growth rate of the aggregate Dynamic Unit TFP during the period 1970-75 is estimated by -0.16 % annually. However it implies that since the annual growth rate of TFP at the base period is negatively high by -1.81%, the contribution of TFP growth in the past has to be evaluated, as it was fairly high. The high contribution of TFP growth in the past is due to the higher speed of the capital accumulation during the period 1960-75 and the rapid growth of sectoral TFP during the same period.

Average annual growth rate of aggregate Dynamic Unit TFP was gradually increasing by 0.5%, 1.3% and 1.7% during every five-year's sub-periods since 1975. Since the growth rates of aggregate TFP in the same sub-periods recorded 0.2%, 0.5%, and 1.0% annually, it implies that the contributions of TFP in the past contributed by around 40-60% to the expansion of the Dynamic TFP growth. It can be shown in Figure 5 that the share of contributions of the past TFP to the growth have been increasing gradually by 4%, 13% and 23% in every five-year's sub-periods. On the other hand, the contribution of the labor input were 2.4%, 1.5% and 1.5% in every five year's sub-periods and the share of contribution to the economic growth has been declining by 52%, 40% and 34% in every five year's sub-periods. After the first oil shock, capital input has been accumulated stably in 5-6% annually. It means that the accumulation of capital stock has not been contributed to the increases of Dynamic Unit TFP in comparison with the contribution in the high economic growth periods in 1960s. However, it is one of interesting characteristics in the recent capital accumulation that the compositions of general machinery and electric machinery in capital goods have been increasing rapidly and the high growth rates of sectoral TFP in both sectors have contributed to the increasing of the growth rate of the Dynamic Unit TFP in almost all sectors. In other words, we could say that the recent technological progress in general and electric machinery sectors as leading sectors could be contributed to the improvement of the production efficiency in almost all sectors through the dynamic process in the capital accumulation. We might conclude that the new technology developed in the commodities such as semi-conductor and computer has been embodied in the capital goods and it could have an enormous spillover effect through the dynamic accumulation process of investment in all sectors.

When we try to observe the sources of the long-run economic growth during the period 1975-90 in Figure 3, the sources are decomposed into the contributions of

[11] It should be noted that the aggregate measure of sectoral TFP growth is completely the same as the measure of the compound Unit TFP growth by definition, in which the compound Unit TFP is measured by the direct and indirect commodity linkage required by one unit of GDE vector as final demand. Therefore, in the aggregate measure we just focus on the aggregate TFP and Dynamic Unit TFP.

capital input, labor input and TFP by 55%, 30% and 15% respectively from the viewpoint of the Static measure. It implies that we can insist the strong contribution of technical progress in the Japanese economic growth. Furthermore, when we try to focus on the dynamic measure in Figure 5, the contribution of TFP would be evaluated to increase by 28% during the period 1975-90, and 39% during the period 1985-90. The dynamic contribution of TFP is evaluated as almost same as that of the labor contribution at the base year.

6.Conclusion

In this paper we intended to evaluate quantitatively the characteristics of the technical progress from the viewpoints of the static and dynamic production linkage. Our analytical framework is based upon the system of the general interdependence in the production, which is specified by input-output framework. In the input-output framework, the system of the general interdependence in production is characterized by three structural parameters; intermediate coefficients, labor coefficients and capital coefficients, by which the technological properties are condensed. Although one picture of the system of the production is characterized by a set of structural parameters, these structural parameters might change through various factors like technical progress, factor prices and so on. We refer it to "structural change".

As we pointed in the paper, we could have observed the structural changes in the system of the economy historically. Our objective in this paper aims to develop certain index for the evaluation of the structural changes quantitatively along with the measurement of technical progress. By using the theoretical framework of input-output analysis, we can describe the interdependence among sectors as a linkage in the current production system by the structural parameters, intermediate input coefficients, while the structural parameters, capital coefficients express the linkages of the present system of production to the past system through the capital accumulation. We tired to develop indices referred to "Static Unit TFP", by which we can describe the properties of technology through the static interdependency among sectors. On the other hand, we also tried to develop indices referred to "Dynamic Unit TFP", by which we can describe the properties of technology through the dynamic linkage among present and past productions. We used these concepts of indices to describe the impacts of technical progress in order to understand the static and dynamic characteristics of the technology in the Japanese economy. According to the results summarized in the aggregate level, the recent contribution of technical progress to the economic growth has been increasing through static interdependence of the technology as well as through dynamic linkages of the technology.

The description of the characteristics of the technical progress in the system of production in this paper seems to be a starting point to construct the analytical model to solve the mechanism of the structural changes endogenously.

Reference

Biørn, E. (1989) *Taxation, technology and the user cost of capital* (Elsevier Science Publishers B.V.).

Diewert, W. E. (1986) *The measurement of the economic benefits of infrastructure Services*, (Springer-Verlag , Vol. 278).

Hulten, C. R. (1979) On the "importance" of productivity change, *American Economic Review*, Vol.69, No.1, pp.126-136.

Hulten, C. R. (1990) The measurement of capital, in: E. R. Berndt and J. E. Triplett (eds) *Fifty Years of Economic Measurement: The Jubilee of the Conference on Research in Income and Wealth*, (University of Chicago Press), chapter 4, pp.119-158.

Jorgenson, D. W. (1963) Capital theory and investment behavior, *American Economic Review*, Vol.53, No.2, pp.247-274.

Jorgenson, D. W. (1989) Capital as a factor of production, in: D.W. Jorgenson and R. Landau (eds) *Technology and Capital Formation*, (MIT Press), chapter 1, pp.1-35.

Kuroda, M., Shimpo K., Nomura K. and N. Kobayashi (1997) *KEO database –Measurement of output, labor and capital inputs*, (Keio University Press), (in Japanese).

Leontief, W .W.(1972) The dynamic inverse, in: A.P. Carter and A. Brody (eds) *Contributions to Input-Output Analysis* (Amsterdam, North-Holland Publishing), pp.17-46.

Nomura, K. (1998) The measurement of capital service price, *KEO Discussion Paper*, Vol.53, pp.1-56, (in Japanese).

Ozaki, I. (1980) The structure of economic development (III) –A determination of economic fundamental structure, *Mita Journal of Economics*, Vol.73, No.5, pp.66-94, (in Japanese).

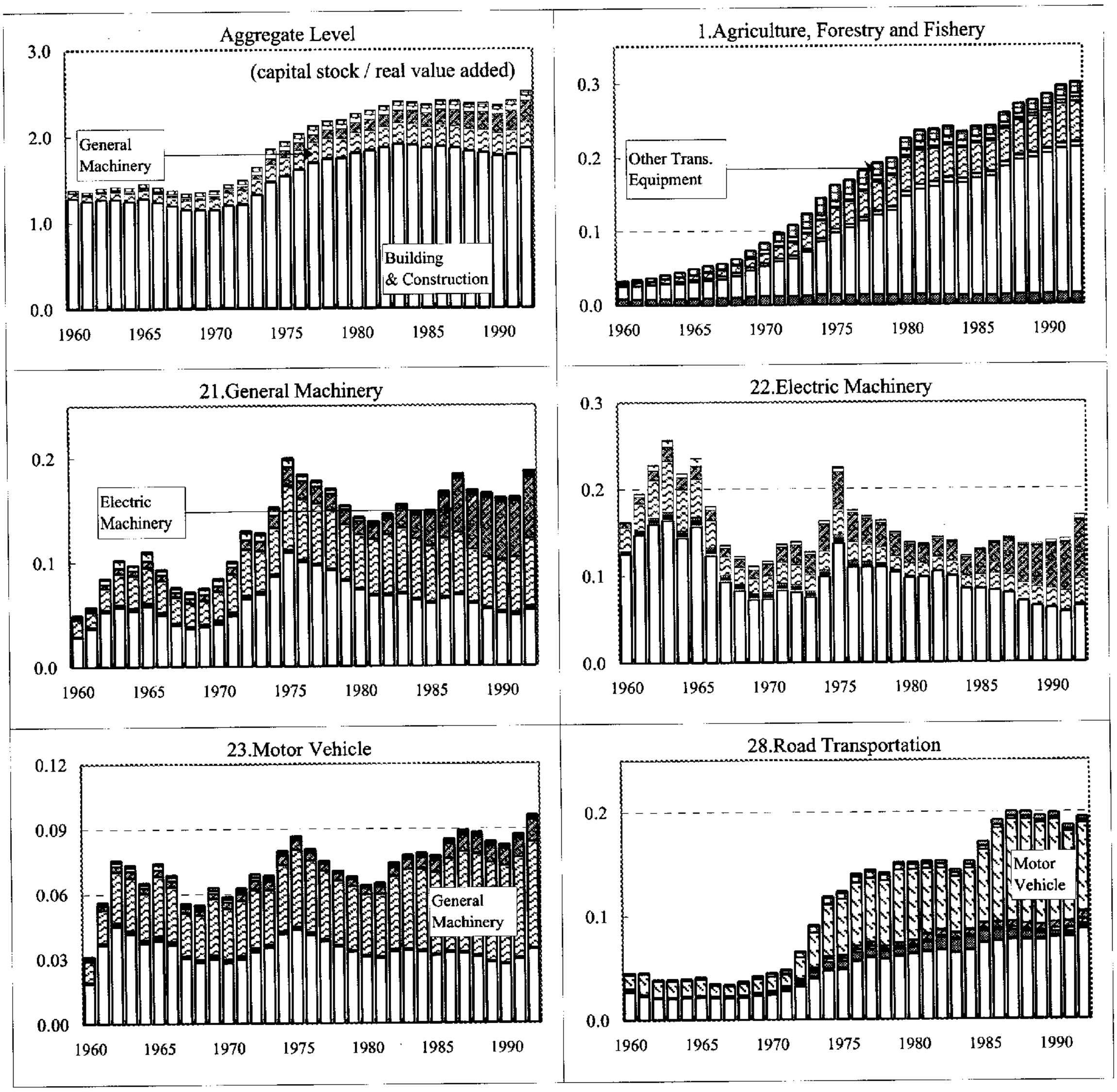

Figure 1: Trends of Capital Coefficient - Aggregate Level & by Industry

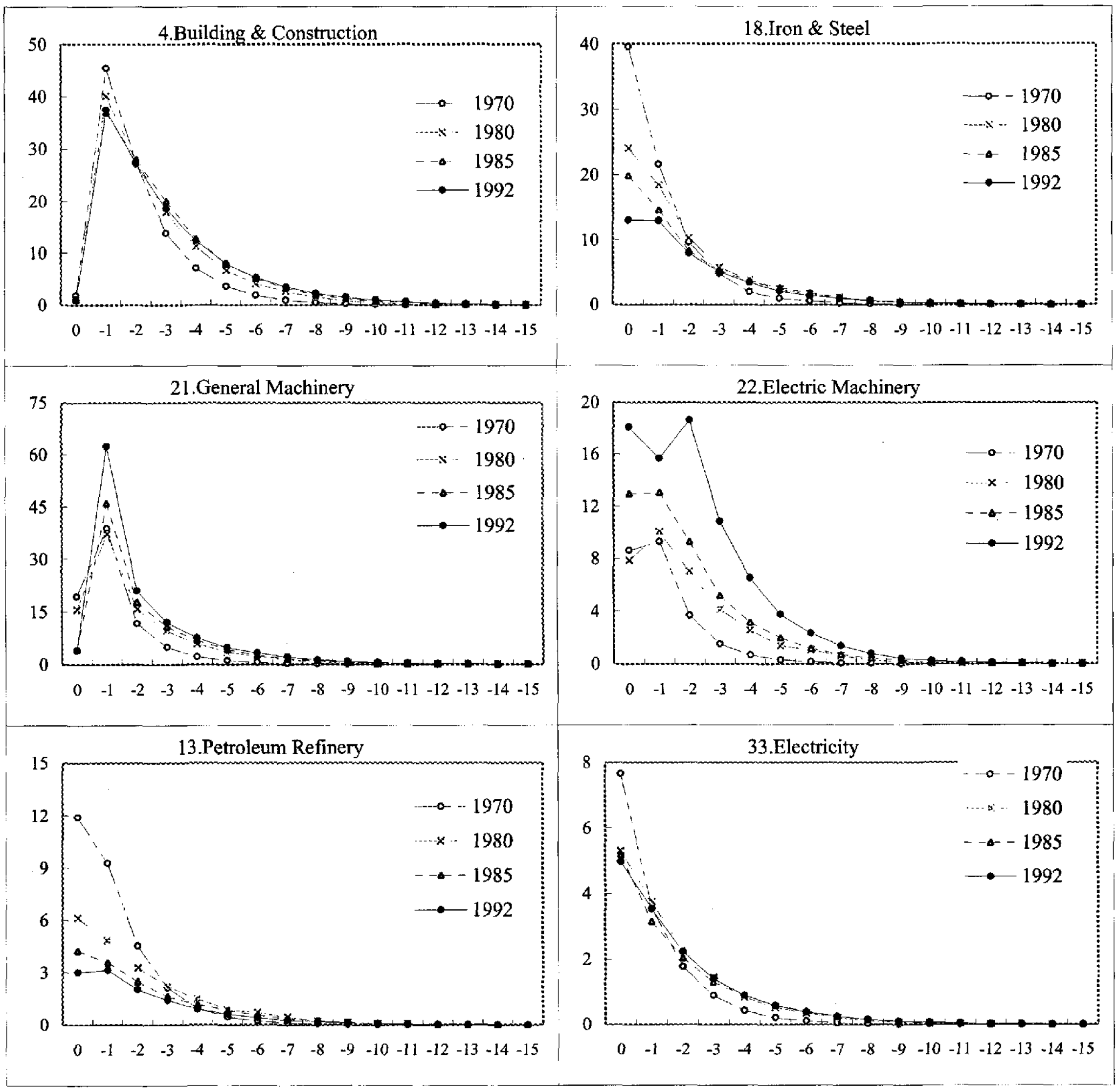

Figure 2: Output Requirement for Motor Vehicle

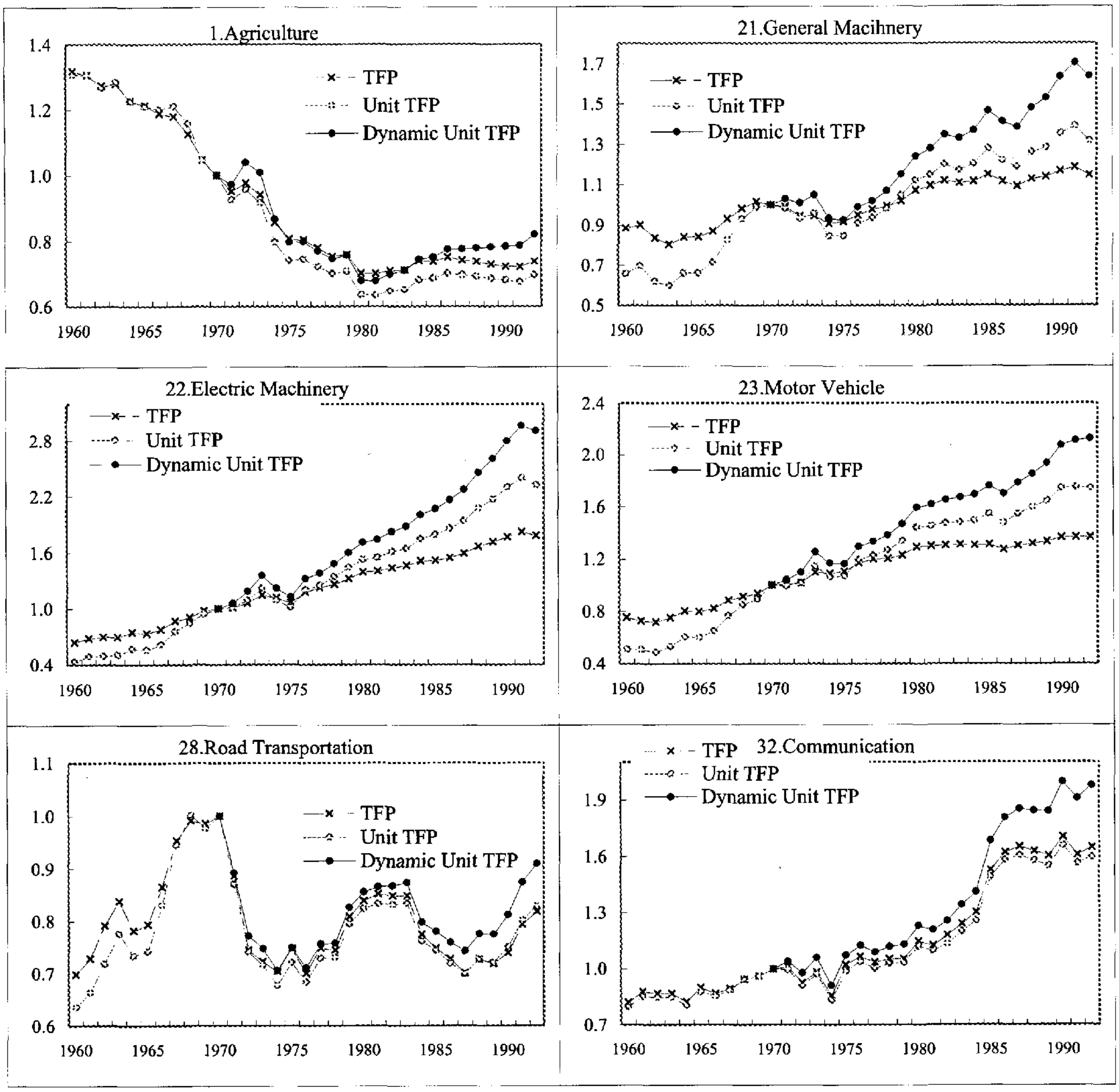

Figure 4: Comparion of TFP Index

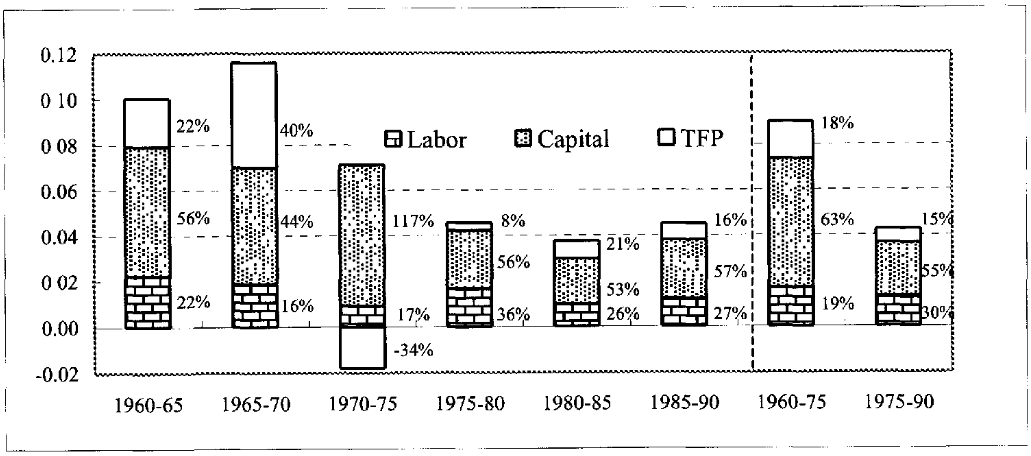

Figure 3: Decomposition of Economic Growth in Japan

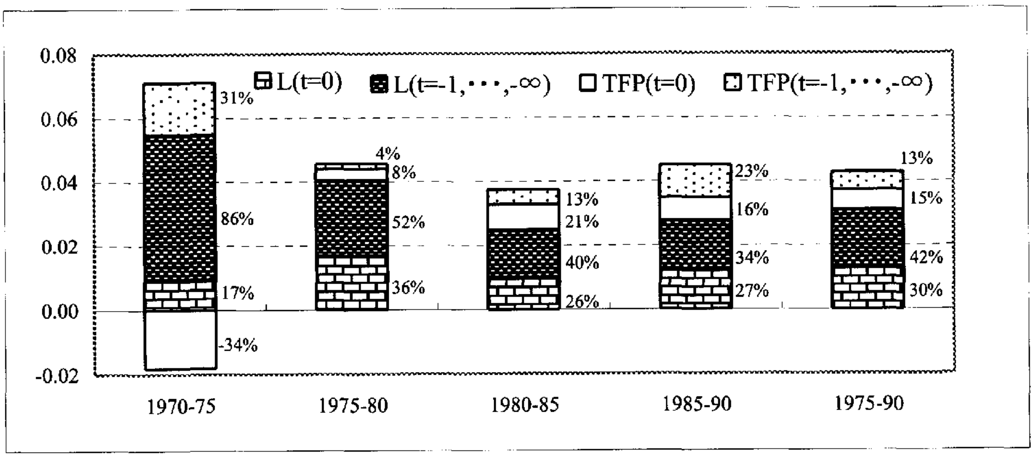

Figure 5: Dynamic Decomposition of Economic Growth in Japan

Table 1: Sector Classification

1. Agriculture.Forestry & Fishery	23. Motor Vehicle
2. Coal Mining	24. Other Trasp. Machinery
3. Other Mining	25. Precision Instruments
4. Building & Construction	26. Other Manufacturing
5. Food Manufacturing	27. Railway Transportation
6. Textile	28. Road Transportation
7. Apparel	29. Water Transportation
8. Woods & Related Products	30. Air Transportation
9. Furniture & Fixture	31. Storage Facility Service
10. Paper & Pulp	32. Communication
11. Publishing & Printing	33. Electricity
12. Chemical Products	34. Gas Supply
13. Petroleum Refinery	35. Water Supply
14. Coal Products	36. Wholesale & Retail
15. Rubber Products	37. Finance & Insurance
16. Leather Products	38. Real Estate
17. Stone & Clay	39. Education
18. Iron & Steel	40. Research
19. Non-ferrous Metal	41. Medical Care
20. Metal Products	42. Other Service
21. General Machinery	43. Public Services
22. Electric Machinery	

Table 2: Dynamic Unit Structure of Motor Vehicle (Base Year =1980)

[1980]	23	22	21	20	18	19	15	13	12	6	33	36	42	c	x
23.Vehicle	42.8											0.2	0.1	100	143
22.Elec.Mach.	4.9	2.0	0.7										0.2		8
21.Machinery	9.9	0.1	5.0		0.1								0.3		16
20.Metal Prod.	1.4	0.1	0.3	0.1			0.1						0.1		3
18.Iron&Steel	8.4	0.3	1.6	0.7	12.7								0.2		24
19.Non-ferrous	2.9	0.5	0.2	0.1	0.2	2.5									7
15.Rubber Prod.	6.7		0.1				0.1								7
13.Petroleum	0.7		0.1		0.4	0.2	0.1	0.2	0.8		1.5	0.3	0.2		6
12.Chemical	1.4	0.1	0.1		0.1	0.1	1.5		3.0	0.1			0.2		8
6.Textile							0.4			0.4			0.1		1
33.Electricity	1.4	0.1	0.2	0.1	1.1	0.6	0.1		0.3			0.2	0.3		5
44.Raw Oil								4.6			0.1				0
45.Natural Gas											0.3				0
28.Road Trans.	1.4	0.1	0.2		0.1		0.1		0.1			0.1	0.2		3
36.Trade	7.7	0.4	0.7	0.1	0.6	0.3	0.4		0.3	0.1	0.1	0.6	0.9		14
42.Other Serv.	6.4	0.8	0.9	0.2	1.0	0.5	0.5	0.3	0.7	0.1	0.3	1.4	0.1		16

[1979]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								35.9	3.6	40.1
23.Vehicle	0.2	0.5						0.4		1.8
22.Elec.Mach.	0.6		2.5	1.6				5.1		10.0
21.Machinery	0.4	0.1	0.2	11.4				24.7		37.2
20.Metal Prod.	3.6		0.2	0.7	0.3					5.6
18.Iron&Steel	1.6	0.1	0.5	4.8	1.5	9.5				18.4
19.Non-ferrous	0.3		0.6	0.5	0.2	0.1	1.1			3.1
33.Electricity	0.3		0.1	0.4	0.1	0.9	0.3			4.9
36.Trade	2.9		0.5	1.6	0.2	0.4	0.1			3.3
42.Other Serv.	2.9		1.1	2.4	0.4	0.7	0.2			3.7

[1976]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								8.6	2.4	11.1
23.Vehicle		0.4						0.7		1.3
22.Elec.Mach.	0.1		0.7	0.3				1.5		2.6
21.Machinery				1.8				3.7		5.8
20.Metal Prod.	0.9			0.1				0.1		1.4
18.Iron&Steel	0.3		0.1	0.6	0.4	2.2				3.8
19.Non-ferrous	0.1		0.2	0.1			0.4			1.0
33.Electricity						0.2				0.8
36.Trade	0.9		0.1	0.3						2.2
42.Other Serv.	0.8		0.3	0.4		0.1				2.9

[1973]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								1.9	0.6	2.6
23.Vehicle								0.2		0.3
22.Elec.Mach.			0.2					0.3		0.6
21.Machinery				0.4				0.9		1.4
20.Metal Prod.	0.3									0.4
18.Iron&Steel				0.2	0.1	0.6				1.1
19.Non-ferrous							0.1			0.3
33.Electricity										0.2
36.Trade	0.2									0.5
42.Other Serv.	0.2									0.9

[1978]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								20.9	6.8	28.0
23.Vehicle	0.2	1.1						1.8		3.5
22.Elec.Mach.	0.3	0.1	1.7	0.7				4.0		7.0
21.Machinery	0.3	0.2	0.1	5.0				9.9		15.8
20.Metal Prod.	2.3		0.1	0.3	0.2			0.3		3.5
18.Iron&Steel	1.0	0.2	0.3	1.9	0.9	5.7				10.4
19.Non-ferrous	0.3		0.6	0.3	0.2		0.9			2.4
33.Electricity	0.2			0.2		0.5	0.2			2.3
36.Trade	2.2	0.2	0.4	0.8	0.2	0.2				5.8
42.Other Serv.	2.0	0.1	0.7	1.1	0.3	0.4	0.1			7.6

[1975]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								4.9	1.6	6.6
23.Vehicle		0.3						0.5		0.9
22.Elec.Mach.			0.3	0.1				0.8		1.4
21.Machinery				1.0				2.3		3.6
20.Metal Prod.	0.5									0.8
18.Iron&Steel	0.2			0.4	0.2	1.3				2.4
19.Non-ferrous							0.2			0.5
33.Electricity						0.1				0.5
36.Trade	0.5			0.2						1.3
42.Other Serv.	0.5		0.2	0.3						2.0

[1972]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								1.1	0.4	1.6
23.Vehicle								0.1		0.2
22.Elec.Mach.								0.2		0.3
21.Machinery				0.2				0.5		0.8
20.Metal Prod.	0.1									0.2
18.Iron&Steel						0.3				0.6
19.Non-ferrous										0.1
33.Electricity										0.1
36.Trade										0.3
42.Other Serv.	0.1									0.5

[1977]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								13.6	4.1	17.9
23.Vehicle	0.1	0.7						1.1		2.1
22.Elec.Mach.	0.2		1.0	0.4				2.4		4.2
21.Machinery	0.2	0.1		3.0				6.0		9.6
20.Metal Prod.	1.4			0.2	0.1			0.2		2.2
18.Iron&Steel	0.5	0.1	0.2	1.0	0.6	3.2				5.8
19.Non-ferrous	0.2		0.3	0.2	0.1		0.6			1.5
33.Electricity	0.1			0.1		0.3	0.2			1.4
36.Trade	1.4	0.1	0.2	0.5		0.1				3.6
42.Other Serv.	1.3		0.5	0.7	0.2	0.2				4.9

[1974]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								3.1	0.9	4.1
23.Vehicle		0.2						0.3		0.5
22.Elec.Mach.			0.3	0.1				0.6		1.1
21.Machinery				0.7				1.5		2.3
20.Metal Prod.	0.4									0.6
18.Iron&Steel	0.1			0.3	0.2	0.9				1.6
19.Non-ferrous							0.2			0.4
33.Electricity										0.3
36.Trade	0.3			0.1						0.9
42.Other Serv.	0.4		0.1	0.2						1.4

[1971]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								0.6	0.2	0.9
23.Vehicle										0.1
22.Elec.Mach.										0.2
21.Machinery				0.1				0.3		0.5
20.Metal Prod.										0.1
18.Iron&Steel						0.2				0.3
19.Non-ferrous										
33.Electricity										
36.Trade										0.2
42.Other Serv.										0.3

Table 3: Dynamic Unit Structure of Motor Vehicle (Base Year=1992)

[1992]	23	22	21	20	18	19	15	13	12	6	33	36	42	c	x
23.Vehicle	68.4											0.1		100	169
22.Elec.Mach.	11.7	5.8	0.2										0.3		18
21.Machinery	2.0	0.2	1.4										0.4		4
20.Metal Prod.	1.3	0.3	0.1	0.1			0.1		0.1						2
18.Iron&Steel	5.7	0.3	0.2	0.6	6.2										13
19.Non-ferrous	3.3	0.6	0.1	0.2	0.1	2.6									7
15.Rubber Prod.	4.5	0.1					0.2								5
13.Petroleum	0.5	0.1			0.1		0.1	0.1	0.5		0.4	0.2	0.2		3
12.Chemical	1.9	0.2			0.1	0.1	1.2		1.9	0.1			0.2		7
6.Textile	0.3						0.2			0.3					1
33.Electricity	2.0	0.2		0.1	0.7	0.2	0.1		0.3			0.2	0.3		5
44.Raw Oil								2.2			0.3				0
45.Natural Gas											0.4				0
28.Road Trans.	1.3	0.1			0.1	0.1	0.1		0.1			0.1	0.2		3
36.Trade	8.4	0.6	0.1	0.1	0.5	0.3	0.2		0.2	0.1	0.1	0.2	0.9		13
42.Other Serv.	7.5	0.8	0.1	0.1	0.4	0.2	0.3		0.5		0.4	1.0	1.0		15

[1991]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								35.3	1.3	37.5
23.Vehicle	0.3	0.7						0.2		1.7
22.Elec.Mach.	0.7	0.1	5.1	2.6				6.6		15.7
21.Machinery	0.5		0.2	21.6				39.6		62.4
20.Metal Prod.	4.0		0.2	1.5	0.4					6.6
18.Iron&Steel	1.2		0.2	3.0	1.7	6.5				13.0
19.Non-ferrous	0.4		0.5	1.0	0.5	0.1	2.1			4.7
33.Electricity	0.3		0.2	0.7	0.2	0.7	0.2			3.1
36.Trade	2.8		0.5	1.9	0.2	0.5	0.2			3.4
42.Other Serv.	2.9		0.8	1.9	0.4	0.4	0.2			3.5

[1990]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.	0.1							20.5	6.1	27.2
23.Vehicle	0.2	1.6						2.0		4.2
22.Elec.Mach.	0.5	0.3	5.7	0.8				11.0		18.6
21.Machinery	0.4		0.2	7.0				13.1		21.0
20.Metal Prod.	2.8		0.3	0.5	0.3			0.3		4.5
18.Iron&Steel	0.9	0.1	0.3	1.2	1.2	4.0				7.9
19.Non-ferrous	0.3		0.6	0.4	0.3		1.4			3.1
33.Electricity	0.2		0.2	0.2	0.1	0.4	0.1			2.2
36.Trade	2.1	0.2	0.7	0.7	0.2	0.3	0.2			6.1
42.Other Serv.	1.9	0.2	1.1	0.6	0.2	0.2	0.1			7.3

[1989]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								14.2	4.1	18.6
23.Vehicle	0.1	1.0						1.4		2.8
22.Elec.Mach.	0.3	0.2	3.4	0.5				6.2		10.9
21.Machinery	0.3		0.1	4.1				7.4		12.1
20.Metal Prod.	1.8		0.2	0.3	0.2			0.2		2.9
18.Iron&Steel	0.6	0.1	0.2	0.7	0.8	2.5				5.1
19.Non-ferrous	0.2		0.3	0.2	0.2		0.9			2.0
33.Electricity	0.1		0.1	0.1		0.2				1.4
36.Trade	1.2	0.2	0.4	0.4	0.1	0.2				3.5
42.Other Serv.	1.3	0.1	0.6	0.4	0.2	0.1				4.7

[1988]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								8.9	3.3	12.4
23.Vehicle		0.7						0.9		1.8
22.Elec.Mach.	0.2	0.1	2.1	0.3				3.7		6.5
21.Machinery	0.2			2.6				4.6		7.5
20.Metal Prod.	1.2		0.1	0.2	0.1			0.1		1.9
18.Iron&Steel	0.5		0.1	0.4	0.5	1.7				3.4
19.Non-ferrous	0.1		0.2	0.1	0.1		0.6			1.3
33.Electricity						0.1				0.9
36.Trade	0.7		0.2	0.2		0.1				2.1
42.Other Serv.	0.8		0.4	0.2	0.1					2.9

[1987]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								5.7	2.1	7.9
23.Vehicle		0.4						0.5		1.1
22.Elec.Mach.	0.1		1.2	0.2				2.1		3.8
21.Machinery				1.7				2.9		4.8
20.Metal Prod.	0.8			0.1						1.2
18.Iron&Steel	0.3			0.3	0.3	1.1				2.1
19.Non-ferrous			0.1				0.3			0.8
33.Electricity										0.6
36.Trade	0.5		0.1	0.1						1.3
42.Other Serv.	0.5		0.2	0.1						1.9

[1986]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								3.8	1.4	5.3
23.Vehicle		0.2						0.3		0.7
22.Elec.Mach.			0.7	0.1				1.3		2.3
21.Machinery				1.2				2.0		3.3
20.Metal Prod.	0.5									0.8
18.Iron&Steel	0.2			0.2	0.2	0.7				1.4
19.Non-ferrous			0.1				0.2			0.6
33.Electricity										0.4
36.Trade	0.3									0.9
42.Other Serv.	0.4		0.1	0.1						1.3

[1985]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								2.6	0.8	3.5
23.Vehicle		0.2						0.2		0.4
22.Elec.Mach.			0.4					0.8		1.4
21.Machinery				0.7				1.3		2.1
20.Metal Prod.	0.3									0.5
18.Iron&Steel	0.1			0.1	0.1	0.5				1.0
19.Non-ferrous							0.1			0.3
33.Electricity										0.3
36.Trade	0.2									0.6
42.Other Serv.	0.3		0.1							0.9

[1984]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								1.6	0.6	2.3
23.Vehicle		0.1						0.1		0.3
22.Elec.Mach.			0.2					0.5		0.8
21.Machinery				0.4				0.8		1.3
20.Metal Prod.	0.2									0.3
18.Iron&Steel						0.4				0.7
19.Non-ferrous										0.2
33.Electricity										0.2
36.Trade	0.1									0.4
42.Other Serv.	0.2									0.6

[1983]	4	23	22	21	20	18	19	Ip	Ig	x
4.Build.&Const.								1.0	0.4	1.5
23.Vehicle								0.1		0.2
22.Elec.Mach.			0.1					0.2		0.4
21.Machinery				0.3				0.5		0.8
20.Metal Prod.	0.1									0.2
18.Iron&Steel						0.2				0.4
19.Non-ferrous										0.1
33.Electricity										0.1
36.Trade	0.1									0.3
42.Other Serv.	0.1									0.4

Table 4: Sectoral TFP (annual growth rate)

	1960-65	65-70	70-75	75-80	80-85	85-90	1960-75	1975-90
1.Agriculture	-1.646	-3.870	-4.288	-2.819	1.010	-0.416	-3.268	-0.742
2.Coal Mining	7.286	5.443	-2.583	-4.187	0.118	-2.469	3.382	-2.179
3.Other Mining	3.943	8.522	-3.776	5.012	-2.611	2.415	2.896	1.605
4.Build.& Const.	-1.253	1.037	-0.602	-1.966	0.164	0.741	-0.273	-0.354
5.Foods	-0.109	0.243	-0.593	0.818	-0.615	-1.316	-0.153	-0.371
6.Textile	0.829	1.308	0.677	1.405	0.873	1.415	0.938	1.231
7.Apparel	0.610	1.453	0.540	1.405	-0.234	-0.608	0.868	0.188
8.Woods	1.595	1.254	1.895	-3.308	4.354	-1.342	1.581	-0.099
9.Furniture	-0.872	1.177	0.164	1.052	0.920	0.181	0.156	0.718
10.Paper & Pulp	2.142	2.459	-1.480	0.406	1.210	2.155	1.040	1.257
11.Publishing	-4.456	-3.594	-2.278	-0.242	0.087	0.637	-3.443	0.161
12.Chemical	2.685	4.710	-1.678	1.058	2.305	1.343	1.906	1.569
13.Petroleum	-0.816	-2.808	-4.384	-1.328	-0.274	5.901	-2.669	1.433
14.Coal Prod.	-0.169	2.039	-5.034	-7.746	0.234	2.102	-1.055	-1.803
15.Rubber Prod.	3.266	3.497	-3.578	-0.674	2.897	2.896	1.062	1.706
16.Leather Prod.	3.133	-0.645	2.813	-2.197	1.523	-0.970	1.767	-0.548
17.Stone & Clay	2.485	1.155	-2.192	0.599	0.954	0.924	0.482	0.826
18.Iron & Steel	0.219	1.991	0.029	0.836	-0.441	0.126	0.746	0.174
19.Non-ferrous	-0.400	1.039	2.945	2.205	1.963	0.228	1.195	1.465
20.Metal Prod.	2.140	3.607	-1.974	1.553	0.777	1.325	1.258	1.218
21.Machinery	-1.009	3.409	-1.709	3.094	1.366	0.337	0.230	1.599
22.Elec.Mach.	2.852	6.140	1.228	5.374	1.752	3.068	3.407	3.398
23.Vehicle	1.131	4.487	1.999	3.184	0.254	0.817	2.539	1.418
24.Oth.Trans.Mach.	4.557	1.176	-5.048	0.594	1.377	1.932	0.228	1.301
25.Precision Inst.	2.770	4.908	0.013	6.184	1.555	-0.320	2.564	2.473
26.Misc.Mng.Prod.	2.308	3.870	-2.388	1.431	0.663	0.773	1.263	0.956
27.Railway	1.982	-2.491	5.667	-10.538	1.300	-1.748	1.719	-3.662
28.Road Trans.	2.550	4.609	-5.813	2.302	-2.287	-0.246	0.449	-0.077
29.Water Trans.	-0.598	7.449	2.025	-2.081	3.905	-3.820	2.958	-0.666
30.Air Trans.	4.142	8.275	8.190	-0.617	2.035	-0.009	6.869	0.470
31.Storage	1.036	3.778	-6.321	8.487	0.866	-0.751	-0.502	2.867
32.Communication	1.815	2.102	0.427	2.342	5.714	2.173	1.448	3.410
33.Electricity	4.441	4.988	-3.409	-1.776	1.539	2.054	2.006	0.605
34.Gas	3.481	0.763	0.380	-0.319	1.314	2.950	1.541	1.315
35.Water	-2.742	-2.203	-2.351	-6.098	0.210	-1.129	-2.432	-2.339
36.Trade	5.505	5.452	-0.240	2.262	-0.448	3.196	3.572	1.670
37.Finance	5.479	1.466	-0.507	-0.410	3.361	1.024	2.146	1.325
38.Real Estate	5.596	-0.204	-2.952	-0.402	0.658	-0.384	0.813	-0.042
39.Education	0.867	3.563	0.992	-5.010	-3.558	-1.481	1.808	-3.350
40.Research	5.950	2.653	-1.360	4.075	-1.863	0.013	2.415	0.742
41.Medical Serv.	1.567	-0.511	5.186	-2.068	-1.134	-3.711	2.081	-2.304
42.Other Serv.	-5.744	1.401	-3.932	0.092	-0.773	-2.601	-2.758	-1.094
43.Public Adm.	4.089	2.467	6.905	-4.968	-0.844	0.450	4.487	-1.787

Table 5: Static Unit TFP (annual growth rate)

	1960-65	65-70	70-75	75-80	80-85	85-90	1960-75	TFP	1975-90	TFP
1.Agriculture	-1.535	-3.814	-6.018	-3.055	1.558	-0.145	-3.789	-0.52	-0.547	0.19
2.Coal Mining	7.975	7.060	-4.138	-4.437	0.608	-2.187	3.632	0.25	-2.005	0.17
3.Other Mining	4.720	9.763	-5.017	5.509	-2.142	3.458	3.155	0.26	2.275	0.67
4.Build.& Const.	0.691	4.830	-2.509	-1.295	0.914	1.412	1.004	1.28	0.344	0.70
5.Foods	-0.448	-0.563	-4.373	-0.167	0.150	-1.183	-1.794	-1.64	-0.400	-0.03
6.Textile	2.560	4.437	-1.177	2.408	2.539	3.060	1.940	1.00	2.669	1.44
7.Apparel	2.962	5.116	-0.790	2.683	0.943	1.016	2.429	1.56	1.547	1.36
8.Woods	1.579	0.318	-1.393	-4.996	5.964	-1.131	0.168	-1.41	-0.054	0.04
9.Furniture	0.983	4.028	-1.542	0.652	2.674	0.686	1.157	1.00	1.338	0.62
10.Paper & Pulp	4.456	5.754	-4.541	0.156	3.041	3.895	1.890	0.85	2.364	1.11
11.Publishing	-3.217	-1.401	-4.506	-0.045	1.177	1.649	-3.042	0.40	0.927	0.77
12.Chemical	5.464	9.124	-4.667	1.765	4.080	2.623	3.307	1.40	2.823	1.25
13.Petroleum	-0.692	-2.462	-5.151	-1.324	-0.072	6.464	-2.768	-0.10	1.689	0.26
14.Coal Prod.	3.930	7.089	-9.706	-11.388	0.669	1.558	0.438	1.49	-3.054	-1.25
15.Rubber Prod.	5.429	7.321	-5.634	-0.033	4.403	4.121	2.372	1.31	2.831	1.12
16.Leather Prod.	7.567	1.700	2.543	-2.655	2.826	-0.676	3.937	2.17	-0.169	0.38
17.Stone & Clay	4.182	4.728	-4.582	1.539	1.236	1.920	1.442	0.96	1.565	0.74
18.Iron & Steel	2.123	7.825	-2.109	0.292	-0.244	0.791	2.613	1.87	0.280	0.11
19.Non-ferrous	2.107	7.028	1.620	4.782	3.759	1.291	3.585	2.39	3.278	1.81
20.Metal Prod.	3.480	7.390	-3.261	2.133	1.213	1.887	2.536	1.28	1.744	0.53
21.Machinery	0.086	8.260	-3.305	5.602	2.608	1.142	1.680	1.45	3.117	1.52
22.Elec.Mach.	4.963	11.687	0.353	8.149	3.197	4.969	5.667	2.26	5.438	2.04
23.Vehicle	3.273	10.144	1.334	6.007	1.372	2.415	4.917	2.38	3.265	1.85
24.Oth.Trans.Mach.	6.639	5.705	-7.220	2.036	2.609	3.114	1.708	1.48	2.586	1.28
25.Precision Inst.	4.503	9.043	-0.771	8.341	2.813	0.349	4.258	1.69	3.835	1.36
26.Misc.Mng.Prod.	4.645	7.932	-5.019	2.132	2.398	1.939	2.519	1.26	2.156	1.20
27.Railway	3.569	-0.819	3.474	-9.996	1.818	-1.538	2.075	0.36	-3.239	0.42
28.Road Trans.	3.092	5.963	-6.544	2.680	-2.047	0.182	0.837	0.39	0.272	0.35
29.Water Trans.	-0.141	10.126	2.401	-2.944	6.065	-4.395	4.129	1.17	-0.425	0.24
30.Air Trans.	5.486	10.379	6.936	-0.584	3.117	0.590	7.600	0.73	1.041	0.57
31.Storage	1.314	4.829	-8.252	8.415	1.326	-0.942	-0.703	-0.20	2.933	0.07
32.Communication	1.949	2.559	-0.257	2.552	5.701	2.128	1.417	-0.03	3.460	0.05
33.Electricity	5.153	5.641	-5.065	-2.280	1.671	2.309	1.910	-0.10	0.567	-0.04
34.Gas	4.335	1.869	-0.158	3.106	1.120	2.964	2.015	0.47	2.397	1.08
35.Water	-2.471	-1.267	-4.292	-6.679	0.957	-0.663	-2.677	-0.24	-2.129	0.21
36.Trade	6.344	6.780	-1.259	2.362	0.043	3.361	3.955	0.38	1.922	0.25
37.Finance	5.226	2.249	-1.598	-0.344	3.769	0.837	1.959	-0.19	1.421	0.10
38.Real Estate	5.724	0.384	-3.306	-0.529	0.870	-0.346	0.934	0.12	-0.001	0.04
39.Education	0.497	4.429	0.517	-5.054	-3.430	-1.422	1.814	0.01	-3.302	0.05
40.Research	5.352	3.610	-2.590	4.080	-1.700	0.007	2.124	-0.29	0.796	0.05
41.Medical Serv.	2.932	1.873	3.598	-1.669	-0.230	-2.977	2.801	0.72	-1.625	0.68
42.Other Serv.	-4.936	3.361	-5.692	0.216	-0.183	-2.185	-2.422	0.34	-0.717	0.38
43.Public Adm.	4.830	3.669	5.921	-4.905	-0.585	0.556	4.807	0.32	-1.645	0.14

Table 6: Dynamic Unit TFP (annual growth rate)

	1970-75	−UTFP	75-80	−UTFP	80-85	−UTFP	85-90	−UTFP	1975-90	−TFP	−UTFP
1.Agriculture	-4.522	1.50	-3.185	-0.13	1.994	0.44	0.865	1.01	-0.007	0.73	0.54
2.Coal Mining	-2.883	1.26	-4.293	0.14	1.188	0.58	-1.383	0.80	-1.255	0.92	0.75
3.Other Mining	-2.759	2.26	5.821	0.31	-1.325	0.82	4.500	1.04	3.374	1.77	1.10
4.Build.& Const.	-0.865	1.64	-1.126	0.17	1.430	0.52	2.322	0.91	1.103	1.46	0.76
5.Foods	-2.790	1.58	-0.189	-0.02	0.646	0.50	-0.235	0.95	0.232	0.60	0.63
6.Textile	0.169	1.35	2.535	0.13	2.925	0.39	3.641	0.58	3.204	1.97	0.53
7.Apparel	0.472	1.26	2.785	0.10	1.312	0.37	1.654	0.64	2.073	1.89	0.53
8.Woods	0.040	1.43	-5.025	-0.03	6.402	0.44	-0.302	0.83	0.495	0.59	0.55
9.Furniture	-0.078	1.46	0.711	0.06	3.108	0.43	1.571	0.89	1.961	1.24	0.62
10.Paper & Pulp	-2.736	1.80	0.422	0.27	3.687	0.65	4.909	1.01	3.310	2.05	0.95
11.Publishing	-3.039	1.47	0.136	0.18	1.696	0.52	2.453	0.80	1.662	1.50	0.73
12.Chemical	-2.760	1.91	1.986	0.22	4.687	0.61	3.758	1.13	3.753	2.18	0.93
13.Petroleum	-3.618	1.53	-1.216	0.11	0.104	0.18	7.147	0.68	2.106	0.67	0.42
14.Coal Prod.	-7.898	1.81	-11.276	0.11	1.418	0.75	2.640	1.08	-2.119	-0.32	0.94
15.Rubber Prod.	-4.144	1.49	0.195	0.23	4.930	0.53	5.036	0.91	3.639	1.93	0.81
16.Leather Prod.	3.934	1.39	-2.559	0.10	3.256	0.43	0.160	0.84	0.461	1.01	0.63
17.Stone & Clay	-2.715	1.87	1.651	0.11	1.736	0.50	2.854	0.93	2.284	1.46	0.72
18.Iron & Steel	-0.085	2.02	0.672	0.38	0.458	0.70	1.970	1.18	1.394	1.22	1.11
19.Non-ferrous	3.745	2.12	4.988	0.21	4.342	0.58	2.412	1.12	4.177	2.71	0.90
20.Metal Prod.	-1.573	1.69	2.277	0.14	1.652	0.44	2.767	0.88	2.426	1.21	0.68
21.Machinery	-1.565	1.74	5.876	0.27	3.296	0.69	2.191	1.05	4.109	2.51	0.99
22.Elec.Mach.	2.377	2.02	8.369	0.22	3.778	0.58	6.053	1.08	6.333	2.94	0.89
23.Vehicle	3.054	1.72	6.264	0.26	1.984	0.61	3.275	0.86	4.130	2.71	0.87
24.Oth.Trans.Mach.	-5.462	1.76	2.200	0.16	3.117	0.51	3.932	0.82	3.307	2.01	0.72
25.Precision Inst.	0.833	1.60	8.626	0.28	3.398	0.58	1.233	0.88	4.708	2.24	0.87
26.Misc.Mng.Prod.	-3.332	1.69	2.287	0.16	2.953	0.56	2.943	1.00	2.965	2.01	0.81
27.Railway	4.539	1.07	-10.043	-0.05	2.102	0.28	-0.726	0.81	-2.810	0.85	0.43
28.Road Trans.	-5.779	0.76	2.677	0.00	-1.850	0.20	0.792	0.61	0.604	0.68	0.33
29.Water Trans.	4.360	1.96	-3.207	-0.26	6.492	0.43	-3.444	0.95	0.002	0.67	0.43
30.Air Trans.	9.238	2.30	-0.796	-0.21	3.616	0.50	1.569	0.98	1.559	1.09	0.52
31.Storage	-7.074	1.18	8.623	0.21	1.919	0.59	0.056	1.00	3.800	0.93	0.87
32.Communication	1.401	1.66	2.768	0.22	6.267	0.57	3.371	1.24	4.395	0.99	0.94
33.Electricity	-2.567	2.50	-2.070	0.21	2.329	0.66	3.898	1.59	1.675	1.07	1.11
34.Gas	1.641	1.80	3.391	0.29	1.529	0.41	3.922	0.96	3.179	1.86	0.78
35.Water	-2.738	1.55	-6.614	0.07	1.403	0.45	0.461	1.12	-1.413	0.93	0.72
36.Trade	0.438	1.70	2.479	0.12	0.520	0.48	4.211	0.85	2.601	0.93	0.68
37.Finance	0.269	1.87	-0.180	0.16	4.335	0.57	1.883	1.05	2.256	0.93	0.84
38.Real Estate	-0.762	2.54	-0.644	-0.11	1.704	0.83	1.628	1.97	1.136	1.18	1.14
39.Education	1.088	0.57	-5.039	0.01	-3.260	0.17	-1.073	0.35	-3.063	0.29	0.24
40.Research	-1.913	0.68	4.174	0.09	-1.421	0.28	0.559	0.55	1.229	0.49	0.43
41.Medical Serv.	5.320	1.72	-1.484	0.19	0.294	0.52	-2.058	0.92	-0.846	1.46	0.78
42.Other Serv.	-3.845	1.85	0.465	0.25	0.429	0.61	-1.196	0.99	0.186	1.28	0.90
43.Public Adm.	6.667	0.75	-4.826	0.08	-0.353	0.23	0.930	0.37	-1.313	0.47	0.33