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An Explanation of The Productivity Paradox: TFP Spillover through Capital Accumulation

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Abstract

Recent statistics from the OECD concerning productivity growth at the macro-economic level show a sort of paradoxical shift in the relationship between the recent upheaval of real investment in new information technology and productivity growth. Table 1 represents the trends of productivity changes in both Japan and the U.S. during the periods 1960-90. Even if there were sizable new investment (including computer and related information facilities) recently, productivity at the macro-economic level could not be improved as well as could be expected by this new investment. These puzzling observations raised a series of discussion points: the so-called 'conceptualization problem', or 'Solow's paradox'. Several hypotheses have been put forward in attempt to explain these observations in a consistent manner and solve these puzzles: 1) The measurement error hypothesis; 2) the time lag hypothesis; 3) the substitutability hypothesis; 4) the externality hypothesis; and, finally 5) the spillover hypothesis. In this paper, we will try to focus on two of these alternative explanations: the measurement error hypothesis, and the spillover hypotheses. In particular, we will try to emphasize the importance of evaluating the new technology embodied in the capital stock. We proposed two new concepts of measurement of TFP growth: 'Static unit TFP' and 'dynamic unit TFP'. "Static and dynamic unit TFP" are extensions of the ordinary TFP measure, in which can evaluate the spillover effects of recent developments in technology. There has been no paradoxical shift in recent years regarding the relationship between TFP growth and new investment by using our new measures of productivity.

Key words: Solow Paradox, Total Factor Productivity, Measurement Error,
Spillover of Technology

JEL classification: C50, E23, O30, O47

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1 Introduction

Recent statistics released by OECD countries suggest that productivity growth at the macro level has not seen a rapid recovery since the great shock of the first oil crisis. In fact, as we can see in Table 1, the annual growth rate of total factor productivity in Japan during the early 1980s was still less than 1 per cent; while in the U.S. it was less than 0.3 per cent, after the economic downturn of the early 1970s. In both countries, we can observe sizable increases in real investment. The recent growth of investment in the U.S. reached a high level of more than 3 per cent per annual. Also, in Japan real investment, especially that in electrical machinery (including computer and information facilities) increased rapidly during the 1980s. We should also note in the table that partial productivity of labor has been increasing gradually since 1960; while the partial productivity of capital has declined during the same period. It seems that increases in the labor productivity are achieved at the cost of decreases in the capital productivity.

The Table shows that there has been a sort of paradoxical shift in the relationship between the trend of real investment and total factor productivity growth during the periods of recent Japanese and U.S. economic recovery. It is our intuitive belief that this situation means productivity growth has not been achieved in spite of sizable increases in real investment,along with new developments in technology, including information technology and high-tech instruments. This is called a 'conceptualization problem', or 'Solow's paradox in productivity'. It seems that these problems originate from the above questions. [1] Although these are, initially, hypothetical questions, they also, however,include various important issues which should be clarified from the viewpoint of new technologies; as well as the measurement of productivity growth. Broadly speaking, there might be several alternative ways of explaining these paradoxical phenomena in productivity trends:

1) Measurement errors: There are two possibile explanations for the errors in productivity measurement. It is often argued that TFP growth measures have a number of possibile measurement errors because of their definitions, whereby they are defined by differences between observed growth rates of input and output. From this perspective, qualitative changes in output and input might be highly important ways of generating measurement errors of productivity. Experiments to revise the price and quantity index numbers including a hedonic approach suggested that considerations regarding qualitative measures of input and output could be expected to produce sizable changes in the results of TFP growth measures. A second source of measurement errors in TFP growth measures comes from an aggregation bias. Measures of input and output in the estimation of TFP growth are defined by an aggregate measure of various heterogeneous types of inputs and outputs, even at the industry level, as well as at the macro level. We can observe changes in the composition of the inputs and outputs in

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[1] Greenspan(1995),(1996).

our historical statistics. In the simple aggregate procedures, which ignored qualitative differences of components and changes in their allocation among sectors, these might create a sort of aggregation bias.

2) There have been many developments in new technologies since the time of the industrial revolution. In addition, there have been occasions in history when it took a considerable amount of time for these developments to diffuse themselves into society and contribute to improve efficiency in production after their theoretical conception. Information technologies might have similar features. It might take some time to apply the knowledge that develops in this field,and as a result, achieve gains in productivity.

3) Substitutability between labor and capital: New technologies, like information technology require sizable real investment for them to be integrated into the production process. It might increase labor productivity by substituting labor input with capital input, while capital productivity might decline. Since increases in labor productivity would be canceled out by decreases in capital productivity, total factor productivity could not be improved as well as might be expected by the new technologies.

4) Externality: Externality is one of the important characteristics of new information technology. Since the external effects of the new technologies could not be evaluated endogenously in terms of market prices, it might be difficult to measure their contributions to productivity by the growth-accounting framework.

5) The spillover effect of technology: Recently developed technologies have contributed to improved efficiency in high-tech machinery sectors. Also, new technologies (including computers and information technologies) have brought about a big change in the composition of investment goods in almost all industrial sectors, where the share of general and electrical machinery in investment would increase dramatically. As a consqunce, the productivity gains in machinery sectors could have a spillover effect on the improvement of productivity in all industrial sectors. The productivity gains in machinery sectors not only could spill over among sectors through the static framework of interdependence of the technology among sectors, but also have a dynamic spillover effect among sectors through capital accumulation. This spillover effect should be distinguished from the external effect of technology. It should be evaluated as a pecuniary impact of the efficiency gains in new technology.

As indicated above, we can provide several alternative explainations for these recent paradoxical and puzzling trends in productivity. Within the previous five alternative explanations, we do not consider the second possibility, ‘the time lag hypothesis’, here. It seems to us to be difficult to identify the validity of the hypothesis by using short-term data over just three decades. With regards to the third explanation, we cannot deny the possibility of a substitution between labor and capital during the process of installing new technology. As shown in Table 1, however, the phenomenon of substitution in order to improve productivity is not necessarily a recent characteristics of new technology. We can often observe the same phenomenon in productivity trends since 1960. Therefore, it is important to explain the implications of installing new technology, where it would be implemented, even at the cost of productivity improvement of capital. As for the externality issues in the fourth explanation, we also cannot deny the effect of externality on new technology. We wonder, however, if there could be some sorts of non-pecuniary effect caused by the installation of new technology: If so,it should be included in the growth rate of the total factor productivity, and should be measured in the residuals where all of pecuniary effects are excluded.

In this paper, we would like to focus on two alternative possibilities in order to explain these puzzling problems. One is an explanation by measurement errors, and the other is an explanation related to spillover effects within the pecuniary framework. In section 2, we would like to focus on the explanation of measurement errors from the viewpoints of qualitative evaluation of inputs and aggregation biases at the macro level. We try to break down the sources of economic growth in Japan into changes of quantities of factor inputs, changes of qualities of factor inputs and changes of allocation of resources of output and input among sectors. This should provide definite verification of the measurement error hypothesis in order to explain the recent puzzling trend of productivity. When it comes to evaluating the effect of qualitative change in capital input, we can observe that there were fairly dominant qualitative changes in capital input recently. This was due to a strict relationship with the increasing shares of machinery,(especially electrical machinery) in the composition of assets in new investment, and capital stock in all industrial sectors. In section 3 we try to summarize our observations concerning the changes of the composition of assets in capital formation and stock. The development of new technologies is assumed to be realized by the changes of composition among capital goods in capital formation and observed by the changes of the capital coefficients in capital stock by assets. We begin with the development of the measures of capital input in current and constant prices for each of the 43 industrial sectors in Japan for the period 1955-92. We have estimated capital matrices in terms of flow and stock in order to evaluate the impact of the structural changes in capital coefficients on the economy, where new technology has been expected to be embodied. Furthermore, when we try to consider the impacts of structural changes in the capital composition on productivity growth, we have to propose a theoretical framework in the productivity measurement in order to evaluate their impacts.

In section 4 we try to quantitatively evaluate the implications of the spillover effect of TFP growth for the structural changes in the Japanese economy. The concept of spillover discussed in this paper should be distinguished from that of externality. Our concerns are related to the structural changes of input coefficients of intermediate inputs and factor inputs,(such as labor and capital), which are brought about by the installation of new technology. Structural changes which are implemented by new technologies might have a sizable impacts on the framework of linkage among various economic sectors, which is the second implication of the spillover effect. We can see that the structural changes brought about by new technologies could produce an extension of the spillover effect of the TFP growth, and contribute to an increase in efficiency within the economy; while the ordinary measure of the TFP growth in each industrial sector is relatively lower. Our analytical framework is based upon an approach of input-output analysis. In our framework, the spillover effect of the structural changes on productivity can be measured not only by the static interdependent relationship among sectors through the transactions of their intermediate goods, but also by the dynamic inter-relationship among sectors through the capital accumulation process. We assume here that the development of new technologies could be embodied in changes of capital stock through new investment, and that this would have a spillover effect on the whole economy through productivity growth. These approaches to the static and dynamic measures of the spillover effect provide us with extended concepts of the measurement of total factor productivity. Our concept of the measurement of the total factor productivity is an extension of the concept of the ordinary TFP measures by sectoral analysis, from the viewpoints of technological properties of commodity production and spillover effect of the technology as a system.

2 Measurement Problems in TFP

The TFP measurements in Table 1 represent figures in both Japan and the U.S., where we have tried to carefully remove the possibility of any measurement errors. By this definition, the growth rate of TFP could be observed only as the difference between growth rates of output and input. Therefore, results depend entirely upon the measurement of quantities of output and input, as well as those of prices of output and input. In particular, they should be carefully adjusted so as to measure changes of quality of output and input in the measurements of quantities and prices. If we try to measure quantities of output and inputs as a simple sum, (where all of outputs and inputs are assumed to be homogeneous as for their qualities), the growth rate of TFP, as the difference of the growth rates of output and input might include some measurement errors. This is because there are, presumably,overlooked qualitative changes in output and input. One of way of explaining the recent paradoxical trends of productivity is attributable to the measurement errors of TFP. Strictly speaking, qualitative changes of output and input are divided into two different sources concerning the measurement of the aggregated level. One is error which arises from neglect of qualitative changes of output and input in specific industrial sectors, and the other is bias which comes from a disregard for allocational changes of output and input among industrial sectors. We try to distinguish the former qualitative changes in one sector from the latter allocational biases in distribution of resources. Concerning the former qualitative changes in output by sector, it should be noted that qualitative changes in output have already taken into account measurements of output deflators in WPI. In particular, recent changes of quality in high-tech commodities, such as computers, have been measured in WPI of commodities by using the hedonic approach method. Here, we just focus on qualitative changes of inputs at the aggregate level of the economy.

Our first objective is to measure value added for the economy as a whole. Our measurements of the sectoral gross output are based upon the input-output accounting framework. Both our input-output accounting framework and the sectoral price functions give aggregate measures of value-added price and factor input prices. These prices create the quantity of aggregate value added and factor inputs as a dual index, in which nominal accounting balances in each sector and economy as a whole are maintained. It should be emphasized that we do not necessarily assume the existence of an aggregate production function or an aggregate price function. The assumption of the existence of an aggregate function imposes stringent restrictions on sectoral models of production. All sectoral price functions must be identical to the aggregate price function; and all sectoral value-added prices, capital service prices and labor service prices must be equal to each aggregate price respectively. Unless these assumptions of the aggregate production model are met, the analysis of sources of economic growth creates differences between sectoral and aggregate models of production and technical change. Contributions of reallocations of value-added and primary factor inputs among sectors can be identified by the rate of aggregate technical change.

We begin with estimates of aggregate value added, based upon our input-output accounting framework. Next, we allocate the growth of value added among its components: the contributions of capital and labor inputs in economy as a whole, and the rate of aggregate technical change. We can further break down the contribution of capital and labor input at the aggregate level into the aggregates of the quality change by the sectoral level and the allocational bias of capital and labor inputs among sectors. Thirdly, we present the methodological framework, in order to allocate the rate of aggregate technical change among a weighted sum of rates of sectoral technical change and reallocations of value added and the primary factor inputs among sectors. Finally, we present the results of the breakdowns of the rate of aggregate technical change in the Japanese economy and give some indication of measurement errors hypothesis as a way of explaining the recent puzzling trend in productivity.

2.1 Aggregate Output

Our measurement of the sectoral gross output is based on the input-output accounting framework. The quantity of aggregate output is defined as the sum of the quantities of value added over all sectors.

Accounting balance in the j-th industrial sector is represented as follows:

$$p_v^j V^j \quad = \quad p_L^j L^j + p_K^j K^j$$

$$= \quad p_I^j Z_I^j - \sum_{i=1} p_i X_i^j, \tag{1}$$

where p_v^j and V_i are respectively the value-added deflator and quantity of the value-added of the j-th sector. p_L^j, L^j and p_K^j, K^j represent price and quantity of labor and capital service inputs of j-th sector. p_I^j, Z_I^j and p_i, X_i^j stand for price and quantity of output of j-th sector and price and quantity of i-th intermediate inputs in j-th sector. Differentiating (1) logarithmically with respect to time, we have:

$$\begin{aligned} \frac{\dot{p}_v^j}{p_v^j} + \frac{\dot{V}^j}{V^j} &= \left\{ \frac{p_I^{j*} Z_I^j}{p_v^j V^j} \left(\frac{\dot{p}_I^j}{p_I^j} \right) - \sum_{i=1} \left(\frac{p_i X_i^j}{p_v^j V^j} \right) \left(\frac{\dot{p}_i}{p_i} \right) \right\} \\ &+ \left\{ \frac{p_I^j Z^j}{p_v^j V^j} \left(\frac{\dot{Z}_I^j}{Z_I^j} \right) - \sum_{i=1} (\frac{p_i X_i^j}{p_v^j V^j}) \left(\frac{\dot{X}_i^j}{X_i^j} \right) \right\}. \end{aligned} \tag{2}$$

In equation (2), the term of the first parenthesis on the right hand side of equation corresponds to the definition of the growth rate of the divisia price index for the value-added deflator. The growth rate of the divisia price index is then subtracted from the rate of growth of net output values in current prices in order to obtain a measure of the growth rate of real value-added.

Next, we define gross domestic products (GDP) – the nation-wide aggregate measure of net output – as the sum of sectoral value added as follows:

$$\begin{aligned} p_v V &= \sum_{j=1}^{n} p_v^j V^j \\ &= \sum_{j=1}^{n} (p_L^j L^j + p_K^j K^j), \end{aligned} \tag{3}$$

where p_v and V are GDP deflator and real GDP respectively.
Differentiating (3) logarithmically with respect to time, we have:

$$\frac{\dot{p}_v}{p_v} + \frac{\dot{V}}{V} = \sum_{j=1}^{n} \frac{p_v^j V^j}{p_v V} \left(\frac{\dot{p}_v^j}{p_v^j} \right) + \sum_{j=1}^{n} \frac{p_v^j V^j}{p_v V} \left(\frac{\dot{V}^j}{V^j} \right). \tag{4}$$

The growth rate of the divisia price index, p_v, which is represented by the first term on the right-hand side of the equation (4), is then subtracted from the rate of growth of the nominal gross domestic products in order to obtain a measure of the growth rate of the real GDP defined by the second term of the right-hand side of the equation. The last term of the right-hand side of the equation (4) gives us the growth rate of the divisia quantity index of the real GDP, V.
The sum of value added in all sectors $p_{vj} V^j$ is equal to the sum of capital compensation

and labor compensation for the economy as a whole. Value added for the economy as a whole is equal to the sum of the value added at current price over all sectors:

$$p_v V = \sum_{j=1}^{n} p_v^j V^j = \tilde{p}_v \sum_{j=1}^{n} V^j, \tag{5}$$

where $\tilde{p}_v$ is an aggregate price index on average which is defined as corresponding to the sum of the quantities of real value-added in all sectors in (5). The divisia price index, p_v is not necessarily equal to the aggregate price index on average, $\tilde{p}_v$. They are equal if and only if prices of value-added in all sectors are identically equal to p_v and value shares w^j in all sectors are constant. On the other hand, we can define the growth rate of the simple summation of the sectoral real value-added as follows:

$$\frac{\dot{V}^*}{V^*} = \sum_j \left(\frac{V^j}{V^*}\right)\left(\frac{\dot{V}^j}{V^j}\right) = \frac{\sum \dot{V}^j}{V^*}. \tag{6}$$

We can then define a measurement of rates of changes of the allocation of real value-added among setors, $\frac{\dot{A}_v}{A_v}$ as a difference between growth rate of divisia aggregate index of real value-added, $\frac{\dot{V}}{V}$ and that of a simple summation of real value-added,$\frac{\dot{V}^*}{V^*}$ as follows.We call it a measure of the allocational bias of the value-added.

$$\begin{aligned} \frac{\dot{A}_v}{A_v} &= \frac{\dot{V}}{V} - \frac{\dot{V}^*}{V^*} = \sum_j \frac{p_v^j V^j}{p_v V}\left(\frac{\dot{V}^j}{V^j}\right) - \sum_j \frac{V^j}{V^*}\left(\frac{\dot{V}^j}{V^j}\right) \\ &= \sum_j \left(\frac{p_v^j V^j - \tilde{p}_v V^j}{p_v V}\right)\left(\frac{\dot{V}^j}{V^j}\right). \end{aligned} \tag{7}$$

The last equation of (7) implies that the allocational bias of the value added is defined by a shift of the allocation of value-added among sectors. If the changes of allocational bias, $\frac{\dot{A}_v}{A_v}$ is positive (negative), resource would be allocated to the sectors which are characterized by the higher (lower) value-added ratio rather than that on average.

2.2 Aggregate Labor and Capital Input

According to our accounting identities, aggregate labor and capital compensations are equal to the sum of compensations paid for each type of labor and capital over all sectors respectively. Let us denote the number of types of labor [2] as the subscript l and the number of types of capital as the subscript k. p_{Ll}^j and L_l^j stand for price and quantity of the l-th labor service input, while p_{Kk}^j and K_k^j stand for price and quantity

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[2] In our analysis, labor inputs are cross-classified by sex, age, education and employment status by industry.

of the k-th capital service input.
We can define the aggregate compensation of labor and capital as follows respectively:

$$p_L L = \sum_j B_L^j = \sum_j \sum_l p_{Ll}^j L_l^j, \tag{8}$$

$$p_k K = \sum_j B_K^j = \sum_j \sum_k p_{Kk}^j K_k^j, \tag{9}$$

where B_L^j and B_K^j stand for the total compensation of labor and capital in the j-th sector, which are defined as the sum of the compensation for all types of labor and capital in the sector.

Let us begin with the definition of the measurement of qualitative change of labor and capital in the j-th sector. Growth rates of divisia aggregate index for labor and capital in j-th sector are defined as follows:

$$\frac{\dot{L}^j}{L^j} = \sum_l \left(\frac{p_{Ll}^j L_l^j}{p_L^j L^j} \right) \left(\frac{\dot{L}_l^j}{L_l^j} \right), \tag{10}$$

where

$$p_L^j L^j = \sum_l p_{Ll}^j L_l^j = B_L^j,$$

and

$$\frac{\dot{K}^j}{K^j} = \sum_l \left(\frac{p_{Kk}^j K_k^j}{p_K^j K^j} \right) \left(\frac{\dot{K}_k^j}{K_k^j} \right), \tag{11}$$

where

$$p_K^j K^j = \sum_k p_{Kk}^j K_k^j = B_K^j.$$

On the other hand, we can define growth rates of a simple summation of labor and capital service inputs in j-th sector as follows. A simple summation suggests that there are assumed to be no differences of quality among the various types of service inputs:

$$\frac{\dot{L}^{*j}}{L^{*j}} = \sum_l \left(\frac{L_l^j}{L^{*j}} \right) \left(\frac{\dot{L}_l^j}{L_l^j} \right) = \frac{\sum_l \dot{L}_l^j}{L^{*j}}, \tag{12}$$

$$\frac{\dot{K}^{*j}}{K^{*j}} = \sum_k \left(\frac{K_k^j}{K^{*j}} \right) \left(\frac{\dot{K}_k^j}{K_k^j} \right) = \frac{\sum_k \dot{K}_k^j}{K^{*j}}. \tag{13}$$

Next, we can define the growth rate of qualitative change of labor and capital inputs in the j-th sector as a difference of the growth rate between divisia aggregate and simple sum indexes of each input:

$$\begin{aligned}\frac{\dot{Q}_L^j}{Q_L^j} &= \frac{\dot{L}^j}{L^j} - \frac{\dot{L}^{*j}}{L^{*j}} \\ &= \sum_l \left(\frac{p_{Ll}^j L_l^j}{p_L^j L^j} - \frac{L_l^j}{L^{*j}}\right)\left(\frac{\dot{L}_l^j}{L_l^j}\right) \\ &= \sum_l \left(\frac{p_{Ll}^j L_l^j}{p_L^j L^j} - \frac{\tilde{p}_L^j L_l^j}{p_L^j L^j}\right)\left(\frac{\dot{L}_l^j}{L_l^j}\right), \qquad (14)\end{aligned}$$

where

$$\tilde{p}_L^j = \frac{p_L^j L^j}{L^{*j}} = \frac{B_L^j}{L^{*j}}.$$

$$\begin{aligned}\frac{\dot{Q}_K^j}{Q_K^j} &= \frac{\dot{K}^j}{K^j} - \frac{\dot{K}^{*j}}{K^{*j}} \\ &= \sum_k \left(\frac{p_{Kk}^j K_k^j}{p_K^j K^j} - \frac{K_k^j}{K^{*j}}\right)\left(\frac{\dot{K}_k^j}{K_k^j}\right) \\ &= \sum_k \left(\frac{p_{Kk}^j K_k^j}{p_K^j K^j} - \frac{\tilde{p}_K^j K_k^j}{p_K^j K^j}\right)\left(\frac{\dot{K}_k^j}{K_k^j}\right), \qquad (15)\end{aligned}$$

where

$$\tilde{p}_K^j = \frac{p_K^j K^j}{K^{*j}} = \frac{B_K^j}{K^{*j}}.$$

$\frac{\dot{Q}_L^j}{Q_L^j}$ and $\frac{\dot{Q}_K^j}{Q_K^j}$ represent the growth rates of quality change of labor and capital service inputs by sector. According to the definitions in (14) and (15), if weights of inputs among various types of labor and capital services were to shift to inputs where the prices are relatively higher than the average input prices $\tilde{p}_L^j$ and $\tilde{p}_K^j$, qualitative changes of inputs should be evaluated to be positive. In our theoretical framework, each input price is corresponding to the marginal productivity. Then the positive (or negative) change of the quality in labor and capital services implies that the total aggregates of the marginal productivity of these inputs in the sector should be increased (or decreased) by the changes of the qualities of the inputs. Now let us turn to the nationwide aggregate of inputs. With regards to inputs like labor and capital, we defined the measure of quality in each sector by the changes of composition among various types of inputs, which have different rates of marginal productivity. At the aggregate level, we can also observe changes of allocation of the factors among sectors. This should be distinguished from the quality measures within these sectors. We will call it a measure of allocational bias of factor. First, let us begin with the definition of growth rate of divisia input quantity indexes of the nation-wide aggregate concerning labor and capital:

$$\begin{aligned}\frac{\dot{L}}{L} &= \sum_j \sum_l \frac{p^j_{Ll} L^j_l}{p_L L} \left(\frac{\dot{L}^j_l}{L^j_l} \right), \\ &= \sum_j \frac{p^j_L L^j}{p_L L} \left(\frac{\dot{L}^j}{L^j} \right), \qquad (16)\end{aligned}$$

where L and L^j stand for divisia aggregate quantity index of the nation-wide and sectoral aggregates for labor service and p_L and p^j_L correspond to their price indexes respectively.

Similarly, we can define divisia quntity index of capital of the nation-wide aggregate as follows:

$$\begin{aligned}\frac{\dot{K}}{K} &= \sum_j \sum_k \frac{p^j_{Kk} K^j_k}{p_K K} \left(\frac{\dot{K}^j_k}{K^j_k} \right) \\ &= \sum_j \frac{p^j_K K^j}{p_K K} \left(\frac{\dot{K}^j}{K^j} \right), \qquad (17)\end{aligned}$$

where K and K^j stand for divisia aggregate quantity index of the nation-wide and sectoral aggregates for capital service and p_K and p^j_K correspond to thier price indexes respectively.

On the other hand, we can define the following two types of growth rate of input quantity index as a simple summation of factor inputs. One is defined by the simple summation of the sectoral divisia quantity of input defined by (10) and (11):

$$\frac{\dot{L}^{**}}{L^{**}} = \sum_j \frac{L^j}{L^{**}} \left(\frac{\dot{L}^j}{L^j} \right) = \frac{\sum_j \dot{L}^j}{L^{**}}, \qquad (18)$$

$$\frac{\dot{K}^{**}}{K^{**}} = \sum_j \frac{K^j}{K^{**}} \left(\frac{\dot{K}^j}{K^j} \right) = \frac{\sum_j \dot{K}^j}{K^{**}}, \qquad (19)$$

where L^{**} and K^{**} represent simple summations of sectoral divisia quantities of labor and capital for the nation-wide aggregates. These indexes suggest that inputs by sector which are adjusted changes of the quality within each sector are homogeneous among sectors and then they can be aggregated by a simple summation. Alternatively, if we could assume that there are no differences of quality of inputs among input types and sectors, we can define the growth rate of the aggregate quantity of inputs by the following simple summation:

$$\frac{\dot{L}^*}{L^*} = \sum_j \sum_l \frac{L_l^j}{L^*} \left(\frac{\dot{L}_l^j}{L_l^j} \right) = \frac{\sum_j \sum_l \dot{L}_l^j}{L^*}, \tag{20}$$

$$\frac{\dot{K}^*}{K^*} = \sum_j \sum_k \frac{K_k^j}{K^*} \left(\frac{\dot{K}_k^j}{K_k^j} \right) = \frac{\sum_j \sum_k \dot{K}_k^j}{K^*}, \tag{21}$$

where L^* and K^* represent indexes defined by the simple summation of all types of labor and capital inputs among types and sectors for the nation-wide aggregate. It implies that all inputs among types and sectors are homogeneous with regards to labor and capital, respectively; and then it can be aggregated to the nation-wide by the simple summation.

We can define a measure by which we can evaluate the changes of the resource allocation among sectors at the nation-wide level. It is defined by the differences between growth rate of the nation-wide divisia aggregate defined by (16) and (17) and growth rate of the simple summation of the sectoral divisia quantities as defined by (18) and (19)concerning labor and capital respectively. As for the difference between (16) and (18), the allocational bias of labor input is formulated as follows:

$$\begin{aligned} \frac{\dot{A}_L}{A_L} &= \frac{\dot{L}}{L} - \frac{\dot{L}^{**}}{L^{**}} \\ &= \sum_j \frac{p_L^j L^j}{p_L L} \left(\frac{\dot{L}^j}{L^j} \right) - \sum_j \frac{L^j}{L^{**}} \left(\frac{\dot{L}^j}{L^j} \right) \\ &= \sum_j \left(\frac{p_L^j L^j - \tilde{p}_L L^j}{p_L L} \right) \left(\frac{\dot{L}^j}{L^j} \right), \end{aligned} \tag{22}$$

where

$$\tilde{p}_L = \frac{p_L L}{L^{**}}.$$

Similarly, as for the difference between (17) and (19), the allocational bias of capital input is formulated as follows:

$$\begin{aligned} \frac{\dot{A}_K}{A_K} &= \frac{\dot{K}}{K} - \frac{\dot{K}^{**}}{K^{**}} \\ &= \sum_j \frac{p_K^j K^j}{p_K K} \left(\frac{\dot{K}^j}{K^j} \right) - \sum_j \frac{K^j}{K^{**}} \left(\frac{\dot{K}^j}{K^j} \right) \end{aligned}$$

$$= \sum_j \left(\frac{p^j_K K^j - \tilde{p}_K K^j}{p_K K} \right) \left(\frac{\dot{K}^j}{K^j} \right), \tag{23}$$

where

$$\tilde{p}_K = \frac{p_K K}{K^{**}}.$$

$\frac{\dot{A}_L}{A_L}$ and $\frac{\dot{A}_K}{A_K}$ represent rates of changes of allocation of the factors among sectors. We call them allocational biases of labor and capital inputs. As shown in the above formulations, $\tilde{p}_L$ and $\tilde{p}_K$ stand for average prices at the nation-wide level of labor and capital services. Then the index of the allocational biases implies that if it is positive (or negative), resources like labor and capital services would be allocated to sectors where the price of the factor seems to be more expensive (less expensive) than the average. From the perspective of the cost efficiency on the resource allocation, positive (or negative) value of the allocational biases implies that resources are allocated less (or more) efficiently by the shift among sectors.

Finally, by rearranging the difference between the growth rate of the nation-wide divisia aggregate index of input defined by (10) or (11) and the growth rate of the nation-wide simple summation index of the corresponding input defined by (20) or (21) respectively, we can decompose sources of change of quality of inputs at the nation-wide aggregate level. By subtracting (20) from (10) or (21) from (11), we can deduce the following formulations:

$$\begin{aligned}
\frac{\dot{L}}{L} - \frac{\dot{L}^*}{L^*} &= \sum_j \sum_l \frac{p^j_{Ll} L^j_l}{p_L L} \left(\frac{\dot{L}^j_l}{L^j_l} \right) - \sum_j \sum_l \frac{L^j_l}{L^*} \left(\frac{\dot{L}^j_l}{L^j_l} \right) \\
&= \sum_j \frac{L^j}{\sum L^j} \sum_l \left\{ \frac{p^j_{Ll}}{p^j_L} - \frac{L^j_l}{L^{*j}} \right\} \left(\frac{\dot{L}^j_l}{L^j_l} \right) \\
&\quad + \sum_j \left\{ \frac{p^j_L L^j}{p_L L} - \frac{L^j}{\sum L^j} \right\} \left(\frac{\dot{L}^j}{L^j} \right) \\
&\quad + \sum_j \sum_l \left\{ \frac{L^j L^j_l}{L^{*j} \sum L^j} - \frac{L^j_l}{L^*} \right\} \left(\frac{\dot{L}^j_l}{L^j_l} \right).
\end{aligned} \tag{24}$$

$$\begin{aligned}
\frac{\dot{K}}{K} - \frac{\dot{K}^*}{K^*} &= \sum_j \sum_k \frac{p^j_{Kk} K^j_k}{p_K K} \left(\frac{\dot{K}^j_l}{K^j_l} \right) - \sum_j \sum_k \frac{K^j_k}{K^*} \left(\frac{\dot{K}^j_k}{K^j_k} \right) \\
&= \sum_j \frac{K^j}{\sum K^j} \sum_k \left\{ \frac{p^j_{Kk}}{p^j_K} - \frac{K^j_k}{K^{*j}} \right\} \left(\frac{\dot{K}^j_k}{K^j_k} \right)
\end{aligned}$$

$$
\begin{aligned}
&+\sum_j \left\{ \frac{p_K^j K^j}{p_K K} - \frac{K^j}{\sum K^j} \right\} \left(\frac{\dot{K}^j}{K^j} \right) \\
&+\sum_j \sum_k \left\{ \frac{K^j K_k^j}{K^{*j} \sum K^j} - \frac{K_k^j}{K^*} \right\} \left(\frac{\dot{K}_k^j}{K_k^j} \right).
\end{aligned} \tag{25}
$$

The formulations (24) or (25) suggest to us that growth rate of quality of input in the nation-wide aggregate as the differences between (10) and (20) or (11) and (21) could be broken down into three components, respectively. The first one is represented by the first term on the right-hand side of the second equation, which is an aggregate measure of qualitative changes among various categories of the factor. The second term of the right-hand side of the second equality represents a measure of the allocational biases defined by (22) or (23). Finally, the third term of the right-hand side of the second equation is a sort of the interactive effect of the above two components.

2.3 Aggregate Productivity Index

We have presented indices of output and input for the economy as a whole. Our next objective is to formulate an index of TFP change for the economy as a whole. We have already presented an index of productivity at the sectoral level as follows:

$$
\begin{aligned}
v_T^j &= \frac{\dot{Z}_I^j}{Z_I^j} - \sum_{i=1} \frac{p_i X_i^j}{p_I^j Z_I^j} \left(\frac{\dot{X}_i^j}{X_i^j} \right) \\
&\quad - \sum_l \frac{p_{Ll}^j L_l^j}{p_I^j Z_I^j} \left(\frac{\dot{L}_l^j}{L_l^j} \right) - \sum_k \frac{p_{Kk}^j K_k^j}{p_I^j Z_I^j} \left(\frac{\dot{K}_k^j}{K_k^j} \right).
\end{aligned} \tag{26}
$$

Alternatively, using the definitions of the value added in the j-th sector as shown in (2), we can write the index of the rate of TFP change v_T^j:

$$
\begin{aligned}
v_T^j &= \left(\frac{p_v^j V^j}{p_I^j Z_I^j} \right) \left(\frac{\dot{V}^j}{V^j} \right) \\
&\quad - \sum \left(\frac{p_{Ll}^j L_l^j}{p_I^j Z_I^j} \right) \left(\frac{\dot{L}_l^j}{L_l^j} \right) - \sum_k \left(\frac{p_{Kk}^j K_k^j}{p_I^j Z^j} \right) \left(\frac{\dot{K}_k^j}{K_k^j} \right).
\end{aligned} \tag{27}
$$

As a nation-wide accounting balance, we can define gross domestic products or a nation-wide aggregate measure of net output in (3). We can rewrite it as follows.

$$
p_v V = p_L L + p_K K, \tag{28}
$$

where V, L, and K stand for divisia aggregate quantity indexes of value-added, labor and capital inputs, while p_v, p_L and p_K are corresponding to the respective price at the aggregate level. The growth rate of each divisia quantity index for net output and inputs at the aggregate level has been already formulated in the previous sections.

With regards to the growth rate of net output at the aggregate level, we defined in (4) as follows:

$$\frac{\dot{V}}{V}=\sum_j \frac{p_v^j V^j}{p_v V}\left(\frac{\dot{V}^j}{V^j}\right)=\frac{\dot{V}^*}{V^*}+\frac{\dot{A}_v}{A_v}. \tag{29}$$

The right-hand side of the second equation represents the decomposition of the growth rate of net output at the aggregate level, which is shown in (7).
On the other hand, we defined the growth rate of labor and capital inputs at the aggregate level in (16) and (17). Moreover, we can formulate the breakdown of the sources of the growth of labor and capital in (22) or (24) and (23) or (25). We can hese rearrange as follows:

$$\begin{aligned}\frac{\dot{L}}{L} &= \sum_j \sum_l \frac{p_{Ll}^j L_l^j}{p_L L}\left(\frac{\dot{L}_l^j}{L_l^j}\right)\\ &= \frac{\dot{L}^{**}}{L^{**}}+\frac{\dot{A}_L}{A_L}\\ &= \frac{\dot{L}^*}{L^*}+\frac{\dot{Q}_L}{Q_L}+\frac{\dot{A}_L}{A_L}+\frac{\dot{I}_{LQA}}{I_{LQA}}.\end{aligned} \tag{30}$$

$$\begin{aligned}\frac{\dot{K}}{K} &= \sum_j \sum_k \frac{p_{Kk}^j K_k^j}{p_K K}\left(\frac{\dot{K}_k^j}{K_k^j}\right)\\ &= \frac{\dot{K}^{**}}{K^{**}}+\frac{\dot{A}_K}{A_K}\\ &= \frac{\dot{K}^*}{K^*}+\frac{\dot{Q}_K}{Q_K}+\frac{\dot{A}_K}{A_K}+\frac{\dot{I}_{KQA}}{I_{KQA}}.\end{aligned} \tag{31}$$

In (30) and (31), $\frac{\dot{I}_{LQA}}{I_{LQA}}$ and $\frac{\dot{I}_{KQA}}{I_{KQA}}$ represent the contribution of the interactive effect of allocational bias and quality change on the growth rate of quantities of labor and capital inputs respectively, which are defined in (24) and (25).

We can define an index of productivity change at the aggregate level by using the aggregate accounting balance, (28):

$$v_T=\frac{\dot{V}}{V}-s_L\frac{\dot{L}}{L}-s_K\frac{\dot{K}}{K}=\sum_j \frac{p_I^j Z_I^j}{p_v V}v_T^j, \tag{32}$$

where

$$s_L=\frac{\sum_j \sum_l p_{Ll}^j L_l^j}{p_v V},\quad s_K=\frac{\sum_j \sum_k p_{Kk}^j K_k^j}{p_v V}.$$

The right-hand side of the second equation in (32) indicates that the growth rate of productivity at the aggregate level is consistent with the weighted sum of the sectoral productivity change, v_T^j defined by (26), where $\frac{p_I^j Z_I^j}{p_v V}$ are utilized as weight.

Finally, we can provide the implications of the breakdown of the sources of the economic growth at the aggregate level by rearranging all of the above formulations. Rearranging the following equation by (29), (30) and (31),

$$\frac{\dot{V}}{V} = s_L \frac{\dot{L}}{L} + s_K \frac{\dot{K}}{K} + v_T,$$

we can obtain the following expression.

$$\begin{aligned} \frac{\dot{V}^*}{V^*} + \frac{\dot{A}_v}{A_v} &= s_L \left(\frac{\dot{L}^*}{L^*} + \frac{\dot{Q}_L}{Q_L} + \frac{\dot{A}_L}{A_L} + \frac{\dot{I}_{LQA}}{I_{LQA}} \right) \\ &\quad + s_K \left(\frac{\dot{K}^*}{K^*} + \frac{\dot{Q}_K}{Q_K} + \frac{\dot{A}_K}{A_K} + \frac{\dot{I}_{KQA}}{I_{KQA}} \right) + v_T. \end{aligned} \tag{33}$$

The final formulation represents an interesting breakdown of the sources of economic growth at the aggregated level. The growth of the net output at the aggregated level was broken down into the contribution of the growth of the factor input, such as labor and capital and the growth of productivity. The contribution of the growth of the factors is broken down into four sources,respectively: The first is the contribution of the growth measure as defined by the growth rate of the simple summation of input quantity formulated as $\frac{\dot{L}^*}{L^*}$ or $\frac{\dot{K}^*}{K^*}$. The second is the contribution of the growth measure defined by the change of the quality of input formulated as $\frac{\dot{Q}_L}{Q_L}$ or $\frac{\dot{Q}_K}{Q_K}$. The third is the contribution of the growth measure as defined by the change of the allocational bias formulated by $\frac{\dot{A}_L}{A_L}$ or $\frac{\dot{A}_K}{A_K}$. Finally, the fourth is the contribution of the interactive effect of changes of quality and allocational bias formulated as $\frac{\dot{I}_{LQA}}{I_{LQA}}$ or $\frac{\dot{I}_{KQA}}{I_{KQA}}$. On the other hand, the contribution of the growth of productivity is measured by v_T, which is defined by the weighted sum of the growth rate of sectoral productivity, v_T^j.

In other words, the index of productivity change at the aggregate level as defined by (32), v_T^j is measured as a residual which is defined by the differences between the growth rate of the real value-added, $\frac{\dot{V}}{V}$ and the contribution of the growth rate of factor inputs, labor and capital, $s_L(\frac{\dot{L}}{L}) + s_K(\frac{\dot{K}}{K})$. In this formulation, we are trying carefully to evaluate changes of quality, changes of allocational bias and their interactive effect of both output and inputs at the aggregate level. On the other hand, the following definition has often been used as a simple measurement of productivity change at the aggregate level:

$$v_T^* = \frac{\dot{V}^*}{V^*} - s_L \left(\frac{\dot{L}^*}{L^*} \right) - s_K \left(\frac{\dot{K}^*}{K^*} \right). \tag{34}$$

In (34), the index of productivity change at the aggregate level is defined simply by the difference between the growth rate of the simple sum of the real value-added, and the contribution of the growth rate of the simple sum of factor inputs. So far, it is clear that the definition of (34), as an index of productivity change at the aggregate level, includes some sorts of measurement errors which are identified as allocational biases of output and inputs, qualitative changes of inputs and their interactive effects.

2.4 Sources of the Measurement Errors of TFP

By using the framework in the previous section, we can identify the measurement errors of the growth rate of TFP. Table 2 presents a summary of the sources of Japanese economic growth during the period 1960-92.

Table 2 shows the average annual rate of growth of output, inputs and productivity at the aggregated level as sources of the economic growth for the economy, which are defined in (32). Values in parentheses in the Table represent the ratio of the contribution to economic growth as sources. The first column represents the average annual rate of net aggregate output. It should be noted that while the average rate per year over the whole period 1960-92 reached more than 6.3 per cent, it was remarkably higher (10.4 percent) during the period of high economic growth, 1960-72, compared with 3.9 percent per year after the period of the first oil crisis: 1972-92. According to the breakdown of the sources, contributions of labor, capital and productivity are shared out on average into 21, 63 and 16 per cent, respectively, during the whole period. One can see, however, that this average trend of the contribution of growth is completely different between the periods before and after the oil crisis. Before the oil crisis, it was one of the interesting features of the economy that the contribution of productivity growth was higher than 25 per cent, while the contribution of productivity growth was negligible after 1972. Even during the period 1960-72, the contribution of productivity growth reached to 26 per cent on average. During the same period, the contributions of capital and labor inputs were 56 and 18 per cent, respectively. On the other hand, after the oil crisis, the contribution of capital inputs increased rapidly by 73 per cent, and that of productivity decreased by about 20 per cent. During the period before the oil crisis, the growth rates of labor and capital inputs were 3.372 and 12.553 per cent annually, while that of output was 10.425 per cent. This means that the partial productivity of labor increased rapidly during the high growth period at the cost of the partial productivity of capital. After the oil crisis, the growth rate of capital input was also higher than the growth rate of output, while the growth rate of labor input was even lower than that. In other words, we can say that the characteristics of the factor substitution between labor and capital have been dominant in Japan since 1960s. It is not necessarily a specific characteristic of recent technology. The contribution of productivity as a source of growth, however, declined to around 16 per cent from 26 per cent before the oil crisis. In particular, after 1990, the growth rate of labor input turned out to be negative, and that of capital input still continued to be higher than that of output. It is impressive that the substitution between labor and capital was rapidly encouraged during the recent period of the Japanese economy. The growth rate of total factor productivity was 1.036 per cent per annum, on average, during the period 1960-92. Before the oil crisis, it was more than 2.781 per cent annually; while after that it rapidly declined to an average negative rate each year.

Table 3 represents the results of the breakdown of the sources of economic growth at the aggregate level, which are formulated in (29), (30) and (31). Concerning the growth rate of value-added, there were sizable contributions made by the allocational changes among the industrial sectors. As mentioned before, the positive biases of the output allocation indicates that the efficiency of the economy would be improved by resource allocation. During the period before the oil crisis, almost one-third of the total growth of output was attributed to increases of the efficiency of the allocation. In particular during the period 1960-65, the contribution was fairly high. After the 1972 the weight of the contribution declined to a level of less than 15 per cent. Especially, during the period 1985-90, it was seen to be negative. It would be expected that there were distortions which disturbed the efficient allocation of the resources.

From the fourth column to the seventh in Table, we can see the results of the breakdowns of labor input: $\frac{\dot{L}^*}{L^*}$ represents the growth rate of the total man-hour labor force. $\frac{\dot{Q}_L}{Q_L}$, $\frac{\dot{A}_L}{A_L}$ and $\frac{\dot{I}_{LQA}}{I_{LQA}}$ represents the rate of qualitative change, the rate of allocational changes and the rate of their interactive effect respectively. The rate of qualitatve changes of labor input was fairly stable and it had a positive effect of 0.7-0.8 per cent annually. It meant that the qualitative change of labor input contributed an improvement in marginal productivity at a constant annual rate of 0.7-0.8 per cent. On the other hand, the rate of change of the allocation of labor input among industries was mostly negative. As mentioned above, the negative changes of the allocational biases in labor input suggests that labor was shifted from industries with expensive labor costs to industries with less expensive labor costs. Consequently, this improved the total efficiency of resource allocation in the economy as a whole. We can observe the breakdown of the sources of capital input from the eighth column to the last in Table. The qualitative change of capital input was positive, but it was not constant like that of labor input. The rate of allocational changes of capital input among industries was seen to be negative. This means that the allocational changes of capital inputs contributed to an improvement in the efficiency of capital input in the economy as a whole. Specifically, qualitative change and allocational bias of capital input have gradually increased recently. Also, the interactive effect of qualitative change and allocational bias of capital input are sizable during the whole period.

Finally, we can summarize the sources of measurement errors of the growth rate of TFP in Table 4. The second column represents the growth rate of TFP measured by (34). The last column represents the growth rate of he true TFP as defined by

(32). Measurement errors of TFP growth rate came from three sources of bias in terms of output, labor and capital. As shown in the table, bias coming from the measurement of output was fairly dominant, while that coming from the measurement of inputs was mostly negative, both in terms of labor and capital with few exceptions. It is interesting that the recent measurement of bias by capital input turned out to be positive. Although there are measurement errors in TFP, which come from allocational bias in the output quantity index, both qualitative changes and allocational biases in labor and capital input index, should be seriously taken into account, since the recent declining trends of productivity growth are not necessarily attributable to measurement errors. If we carefully correct the recent measurement error, productivity growth shows a more seriously declining trend. It is one of the interesting suggestions, from the discussions of measurement errors, that measurement errors attributed to capital input turned out to be positive recently, while the growth rate of labor input turned to be negative. We can understand that these phenomena are characteristics of recent technologies, where partial labor productivity increased rapidly at the cost of increases in partial capital productivity as a result of the substitution between labor and capital. Consequently, since the increases of the labor productivity are cancelled out by the decreases of the capital productivity, efficiency increases by the measure of total factor productivity would be moderate.

3 Characteristics of Capital Formation in Japan

3.1 Capital Input and Capital Stock: Measurement

According to our approach, concerning measurement error hypothesis in order to explain the paradoxical trends of recent productivity growth in the previous section, measurement errors are not necessarily dominant sources of the paradox; although the correction of errors is important in order to measure the true growth of the total factor productivity. Nevertheless, we can point out several important findings from above approaches. 1) Recently the contribution of capital input to the economic growth increased rapidly, while the contribution of labor input turned out to be negative. 2) Although this suggests that the substitution between labor and capital turned out to be dominant, substitution, by itself is not necessarily a specific feature in recent technology. This is because we could observe the substitution between labor and capital since the 1960s. However, recent changes in the growth rates of labor and capital suggest to us somewhat different patterns of substitution among factors. 3) Concerning sources of the errors in TFP measurement, sources coming from capital input turned out to be overwhelmingly positive. All of these findings suggest to us that we shall carefully analyze features of recent capital formation related to new technology.

We assume that all of the new technologies are originally embodied in the new investment, and changes of composition of capital stock might have an impact on the substitution of factor inputs and TFP growth. In order to analyze quantitatively the impact of new technologies embodied in capital formation on TFP growth, we should begin with the estimation of capital flow and stock matrices. Our estimated capital flow and stock matrices are divided into private and government owened enterprises; capital classified by industry; and social overhead capital unclassified by industry. Both private and government enterprises are classified by 43 industrial sectors, as shown in Table 5. On the other hand, capital formation in each industrial sector is classified by 78 types of capital goods as types of assets; which correspond to the commodity classification in the input-output table.[3] We estimated capital stock matrix that to be consistent with the flow matrices of capital formation.

Let us summarize the findings in the trends of the capital formation in Japan during the period 1955-92. Table 6 represents average annual rates of growth in capital stock of private enterprises by industry during the period 1955-90, where the period is divided into the following seven sub-periods; 1955-60, 1960-65, 1965 70, 1970-75, 1975-80, 1980-85, and 1985-90, in order to clarify features of the capital accumulation in the Japanese economy. According to the results in these Tables, growth rates of the private capital accumulation in all sectors (except water supply) since 1975 clearly slowed down in comparison with the rapid growth up to 1975, while those in 1980s gradually recovered in some sectors, such as electrical machinery, motor vehicle, precision instrument, communication, and education. Annual growth rates of capital stock during the three sub-periods since 1960 were significantly higher than those of labor input by sector in the same periods. [4] In particular, during the second sub-period 1960-65, twenty-eight sectors out of 43 sectors accomplished high growth of capital stock at more than 10 percent annually. These trends continued during the next two terms until 1975. After the oil crisis almost all industries (except electricity, gas, medical and other services) experienced a dramatic slowing down of growth in terms of capital stock.[5] During the fifth sub-period, 1975-80 growth rates of capital stock deteriorated by less than half of the growth rate in the previous sub-periods by sectors. During the period 1955-75 capital input by sector grews rapidly, showing a higher growth rate more than the historical standard of the Japanese economy. After 1980, capital formation by sector gradually recovered. Annual growth rate of capital stock increased in sixteen industries during the period 1980-85; and in twenty-six industries after 1985. It is one of the interesting characteristics of the economy that the capital formations in the specific industries such as electrical machinery, precision machinery

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

[4] See Table 3.

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

and communications increased rapidly after 1985. [6]

[Table 7] represents a series of estimated capital stocks by government enterprises. Annual growth rates of capital accumulation in government enterprise show constantly rapid growth such as 6.00, 10.90, 9.77, 13.37, 8.18, 4.55, 2.28 per cent every five years since 1955 respectively. We should note that the values after 1989 in Table are not adjusted according to the privatization trends in government enterprises.

3.2 Structural Changes in Capital Coefficients

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

$$b_{ij} = K_{ij}/Z_j, \quad (i = 1, ..., 12, j = 1, ..., 43). \tag{35}$$

We can recognize structural changes from trends of capital coefficients by industry. The volume of coefficients designates the degree of capital intensity in industry, and the trend or change of coefficients during the periods represents the patterns of the structural changes, in terms of capital intensity, or capital productivity. We assume properties of recent new technologies are embodied in the new capital formation and accumulated in the capital stock. Properties embodied in capital should be reflected in changes of capital coefficients as structural parameters. We can investigate the changes of capital coefficients preliminary. [Figure 1] represents change of capital coefficients at the macro level during the period 1955-92, where the poll in figure stands for the level of capital coefficient and number in each poll corresponds to the asset types classified into twelve categories. We can observe that capital coefficients at the macro level increased from 1.5 in 1955 to 2.5 in 1992 and, moreover, compositions of machinery and electrical machinery among assets have gradually increased, instead of building and construction. The figures also show the relationship between real value added and volume of capital stock by a solid line (*) during the period 1960-92. This also represents a rapid increase in capital-output ratio in terms of value-added base.

When it comes to the development of technologies, we should focus on observations at the industry level instead of macro level. We can detect certain typical changes of coefficients by industries: 1.agriculture, 4.construction, 6.textile, 18.iron, 21.machinery, 22.electric machinery, and 23.motor vehicle. Capital coefficients in agriculture

---

[6] Japan National Railway and National Telecommunication Company were privatized in 1987 and 1985 respectively. Growth rates of both industries in Table 6 include their impacts.

increased rapidly from 0.3 in 1960 to 3.0 in 1992 in terms of the sum of coefficients, which suggests that capital productivity has been declining historically. Growth rates slightly decreased during the first half of the 1980s, but recovered during the last half of the 1980s. Although the capital coefficient of machinery has been increasing rapidly, more than 70 per cent of assets are shared by construction. We have to note in the agricultural sector that capital accumulation, especially for construction, owed mainly to that in government enterprises. Capital productivity in the construction sector has also been declining gradually, and the assets mostly consist of own products. In the textile industry changes of coefficients were more characteristic, where they were fairly stable in the 1960s and shifted higher in the 1970s and then continued to increase gradually in the 1980s. Volume of coefficients changes from 0.2 in 1960 to 0.7 in 1992. Recently we can observe rapid increases of capital coefficient in machinery and electrical machinery in the textile industry. In the iron and steel industry, capital coefficients increased from 0.2 in 1960 to 1.0 in 1992, where the rate of increase slowed down,especially after 1985. Here again, the shares of machinery and electrical machinery in assets have increased, while the share of construction has been declining recently. In machinery, the level of capital coefficients in total capital stock shifted after the oil shock from 0.3 to 0.5, where decreases of capital coefficients for construction instead of increases of those in electrical machinery after 1975 are one of the specific characteristics. Electrical machinery is an exceptional example where the capital coefficients showed a decreasing trend from the beginning of the 1960s. This means that in the electrical machinery sector capital productivity increased rapidly. After 1975, capital coefficients of input for construction in electrical machinery sector were decreasing gradually; while those from electrical machinery in itself were increasing rapidly. Capital coefficients of motor vehicles were relatively stable, although after 1975 they indicate a gradually declining trend. While total volume of capital coefficient in motor vehicle were stable, the composition of capital coefficient has been changed remarkbly, where coefficient of construction has been decreasing and coefficients of machinery and electric machinery increased rapidly in the recent years.

Capital coefficients for private and government capital including social overhead capital, have been changing since 1960. In particular, capital asset shares of machinery and electrical machinery instead of those of construction, have been increasing rapidly in almost all sectors recently. Simultaneously, we must note that capital productivity in machinery and electrical machinery sectors have improved historically, and that such trends of capital productivity in these sectors were really rare exceptions among 43 industries. It seems to be one of the important characteristics of the recent movement of capital formation. In the economy, changes of capital coefficients have an impact 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.

4 Unit Structure and Dynamic Spillover

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

We will return to our definition of the growth rate of total factor productivity at the macro level formulated in (32) and begin to clarify the meanings of the definition of this measure from the viewpoint of the spillover effect of changes in productivity. Rearranging (32) by using the input-output framework of the economy, we can obtain the following relationship:

$$\begin{aligned}
v_T^t &= \sum_j \frac{p_I^{jt} Z_I^{jt}}{p_v^t V^t} v_T^{jt} \\
&= \sum_i \frac{p_i^t f_i^t}{p_v^t V^t} \left(\frac{\dot{f}_i}{f_i}\right)^t - \sum_j \sum_l \frac{p_{Ll}^{jt} L_l^{jt}}{p_v^t V^t} \left(\frac{\dot{L}_l^j}{L_l^j}\right)^t - \sum_j \sum_k \frac{p_{Kk}^{jt} K_k^{jt}}{p_v^t V^t} \left(\frac{\dot{K}_k^j}{K_k^j}\right)^t \\
&= \sum_i \frac{p_i^t f_i^t}{p_v^t V^t} \left(\frac{\dot{f}_i}{f_i}\right)^t - s_L \left(\frac{\dot{L}}{L}\right)^t - s_K \left(\frac{\dot{K}}{K}\right)^t . \qquad (36)
\end{aligned}$$

This is a measure of the growth rate of TFP at the macro level as defined in section 2. The right-hand side of the second equation indicates that the measure of growth rate of TFP at the macro level is simultaneously explained as a difference between the aggregate measure of the growth rate of final demand and that of factor inputs including labor and capital. The aggregate measure of the growth rate of final demand is defined by a divisia growth rate index of final demand components weighted by nominal shares of each component in the nominal GDP. In order to clarify the meanings of the aggregate measure from viewpoints of the spillover effect of productivity changes, we should propose a concept of 'unit structure'. By using this concept, we can clarify the interdependent relationships among commodities as characteristics of the specific commodity production technology. [7] A unit structure of the specific commodity represents the internal linkages among production directly and indirectly, which are described by intermediate input coefficients, A_t and factor input coefficients such as labor and capital, l_t and k_t. In this concept, we can define the static measure of the production efficiency for a specific commodity, where the measure defined here is closely related to the traditional measure of "Total Factor Productivity".

We begin with the explanation of the concept of 'unit structure'. In the input-output framework, the system of production can be described in terms of input coefficient matrix, A_t, vector of final demand, F_t, vector of output, Z_t, vector of value added, V_t and unit vector, i as follows:

$$A_t Z_t + F_t = Z_t. \tag{37}$$

$$i' V_t = F_t i. \tag{38}$$

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

$$Zt = (I - A_t)^{-1} F_t = B_t F_t. \tag{39}$$

We will call the following equation the 'unit system' of j-th commodity production:

$$A_t \hat{B}_j i + f_j^* = B_j, \tag{40}$$

and

$$i' v^* = f_j^* i, \tag{41}$$

where $\hat{B}_j$ represents a diagonal matrix with j-th column vector of inverse matrix $(I - A_t)^{-1}$ as elements, f_j^* stands for the final demand vector with unity as j-th element and zero as other elements and v^* is a row vector of the unit value added. In the system of the equation (40), the following matrix is referred to as the 'static unit structure' peculiar to j-th commodity:

$$U^{(j)} = u_{ik}^{(j)} = A_t \hat{B}_j. \tag{42}$$

The technology of the economy is described by the compound system of the 'unit structure' of the various commodities. Each unit structure of j-th commodity represents the characteristics of the technology involved in production. If we can give factor input coefficients such as labor and capital, l_t and k_t, we can define the vectors of labor and capital inputs corresponding to the unit structure L_t and K_t. These represent the direct and indirect input requirements of labor and capital by sectors in the production of the final demand f_j^*. We understand that a 'unit structure' for j-th commodity represents

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[7] Ozaki(1984).

the direct and indirect input requirements in terms of intermediate inputs, labor and capital inputs which are needed to supply one unit of final demand of j-th commodity. We can define a measure of the production efficiency of any $k_{th}(k = 1, .., n)$ sector in the production system based upon 'unit structure' for j-th commodity production as follows:

$$v_{Tk}^{jt} = \left(\frac{\dot{Z}_{Ik}^{j}}{Z_{Ik}^{j}} \right)^{t} - \sum_{i} s_{xik}^{jt} \left(\frac{\dot{X}_{ik}^{j}}{X_{ik}^{j}} \right)^{t} - s_{Lk}^{jt} \left(\frac{\dot{L}_{k}^{j}}{L_{k}^{j}} \right)^{t} - s_{Kk}^{jt} \left(\frac{\dot{K}_{k}^{j}}{K_{k}^{j}} \right)^{t}, \tag{43}$$

where Z_{Ik}^{j}, X_{ik}^{j}, L_{k}^{j}, K_{k}^{j} represent output, intermediate inputs, labor and capital inputs of k-th commodity which are needed to supply one unit of j-th final demand, directly and indirectly, and s_{xik}^{j}, s_{Lk}^{j}, s_{Kk}^{j} stand for the cost share of each input respectively. We should note that the TFP measure defined by equation (43) exactly corresponds to an ordinary measure of sectoral TFP. Furthermore, we can define an aggregate measure of the production efficiency in the framework of unit structure as follows:

$$\begin{aligned} v_{Tj}^{t} &= \sum_{k} \frac{p_{I}^{kt} Z_{I}^{kt}}{p_{v}^{t} V^{t}} v_{Tk}^{jt} \\ &= \left(\frac{\dot{f}_{j}^{*}}{f_{j}^{*}} \right)^{t} - \sum_{k} \frac{L_{k}^{jt} p_{Lk}^{t}}{p_{v}^{t} V^{t}} \left(\frac{\dot{L}_{k}}{L_{k}} \right)^{t} - \sum_{k} \frac{K_{k}^{jt} p_{Kk}^{t}}{p_{v}^{t} V^{t}} \left(\frac{\dot{K}_{k}}{K_{k}} \right)^{t}, \end{aligned} \tag{44}$$

where p_{I}^{kt} represents output price of k-th commodity and $p_{v}^{t} V^{t}$ stands for aggregate nominal value-added, which is defined by the sum of sectoral labor and capital compensations, $\sum_{k} L_{k}^{jt} p_{Lk}^{t}$ and $\sum_{k} K_{k}^{t} p_{Kk}^{t}$. v_{Tj}^{t} is an aggregate measure of the production efficiency in term of the unit structure of j-th commodity. This measure designates the production efficiency of j-th commodity production, where the production efficiency is evaluated as a measure of the total factor productivity and as a system which is needed to supply one unit of j-th commodity as final demand. Aggregate measure of TFP growth defined by equation (44) has to be distinguished from growth rate of TFP in the ordinary measure at the macro level. The measure defined here corresponds to an aggregate measure of production efficiency in terms of the unit structure of j-th commodity. We will refer to this measure, v_{Tj}^{t}, as a 'static unit TFP on j-th commodity as its unit structure'.

In the framework of static unit TFP, we can give a final demand vector, f instead of f_{j}^{*}. Here, f stands for a final demand vector which corresponds to the composition of final demand such as consumption, fixed capital formation, exports, etc. We can define the aggregate measure corresponding to (44), which suggests a 'static unit TFP on a specific final demand components as a vector'. In particular, if we give total final demand vector as corresponding to GDP as f, the definition of the aggregate measure (44)is back to the definition of the growth rate of TFP defined in (32) or (36).

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

We will turn again to the basic definition of an aggregate measure of the growth rate of TFP, (36). In this definition, a term, $\left(\frac{\dot{K}}{K}\right)^t$ represents a divisia growth rate of capital service input at the macro level. We assume that the volume of capital service is proportional to the amount of aggregate capital stock at the beginning of the year t. Aggregate capital stock has been accumulated by the capital formation in the past years. The capital formation in each time period of the past was characterized by the technological structure at that time. If there is some installation of facilities embodied within new technologies, it could be influenced by the capital service flow induced from the accumulated capital stock, and the efficiency through input of the capital service in the production process.

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

$$S^t = (1-\delta)\, S^{t-1} + I^{t-1}. \tag{45}$$

Differentiating (45) logarithmically with respect to the time t,

$$\left(\frac{\dot{K}}{K}\right)^t = \left(\frac{\dot{S}}{S}\right)^t = (1-\delta)\,\frac{S^{t-1}}{S^t}\left(\frac{\dot{S}}{S}\right)^{t-1} + \frac{I^{t-1}}{S^t}\left(\frac{\dot{I}}{I}\right)^{t-1}, \tag{46}$$

where δ stands for the rate of depreciation.

On the other hand, we can define the similar relationship of the growth rate of TFP in the previous year t-1 as (36) as follows:

$$v_T^{t-1} = \sum_j \frac{p_I^{jt-1} Z_I^{jt-1}}{p_v^{t-1} V^{t-1}} v_T^{jt-1}$$

$$= \sum_i \frac{p_i^{t-1} f_i^{t-1}}{p_v^{t-1} V^{t-1}} \left(\frac{\dot{f}_i}{f_i}\right)^{t-1} - \sum_j \sum_l \frac{p_{Ll}^{jt-1} L_{Ll}^{jt-1}}{p_v^{t-1} V^{t-1}} \left(\frac{\dot{L}_{Ll}^j}{L_{Ll}^j}\right)^{t-1} - \sum_j \sum_k \frac{p_{Kk}^{jt-1} K_{Kk}^{jt-1}}{p_v^{t-1} V^{t-1}} \left(\frac{\dot{K}_{Kk}^j}{K_{Kk}^j}\right)^{t-1}. \tag{47}$$

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

$$\left(\frac{\dot{I}}{I}\right)^{t-1} = \sum_i \frac{p_i^{t-1} f_i^{t-1}}{p_v^{t-1} V^{t-1}} \left(\frac{\dot{f}_i}{f_i}\right)^{t-1}. \tag{48}$$

Rearranging the definition of the growth rate of capital service at the macro level by using (48) and (46),

$$\begin{aligned}
&\sum_j \sum_k \frac{p_{Kk}^{jt} K_{Kk}^{jt}}{p_v^t V^t} \left(\frac{\dot{K}_{Kk}^j}{K_{Kk}^j}\right)^t \\
= \; & \frac{p_K^t K^t}{p_v^t V^t} \left[(1-\delta) \frac{S^{t-1}}{S^t} \left(\frac{\dot{S}}{S}\right)^{t-1} + \frac{I^{t-1}}{S^t} \left\{ v_T^{t-1} + \frac{p_L^{t-1} L^{t-1}}{p_v^{t-1} V^{t-1}} \left(\frac{\dot{L}}{L}\right)^{t-1} + \frac{p_K^{t-1} K^{t-1}}{p_v^{t-1} V^{t-1}} \left(\frac{\dot{K}}{K}\right)^{t-1} \right\} \right] \\
= \; & \frac{p_K^t K^t}{p_v^t V^t} \frac{I^{t-1}}{S^t} v_T^{t-1} + \frac{p_K^t K^t}{p_v^t V^t} \frac{I^{t-1}}{S^t} \frac{p_L^{t-1} L^{t-1}}{p_v^{t-1} V^{t-1}} \left(\frac{\dot{L}}{L}\right)^{t-1} \\
& + \frac{p_K^t K^t}{p_v^t V^t} \left\{ (1-\delta) \frac{S^{t-1}}{S^t} + \frac{I^{t-1}}{S^t} \frac{p_K^{t-1} K^{t-1}}{p_v^{t-1} V^{t-1}} \right\} \left(\frac{\dot{S}}{S}\right)^{t-1}.
\end{aligned} \tag{49}$$

Capital stock at the beginning of the year t-1 can be formulated similarly as (46),

$$\left(\frac{\dot{K}}{K}\right)^{t-1} = \left(\frac{\dot{S}}{S}\right)^{t-1} = (1-\delta) \frac{S^{t-2}}{S^{t-1}} \left(\frac{\dot{S}}{S}\right)^{t-2} + \frac{I^{t-2}}{S^{t-1}} \left(\frac{\dot{I}}{I}\right)^{t-2}. \tag{50}$$

On the other hand, we can define a static measure of growth rate of TFP at the year t-2 by definition of (47) as follows:

$$\begin{aligned}
v_T^{t-2} &= \sum_j \frac{p_I^{jt-2} Z_I^{jt-2}}{p_v^{t-2} V^{t-2}} v_T^{jt-2} \\
&= \sum_i \frac{p_i^{t-2} f_i^{t-2}}{p_v^{t-2} V^{t-2}} \left(\frac{\dot{f}_i}{f_i}\right)^{t-2} - \sum_j \sum_l \frac{p_{Ll}^{jt-2} L_l^{jt-2}}{p_v^{t-2} V^{t-2}} \left(\frac{\dot{L}_l^j}{L_l^j}\right)^{t-2} - \sum_j \sum_k \frac{p_{Kk}^{jt-2} K_k^{jt-2}}{p_v^{t-2} V^{t-2}} \left(\frac{\dot{K}_k^j}{K_k^j}\right)^{t-2}.
\end{aligned} \tag{51}$$

Therefore if we can assume the equality between real volume of the final demand and the capital formation at the year t-2, we can deduce the following equation as for the third item of the second equation in (49):

$$
\begin{aligned}
& \frac{p_K^t K^t}{p_v^t V^t}\left\{(1-\delta)\frac{S^{t-1}}{S^t}+\frac{I^{t-1}}{S^t}\frac{p_K^{t-1}K^{t-1}}{p_v^{t-1}V^{t-1}}\right\}\left(\frac{\dot{S}}{S}\right)^{t-1} \\
= \; & \frac{p_K^t K^t}{p_v^t V^t}\Phi^{t-2} \\
& \left[(1-\delta)\frac{S^{t-2}}{S^{t-1}}\left(\frac{\dot{S}}{S}\right)^{t-2}+\frac{I^{t-2}}{S^{t-1}}\left\{v_T^{t-2}+\frac{p_L^{t-2}L^{t-2}}{p_v^{t-2}V^{t-2}}\left(\frac{\dot{L}}{L}\right)^{t-2}+\frac{p_K^{t-2}K^{t-2}}{p_v^{t-2}V^{t-2}}\left(\frac{\dot{K}}{K}\right)^{t-2}\right\}\right] \\
= \; & \frac{p_K^t K^t}{p_v^t V^t}\Phi^{t-2}\frac{I^{t-2}}{S^{t-1}}v_T^{t-2}+\frac{p_K^t K^t}{p_v^t V^t}\Phi^{t-2}\frac{I^{t-2}}{S^{t-1}}\frac{p_L^{t-2}L^{t-2}}{p_v^{t-2}V^{t-2}}\left(\frac{\dot{L}}{L}\right)^{t-2} \\
& +\frac{p_K^t K^t}{p_v^t V^t}\Phi^{t-2}\left\{(1-\delta)\frac{S^{t-2}}{S^{t-1}}+\frac{I^{t-2}}{S^{t-1}}\frac{p_K^{t-2}K^{t-2}}{p_v^{t-2}V^{t-2}}\right\}\left(\frac{\dot{S}}{S}\right)^{t-2}, \qquad (52)
\end{aligned}
$$

where

$$
\Phi^{t-2}=(1-\delta)\frac{S^{t-1}}{S^t}+\frac{I^{t-1}}{S^t}\frac{p_K^{t-1}K^{t-1}}{p_v^{t-1}V^{t-1}}. \qquad (53)
$$

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

$$
\begin{aligned}
\left(\frac{\dot{\mathbf{T}}}{\mathbf{T}}\right)^t &= v_T^t+\frac{p_K^t K^t}{p_v^t V^t}\sum_{\tau=t-1}^{-\infty}\Phi^\tau\frac{I^\tau}{S^{\tau+1}}v_T^\tau \\
&= \sum_i\frac{p_i^t f_i^t}{p_v^t V^t}\left(\frac{\dot{f}_i}{f_i}\right)^t-\frac{p_K^t K^t}{p_v^t V^t}\sum_{\tau=t-1}^{-\infty}\Phi^\tau\frac{I^\tau}{S^{\tau+1}}\frac{p_L^\tau L^\tau}{p_v^\tau V^\tau}\left(\frac{\dot{L}}{L}\right)^\tau, \qquad (54)
\end{aligned}
$$

where

$$
\Phi^\tau=\begin{cases}1 & (\tau=t-1)\\ \Phi^{\tau+1}\left\{(1-\delta)\frac{S^{\tau+1}}{S^{\tau+2}}+\frac{I^{\tau+1}}{S^{\tau+2}}\frac{K^{\tau+1}r^{\tau+1}}{p_v^{\tau+1}V^{\tau+1}}\right\} & (\tau=t-2,\cdots,-\infty)\end{cases} \qquad (55)
$$

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

5 Structural Change and Trends of Efficiency in Japan

We begin with a comparison between ordinary measures of growth rate of sectoral TFP and the growth rate of static unit TFP as unit structure of j-th commodity as shown in Tables 8 and 9, respectively. Ordinary measures of sectoral TFP, represent the efficiency of j-th commodity production of its own. On the other hand, static unit TFP, based upon unit structure, indicates the total efficiency in j-th commodity production, where we can evaluate the efficiency of direct and indirect linkages of the technology as a system of j-th commodity production. According to the results shown in Table 8, high growth of TFP in the 1960s rapidly deteriorated during the first half of the 1970s in almost all industries. After a slight recovery during the second half of the 1970s was observed in some sectors, growth of TFP turned out to be lower again during the second half of the 1980s. It should be noted, however, that there were some exceptional sectors such as chemical, rubber products, metal products, machinery, electrical machinery, precision instruments, communication and trade, where TFP grew at a stable rate during these periods. On the other hand, according to the results shown in Table 9, efficiency based upon unit structure seems to be exaggerated by the interdependency of the production linkages. During the first half of the 1970s, when TFP growth in almost all of sectors deteriorated, growth rates of 'static unit TFP' worsened in comparison with those of ordinary TFP in almost all industries except rubber products. Conversely, in the 1980s, growth rates of static unit TFP indicated a smooth recovery of production efficiency in many sectors. This suggests that efficiency gains in the sectors in which the efficiency of their own technology has improved could compensate for efficiency loss in the sectors in which their own efficiency has deteriorated. Especially, it might be expected that there were some leading sectors where the production efficiency increased rapidly in recent years. For example, in the agricultural sector, its growth rates of static unit TFP have been compensated by the technology linkages to other sector during these periods, except the first half of the 1970s; while its own efficiency has deteriorated during the whole period; except the period 1980-85. In machinery and electrical machinery, the efficiency gain increased in the unit measures rather than in its own measure during the whole periods.

Let us turn to the dynamic approach. By using the framework of the dynamic inverse, we can estimate sectoral output requirements in the past which are needed to supply a certain amount of final demand in the reference year. Dynamic output requirements for the final demand of one dollar's worth of all commodities in the past have diminished until the last eight to ten years. The value of the dynamic multiplier in investment goods such as construction, chemical, stone, iron, metal, machinery, electrical machinery and vehicles, and services, conyinues to remain fairly high. We can estimate a measure of dynamic unit TFP defined in equation (54), in which we can evaluate, dynamically, the total efficiency of the production which is directly, and indirectly, required to supply one unit of j-th commodity final demand at the year t. Table 10 shows the results. Since dynamic impacts of production chains for one unit of production of j-th commodity of final demand seem to diminish until the past ten years past; and, as mentioned above, our estimates of dynamic aggregate TFP can be evaluated after the period 1970. In Table 10 we can show the annual growth rate of this measure for every five years since 1970 in each sector.

The results are shown in Table 10. Each value in the table represents the average annual growth rate of dynamic unit TFP as a measure of the impact of structural change during each sub-period. The growth rate is evaluated by the difference per year between the dynamic unit TFP corresponding to the structure of the beginning year, and that of the ending year in each sub-period. Then, each value in the table indecates the degree of the annual impact by the structural changes during each sub-period. According to our results, the impact of structural changes was fairly high in every sector. We try to focus upon the recent impacts of new technologies on TFP growth during the period 1985-90. As mentioned above, the values of capital coefficients of machinery and electrical machinery have rapidly increased in almost all of sectors, in which these changes of composition in capital coefficients are expected to embody recent new development of technologies in production. In spite of this hypothesis, it is quite difficult to detect the impact on productivity growth in the results of ordinary measures of TFP growth, as shown in the last column of Table 8. In 23 out of 43 sectors, annual growth rates of TFP in the ordinary measures deteriorated during the period 1985-90 rather than in the previous sub-period. It might suggest that there are initial intuitive questions regarding the so-called 'productivity paradox' in recent years. When it comes to focussing upon the measures defined by the static unit TFP (as shown in Table 9), the number of industries showing a deterioration of TFP growth during the period 1985-90 decreased from enty-three in the ordinary measures to twenty in the static unit TFP measures. On the other hand, if we try to measure TFP growth in the dynamic unit TFP concept (as shown in Table 10), the deterioration of TFP growth can be observed only in eleven of 43 sectors. In comparison with the static unit TFP, the dynamic unit TFP represents an improvement of production efficiency in almost all sectors, except coal mining, coal products and real estate. We can conclude that there was fairly dominant impact of new technologies on TFP growth even in these sectors. This can be verified by changes of capital coefficients, especially capital coefficients of machinery and electric machinery in which are expected to be embodied new technologies in recent years.

Finally, we can evaluate the impact of new technology development on the productivity growth at the macro level by using the framework of static and dynamic TFP measures. In order to evaluate these impacts at the aggregate level, we can estimate measures of static and dynamic TFP growth rates by giving one unit of final demand along with observed weights of commodities in a specific final demand instead of one unit of a special commodity as a final demand. As weights of commodities in final demand, we can select alternative weights on consumption, investment, export and total domestic final demand as final demand, respectively. By using the formulations, (44) and (54) separately, we can estimate TFP growth rates at the macro level, in terms of the static and dynamic TFP measures, in order to realize one unit of the specific final demands such as consumption, investment, export and total domestic final demand. Table 11 represents the results. The first row in Table 11 represents the growth rates of the ordinary TFP measure at the macro level. We can confirm, from result of the trend of the ordinary TFP measures, that the growth rate of TFP declined at the beginning of the 1970s, and continued at a lower stable level after 1975; even if a slight recovery could be observed after 1985. In the ordinary measure of TFP, we cannot identify the impact of new technology on the productivity growth at the macro level. It is because the deterioration of TFP growth needed to realize one unit of consumption contributed sharply to the decline of the TFP growth, in terms of total final demand. On the other hand, if we try to evaluate the TFP growth by dynamic measure at the macro level, we can observe a drastic recovery of TFP growth after 1975, especially after 1985. After 1975, the growth rate of TFP by the dynamic measure along with total final demand as weights increased continuously at annual average growth rates of 0.5233, 1.6005 and 2.2004 per cent during the periods, 1975-80, 1980-85 and 1985-90 respectively. In the dynamic measure, TFP growth in terms of consumption as weights recovered gradually after 1975. Also, we can see that the TFP growth in terms of investment and export as weights completely recovered after 1975. It might be concluded that the impact of new technology on productivity growth should be evaluated to be sizable in terms of investments and exports, especially after 1975.

6 Conclusion

In this paper, we have tried to evaluate the impact of new technology on TFP growth. We started from the intuitive observation of TFP growth in countries which have joined the OECD. Statistics of macro TFP measures in OECD countries designate the so-called ‘productivity paradox’, where TFP growth has been deteriorating recently, in spite of increases in the real investment. ‘Productivity paradox’ should finally come to a conclusion in order to evaluate the real impact of new technology on productivity growth. There have been proposed several alternative hypotheses to explain and solve these paradoxical trends of recent productivity growth. We began with a consideration of the measurement error hypothesis. Broadly speaking, sources of measurement errors are divided into two sources. One involves the measurement errors arising from the evaluation of qualitative changes in inputs and output measures. The other is the aggregation bias in the measurement of inputs and outputs. According to our results, although the measurement errors are one of the important issues in order to estimate growth rates of productivity correctly, it doesn't sufficiently explain the recent puzzling trends in productivity. When we tried to carefully measure qualitative changes of inputs and allocational biases of output and inputs, we could observe that the partial productivity of labor increased rapidly, while that of capital has deteriorated gradually since the 1960s in Japan. Furthermore, these trends have been exaggerated recently. In particular, the growth rate of labor input turned out to be negative instead of a positive growth of capital input. We can conclude there are significant substitutions between labor and capital in the new development of technology.

We can assume that such new technology might be embodied in the new investment, and that changes in composition by assets in capital stock, along with new investment, should have an impact on the TFP growth. We try to measure the changes in compositions of assets in capital stock caused by new technology as distinct from changes of trends in capital coefficients in each industrial sector. We can observe remarkable changes in the capital coefficients, where the capital coefficients of machinery and electrical machinery as capital goods in each sectors have increased rapidly, instead of the decreases of construction as capital goods in almost all sectors recently. In order to clarify the implications of observed substitutions between labor and capital and evaluate the impacts of the changes of the composition in capital coefficients, we proposed new measures of TFP growth. In this case, TFP growth in specific commodity production is evaluated by a unit system, in which spillover effect of the productivity is taken into accounts directly and indirectly. It is an extension of ordinary TFP growth measures. New measurement of TFP growth is divided into two concepts, 'static unit TFP' and 'dynamic unit TFP'. While in the measure of static unit TFP direct and indirect spillover effects of TFP growth among sectors are taken into accounts in the static input-output framework, dynamic unit TFP growth measures try to evaluate direct and indirect spillover effects of TFP growth dynamically. Dynamic unit TFP growth represents the reasonable impact of the newly development of technology. It implies that there are no paradoxical movements in the recent years from the viewpoint of the relationships between TFP growth and new investment.

Although we try to present one of the implications concerning the 'productivity paradox' in recent years, the analysis of the conceptualization in productivity growth still has several remaining issues. One is the evaluation of the impact of new technologies on the labor market. In our context of the analysis, we can extend our analysis to the evaluation of changes of labor coefficients related to those of capital coefficients. These might have an impact on the substitutability among labor and capital from new technology. This might be expected to involve some time lag in the changes of labor coefficients in the adjustment process to new technologies. The other issue remaining here is the effect of the externality of the new technologies. In particular, new information technology might be expected to have some impact on the externality, along with the network in the society.

Table 1: Aggregated Productivity in Japan and the United States (annual growth rate)

		1960-65	1965-70	1970-75	1975-80	1980-85	1985-90
Total Factor	Japan	2.62	4.58	-2.08	-0.02	0.69	0.91
Productivity	U.S.	1.23	0.52	0.26	0.04	0.23	0.18
Labor	Japan	6.78	8.13	3.70	1.40	1.95	2.40
Productivity	U.S.	2.21	1.49	1.67	0.64	0.67	0.19
Capital	Japan	-2.40	0.69	-9.45	-2.31	-1.27	-1.23
Productivity	U.S.	1.61	-1.19	-1.84	0.09	-1.31	-0.59
Capital Input	Japan	12.52	11.10	14.46	6.58	5.06	5.86
	U.S.	2.95	4.30	4.29	3.51	3.54	3.07
[ref.] Asset Share of Capital Stock in Japan							
	1960	1965	1970	1975	1980	1985	1990
Build.&Const.	91.00	85.23	80.42	75.35	76.33	74.84	70.86
General Machinery	4.25	7.31	9.81	11.86	10.83	11.02	11.89
Electric Machinery	0.74	1.52	2.42	4.68	5.92	7.78	10.64
Motor Vehicle	0.45	1.17	1.82	2.90	2.89	2.45	2.77
Other Trans. Mach.	2.25	3.05	3.04	2.88	1.99	1.74	1.56
Precision Instrument	0.11	0.21	0.28	0.36	0.44	0.54	0.65

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

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

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

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

Table 4: Aggregation Error of the Growth Rate of TFP (annual growth rate)

		Decompsosition of Errors			True TFP
	v_T^*	$Bias_V$	$Bias_L$	$Bias_K$	v_T
1960-65	0.523	5.691	-0.860	-2.735	2.619
1965-70	4.175	1.833	-0.560	-0.874	4.575
1970-75	-0.618	0.188	-0.914	-0.737	-2.080
1975-80	-0.042	0.844	-0.719	-0.101	-0.019
1980-85	1.311	0.224	-0.807	-0.037	0.690
1985-90	1.570	-0.352	-0.374	0.065	0.909
1990-92	-0.008	0.134	-0.410	0.116	-0.167
1960-72	2.220	3.038	-0.763	-1.714	2.781
1972-92	0.426	0.297	-0.658	-0.077	-0.012
1960-92	1.054	1.325	-0.690	-0.654	1.036

Table 5: Industry Classification

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

Table 6: Annual Growth Rate of Private Capital Stock

(unit:%)

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

Table 7: Estimated Capital Stock : Government Enterprises

(unit:1 billion yen at 1985 price)

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

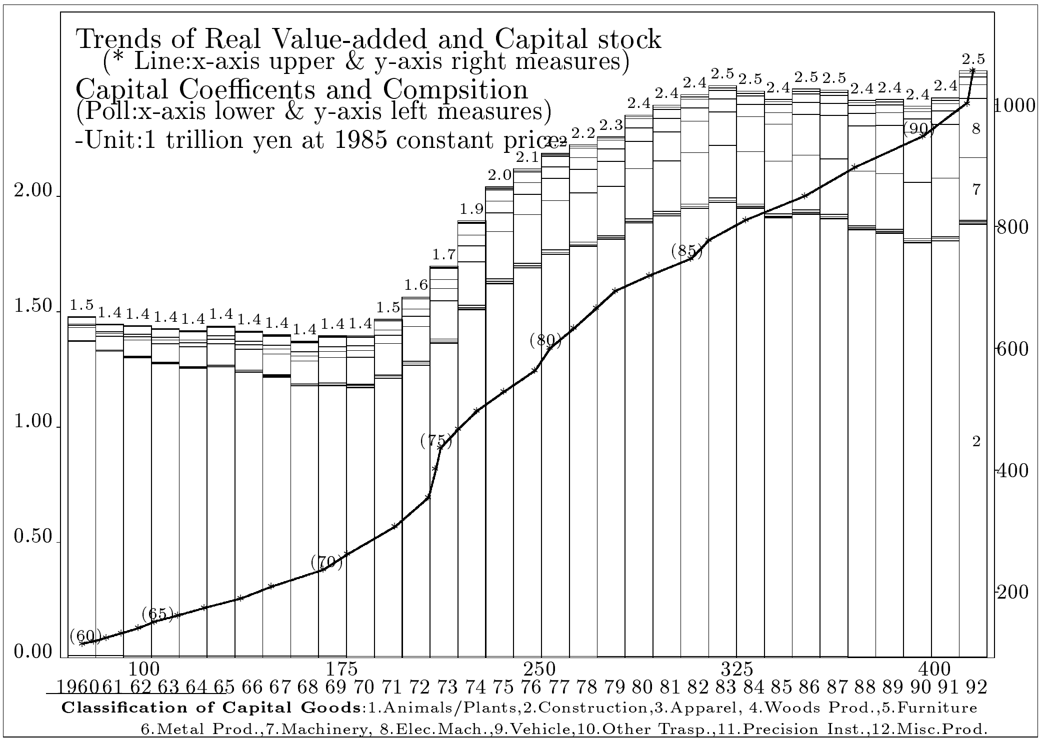

Figure 1: Trends of Capital Coefficients and Changes of Capital Composition

Table 8: Ordinary TFP (annual growth rate)

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

Table 9: Static Unit TFP (annual growth rate)

	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90	1970-90
1.Agriculture	-1.243	-3.888	-6.360	-3.241	2.082	0.072	-1.862
2.Coal Mining	7.135	4.615	0.514	-2.368	1.406	-1.024	-0.368
3.Other Mining	5.327	10.454	-5.503	5.447	-1.826	3.680	0.449
4.Build.&Const.	1.023	5.157	-2.623	-1.230	1.077	1.651	-0.281
5.Foods	-0.500	-0.364	-5.146	1.046	1.321	-1.014	-0.948
6.Textile	2.731	4.459	-1.120	2.404	2.769	3.284	1.834
7.Apparel	3.138	5.126	-0.589	2.656	1.179	1.095	1.085
8.Woods	1.689	0.269	-1.606	-5.074	6.337	-0.878	-0.305
9.Furniture	1.176	4.161	-1.525	0.731	2.725	1.093	0.756
10.Paper&Pulp	4.507	5.833	-4.524	0.205	3.282	4.150	0.778
11.Publishing	-3.017	-1.174	-4.458	-0.007	1.259	1.990	-0.304
12.Chemical	5.724	9.352	-4.811	1.777	4.266	2.806	1.010
13.Petroleum	5.056	1.094	-6.473	-1.417	0.272	8.168	0.138
14.Coal Prod.	3.187	5.328	-6.531	-8.716	0.650	2.474	-3.031
15.Rubber Prod.	5.544	7.420	-5.582	0.037	4.486	4.387	0.832
16.Leather Prod.	7.497	1.639	2.839	-2.525	3.134	-0.520	0.732
17.Stone&Clay	4.768	5.448	-4.899	1.663	1.438	2.277	0.120
18.Iron&Steel	2.314	7.936	-1.974	0.507	-0.051	1.071	-0.112
19.Non-ferrous	3.141	9.548	1.717	5.120	3.974	1.495	3.076
20.Metal Prod.	3.722	7.670	-3.200	2.226	1.353	2.141	0.630
21.Machinery	0.283	8.520	-3.196	5.639	2.768	1.404	1.654
22.Elec.Mach.	5.221	12.347	0.574	8.207	3.475	5.041	4.324
23.Vehicle	3.800	10.786	1.506	6.176	1.906	2.205	2.948
24.Oth.Trans.Mach.	6.874	5.901	-7.290	2.158	2.841	3.332	0.260
25.Precision Inst.	4.986	9.355	-0.556	8.395	2.873	0.391	2.776
26.Misc.Mng.Prod.	4.981	8.107	-4.854	2.135	2.663	2.020	0.491
27.Railway	3.608	-0.773	1.675	-11.552	2.910	-1.924	-2.223
28.Road Trans.	3.822	6.436	-7.188	2.281	-2.016	0.665	-1.564
29.Water Trans.	0.411	10.121	2.473	-3.215	6.572	-3.793	0.509
30.Air Trans.	5.997	12.093	7.662	-0.949	3.172	1.894	2.945
31.Storage	1.796	4.571	-7.609	8.018	1.154	-0.122	0.360
32.Communication	1.984	2.655	0.250	2.305	5.695	2.822	2.768
33.Electricity	5.199	6.380	-4.926	-2.146	2.276	1.905	-0.723
34.Gas	4.518	2.484	-0.051	2.660	1.177	3.173	1.740
35.Water	-2.330	-2.060	-5.024	-6.487	1.017	-1.117	-2.903
36.Trade	6.539	6.946	-1.234	2.400	0.279	3.677	1.280
37.Finance	5.252	2.111	-1.709	-0.600	4.143	0.623	0.614
38.Real Estate	5.758	0.413	-3.360	-0.585	0.961	-0.422	-0.852
39.Education	0.607	4.487	0.511	-5.066	-3.403	-1.387	-2.336
40.Research	5.426	3.734	-3.938	4.046	-1.877	-0.181	-0.488
41.Medical Serv.	3.127	1.899	3.515	-1.480	-0.251	-2.903	-0.280
42.Other Serv.	-4.381	3.691	-5.600	0.451	-0.029	-1.876	-1.763
43.Public Adm.	4.971	3.769	-3.889	-4.919	-0.514	0.641	0.274

Table 10: Dynamic Unit TFP (annual growth rate)

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

Table 11: Comparison of Alternative Measures of TFP at aggregated level(annual growth rate)

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

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