Economic Nonlinear Transition Mechanism and Nonparametric Estimation Model of Productivity

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Abstract

Productivity is one of the main drivers of economic sustainable developments and given its importance should be evaluated from a wide perspective. This is especially so where economies face nonlinear changes which can influence the shapes of production functions. In such cases therefore, productivity needs to be calculated by use of a model which corresponds to the nature of these changes.

In the real world, economic activities and production activities have sometimes faced nonlinear changes with occurring large shocks, such as economic crises and natural disasters. The fact has been widely acknowledged empirically but not been acknowledged theoretically. This thesis clarifies the mechanism by developing an appropriate model. The nonlinear transition movements in our economy indicate the importance to develop a nonparametric model, which does not presume a specific parametric production function like the existing parametric models, in order to estimate the phenomena. Therefore, this thesis investigates a nonparametric and time series analysis method, which allows the evaluation of productivity, by applying the Data Envelopment Analysis (DEA) approach. The developed model is a general one and can be applied to explain the economic and production activities. Through the analyses of the Japanese economy, its productivity can be accurately grasped and the results would indicate some implications for the economy. The discussion implies that Japan, whose aging society holds downward pressures for its economic growth, has to improve its productivity in order to increase its economic growth and competitive power in the world.

This thesis is set out as follows. Chapter 1 provides the introduction and the motivation behind this study. The main topic of Chapter 2 is the nonlinear transition mechanism of production. A new model is constructed to show the jumping process in production. Using empirical data drawn from Japanese manufacturing sectors and the constructed model, it searches for the presence of the nonlinear transition process. Chapter 3 has estimations of productivity based on a nonparametric approach. It describes the construction of a new time series analysis method —DEA time series analysis— for calculating productivity using a nonparametric approach. The model combines the idea in the Kalman filter and the Markov switching for arranging data, and it succeeds in overcoming the disadvantages for time series analysis in usual nonparametric approaches. It also has an empirical study for the Japanese manufacturing sectors, based on the constructed time series analysis method. Chapter 4 shows some practical applications of the DEA model. The DEA model introduced in Chapter 3 is applicable to a broad field of

studies. This chapter includes an estimation model of turning points of business cycle and a prediction model of bank failure which are exercises for using the DEA approach. Chapter 5 concludes the thesis by summarizing the findings, discussing some extensions, and proposing suggestions for future studies.

Contents

Chapter 1

Introduction

Productivity is one of the main drivers of sustainable developments in economies and organizations. It must be evaluated from a wide perspective. Especially, in the case that economies and organizations face large and dramatic changes which would put pressure on the shapes of production functions, productivity should be calculated based on a model corresponding to the changes. These changes seem to nonlinear transitions and we have to confirm the existence of them. In that case, a new calculating method of productivity for grasping changes would be needed. It should be noted that this study uses the word of “nonlinearity” when the activities of economies and organizations (e.g. productions and consumptions) clearly depart from their steady states.

1.1 Nonlinearity in economy

Our economy occasionally faces structural changes, which lead to transition jumps of economic activities[1]. These jumps are empirically well known, however the actual mechanisms are not clearly specified.

Important examples of this phenomenon are to be found in the Japanese economy. The first is its quite dramatic growth from the mid-1950s to the early 1970s and which has become known as Japan's post-World War II rapid economic growth period. Recent emerging economies, such as Chinese economy, have, in a very similar fashion, recorded their own rapid economic growth period over the past decades. Illustrated is that these very high growth phases are clearly well above that experienced in these countries in the preceding periods and that the production functions between the former phases and the later phases are of a markedly different character.

The second is the global financial crisis in 2007-2008, which is produced a large worldwide production reduction included Japan. Gries and Naude (2010) indicates that the global financial crisis affected on the dynamic of structural change and widened global disparities. Gokay (2009) points out that the financial crisis as an expression of the structural changes, then the study indicates that the global system comes to hold deep-rooted contradictions.

The third is the Great East Japan Earthquake in 2011, which produced a significant decline in a number of production facilities in the affected area. Nakamura (2011) in his analysis of the effect of the earthquake shows that the shape of the production function can change over time as a result of such large shocks.

The fourth is the aging population problem combined with the diminishing number of children in Japan. This is putting considerable downward pressure on its economic growth. Japanese government has sought the engines for the development and announced its growth strategies many times. Most of its strategies had included the topic of the Japanese population problem[2]. Cabinet Office, Government of Japan (2003) mentions the aging society and its structural changes on the economy. The study indicates that the aging society leads to slow economic growth through slower labor and capital growth. The repeated same topic implies that the problem has stagnated and has not been transacted. While discussing the strateagies, the problem has been becoming a more serious one. For instance, the Japanese population aging rate, in which the ration of total population and

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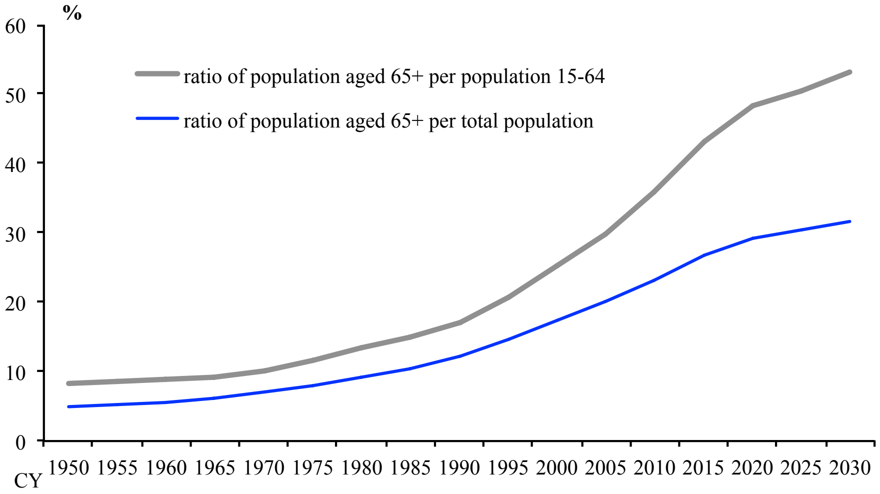
[1] Calvo (1998) mentions the transition phenomena and names the economic rapid decrease "sudden stop."

[2] For example, see Prime minister of Japan and his cabinet (2015).

population above age 65, in 1980 was 9%, that in 1990 was 12%, that in 2000 was 17%, that in 2010 was 23%, that in 2020 is estimated 29%, and that is in 2030 is estimated 32% (Figure 1.1).

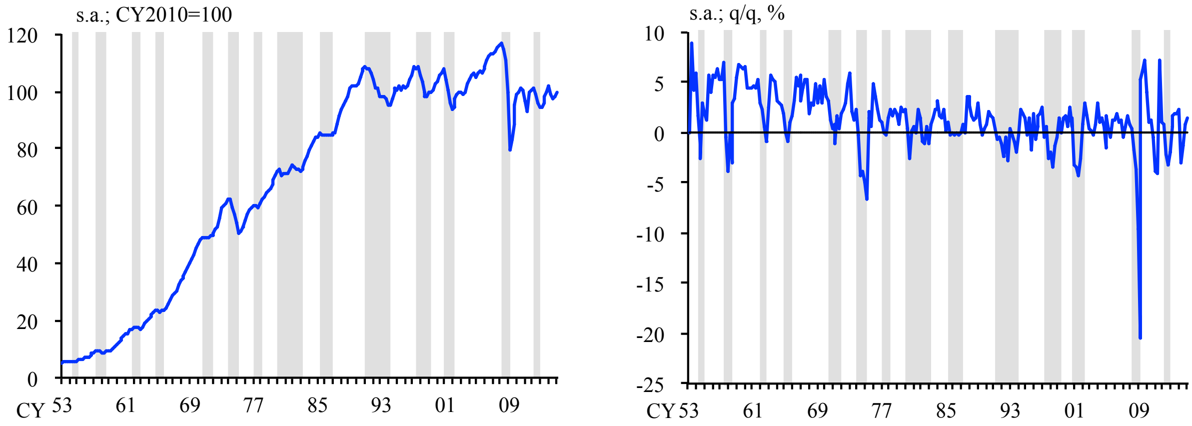


Source: United Nations "World Population Prospects, the 2015 Revision."

Figure 1.1: Old-age dependency ratio

These changes are not mildly cyclical but structural, and that the aging problem is a gradual process while the previous examples represent sudden changes. Figure 1.2 shows the movements of Japanese industrial production. Shaded areas indicate recession periods. Through these events, the structure of our economy would have changed. It is noticeable that above examples mainly discuss Japanese experiences, but developing countries have followed the first example's pass of Japan, as well as these developing and other developed countries would follow the fourth example, the aging problem, in the future. In addition, the third example, disaster, can occur in all countries. Thus, considering these jumps are significant for the economy.

The transition jumps are empirically well known, however the actual mechanisms are not clearly specified. Considering these dramatic changes, the functions of production would have changed, hence we have to accurately grasp the transition and know the mechanism of changing in production functions. An imprtant issue is whether there are some thresholds for the jumps. In detail, there are empirical evidences that structural factors (e.g. "economies of scale") shift the production frontier curves and change production functions. In addition, "the operating rate" is also known to affect the frontier curves. There is a recent focus on the effect of "the vintage facilities" (defined here as aging or outdating of facilities and equipment), which can have impacts on production. There has



Note: Shaded areas indicate recession periods. Source: Ministry of Economy, Trade and Industry, Japan "Indices of Industrial Production."

Figure 1.2: Industrial Production of Japan

also been a focus on the role of "the international transfer of facilities" on production although its impact is not described with precision.

For realizing our economy's future continuous development, we have to know the mechanism of transition jumps. This is the first purpose of this study. By considering a basic economic framework, these jumps would be explained in a model. Note that this study uses the word of "nonlinearity" when the activities of economies and organizations (e.g. productions and consumptions) clearly depart from their steady states.

1.2 Productivity

Which engines should our economy select for its future continuous development under these changing economic situations? This question looks like a difficult one, however the point at issue is clear for develped countries like Japan. The production function approach usually assumes a Cobb-Douglas production function with two types of inputs (capital and labor):

$$Y = AK^{\alpha}L^{1-\alpha} \tag{1.1}$$

where Y is output, A is productivity, K is capital stock, L is labor input, and α is the capital share. For continuous development, the economy has to improve labor inputs, capital stocks, and/or productivity (additionally, changing the distribution ratio would lead to increasing of economy, but the contribution might be limited). Under the aging society, and if we do not consider immigration for solving the problem, it would be difficult to significantly increase labor inputs. In addition, for developed countries, their capital stocks mildly increase, though crises suddenly crush them. Therefore, we, developed countries, should concentrate on improving productivity for the economic continuous growth.

This suggestion leads to an additional question. How can productivity be calculated under changing economy? Our economy would dramatically changes as discussed above, thus we have to estimate the economic productivity with a model which considers the changes. For calculating productivity, almost all of related studies use the total factor productivity (TFP) approach. This approach is a parametric approach and an assumed function is used. However, in the case that we have faced to dramatic changes, a nonparametric approach, which does not presume a specific parametric function, would be needed to calculate productivity. Then, we should estimate productivity with not only a traditional model, such as the TFP approach, but also a model which considers a couple of structural changes.

As for estimation of productivity, studies with the parametric approach have been accumulated. By contrast, the nonparametric approach is a developing one and the number of studies is limited, compared of that in the parametric approach. As this study discussed above, the nonparametric approach is needed for accurate valuations of productivity under changing economies. In addition, productivity is an important issue for development and it is desirable to be estimated as well as compared with wide various approaches. Thus, the nonparametric approach model for calculating productivity should be developed and accumulation of a lot of demonstrations with the model are strongly needed.

Under the circumstances, we have to catch the time series movement of productivity for evaluating it and considering the future problem. However, the nonparametric approach is often inferior for time series analyses. The approach has mainly focused on one time period problem. Some studies have tried to overcome the weakness, but there are still defect issues. By introducing the time order assumption, a time series model should be derived.

Productivity should be calculated by the exacted and some sided ways. The development of a nonparametric and time series analysis method for estimating productivity is therefore the second purpose of this study.

1.3 Summary of the study

This study mainly focuses on two points. Firstly, the study clarifies the nonlinear transition mechanism of production. The discussion of this mechanism implies changes in production functions over time. Secondly, the study investigates a nonparametric model, whch does not assume a specific production function, in order to grasp nonlinear jumps of productions and productivity in the real economy. Through these exercises, this study tries to show some implications for the Japanese future development. We have to live with the aging society and maintain or improve our competitive power in the world. Grasping productivity accurately and analyzing the results would have hints for our economy.

This study is set out as follows. Chapter 2 mentions nonlinear transition mechanism of production. It constructs a new model to show the jumping process in production. Then, using empirical data drawn from the Japanese manufacturing sector and using the constructed model, it searches the presence of nonlinear transition process. Chapter 3 contains estimations of productivity based on a nonparametric approach. It describes the construction of a new time series analysis method —DEA time series analysis— for calculating productivity using a nonparametric approach named the Data Envelopment Analysis (DEA). Then, it has an empirical study for the Japanese manufacturing sector, based on the constructed time series analysis method. Chapter 4 shows some practical applications of the DEA model. The DEA model, which is introduced in Chapter 3, holds the possibility for using a wide range of studies. This chapter includes an estimation model of turning points of business cycle and a preduction model of bank failure. These findings are based on the DEA approach. Chapter 5 concludes the study by summarizing the findings, discussing some extensions, and proposing suggestions for future studies.

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Chapter 2

Nonlinear transition mechanism of production

This chapter theoretically clarifies the nonlinear transition mechanism of production and Japanese economic development. This mechanism is empirically known but the precise nature of the shifts is unclear and has yet to be specified theoretically. The study focuses on four factors: economies of scale, the operating rate, the vintage facilities, and the international transfer of facilities, all of which would impact on the transition mechanism and from which a new model is derived. This model demonstrates the jumping processes involved in production highlighting the existences of thresholds, which induce them. These thresholds relate to the identified factors and which provide an explanation for rapid increases and sudden declines in production. This study investigates specific cases of such changes in the Japanese manufacturing sector and reviews the role of these four factors. Illustrated is the nonlinear nature of the transition mechanism in its effect on the Japanese economic growth.

The main part of this chapter is published as "Non-linear Transition Mechanism of Production and Japanese Development" in *Economic Analysis and Policy*, Vol.47, pp. 34-47, 2015.

2.1 Introduction

An economy occasionally faces structural changes. McMillan and Rodrik (2011) mention that "*One of the earliest and most central insights of the literature on economic development is that development entails structural change.*" Such changes sometimes follow nonlinear transition paths. An important example is that of the Japanese economy which achieved quite dramatic growth from the mid-1950s to the early 1970s and which has become known as Japan's post-World War II rapid economic growth period. The Chinese economy has, in a very similar fashion, recorded its own rapid economic growth period over the past two decades. Other emerging economies have also grown rapidly. Illustrated is that these very high growth phases are clearly well above that experienced in these countries in the preceding periods and that the production functions between the former phases and the later phases are of a markedly different character.

Contrastingly, there have also occurred periods of sudden declining growth in national economies. The global financial crisis in 2007-2008 produced a dramatic worldwide production decline. In response to this crisis, companies were forced into often quite radical changes to their production and sales strategies. For many, this change was viewed as a structural one leading to restructured production strategies. For others, this crisis was seen as a super long-term cyclical change with strategies adjusted accordingly. Irrespective of the differing view, the outcomes were a shift in production possibilities frontiers (frontier curves) and a change in production functions. Additionally, the Great East Japan Earthquake in 2011 produced a significant reduction in the number of production facilities in the area and therefore a substantial structural change has happened in the area's production functions and levels.

This study aims to theoretically clarify the nonlinear transition mechanism of production and Japanese development. In detail, the study examines four phenomena that can fundamentally change the economy and production function capabilities. First, related studies have provided empirical evidences of the way in which structural factors, and in particular "economies of scale," shift the production frontier curves as well as change production functions. Second, cyclical factors such as "the operating rate" are also known to affect frontier curves. Bodkin and Klein (1967) point out that production functions and their associated relationship with marginal productivity are essentially nonlinear in nature. Coyle, Bardi and Langley (1988) explore the phenomenon of economies of scale and the process by which scale merit is based on business activities. A number of other studies introduce the notion of the jumping processes in production functions.

The Markov switching model of the production function in Hamilton (1989) is frequently referenced in such studies. Kim and Nelson (1999) use this model by assuming that economic movements during expansionary periods and those during recessionary periods follow the Markov switching process. In other words, an economy can experience a jumping processes based on cyclical factors. While their model assumes only one structural change point, Uchiyama and Watanabe (2004) apply the Markov switching model successfully including some change points. Diebold and Rudebusch (1996) propose a new multivariable dynamic factor model with regime switching that simultaneously captures change points in the business cycle. These studies consider the change activities under the given conditions, but to the best of our knowledge there are no clear studies, which clarify the jumping mechanisms for production.

Third, there is a recent focus on the effect of "the vintage facilities" (defined here as aging or outdating of facilities and equipment), which would have impacts on production. The Japanese Cabinet Office (2013) states that the vintage facilities' effect on the Japanese manufacturing sector could lead to a decline in its productivity. Factories do renew facilities, but tend to do so in periods of high growth and therefore when they have plenty of cash. In this way, the renewal of vintage facilities tends to be cyclical. In periods of low or negative growth, when the pace of regeneration is slowed, downward structural effects on production are the outcome. Finally, there has also been a focus on the role of "the international transfer of facilities" on production although its impact is not described with precision. The Japanese Ministry of Economy, Trade and Industry (2010) states that the international transfer of facilities has an entirely negative impact on production in the country from which the transfers are made. By contrast, Lipsey, Ramstetter and Blomström (2000) consider that increases in production in foreign facilities lead to increases in production and export in the home country. Blonigen (2001) studies the relationship between the foreign direct investments of the Japanese automobile sector in the United States and the automobile sector's exports from Japan to the United States, and indicates that the foreign direct investments of assembling facilities lead to an increase in the export of automobile parts from Japan to the United States.

The literatures therefore indicate that these four phenomena —economies of scale, the operating rate, the vintage facilities, and the international transfer of facilities— can lead to dramatic changes in productions as well as to shifts in frontier curves and production functions. Also indicated is that these transition jumps of production are empirically known, however the actual mechanisms are not clearly specified. In particular, what are the specific catalysts for the jumps and what are the nature of thresholds which produce the jumps?

To maintain sustainable growth, it is important to clarify the mechanisms and reasons for economic growth changes. An economy grows and declines because of both permanent and temporal effects. To understand these fundamental dynamics of an economy, its potential growth level needs to be grasped. This study attempts to theoretically clarify the jumping processes which affect the growth of production by constructing a new model, for contributing to the understanding. In doing so, it takes into account the presence of thresholds relating to structural and cyclical factors and which produce sudden boosts and/or falls to production. This study also investigates cases in the Japanese manufacturing sector based on the proposed model and tries to show the nonlinear and transition changes in Japan.

This paper is set out as follows. Chapter 2.2 constructs a model to show the jumping process in production. Using empirical data drawn from the Japanese manufacturing sector and using the constructed model, Chapter 2.3 investigates the presence of a nonlinear transition process. Chapter 2.4 concludes the paper by summarizing the findings, discussing some extensions, and providing suggestions for further studies.

2.2 The model

This study calibrates a simple one time period model[1]. There are two active agents: a producer and a consumer. The producer, such as a firm, concentrates on generating outputs for the economy. The consumer, such as a household, tries to maximize its consumption and utility. The output level (y) can be explained by productivity (A), the accumulation level of equipment (K), and the input level of labor (L) as:

$$y = F(A, K, L) \tag{2.1}$$

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[1] This study follows Calvo's (1988) basic methodology in his study of country debt problems which shows the existence of nonlinear and transition movements in the debt repudiation processes. Calvo introduces a repudiation proportion interval to construct a jumping model for interest rates. This study uses this interval portion idea and develops a new economic model.

The production function is assumed to have diminishing returns, hence the equation (2.1) satisfies the following conditions:

$$\frac{\partial F}{\partial K} > 0 \quad , \quad \frac{\partial^2 F}{\partial K^2} < 0 \tag{2.2}$$

$$\frac{\partial F}{\partial L} > 0 \quad , \quad \frac{\partial^2 F}{\partial L^2} < 0 \tag{2.3}$$

The economy holds a level of production ability (Y_b) and its operating rate (θ) varies in the interval $(0, 1]$. In this model, the firm is assumed to always produce some output and the parameter θ is larger than zero. The gross production level (Y) is defined by Y_b and θ:

$$Y = \theta Y_b \tag{2.4}$$

Thus, the following relationship can be written:

$$\begin{aligned} y &= Y - g \\ &= \theta Y_b - g \end{aligned} \tag{2.5}$$

where y and g are income (the net output level for this economy) and expenditure. Its operating rate is a variable term and it is acknowledged that there might be an opportunity cost that the firm tries to control in this time period. Considering this cost and its original potential net output level ($\overline{y}$), the following relationship can be written as:

$$\begin{aligned} \overline{y} &= y + \eta(1-\theta)Y_b \\ &= \theta Y_b - g + \eta(1-\theta)Y_b \end{aligned} \tag{2.6}$$

where $\eta(1-\theta)Y_b$ indicates the opportunity cost that relates to the surplus ability. The parameter η is a variable value indicating the cost for resting capacity ($(1-\theta)Y_b$) in an interval $[0, 1)$. Additionally, for the original potential gross output for this economy ($\overline{Y}$), there is

$$\overline{y} = \overline{Y} - \overline{g} + \zeta \tag{2.7}$$

where $\overline{g}$ is an assumed averaged expenditure and ζ shows an error term.

Here, the household uses all of its wealth; so assuming that this firm's expenditure does not directly affect private consumption at this time, the level of consumption (c)

can be written as:

$$c = x + \pi(\theta Y_b - \overline{Y}) - z(\overline{y}) \tag{2.8}$$

where $x(\leq y)$ denotes the basic (regular) income for the household and $z(\overline{y})$ measures the expenditure for this household and the deadweight loss in this economy under the following assumptions:

$$z(0) = 0, z'(0) = 0, z"(\overline{y}) > 0 \tag{2.9}$$

In equation (2.8), π is in an interval [0, 1], and the term $\theta Y_b - \overline{Y}$ indicates the difference between the potential output level and the actual output level. This study assumes that the output equals the planned expenditure and that the difference affects consumption through an additional income (bonus) for the household. Under conditions of an economic boom ($\theta Y_b > \overline{Y}$), the household would enjoy such bonuses thereby boosting consumption. On the other hand, under economic recessions ($\theta Y_b < \overline{Y}$), the household would receive no bonus cutting its income and consequently decreasing its consumption.

Assuming that the firm tries to maximize its output and the household tries to maximize its consumption, subject to its constraint. This means that the economy controls its activity to minimize:

$$z(\overline{y}) - \pi(\theta Y_b - \overline{Y}) \tag{2.10}$$

Using this basic mechanism, the following sections consider the effects of economies of scale, the operating rate, and the vintage facilities on production. The model is then expanded to consider the effect of the international transfer of facilities on production.

2.2.1 Economies of scale

The equation (2.10) is subjected to equation (2.6) and $0 < \theta \leq 1$. In other words, the problem is to minimize equation (2.10) by choosing $\overline{y}$ subject to its constraint. Thus, this equates to restricting $\overline{y}$ in the following bands subject to the constancy of the other variables:

$$\eta Y_b - g < \overline{y} \leq Y_b - g \tag{2.11}$$

The left side of equation (2.11) corresponds to the case of $\theta \simeq 0$, and the right side corresponds to the case of $\theta = 1$. The sector is constrained by having $\overline{y}$ between two lines (see Figure 1). Let us consider that there is a line: $Y_b = Y_b^*$ which cuts across the two constrained lines. If Y_b^* is located as shown in Figure 1, then this sector could attain the unconstrained maximum $\overline{y}$, with $\overline{y}$ lying between $(\eta Y_b^* - g)$ and $(Y_b^* - g)$. The sector starts to increase its income by moving its operating ratio from the lower level ($\theta \simeq 0$)

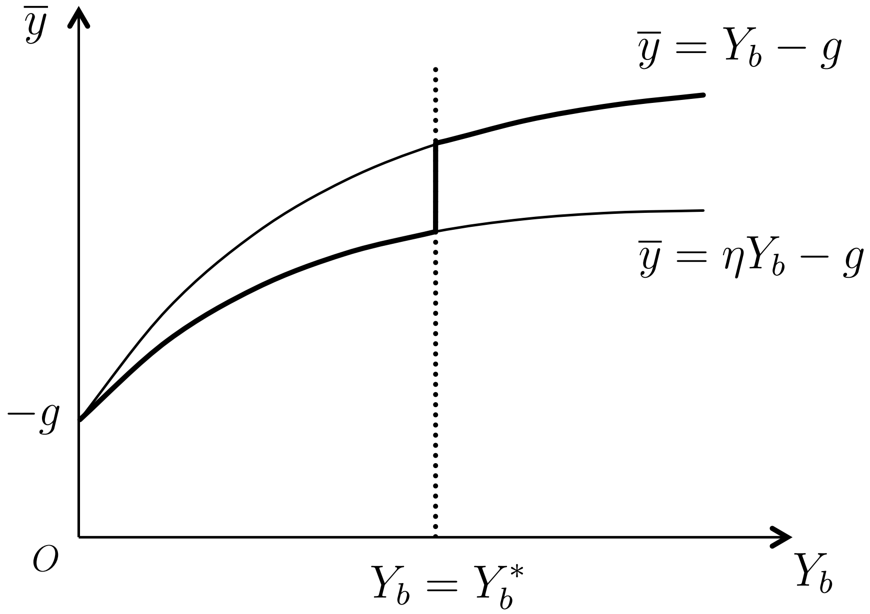

Figure 2.1: Reaction function: economies of scale

to the higher level ($\theta = 1$). Hence, if Y_b is smaller than Y_b^*, the sector rests around the lower line that corresponds to the case of the lower operation rate ($\overline{y} = \eta Y_b - g, \theta \simeq 0$). Y_b is larger than zero, but its output could be a negative figure, particularly in cases of an initial start-up. In this case there are high initial costs at an early stage (with correspondingly very low operation rates) and then $\overline{y}$ would start as a negative figure. When Y_b reaches Y_b^*, θ increases from the lower level to the higher level. Therefore, if Y_b is larger than Y_b^*, the upper line ($\overline{y} = Y_b - g$), which corresponds to the case of $\theta = 1$, is selected. The maximum problem for the producer is depicted in Figure 2.1 which shows how the parameter $\overline{y}$ moves on the bolt lines. The production function is assumed to follow diminishing returns (equations (2.2) and (2.3)) and the level of the production ability in equation (2.11) also exhibits diminishing curves[2]. Thus, the reaction function for $\overline{y}$ is:

$$\overline{y} \begin{cases} \simeq & \eta Y_b - g & (Y_b < Y_b^*) \\ = & (\eta Y_b - g, Y_b - g] & (Y_b = Y_b^*) \\ = & Y_b - g & (Y_b > Y_b^*) \end{cases} \tag{2.12}$$

This function indicates the existence of structural factors, such as economies of scale.

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[2] The equations (2.1), (2.2), (2.3), and (2.4) imply that Y_b is also affected by A, K and L in addition to holding diminishing returns.

The output jumps when Y_b —indicating economies of scale— reaches a certain level Y_b^*, and this effect is a nonlinear and transition movement. It also shows that $\overline{y}$ might suddenly decline when Y_b decreases. Hence, Y_b^* is a sector threshold for dramatic changes in its production. Although the potential growth rate gradually moves in general, when significant changes occur —such as the structural changes of the financial crisis in 2007–2008 and the Great East Japan Earthquake in 2011—, the rate would suddenly shift, as discussed in the former section (introduction).

$\overline{Y}$ represents the sector's original potential gross output. Then, the reaction function (2.12) is improved:

$$\overline{Y}\begin{cases} \simeq & \eta Y_b + g(g,\overline{g},\zeta) & (Y_b < Y_b^*) \\ = & (\eta Y_b + g(g,\overline{g},\zeta), Y_b + g(g,\overline{g},\zeta)] & (Y_b = Y_b^*) \\ = & Y_b + g(g,\overline{g},\zeta) & (Y_b > Y_b^*) \end{cases} \tag{2.13}$$

where $g(\cdot)$ represents a function which is determined by $g, \overline{g}, \zeta$. This function implies a similar outcome to function (2.12) which is a nonlinear transition process involving sudden increases and sudden declines in production.

2.2.2 Operating rate

A further mechanism for the operating rate can be displayed using a similar framework. To derive equation (2.12), the subjection of equation (2.6) and the term of $0 \leq \eta < 1$ can be introduced. Thus, this equation —subject to the constancy of the other variables— becomes:

$$\theta Y_b - g \leq \overline{y} < Y_b - g \tag{2.14}$$

The left side corresponds to $\eta = 0$, and the right side corresponds to $\eta \simeq 1$. The parameter $\overline{y}$ is a function of θ. By introducing the existence of parameter $\theta = \theta^*$, which cuts across the two lines for $\overline{y}$ in equation (2.14), the reaction function for $\overline{y}$ can be shown as:

$$\overline{y}\begin{cases} = & \theta Y_b - g & (\theta < \theta^*) \\ = & [\theta Y_b - g, Y_b - g) & (\theta = \theta^*) \\ \simeq & Y_b - g & (\theta > \theta^*) \end{cases} \tag{2.15}$$

$\overline{y}(\theta)$ is an increasing function, and the parameter $\overline{y}$ moves on the bolt lines in Figure

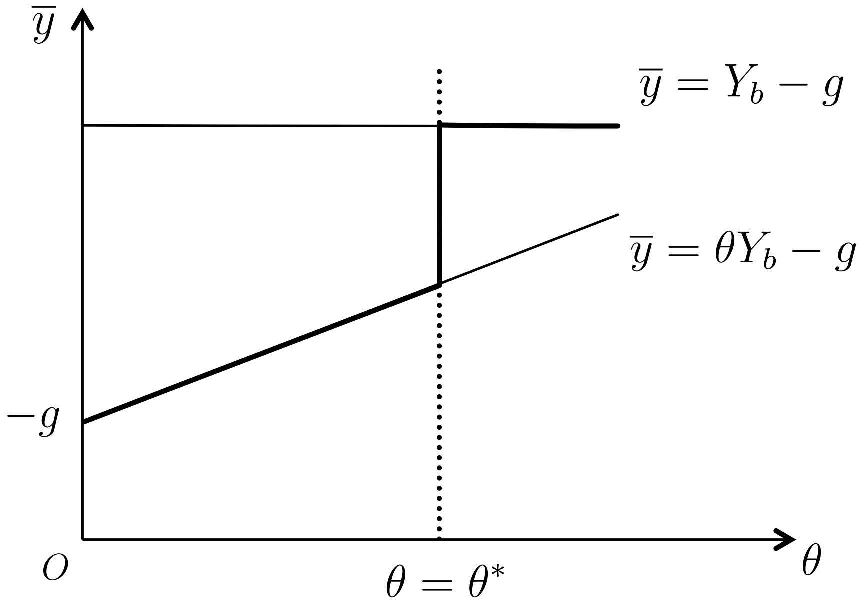

Figure 2.2: Reaction function: operating rate

2.2. This reaction function implies that there is a relationship between the operating rate and the yield of production. A higher operation rate would lead to a higher yield rate of production. In this figure, $\overline{y}$ is drawn as a constant line over its threshold ($\theta = \theta^*$), given that other parameters are now considered as constant values. In cases where other parameters are considered as variable values, $\overline{y}$ would have an increasing function above its threshold.

The reaction function for $\overline{Y}$ shows a similar result to that in Section 2.2.1:

$$\overline{Y} \begin{cases} = & \theta Y_b + g(g, \overline{g}, \zeta) & (\theta < \theta^*) \\ = & [\theta Y_b + g(g, \overline{g}, \zeta), Y_b + g(g, \overline{g}, \zeta)) & (\theta = \theta^*) \\ \simeq & Y_b + g(g, \overline{g}, \zeta) & (\theta > \theta^*) \end{cases} \tag{2.16}$$

The parameter θ indicates the firm's operating rate (its business cycle). Hence, this function shows the existence of a business cycle that follows a nonlinear and transition process. It therefore plays a role in shifting the production frontier curve[3].

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[3] It could be argued that $\overline{y}$ is a potential production level and that it indicates the maximum output of the economy with the highest rate of operations ($\theta = 100\%$). By contrast, some economic approaches for measuring a potential output in real data assume that it is a historical averaged operating ratio. There are several methods to calculate a potential production level: Cècile *et al.* (2006) detail these methods.

2.2.3 Vintage facilities

As mentioned in Section 2.1, in some cases the initial cost exerts a downward pressure on production. Aging facilities may also impose a similar effect given this phenomenon, which leads to change the sector's opportunity cost. The parameter δ indicates the vintage of the producer's facilities and holds an interval of $0 < \delta \leq 1$. In other words, the parameter δ shows a natural decreasing ratio for this facility. Thus, equation (2.6) can be rewritten and similarly modified as:

$$\overline{y} \;=\; y + \delta\eta(1-\theta)Y_b \tag{2.17}$$

The vintage parameter δ indicates a new facility with $\delta = 1$ and an old facility with $\delta \simeq 0$. This study assumes the existence of opportunity cost, so δ does not hold zero: this model assumes that the firm always produces some outputs. Thus, equation (2.12) can be extended. In cases of a new facility ($\delta = 1$), the sector holds the same reaction function (2.12). However, as the facilities age, the parameter δ departs from one and the lower line is revised down (Figure 2.3). For example, some difficulties leading to a decrease in the operation efficiency result in a considerable production decrease. Thus, the reaction function of $\overline{y}$ is written as:

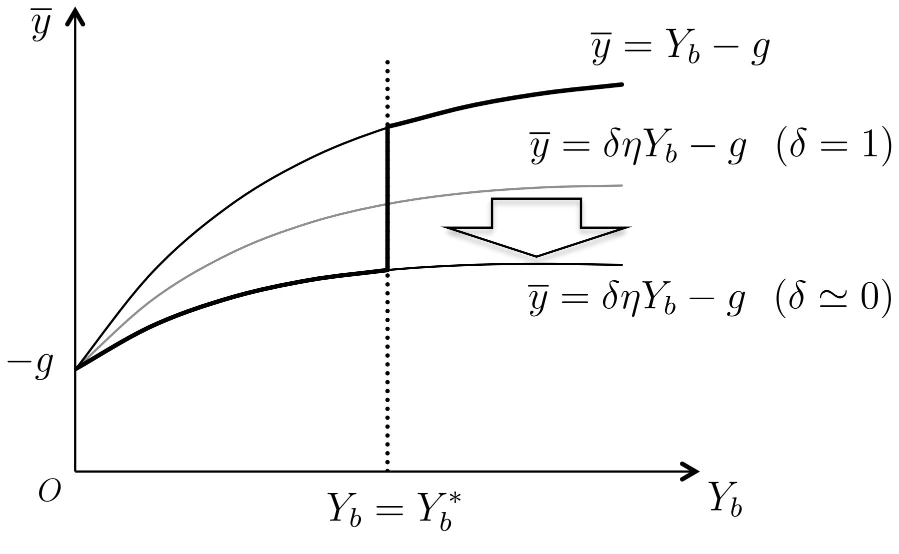

Figure 2.3: Reaction function: vintage

This study considers that the operating ratio relates to the economic cycle and would therefore boost the potential production level upwards or downwards.

$$\overline{y}\begin{cases} \simeq & \delta\eta Y_b - g \quad (Y_b < Y_b^*) \\ = & (\delta\eta Y_b - g, Y_b - g] \quad (Y_b = Y_b^*) \\ = & Y_b - g \quad (Y_b > Y_b^*) \end{cases} \tag{2.18}$$

The reaction function can also be written assuming that $\overline{y}$ is a function of θ as well as assuming that $\overline{Y}$ is a function of Y_b and θ by applying the above reaction functions. This model implies that time-worn and vintage facilities could lead to a sudden decline in production, in addition to a gradual decline in production by moving the parameter δ $(0 < \delta \leq 1)$. A gradual decline would take a long time, and it should be checked with a plural time series model. This study applies the overlapping-generations model to explain the role of vintage facilities. Assuming an equilibrium condition for the economy at time t, a young generation is born at time t and an elder generation is born at time $t-1$.

$$F = c_{yt}L_t + c_{et}L_{t-1} + \delta_{t+1}K_{t+1} - \delta_t Kt \tag{2.19}$$

Subject to

$$\delta_{t+1}K_{t+1} - \delta_t K_t = s_t L_t - \delta_t K_t \tag{2.20}$$

In equation (2.19), $c_{yt}L_t$ and $c_{et}L_{t-1}$ correspond to the consumptions of the young generation and the elder generation respectively (c_{yt} and c_{et} indicate the respective consumption per unit). The left side of equation (2.20) shows the investment. The right side, $s_t L_t$ shows the saving of the young generation at time t (s_t indicates the saving of the young generation per unit), and $\delta_t K_t$ shows the stock for this economy at time t. Dividing the equation (2.19) by L_t, gives:

$$\frac{F}{L_t} = c_{yt} + c_{et}\frac{L_{t-1}}{L_t} + \delta_{t+1}\frac{K_{t+1}}{L_t} - \delta_t\frac{Kt}{L_t} \tag{2.21}$$

This equation can be rewritten as:

$$f(k_t) = c_{yt} + c_{et}\frac{1}{1+n} + \delta_{t+1}(1+n)k_{t+1} - \delta_t k_t \tag{2.22}$$

where f, $1+n$, and k indicate the production per one unit of labor, the changing rate of labor, and the ratio of K and L. To consider the steady state of this problem, the following conditions can be added:

$$k = k_{t+1} = k_t \tag{2.23}$$

$$\delta = \delta_{t+1} = \delta_t \tag{2.24}$$

Additionally, the total consumption for this economy at time t can be explained as $c = c_{yt} + c_{et}\frac{1}{1+n}$. Then, the problem becomes:

$$f(k) = c + \delta n k \tag{2.25}$$

This function shows that as the facilities age the level of production declines. The role of vintage facilities is also indicated in the time-series model. If it is assumed that the function satisfies the relation $f(0) = 0$, then when its vintage becomes time-worn, both consumption and production levels decline.

2.2.4 International transfer of facilities

The presence of the international transfer of facilities adds an interesting twist to the model. By assuming that the sector shifts its production ability abroad and that the transferred facilities are used only for foreign countries, this study's model can be applied. International transfer directly affects output and also changes the opportunity cost. In this case, its level of production ability (Y_b) has declined by shifting and closing the domestic facilities, or its operating rate (θ) has declined by retaining the domestic facilities. This changes its constraint (2.6) by adding a parameter κ ($0 < \kappa \leq 1$) that indicates the ratio of the production level abroad compared with that in the home country, and is rewritten as:

$$\overline{y} \;=\; y + \kappa\eta(1-\theta)Y_b \tag{2.26}$$

Generally, when moving abroad a factory gradually improves its ability and the production function also gradually changes. When the transfer occurs rapidly, some frictions would be bound to arise —such as employment issues in the home country— and the reaction function may shift to a lower level in equations (2.12) and (2.15). This would lead to a sudden decline in production.

By contrast, the international transfer of facilities can incur export inducement effects (increases in procurement from the home country). In this case, the facilities in Japan are still used and the opportunity cost would not change (from the view point of the macro home economy). Introducing a parameter λ (> 0) explains this phenomena, and equation (2.26) can be expanded as:

$$\overline{y} \;=\; y + \lambda\kappa\eta(1-\theta)Y_b \tag{2.27}$$

The parameter λ could cancel out the negative effects of κ in this equation. Notice that these international transfer equations are written from the view point of a short-term period model. Shifting facilities abroad would lead to changes in the opportunity cost itself, and changes in the output level in the long-term.

2.3 An empirical study of Japanese manufacturing

This section uses Japanese manufacturing data and applies the theory in Section 2 to actural empirical cases.

2.3.1 The estimation model

To show the movement using a simple methodology, this study assumes that production follows the first-order autoregressive process, AR(1)[4]:

$$LN(\overline{y}_t) \;=\; \alpha + \beta \cdot LN(\overline{y}_{t-1}) + \epsilon_1 \tag{2.28}$$

where LN denotes the natural logarithm. Additionally, if the transition mechanisms actually work, the following dummy added model might work:

$$LN(\overline{y}_t) \;=\; \alpha' + \beta' \cdot LN(\overline{y}_{t-1}) + \gamma \cdot D \cdot LN(\overline{y}_{t-1}) + \epsilon_2 \tag{2.29}$$

where D is a dummy variable. The dummy variable D holds to one when the economic conditions, such as economies of scale and the operating rate, are above their thresholds: it holds to zero when these conditions are under their thresholds. This study picks a specific number for the threshold of the dummy variable and moves it as a rolling

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[4] This study uses level variables in the estimation model. Enders (1994) argues that having differences in a function reduces the information that is included in each variable. Hamilton (1994) mentions that when all level variables are estimated in a model, especially in a vector auto regression model, the consistency of the estimated parameters is guaranteed. Christiano and Ljungqvist (1988) propose simulating data from their estimated level model. Additionally, the unit root tests for data in this study allow these estimation models.

estimation. ϵ_1 and ϵ_2 follow independent and identically distributed random variables. If there is a threshold, then the total value of the coefficients $(\beta' + \gamma)$ in equation (2.29) is sufficiently larger than the coefficient value of the base value (β) in equation (2.28).

2.3.2 The data

The sample consists of data for the Japanese manufacturing industry. The main data are from the Indices of Industrial Production (IIP), which is published monthly by the Japanese Ministry of Economy, Trade and Industry from 1978–2013. All data are normalized (averaged using the CY2010 =100 as a baseline). This study considers that the IIP's Production Capacity Index refers to economies of scale, and the IIP's Operating Ratio Index refers to the operating rate. The potential net output $\overline{y}$ is calculated using the Hodrick-Prescott filtering approach. The data for the operating rate and the output are seasonally adjusted.

The data for vintage facilities are from the Preliminary Estimates of Gross Capital Stock of Private Enterprises, published quarterly by the Japan Cabinet Office from 1980–2012. This study calculates vintage facilities (δ) as:

$$\delta_t = \frac{(\delta_{t-1} + 1)(K_{t-1} - R_t) + I_t/8}{K_t} \tag{2.30}$$

where R and I, indicate excluded stock and new investment, respectively, and K_t shows capital of the end of time t. Vintage facilities data are normalized (average CY2010=100).

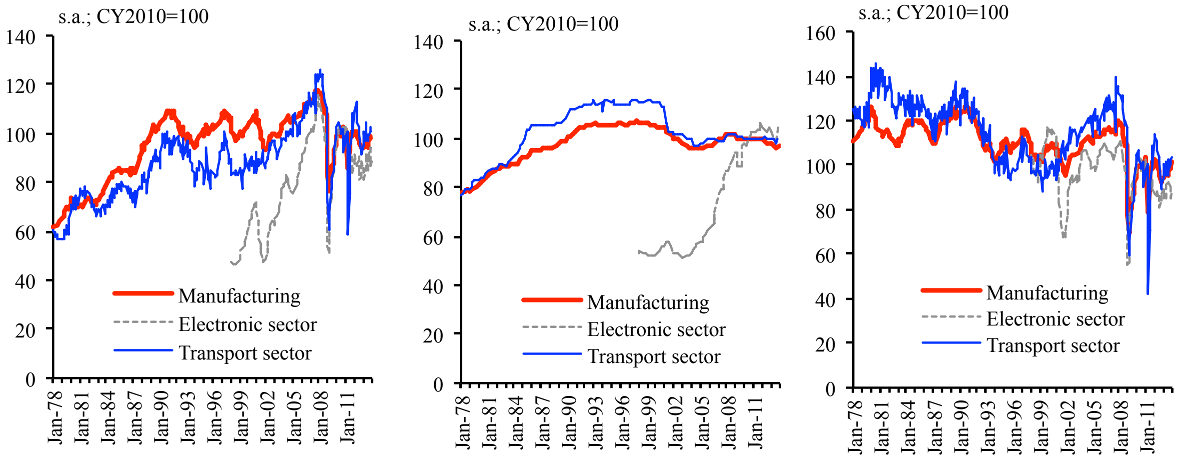
International transfer of facilities data are from the Quarterly Survey of Overseas Subsidiaries published by the Japan Cabinet Office, and the Financial Statements Statistics of Corporations by Industry published quarterly by the Japan Ministry of Finance from 1996-2012. This study calculates the international production ratio (κ) as:

$$\kappa = \frac{S_f}{S_f + S_h} \tag{2.31}$$

where S_f, and S_h indicate the volume of sales abroad and those in the home country respectively.

This study focuses on Japanese manufacturing activities that hold pertinent to its economy, and analyze the overall movement in its growth as well as two important sectors in the entirety: electronics and transport (Figure 2.4). Regarding Japan's manufacturing sector, the IIP indicates an increasing trend prior to 1990 after which there is a flattening out of growth for a considerable period. Of note are two recent sudden declines in growth

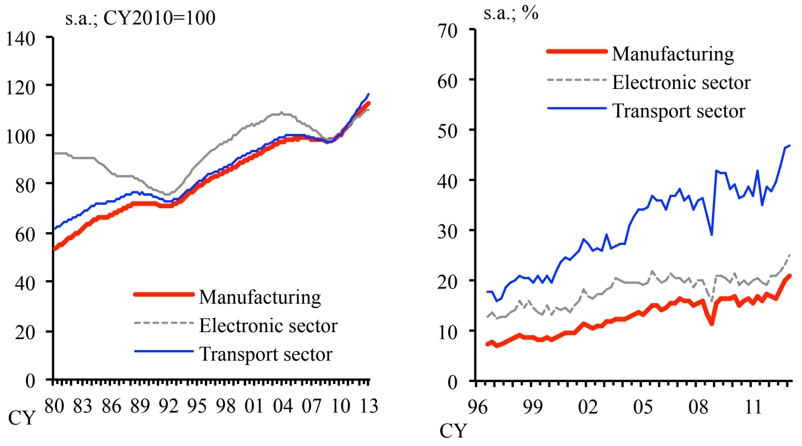
—the products of the financial crisis in 2007-2008 and the Great East Japan Earthquake in 2011. Japan's production capacity showed an increasing trend prior to the mid-1990s, but this has been followed by period of stagnation since then.



IIP

Production capacity

Operating rate



Vintage

International Transfer

Figure 2.4: Basic data

In line with production capacity, the operating rate for Japan's manufacturing sector was high prior to 1990, subsequently shifting to a lower level. The vintage facilities and the international transfer ratio both exhibit overall upward trends. The electronic sector and the transport sector follow similar patterns to the overall movement of manufacturing. Of particular note is the rapid growth of the electronic sector prior to the financial crisis. Table 2.1 shows the correlations among these values.

Table 2.1: Correlation

Manufacturing

	IIP	production capacity	operating rate	vintage	international production ratio
IIP	1.000	0.854	-0.054	0.805	-0.119
production capacity		1.000	-0.300	0.747	-0.278
operating rate			1.000	-0.436	-0.741
vintage				1.000	0.952
international production ratio					1.000

Electronic sector

	IIP	production capacity	operating rate	vintage	international production ratio
IIP	1.000	0.684	0.316	0.401	0.646
production capacity		1.000	-0.267	0.188	-0.167
operating rate			1.000	-0.117	0.560
vintage				1.000	0.712
international production ratio					1.000

Transport sector

	IIP	production capacity	operating rate	vintage	international production ratio
IIP	1.000	0.474	-0.001	0.654	0.379
production capacity		1.000	-0.394	0.536	0.021
operating rate			1.000	-0.561	-0.862
vintage				1.000	0.926
international production ratio					1.000

Note: Data are taken the natural logarithim.

The unit root tests are first examined for IIP data that take the natural logarithm. The Augmented Dickey-Fuller (ADF) test rejects the null hypotheses that the IIP of overall manufacturing (t-value: -2.8) and the IIP of the transport sector (t-value: -3.1) have unit roots. The DF-GLS test rejects the hypothesis for the electronic sector (t-value: -2.7). The study uses the estimation functions (2.28) and (2.29) to extract further valuable information from the data a methodology followed by Enders (1994), Hamilton (1994), as well as Christiano and Ljungqvist (1988). The results are discussed below.

2.3.3 Results and discussion

Table 2.2 shows the main results of equation (2.28) calculated by use of monthly data. All coefficient values are significant, and these factors satisfy the AR(1) process[5]. The

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[5] As discussed in the above study, the empirical estimation model uses level values based on Enders (1994), Hamilton (1994), as well as Christiano and Ljungqvist (1988). The coefficient values in this case are expected to hold a value of around one, although the coefficient values in Table 2.2 are less than one. This is partly because Japan's economy had "two lost decades" of economic stagnation in the 1990s and the 2000s.

dummy variable is introduced as in equation (2.29). This study has changing thresholds with a rolling process. Moreover, Figures 2.5, 2.6, 2.7, 2.8, and 2.9 show movements of the coefficients $(\beta' + \gamma)$. Broken lines in the figures represent the baseline in equation (2.28) and solid lines represent the rolling results in the dummy added in equation (2.29). The shaded areas represent one standard error. When the rolling results significantly apart from the baseline, the factors, such as economies of scale, the operating rate, the vintage facilities, and the international transfer of facilities, would have significant impacts on production functions.

Table 2.2: Estimation results in base case

	Manufacturing	Electronic sector	Transport sector
coefficient values			
β	0.991 *** (0.001)	0.986 *** (0.001)	0.991 *** (0.001)
α (const.)	0.042 *** (0.003)	0.062 *** (0.006)	0.044 *** (0.004)
Adjusted R-squared	0.9	0.9	0.9

Note: Values in parentheses are standard errors. Electronic sector is data on electronic parts and devices, and transport sector is data on transport equipment. *** indicates 1% significant levels.

Economies of scale

Figure 2.5 shows the estimated results of equation (2.29) incorporating the thresholds of production capacity that relate to economies of scale. Figure 5 reveals two main findings relating to the overall manufacturing sector. i) The total value of the coefficients $(\beta' + \gamma)$ jumps when the threshold reaches approximately 95, which is a nominalized value (CY2010 = 100). This means that its production volume suddenly increases when its production capacity increases and reaches a certain point (threshold). In other words, it demonstrates the existence of economies of scale (scale merit). The timing corresponds to specific events, such as Japanese economic boom period in 1980s. The results imply that the production function in Japan would have changed when the threshold reached the certain level, and it could enjoy the scale merit. ii) The total value of the coefficients peaks nearly 100 and gradually declines above the point. This indicates that the production function holds diminishing returns, as the conditions (2.2) and (2.3) indicate[6].

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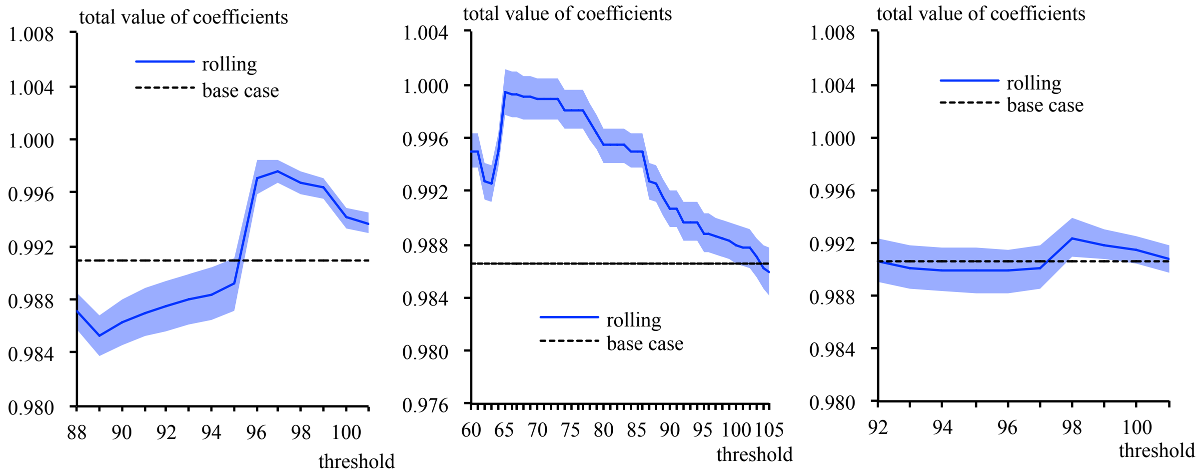
[6] Beason and Weinstein (1996) in their study of Japanese growth indicate that *"decreasing returns to scale seem to be better descriptions of the technology present in Japanese industries."*



Manufacturing Electronic sector Transport sector

Note: Thresholds for the dummy variable in equation (2.29) are selected by figures of production capacity (CY2010=100). Shadow area means ± one standard error.

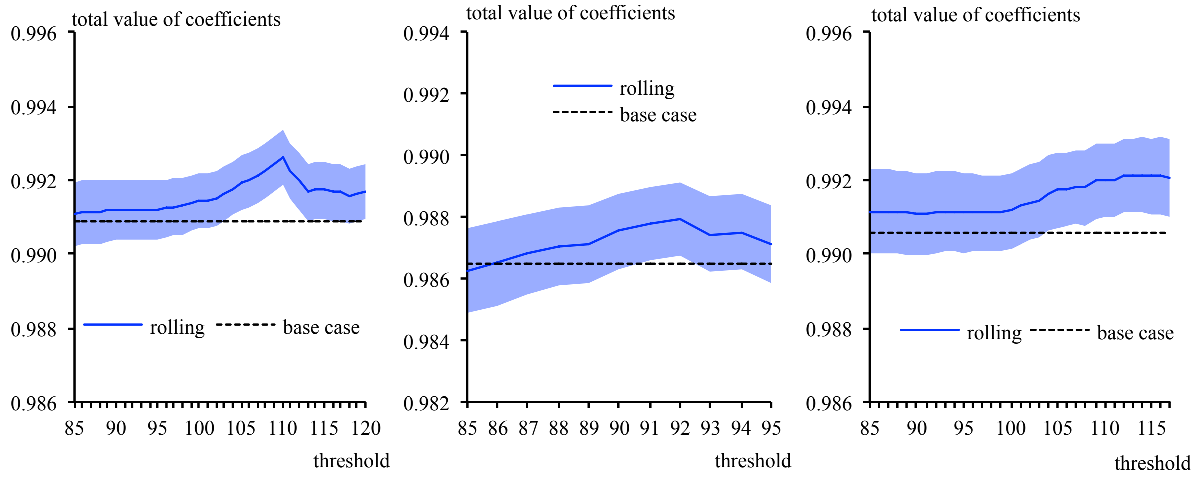
Figure 2.5: Rolling estimation result: economies of scale

The electronic sector result is similar to that of manufacturing: when its threshold reaches approximately 65, its production level jumps up. The timing corresponds to specific economic events in Japan, such as the dot-com bubble, which appears to have exerted an upward pressure on the electronic sector's production function. When its threshold reaches approximately 75, its production level gradually decreases. The transport sector result is also similar to that of manufacturing, although there is a smaller jumping level. Such results imply the existence of economies of scale in these sectors.

Operating rate

Figure 2.6 shows the results of equation (2.29) using the operating rate thresholds. When the threshold is under approximately 100 for the manufacturing sector, the total value of coefficients $(\beta' + \gamma)$ is almost stable. When the threshold is above 100, the total value of the coefficients significantly shifts from the baseline coefficient value. This result implies the existence of a nonlinear transition jump of production. The jump point corresponds to events, such as the global financial crisis and the Great East Japan Earthquake. At the point, the operating rate had suddenly declined. Then, its production function would have faced a downward pressure. Additionally the total value of coefficients gradually declines after peaking out. This implies that the production function hold diminishing returns.

The electronic sector results do not display significant values, but both the upward



Manufacturing   Electronic sector   Transport sector

Note: Thresholds for the dummy variable in equation (2.29) are selected by figures of operating rate (CY2010=100). Shadow area means ± one standard error.

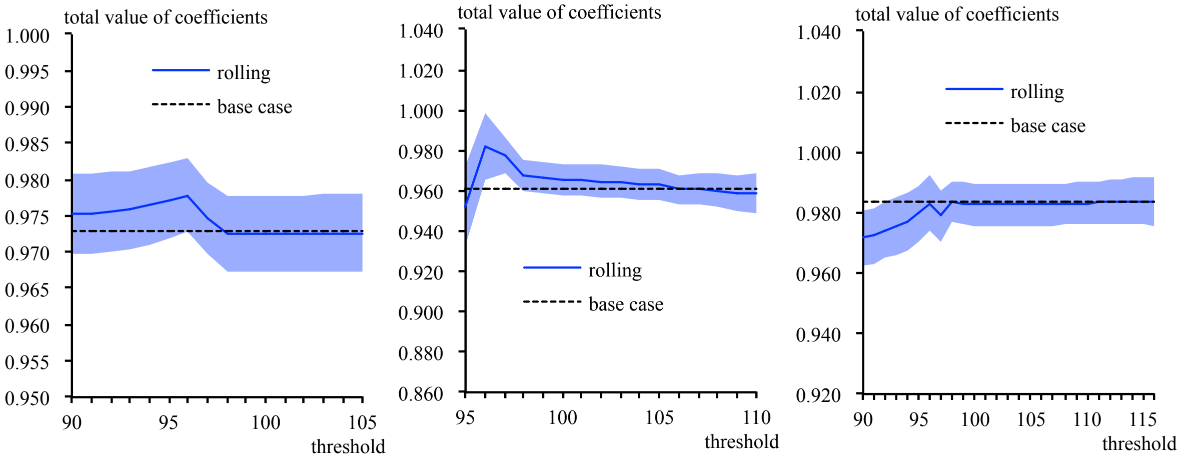
Figure 2.6: Rolling estimation result: operating rate

and the downward pressures based on its thresholds are visible. The transport sector exhibits a significant production transition process given the total value of coefficients jump up after its threshold reaches approximately 100.

Vintage facilities

Figure 2.7 shows results of the equation (2.29) relating to the vintage facilities' thresholds that are calculated from quarterly data. The manufacturing results show that aging facilities appear to exert downward pressure on production after reaching the threshold of approximately 96. The electronic sector exhibits a similar result where vintage facilities are shown to exert a gradual downward pressure on production. This appears to have contributed to Japan's recent slow or decreasing growth.

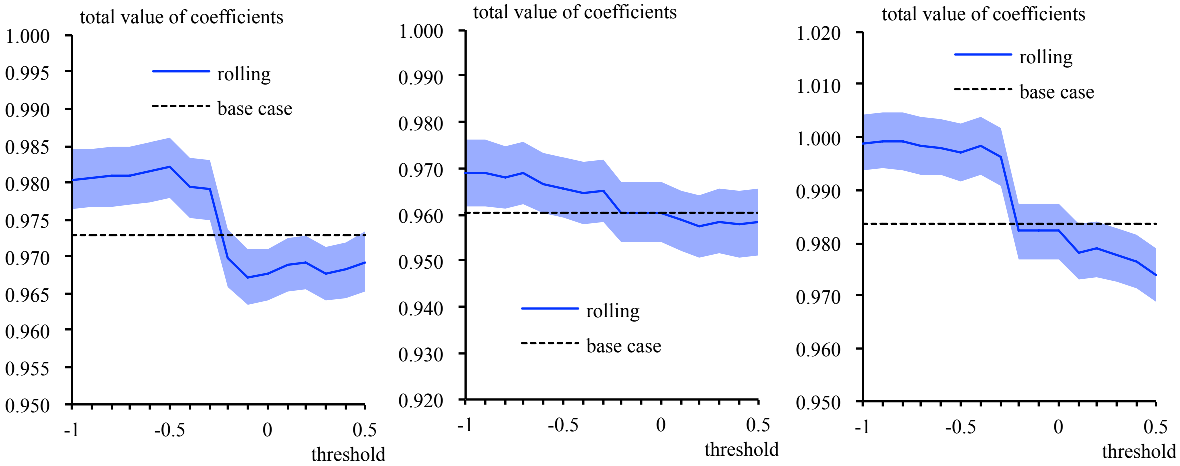
The transport sector follows a different pattern. The total value of coefficients does not decline. This may be partly because Japan's transport sector is highly competitive on a global basis and has increased its export volume: this could allow the retention of its increasing production trend despite having vintage facilities. However, its total value of coefficients holds an almost constant value above the 100 threshold. Hence, the presence of vintage facilities in the transport sector might exert somewhat downward pressures on production, although the pressures are limited.



Manufacturing Electronic sector Transport sector

Note: Thresholds for the dummy variable in equation (2.29) are selected by figures of operating rate (CY2010=100). Shadow area means ± one standard error.

Figure 2.7: Rolling estimation result: vintage



Manufacturing Electronic sector Transport sector

Note: Thresholds for the dummy variable in equation (2.29) are selected by figures of vintage (defference between actural and trend of vintage level). Shadow area means ± one standard error.

Figure 2.8: Rolling estimation result: vintage

In regard to the vintage facilities data, a monotonic increasing trend is apparent (Figure 2.4), and which may have an effect on the above results. This study also tries other thresholds as dummy variables D. Instead of the above dummy variable which holds to a value of one when vintage facilities is above a specific level, the alternative dummy variable holds to a value of one when the residual (the differences between actual level and trend level) is above a specific value. Thus, when the vintage facilities factor is increasing rapidly, repairs and maintenance would not catch up and lead to a decline in the production efficiency and production level.

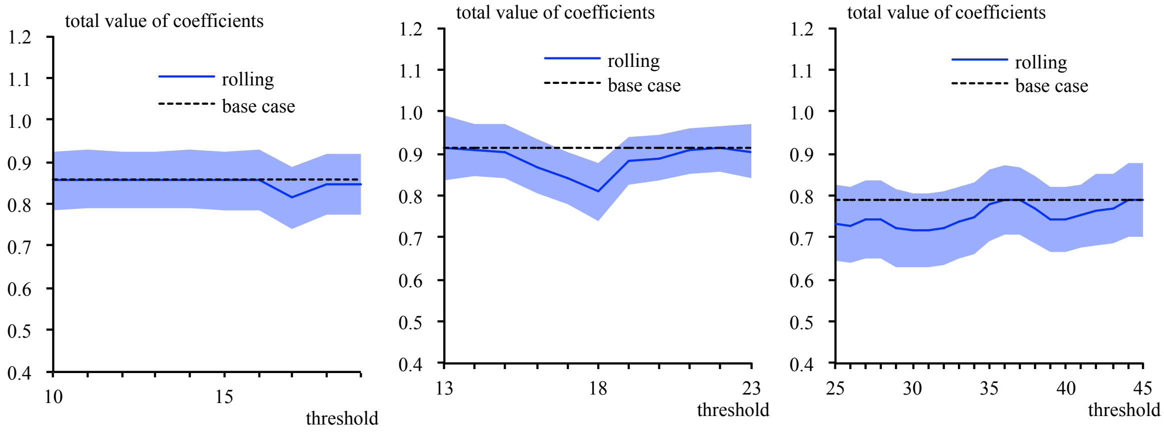
Figure 2.8 shows the result of the alternative estimation. When the alternative threshold is around zero, the total value of coefficients ($\beta' + \gamma$) for the manufacturing sector is revised down. Losing touch with its vintage facilities' trend (rapid aging of facilities) appears to decrease production. In this case it may be assumed that the rapid aging creates problems for management which controls the productivity of facilities. The electronic sector and the transport sector display similar results to that of total manufacturing. As discussed above, while Japan's transport sector has a highly competitive power, the effect of vintage facilities nevertheless exerts a negative impact on production. Thus, the aging in vintage facilities has a negative pressure on production.

International transfer of facilities

Figure 2.9 shows the results of equation (2.29) relating to the foreign production ratio which is calculated from quarterly data. The rolling estimated manufacturing results exhibit an almost constant values and are not significantly different from the base case. The electronic sector shows similar results (although the rolling estimated electronic sector results depart from the base case when its threshold is approximately 15–18, they return to around the base case when its threshold is over approximately 19). The transport sector indicates similar results to that of manufacturing as a whole.

It might be assumed that in recent times the international transfer of facilities is holding a downward pressure on production in Japan, although the effect is not clear from this chart. It may be that the negative impact of the transfer of facilities is cancelled out by the positive impact of export inducement effects, as discussed in the former section (equations (2.26) and (2.27)).

There would appear to be a number of specific reasons for the movements depicted in Figure 8. Firstly, as noted, international transfers can sometimes produce a positive effect on domestic production through the export of related materials to the foreign facilities. This is particularly true for the Japanese transport sector, which has a globally



Manufacturing Electronic sector Transport sector

Note: Thresholds for the dummy variable in equation (2.29) are selected by figures of foreign production ratio (%). Shadow area means ± one standard error.

Figure 2.9: Rolling estimation result: international transfer

highly competitive power allowing it to increase in its production and sales in Japan and worldwide. Secondly, many Japanese manufacturing companies have attempted to gradually transfer their domestic abilities to foreign countries, partly to avoid some of the trade frictions mentioned in Section 2. In this case, the results in this study would not hold clear ones. Lastly, it would be difficult to enjoy the significant impacts of international transfers on a macro level, however on a micro level the companies —the complementarity of assembly facilities, materials facilities, and components suppliers— may enjoy positive impacts or face negative impacts of transfers.

Thus, considering the total effects on Japan's economy in regard to the international transfer of facilities, the negative impacts can be assumed to be cancelled by the positive impacts. Therefore, the drastic changes that are projected in the model in equation (2.26) did not occur and the model represented by equationl (2.27) better reflects the real state of economic activity in Japan. However, international competition has significantly increased, and there might be companies which face sudden declines in micro activities.

It is noticeable that some correlations between IIP and the production capacity, the operating rate, vintage facilities, as well as the international production ratio can hold high values (Table 2.2). Additionally, the time series data of some values, such as vintage facilities in manufacturing, have increasing trends. Lastly, in terms of trends, if the variables are largely gap from a HP-filtered trend, the turning points might be easily found, and results in the study would be more clear. The estimation of a HP-filtered approach partly depends on the end points. Thus, although the results in this section imply the roles of economies of scale, the operating rate, vintage facilities, and the international transfer on production, there may be some degree of uncertainty with these relationships.

2.3.4 Robustness of results: chow breakpoint test

Table 2.3 presents the results of chow breakpoint tests for structural changes in IIP data. Breakpoint candidates for tests are selected based on the results in Section 2.3.3. In testing the hypothesis that breakpoints exist for each turning point, which is implied in the former section, a number of breakpoints are found. These points almost correspond to the timing of jumping thresholds in the rolling results in Section 2.3.3.

Table 2.3: Chow breakpoint test

Manufacturing

Breakpoint	No breakpoint hypothesis		
	F-statistic	Probability	Conclusion
Dec-86	3.96	0.02	Breakpoint
Feb-94	2.38	0.09	No Breakpoint
Sep-98	1.87	0.16	No Breakpoint
Dec-01	2.00	0.14	No Breakpoint
Apr-09	17.23	0.00	Breakpoint
Mar-11	15.91	0.00	Breakpoint

Electronic sector

Breakpoint	No breakpoint hypothesis		
	F-statistic	Probability	Conclusion
Jun-00	0.84	0.43	No Breakpoint
Dec-01	4.20	0.02	Breakpoint
Jul-02	1.89	0.15	No Breakpoint
Oct-08	3.44	0.03	Breakpoint
Mar-11	6.79	0.00	Breakpoint

Transport sector

Breakpoint	No breakpoint hypothesis		
	F-statistic	Probability	Conclusion
Nov-82	2.77	0.06	No Breakpoint
Jun-87	6.87	0.00	Breakpoint
Oct-08	9.48	0.00	Breakpoint
Mar-11	11.44	0.00	Breakpoint

Manufacturing exhibits three breakpoints from the results of chow tests. These points are approximately equal to the timing of thresholds in the former section and correspond to manufacturings economic boom period in late 1980s, the global financial crisis, and the Great East Japan Earthquake. The electronic sector has three breakpoints, which correspond to the timing of thresholds in the former section. The timing is proximate to the collapsing of the dot-com bubble, the global financial crisis, and the Great East Japan Earthquake. The transport sector also holds three breakpoints. These correspond to the timing of thresholds in the former section the economic boom period in late 1980s, the global financial crisis, and the Great East Japan Earthquake. In this way, the results for manufacturing, the electronics and transport sectors confirm the robustness of the results in Section 2.3.3 of this study.

2.4 Conclusion

This study provides a theoretical description of the nature of the nonlinear transition mechanism of production, which has been widely acknowledged empirically. Through the construction of a new model, it is shown how structural factors such as economies of scale, and cyclical factors such as the operating rate, lead to shifts in the frontier curves and changes in the production function. Illustrated is the way in which these factors can lead to a sudden increase and a sudden decline in production. Specifically it is shown that vintage facilities exert a downward pressure on production as do international transfer of facilities, although in this latter case it is seen that this effect would be cancelled by the positive impact of the export inducement effects.

A further key finding of this study is that the Japanese manufacturing sector provides evidence of the existence of such nonlinear transition mechanisms, particularly in terms of economies of scale, the operating rate, and the vintage facilities. In terms of international transfer of facilities, shifting facilities from a home country to foreign countries, would normally exert a negative impact on the domestic economy, although the transfer's indirect inducement to exports (to the offshore facility) in fact can produce a positive impact on the domestic economy.

The findings in this chapter confirm the existence of nonlinear jumps in production implying changes in production functions over time. Under the large changes, the estimation method for productivity should correspond to the movements, although productivity is usually estimated using a non-variable parametric method in the TFP approach. There are two considerable and possible ways for calculating productivity in changing economies.

The first is making a production function with variable factors and estimating productivity. The second is making a nonparametric model in order to estimate productivity in the real economy. However, the first approach holds difficulties for considering and calculating variable parameters. For instance, in the case that we separate samples in some groups (e.g. the normal situation and the nonlinear transited situation) for estimating variable parameters, it is not easy to eliminate the arbitrariness in the separation. In addition, we would be able to have rolling estimations for grasping valuable parameters, but it is difficult to hold optimal bands of periods (opposite samples might be merged in a estimation period). Therefore, this study tries to develop a new nonparametric variable model, which could indicate changes and shifts in production functions over time, for calculating productivity in the following chapter. The model is a nonparametric model and considered transition and shifts in the shape of production function, which is indicated in this chapter.

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Chapter 3

Estimation of productivity based on a nonparametric approach: DEA time series analysis

This chapter develops a new time series analysis method —the DEA time series analysis— for estimating productivity using a nonparametric approach called the Data Envelopment Analysis (DEA). The DEA does not presume a specific parametric production function, and the new model is expected to be able to accurately grasp dramatic changes in the economy, such as those caused by the global financial crisis and the Great East Japan Earthquake. The DEA approach tends to have disadvantages for time series analyses, but this study has overcome these weaknesses by combining it with ideas from the Kalman filter and the Markov switching to derive a new model. This study estimates Japanese productivity based on the new model. The estimated results minutely grasp sudden and dramatic changes that would have knock-on effects to production mechanisms in the economy. The new model can be evaluated that it can accurately evaluate productivity in typical and atypical periods, compared to other traditional approaches.

3.1 Introduction

Productivity is the main driver of developments in economies and organizations. It must be evaluated from many perspectives. There are two main approaches for measuring productivity: the parametric approach and the nonparametric approach.

The parametric approach assumes a specific production function, which it uses to estimate the productivity. The total factor productivity (TFP[1]) method is the most common parametric approach. The assumed function is useful for time series modeling, but can lead to some difficulties when evaluating data that include dramatic and structural changes. Lynde and Richmond (1999) have referred to productivity growth as "*conventionally it (productivity growth) is understood to be an upward shift of the production function*". Yagi and Takahashi (2015) have theoretically demonstrated nonlinear production transition mechanisms, which imply changes in production functions over time. For example, the shock of the global financial crisis in 2007–2008 was extremely large and resulted in discontinuities in activities. Additionally, the Great East Japan Earthquake in 2011 significantly reduced the number of production facilities in the affected area. This shock led to sudden and large structural changes in production functions and levels.

The Data envelopment analysis (DEA) method is a popular nonparametric approach that was originally proposed by Farrell (1957). Many studies have attempted to improve the DEA model for calculating productivity, such as Charnes *et al.* (1978) and Seiford and Thrall (1990). However, the nonparametric approach is often inferior for time series analyses. Some studies have tried to overcome this weakness. For instance, Bowlin (1987) has proposed a window analysis for the DEA, which aggregates the data and evaluates the efficiencies in each aggregation. Sueyoshi (2001) has used window analysis to measure the efficiencies of companies. These studies mainly focus on two time periods (times t and $t + 1$), and cannot be used to analyze long time series. Additionally, Thore *et al.* (1994) have improved the method and tried to combine different time periods using an index. This method is called the Malmquist index (MI), and the study has applied it to the US computer industry. Färe *et al.* (1994) have combined the DEA with the MI, and decomposed productivity into two component measures, technical change and efficiency change. They found that technical changes cause slightly higher productivity growth in the United States. Japan's productivity growth was the highest in the sample, and half of it can be attributed to efficiency changes.

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[1] The TFP approach is detailed in many papers, such as Caves *et al.* (1982a) and Caves *et al.* (1982b).

Most recent studies that applied the DEA to a time series used the MI method. There are two defect issues. First, this method uses one specific frontier curve, which is suitable for the base case, for other cases. This means that there is a strong assumption that the efficiency at other time periods can be calculated using a frontier curve at a different time. This is the same as the parametric approach. Second, it simply combines data in the different time periods and constructs a model, but a decision maker cannot access future information. The time order assumption is essential when deriving a time series analysis.

Lynde and Richmond (1999) have proposed an expanded the DEA method. Their study analyzes productivity and efficiency for the entire UK manufacturing sector. They investigate a time series output index for the United Kingdom, consider data in multiple time periods as decision making units, and compare the outputs of different periods. In contrast, typical DEA studies investigate the outputs of comparable organizations, put the data in the same time period as decision making units, and compare the outputs of the different organizations. They apply the one time period DEA model to a time series model. However, Lynde and Richmond (1999) have simply combined data from different time periods and the weak points of the nonparametric approach, which are described above does not be overcome. Ueda and Hoshino (2005) have found that the Kalman filter holds the minimum mean squared error of forecasts, which is appropriate for analysis of future performance. They have proposed that the DEA would be expand as a historical analysis by using the Kalman filter. Their model assumes to make a DEA model using plural organizations data, and it is not suitable when we use one dependent variable.

Therefore, this study proposes a new time series analysis method for estimating productivity using a nonparametric approach: DEA. We apply the idea from Lynde and Richmond (1999), where the data from each time point is applied as a decision making unit. This study attempted to arrange data in advance using forecasting methods by adding the idea in Ueda and Hoshino (2005), and develop a new DEA model: the DEA time series analysis.

The main study features of this paper are as follows. Chapter 3.2 describes the construction of a nonlinear time series analysis method for estimating productivity. Chapter 3.3 presents an empirical study for the Japanese manufacturing sector, based on the constructed model in Chapter 3.2. Chapter 3.4 discusses estimated results and shows keys for Japanese future development. Chapter 3.5 concludes the paper by summarizing our findings, discussing some extensions, and proposing suggestions for further studies.

3.2 The model

In this section, we describe three well-known models: the Kalman filter, the Markov switching, and the DEA model. This study combines them to develop a new nonlinear time series analysis method for estimating productivity. The main idea is as follows. First, we cannot access information at time $t+1$ before $t+1$, but we can forecast the future performance using information from the past. Therefore, this study uses the Kalman filter and arranges the data in advance. Second, the study also focuses on nonlinear jumps in production, so we use the Markov switching process. Third, the study expands the DEA model and uses the data arranged in the first and the second steps as input.

3.2.1 Kalman filter

We cannot access information for time $t+1$ before $t+1$, but we can forecast the future performance using present and past information, by considering the noise in the information. These actions can be written using the following equations, which are used in the Kalman filter[2]. Assuming a discrete time and nonlinear state space representation:

$$\begin{aligned} \mathbf{x}(t) &= \mathbf{F}\{\mathbf{x}(t-1), \epsilon_{\mathbf{x}}(t)\} \\ \mathbf{y}(t) &= G\{\mathbf{x}(t), \epsilon_{\mathbf{y}}(t)\} \end{aligned} \tag{3.1}$$

where $\mathbf{F}$ is a vector function of $\mathbf{x}(\cdot)$, G is a scalar function of $\mathbf{x}(\cdot)$, $\mathbf{x}(\cdot)$ and $\mathbf{y}(\cdot)$ are sets of input and output factors. $\epsilon_{\mathbf{x}}$ and $\epsilon_{\mathbf{y}}$ are noises that are assumed to the following distributions, such that:

$$\begin{aligned} \epsilon_{\mathbf{x}} &\sim N(o, {\sigma_{\mathbf{x}}}^2) \\ \epsilon_{\mathbf{y}} &\sim N(o, {\sigma_{\mathbf{y}}}^2) \end{aligned} \tag{3.2}$$

Equation (3.1) indicates that data at time $t+1$ are based on their past information and are not accessed before this time. The study focuses on nonlinear movements, so we select the nonlinear Kalman filter. Then, the extended Kalman filter can convert nonlinear functions into linear functions, and we can estimate the state value using:

$$\hat{\mathbf{x}}(t) = \tilde{\mathbf{x}}(t) + \mathbf{j}(t)\{\mathbf{y}(t) - G(\tilde{\mathbf{x}}(t))\} \tag{3.3}$$

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[2] The detailed idea of the Kalman filter as well as combining it and the DEA is shown in Ueda and Hoshino (2005).

where $\mathbf{j}$ is the Kalman gain, $\tilde{\mathbf{x}}(\cdot)$ is a forecasted value, and $\hat{\mathbf{x}}(\cdot)$ is an estimated value.

3.2.2 Markov switching

We use the Markov switching model in this study. As stated in Yagi and Takahashi (2015), economic activities are subject to business cycles that occur as transition processes. This effect may shift the frontier curve and occur with a certain probability. Therefore, we explicitly put such movements into the model. To incorporate this effect into the model, we use a switching model based on Hamilton (1989), that is:

$$S(t) = \begin{cases} 0 & \text{(recession terms)} \\ 1 & \text{(expansion terms)} \end{cases} \tag{3.4}$$

Combining ideas from the Kalman filter and Markov switching, a new equation can be driven for the following. This equation assumes that the process is $AR(p)$, where h is chosen as the most suited value for the estimated equation.

$$\mathbf{y}(t) = \mu(t) + \omega_1(\mathbf{y}(t-1) - \mu(t-1)) + \cdots + \omega_p(\mathbf{y}(t-p) - \mu(t-p)) + G\mathbf{x}(t) + \epsilon(t) \tag{3.5}$$

where ϵ follows a normal distribution $(0, \sigma^2)$. Additionally, μ is the average output of $\mathbf{y}(\cdot)$ for the period between the start and the current time. We assume that the average output of the recession terms is μ_0 and of the expansion terms is μ_1, and that μ_1 is larger than μ_0. Then, $\mu(t)$ can be written as:

$$\mu(t) = \mu_0(1 - S(t)) + \mu_1 S(t) \tag{3.6}$$

The difference between μ_0 and μ_1 indicates the effect of business cycles. This study uses the maximum likelihood estimation method to determine change points of the cycles, which was proposed in Hamilton (1989).

3.2.3 New method for estimating productivity using a nonparametric approach: DEA time series analysis

Combining the above ideas (for time series analysis) and the DEA method (for nonparametric analysis), this study proposes a new time series analysis method —the DEA time series analysis— for estimating productivity based on a nonparametric approach. We applied the basic idea of DEA (i.e., studying the relative efficiencies of different units using a nonparametric approach), by defining a nonparametric frontier curve and measuring the efficiency of each unit relative to this frontier. There are two approaches for measuring the efficiency using the DEA method: the Charnes–Cooper–Rhodes (CCR) model and the Banker–Charnes–Cooper (BCC) model. The mechanisms of CCR and BCC models are detailed in Sueyoshi (1995). The CCR model is written as:

$$\begin{array}{rc} & \text{Minimize} \quad \phi_i \\ \text{subject to} & -\sum_{j=1} x_{pj}\lambda_j + \phi_i x_{pi} \geq 0 \quad (p = 1, 2, \ldots) \\ & \sum_{j=1} y_{qj}\lambda_j \geq y_{qi} \quad (q = 1, 2, \ldots) \\ & \lambda_j \geq 0 \quad (j = 1, 2, \ldots) \end{array} \tag{3.7}$$

where ϕ_i is the efficiency of unit i, x and y are the input and output, as well as p, q, and j are the numbers of inputs, outputs, and $DMUs$. λ_j indicates weights. In this equation, coefficients of determination are ϕ_i and λ_j. In the BCC model for DMU_i, $\sum_{j=1} \lambda_j = 1$ is added to equation (3.7) and the model is:

$$\begin{array}{rc} & \text{Minimize} \quad \phi_i \\ \text{subject to} & -\sum_{j=1} x_{pj}\lambda_j + \phi_i x_{pi} \geq 0 \quad (p = 1, 2, \ldots) \\ & \sum_{j=1} y_{qj}\lambda_j \geq y_{qi} \quad (q = 1, 2, \ldots) \\ & \lambda_j \geq 0 \quad (j = 1, 2, \ldots) \\ & \sum_{j=1} \lambda_j = 1 \end{array} \tag{3.8}$$

By combining the outputs from these models, we can separate the efficiency into "technical efficiency (TE)" and "scale efficiency (SE)".

The equations in Section 3.2.1 and 3.2.2 restrict data overlaps (information before time t cannot access future information at time $t+1$) and allow the shifts in the frontier curves. Therefore, these ideas expand the one time period model (from the basic CCR and BCC models) to the multiple period model (time series analysis). The CCR model for a decision making unit i (DMU_i) can be expanded to:

$$\begin{array}{rc} & \text{Minimize} \quad \sum_{t=1} \phi_i(t) \\ \text{subject to} & -\sum_{j=1} x_{pj}(t)\lambda_j(t) + \phi_i(t) x_{pi}(t) \geq 0 \quad (p = 1, 2, \ldots) \\ & \sum_{j=1} y_{qj}(t)\lambda_j(t) \geq y_{qi}(t) \quad (q = 1, 2, \ldots) \\ & \lambda_j(t) \geq 0 \quad (j = 1, 2, \ldots) \\ \multicolumn{2}{c}{\mathbf{y}(t) = \mu(t) + \omega_1(\mathbf{y}(t-1) - \mu(t-1)) + \cdots + \omega_p(\mathbf{y}(t-p) - \mu(t-p)) + G\{\mathbf{x}(t), \epsilon_y(t)\}} \\ \multicolumn{2}{c}{\mathbf{x}(t) = \mathbf{F}\{\mathbf{x}(t-1), \epsilon_{\mathbf{x}}(t)\}} \\ \multicolumn{2}{c}{\mu(t) = \mu_0(1 - S(t)) + \mu_1 S(t)} \end{array} \tag{3.9}$$

where ϕ_i is the efficiency of unit i, x and y are the input and output, as well as p, q, and j are the numbers of inputs, outputs, and $DMUs$. λ_j indicates weights. In this equation, coefficients of determination are ϕ_i and λ_j. We arrange the time series data and predict them using the Kalman filter, which can be applied to $DMUs$. In the BCC model for DMU_i, $\sum_{j=1} \lambda_j(t) = 1$ is added to equation (3.9) and the model is:

$$
\begin{gathered}
\text{Minimize} \quad \textstyle\sum_{t=1} \phi_i(t) \\
\text{subject to} \quad -\textstyle\sum_{j=1} x_{pj}(t)\lambda_j(t) + \phi_i(t)x_{pi}(t) \geq 0 \quad (p = 1, 2, \ldots) \\
\textstyle\sum_{j=1} y_{qj}(t)\lambda_j(t) \geq y_{qi}(t) \quad (q = 1, 2, \ldots) \\
\lambda_j(t) \geq 0 \quad (j = 1, 2, \ldots) \\
\textstyle\sum_{j=1} \lambda_j(t) = 1 \\
\mathbf{y}(t) = \mu(t) + \omega_1(\mathbf{y}(t-1) - \mu(t-1)) + \cdots + \omega_p(\mathbf{y}(t-p) - \mu(t-p)) + G\{\mathbf{x}(t), \epsilon_y(t)\} \\
\mathbf{x}(t) = \mathbf{F}\{\mathbf{x}(t-1), \epsilon_{\mathbf{x}}(t)\} \\
\mu(t) = \mu_0(1 - S(t)) + \mu_1 S(t)
\end{gathered}
\tag{3.10}
$$

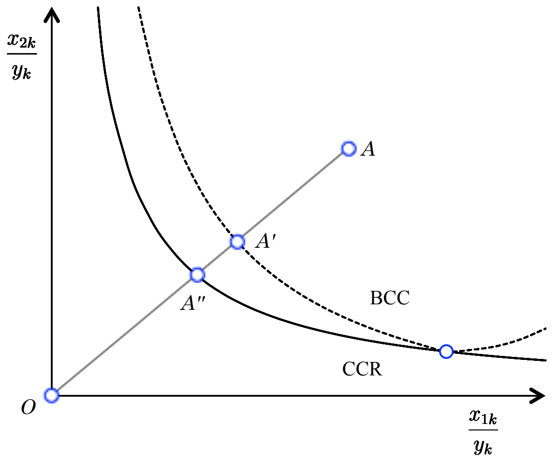


Figure 3.1: Sketch of CCR and BCC

Figure 3.1 shows a model of the DEA that includes the CCR and BCC curves at time $t = 0$. To simply sketch the model, we consider two input factors (x_{1k} and x_{2k}) and one output (y_k) for DMU_k. If the curve shifts to a lower level in the graph it becomes more efficient. When a unit exists at A, we can draw a straight line between $O(0, 0)$ and A. Then, the line crosses the BCC curve at A' and the CCR curve at A”. When the unit reaches its technical efficiency (which can be observed using the BCC curve) it shifts from

A to $A^{'}$. Hence, its technical efficiency (TE) is:

$$TE = \frac{OA'}{OA} \tag{3.11}$$

Additionally, the unit reaches scale efficiency (which can be observed using the CCR curve) when it shifts to $A^{"}$. Hence, its scale efficiency (SE) is:

$$SE = \frac{OA^{"}}{OA'} \tag{3.12}$$

When DMU_i is at A, it can reduce its inputs to $A^{'}$. In other words, its technical inefficiency is $(OA - OA^{'})/OA$. Then, it can also manage its scale to reach $A^{"}$. In other words, its scale inefficiency is $(OA^{'} - OA^{"})/OA$. The objective function in equation (3.9) and (3.10) can be derived from the basic equations of the original CCR and BCC models to estimate productivity in variable periods. In these basic functions, one ϕ is specified and estimated. This study develops a time-series analysis that expands on these basic models. We can avoid data overlaps using subjections in equation (3.9) and (3.10). Then, the CCR and BCC models are expanded from one time period analyses to multiple time period analyses. We must observe the effects of these restrictions in experimental tests.

3.3 An empirical study of Japanese manufacturing

We apply the proposed method of analysis —the DEA time series analysis— to Japanese manufacturing data. In this study, the basic equation is:

$$Y = f(K, L) \tag{3.13}$$

where Y, K, and L are the outputs, capital inputs, and labor inputs. We use this equation and the proposed model, eqution (3.9) and (3.10), to calculate the technical and scale efficiencies in a time series analysis. Corresponding to eqution (3.9) and (3.10), the input data (x) are the capital input and the labor input, as well as output data (y) is the value-added production for the model. The data from each time point is applied as a DMU. We set up Y, K, and L based on the basic economic model, in order to comparing the results with the TFP approach. In the following, the indexes that calculate the technical and scale efficiencies in the DEA time series analysis are $TSTE$ (time series technical efficiency) and $TSSE$ (time series scale efficiency).

3.3.1 The data

The sample consists of data from the Japanese manufacturing industry. In detail, we pick up the data of total of manufacturing, electronic sector, and transport sector in Japan. The main data are from the *Japan Industrial Productivity Database 2014* (JIP 2014), which is published by the Research Institute of Economy, Trade and Industry, Japan. This database provides elements of productivity (such as capital and labor inputs). It contains annual data from 1970 to 2011. We used these annual growth data to calculate the efficiency indexes.

To separate the data based on the business cycle (as discussed in Section 3.2.2), we use the "turning point of a business cycle" derived by the Cabinet Office, Government of Japan.

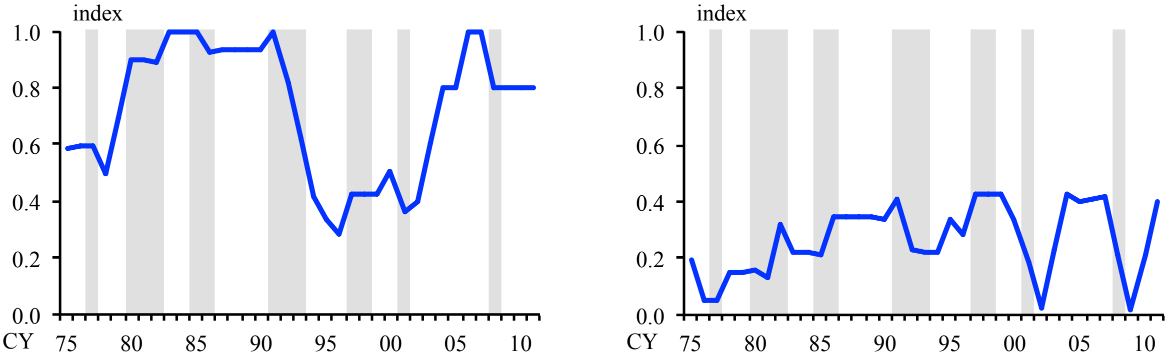
3.3.2 Results

The main results are shown in Figures 3.2, 3.3, and 3.4. The bolt lines indicate the estimated results (5-year moving average). The shaded areas indicate recessions that were determined using the turning point of a business cycle defined by the Cabinet Office of the Government of Japan.

Manufacturing

Figure 3.2 shows the technical efficiency ($TSTE$) and the scale efficiency ($TSSE$) of manufacturing in Japan, as calculated by this study. The estimated technical efficiency is higher in the 1980s, when Japan was in an economic bubble and had highly competitive industrial products. The estimates imply that Japanese growth in the 1980s was supported by developments in technical efficiency. However, the estimated technical efficiency drops in the early 1990s, which corresponds with the collapse of the economic bubble. The 1990s are sometimes referred to as "a lost decade" in Japan, because there was a long economic recession. The calculated technical efficiency implies that there was a decrease in Japanese competitive power and technical abilities in the 1990s. In the early 2000s, the technical efficiency gradually recovered.

The scale efficiency highlights some clear changes in Japanese manufacturing. The estimated scale efficiency has increased during the economic bubble. Japanese manufacturing had expanded its production capacity, and this produced "economies of scale" that lead to sudden expansions in the economy. The estimated scale efficiency has suddenly declined around 2001 and 2008. This implies that the collapse of the dot-com bubble and



Technical (TSTE)

Scale (TSSE)

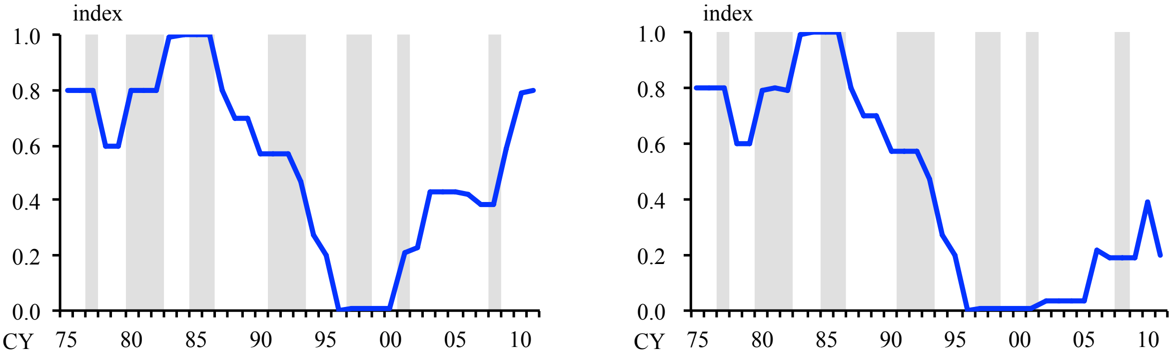
Note: Shaded areas indicate recession periods (the same shall apply hereafter).

Figure 3.2: Efficiency of manufacturing

the financial crisis had related to declining of its scale efficiency. Japanese manufacturing companies declined and stopped operations during these events, which decreased the effect of the economies of scale.

Electronic sector

Figure 3.3 shows the estimated technical and scale efficiencies for the electronic sector of Japan. The estimated technical efficiency holds a high level in the early 1980s. During this period, Japanese electronic companies matured and their competitive power increased. However, the estimated technical efficiency has suddenly declined in the late 1980s and dropped in the 1990s, when Japanese electronic companies had suffered from low growths. Then, the efficiency increased in the 2000s. Japanese electronic companies increased their efficiency by making structural reforms, which can be seen in the result.



Technical (TSTE)

Scale (TSSE)

Figure 3.3: Efficiency of electronic sector

The estimated scale efficiency of the electronic sector is high in the middle of the 1990s, but it has remained at a lower level following that period. There has been a decrease in the competitive power of Japanese electronic companies, and some have moved their production facilities abroad or use foreign production companies, such as original equipment manufacturing (OEM) and original design manufacturing (ODM). The lower efficiencies during these periods may be caused by these reforms. The estimated efficiency slightly increases in the late 2000s, but suddenly and slightly drops after the Great East Japan Earthquake.

Thus, the Japanese electronic sector maintained its operations, mainly by increasing technical efficiency. Production has been moved abroad and so scale efficiency in Japan will not be maintained at a higher level.

Transport sector

Figure 3.4 shows the estimated technical and scale efficiencies for the transport sector of Japan. The estimated technical efficiency has increased in the late 1980s during the Japanese economic bubble, but slightly decreased after its collapse. It has increased in the middle of the 1990s and 2000s, when Japanese motor vehicle companies became more competitive. Our results imply that their increase in worldwide sales was partly due to developments of their higher technical efficiency.

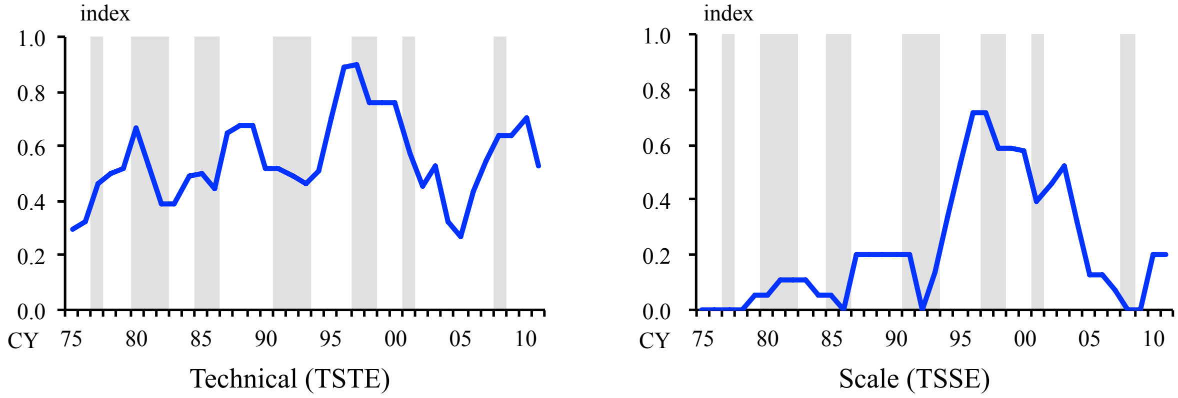


Figure 3.4: Efficiency of transport sector

The results for the scale efficiency are interesting. The estimated scale efficiency is only high in the late 1990s. Japanese transport companies have moved production facilities abroad. They have focused on making and selling products in nearby areas. The scale efficiency results reflect this international transfer of capacities.

Thus, the Japanese transport sector has increased its technical efficiency and increased its activities. However, production has moved abroad and the scale efficiency in Japan has not been maintained at a high level.

3.3.3 Robustness of results

We have checked the robustness of the estimated results by comparing them with results of existing methods: TFP and the MI approaches.

Estimated efficiency (TSTE) and TFP approach

In Figures 3.5, 3.6, and 3.7, the bold lines represent the results using the proposed method, and the thin lines are the rate of change of TFP. TFP data are calculated using JIP 2014. The changes to the technical efficiency, which is calculated using the proposed DEA method, are similar to those of TFP, and the estimated results appear reasonable. Additionally, the new model does not assume the shapes of the production functions. These results show that the new method can model dramatic changes and shocks, such as the collapse of its bubble economy, and can accurately evaluate the productivity in typical as well as atypical periods.

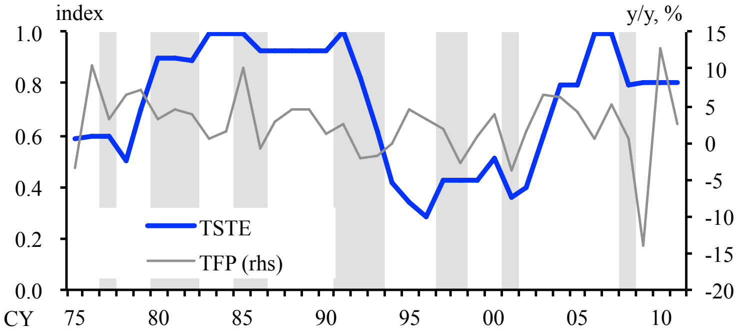


Figure 3.5: Efficiency of manufacturing: TSTE and TFP

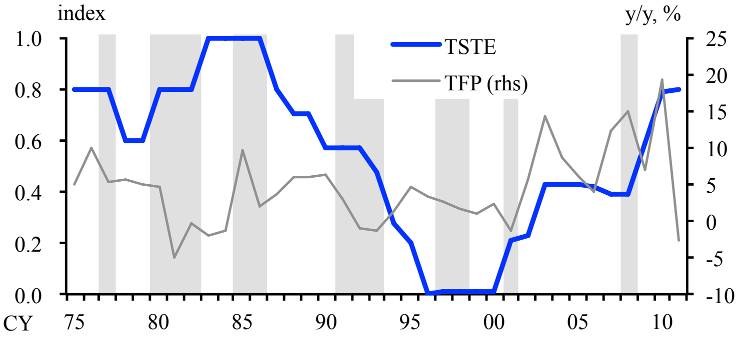


Figure 3.6: Efficiency of electronic sector: TSTE and TFP

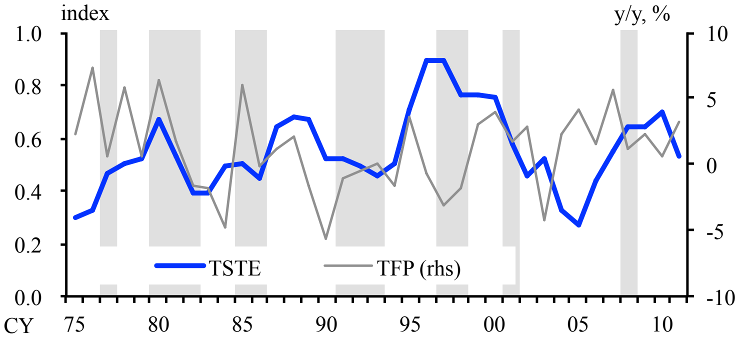


Figure 3.7: Efficiency of transport sector: TSTE and TFP

Estimated efficiency (TSTE) and MI approach

The MI approach is described in Färe *et al.* (1994). This study uses 53 subgroups of Japanese manufacturing from the JIP 2014 database, and constructs the MI series. Then, we compare the indexes proposed in this study with the results using the MI approach.

Figures 3.8 and 3.9 show the estimated results. The movements in the new indexes (TSTE) and the MI approach are similar, so the new approach appears reasonable. The TSTE sometimes highlights movements more clearly, but the movements in the MI results are smoother and flatter. This is partly because the MI approach uses future and unknown frontier curves (for exapmele, it considers a frontier curve at $t + 1$ for data at t). This produces smoother movements, but we cannot access this future information and the MI assumption is a strong restriction. These results indicate that the new model can clearly capture dinamic economic movements.

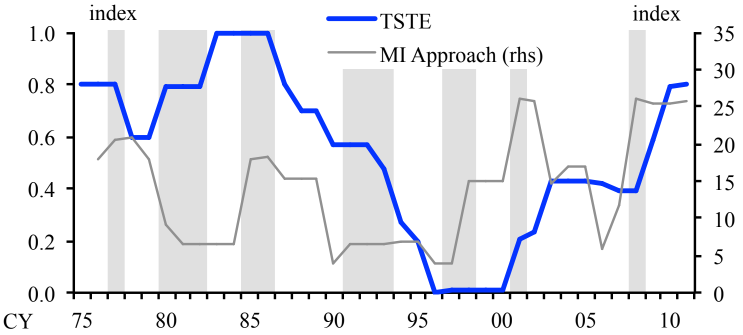


Figure 3.8: Efficiency of electoronic sector: TSTE and MI approach

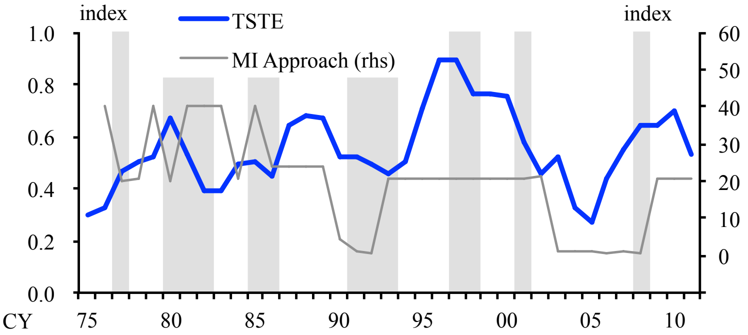


Figure 3.9: Efficiency of transport sector: TSTE and MI approach

3.4 Discussion and keys for Japanese future development

Let us consider hints for Japanese future continuous development based on the results in this chapter. This study tries to separate efficiency into technical efficiency and scale efficiency. As a result, Japan had developed by using the scale efficiency in the 1970s, the 1980s, and the early 1990s. Then, Japanese manufacturing companies were more competitive globally. However, these companies have shifted from a developing period to a developed and mature period, and recently it seems to be difficult to dramatically raise their scale efficiency by the results. In other words, they already hold enough facilities.

By contrast, it would be possible to keep and raise technical efficiency for Japanese companies. For example, the Japanese electronic sector succeeded in increasing its technical efficiency after the collapse of the economic and dot-com bubbles. This is partly because, Japanese electronic companies increased their efficiency by making structural reforms, and proceeded to scrap and build in their business. Considering the higher personal cost, it would be difficult for focusing on making general-purpose products. The cost is clearly cheaper in developing countries. On the other hand, as the results in the study shows, Japanese companies hold technical efficiency, so by concentrating on making the most advanced products, they would keep their higher competitive power. Indeed, Japanese motor vehicle companies have maintained their higher technical efficiency, and are still highly competitive globally, as the study shows. It would be a main driver for the future development of the Japanese manufacturing sector to keep and raise its technical efficiency.

3.5 Conclusion

This study develops a new time series analysis method —the DEA time series analysis— for estimating productivity using a nonparametric approach. The DEA method is a well-known nonparametric approach. It does not presume a specific parametric production function and can grasp changes in production mechanisms (such as the results of the global financial crisis, and the Great East Japan Earthquake). However, the DEA approach tends not to be appropriate for time series analyses, and there are few studies that considered overlapping periods. This study uses three steps to overcome the weaknesses of the DEA and derive a new model. Firstly, we forecast the future performance using the Kalman filter to arrange data in advance. Secondly, we focus on nonlinear jumps in the production and changes to the production function by introducing the Markov switching process. Thirdly, we improve the DEA and develop a new method —the DEA time series analysis—, which uses the results of the first two steps as its inputs.

This study estimates the productivity of Japanese manufacturing sectors based on the proposed DEA time series analysis. This model can minutely grasp sudden and dramatic changes, which can induce shifts in the production mechanism of an economy. We have compared the results to other traditional approaches, such as TFP and the MI methods, and the new model can be evaluated so that it can accurately evaluate the productivity in typical and atypical periods.

There are some points with this model which might be able to improve it. Firstly, the model uses the Markov switching process to incorporate business cycles. The estimated technical efficiencies and TFP have similar paths. Recent studies have tried to exclude the cycles from TFP. The new model would be improved by considering pure productivity without business cycles. Secondly, the study uses annual data, and some of the estimated results contain extreme values. For instance, some results have stayed around zero. By using more data (e.g., quarterly or monthly data), the movements would be much smoother. Future research would be expected to implement these ideas, and apply the method to more exercises.

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Chapter 4

Practical application of DEA model

This chapter contains two practical application of the DEA model. As the previous chapter indicates, the DEA model has a useful potential for nonparametric estimations. The number of related studies concerning the DEA is less than that of other productivity approaches (e.g. TFP). This chapter tries to accumulate studies based on the DEA. By showing highly accuracy of the model, the reliability of the model would increase and the former analysis would be also supported as a result. The first study in this chapter is the estimation of business cycle turning points using a DEA applied model (DEA-discriminant analysis). The second study is the prediction model of bank failure using the same model. These studies show that the DEA-discriminant analysis can separate samples (economic expanding and recession terms, as well as bank continuing samples and default samples), hence it is useful for a forecasting model. The DEA is a nonparametric model and does not presume specific functions, and then it would be able to correspond to sudden economic shocks for estimating data. Both results indicate the significant utility and expansion possibilities of the DEA model.

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4.1 Business cycle turning points based on DEA-discriminant analysis

4.1.1 Motivation

The turning points of business cycle are decided from wide viewpoints. In the case of Japan, the President of the Economic and Social Research Institute has determined the points based on the discussion of the Committee for Business Cycle Indicators, which are organized by economists and professors. The decisions are made not in real-time but after passing a couple of years from the turning points. For instance, in July 2015, the President determined the President determined that a peak in business activities occurred in the Japanese economy in March 2012 and a trough occurred in November 2012. Therefore, some organizations, such as the Bank of Japan and Cabinet Office, Government of Japan, have real-time monthly judgments of economic conditions by collecting and analysing wide data.

This study tries to develop a model for judging the turning points in real-time, and provide rapid information about economic activities for market participants and researchers to know economic situations. Some related studies have tried to construct real-time models for predicting economic situations. Almost all studies select the parametric approach and use the Markov switching model. Hamilton (1989) has constructed a Markov-switching model and estimates probability of recession in the United States. The study indicates that the periodic shift from a positive growth rate to a negative growth rate is a recurrent feature of the US business cycle. Kim and Nelson (1998) have used this approach and held a model of spacetime data for the United States. In addition, Maddala (1992) has used the Probit model for the analysis. Elhorst (2001) and Anselin (2010) have held detailed survey of these predicting models for economic situations. In addition, the Organisation for Economic Co-operation and Development (OECD) combines some historical economic data and routinely maintains as well as revises a system of business cycle indicators of its members (see Burns and Mitchell (1946)). Artis, Bladen-Hovell, and Zhang (1995) have evaluated the OECD models performance and indicate that there are a couple of poor results. Bry and Boschan (1979) have developed a model, which is known as BryBoschan model. The model separates the economic samples searching the lengths of expansion and recession terms in an algorithm.

In terms of Japanese cases, Fukuda and Onodera (2001) have made a model by using the Markov switching approach. The result of the study is noteworthy that several research institutes in Japan would make serious errors in forecasting business cycles and prolonged recessions in the 1990s. The study uses data in the Indexes of Business Conditions by the Cabinet Office, Government of Japan. Watanabe (2003) has improved the model by using a dynamic approach of the Markov switching and combining a Bayesian method. The study shows that the model holds a highly performance and the estimated results of turning points have closed to the reference data.

These models presume specific functions; however, as Yagi and Takahashi (2015) have indicated, our economies sometimes face large shocks, such as the global financial crisis in 20072008 and the Great East Japan Earthquake in 2011, and production functions would change. Corresponding to these non-continuous changes, non-parametric models should be developed to capture economic situations. There are few studies predicting economic recession model with non-parametric approaches.

In this study, we apply the data envelopment analysis-discriminant analysis (DEA-DA), constructed by Sueyoshi (1999), and make an estimating model for turning points of business cycle. Sueyoshi (1999) has combined the idea in the DEA, which is a non-parametric model for evaluating efficiencies of organizations and economies, and in the DA. Sueyoshi (2005) uses this constructed DEA-DA and succeeds to separate bankruptcy samples of the US electrical power industry. In addition, Yagi and Takahashi (2007) have used the DEA-DA in the bankruptcy of Japanese banking sector and found that the prediction probability of the DEA-DA is higher than that of other traditional parametric methods, such as the logit model. Sueyoshi and Goto (2011) have applied the DEA-DA and measure returns to scale and damages of environmental assessment. These studies, which are constructed with Sueyoshi's non-parametric model, hold higher prediction probability and imply the model might be able to apply to distinguish economic situations (expanding terms and recession terms).

This study develops the DEA-DA model for separating periods in expanding and recession terms of Japanese economy. The main study features are as follows. Chapter 4.1.2 explains the DEA-DA model for judging economic situations. Chapter 4.1.3 studies the empirical data for Japan and examines the discriminants. Chapter 4.1.4 concludes the paper by summarizing the findings, discussing some extensions and proposing suggestions for further studies.

4.1.2 The model

This study uses and applied the DEA-DA. The basic idea of the model is detailed in Sueyoshi (1999). The essences of the model are the following. Firstly, this study considers that there are n DMUs (Decision Making Units, $j = 1, \dots, n$), which hold k factors ($i = 1, \dots, k$) for evaluating their performance. The data in sample are separated by Group 1 (G_1) and Group 2 (G_2). For example, G_1 includes economic expanding periods and G_2 includes economic recession periods. These two groups have n_1 and n_2 DMUs, and $n_1 + n_2 = n$. The discriminant analysis (DA) of the stage 1 is formulated as follows:

$$\begin{array}{rl} \text{Minimize} & \sum_{j\in G_1} S^+_{1j} + \sum_{j\in G_2} S^-_{2j} \\ \text{subject to} & \sum_{i=1}^{k} \alpha_i z_{ij} + S^+_{1j} - S^-_{1j} = d + \epsilon \quad (j \in G_1) \\ & \sum_{i=1}^{k} \alpha_i z_{ij} + S^+_{2j} - S^-_{2j} = d \quad (j \in G_2) \\ & \sum_{i=1}^{k} |\alpha_i| = 1 \\ & S^+_{1j}, S^-_{1j}, S^+_{2j}, S^-_{2j} \geq 0 \end{array} \tag{4.1}$$

where α indicates weights, as well as z and S mean explanatory variables and slacks for DMUs. d and ϵ separate samples. The stage 1 would separate samples for three groups (samples for accurately separated, samples for overlap zone between d and $d + \epsilon$, samples for incorrectly separated). Secondly, samples for overlap and incorrectly separated (G1' and G2' includes such vague samples in G1 and G2) are picked up and the stage 2 is formulated as follows:

$$\begin{array}{rl} \text{Minimize} & \sum_{j\in G_{1'}} S^+_{1'j} + \sum_{j\in G_{2'}} S^-_{2'j} \\ \text{subject to} & \sum_{i=1}^{k} \beta_i z_{ij} + S^+_{1'j} - S^-_{1'j} = e \quad (j \in G_{1'}) \\ & \sum_{i=1}^{k} \beta_i z_{ij} + S^+_{2'j} - S^-_{2'j} = e \quad (j \in G_{2'}) \\ & \sum_{i=1}^{k} |\beta_i| = 1 \\ & S^+_{1'j}, S^-_{1'j}, S^+_{2'j}, S^-_{2'j} \geq 0 \end{array} \tag{4.2}$$

where β indicates weights, and e separates samples. In the stage 1, the model holds a overlap zone, (between $d+\epsilon$ and d) and in the stage 2, the model calculate these overlaped and incorrect samples again. Then, for these vague samples, the detailed judgment is put in practice. These two stages are formulated for making a higher precision model.

4.1.3 Estimation for Japanese Economy

This section has an empirical study of the DEA-DA for Japanese economy, and tries to know the probability of discriminant level of the model.

The Data

The Cabinet Office, Government of Japan has monthly publish a statistics: *Indexes of Business Conditions*. The statistics includes the leading index, which would be expected to indicate the economic movement in advance, the coincident index, which would be expected to indicate it at once, and the lagging index, which would be expected to indicate it in delay. Each of the indices is made by some economic indicators.

This study uses data in these indices and makes the DEA-DA model for separating samples in G_1, which is in economic expanding periods, and G_2, which is in economic recession periods. The study tries to predict economic situation in real time, so the leading index and the coincident index are used for the models. The data are from 1985 to 2014 and converted to yearly base (year-on-year rates of changes are used). In terms of expanding and recession periods, this study follows the "turning point of business cycle" by the Cabinet Office, Government of Japan. In other words, this study has an empirical exercise under these given conditions for the turning points. Note that the Cabinet Office, Government of Japan decides the turning points on monthly bases. This study assumes years when includes at least a recession (between "peak" and "trough") month as recession periods for constructing and calculating the model.

Model developments and results

Firstly, this study uses the leading index. Table 4.1 means correlations of indicators in the index. There are no indicators, which hold higher correlations and these data are inputted for making a model.

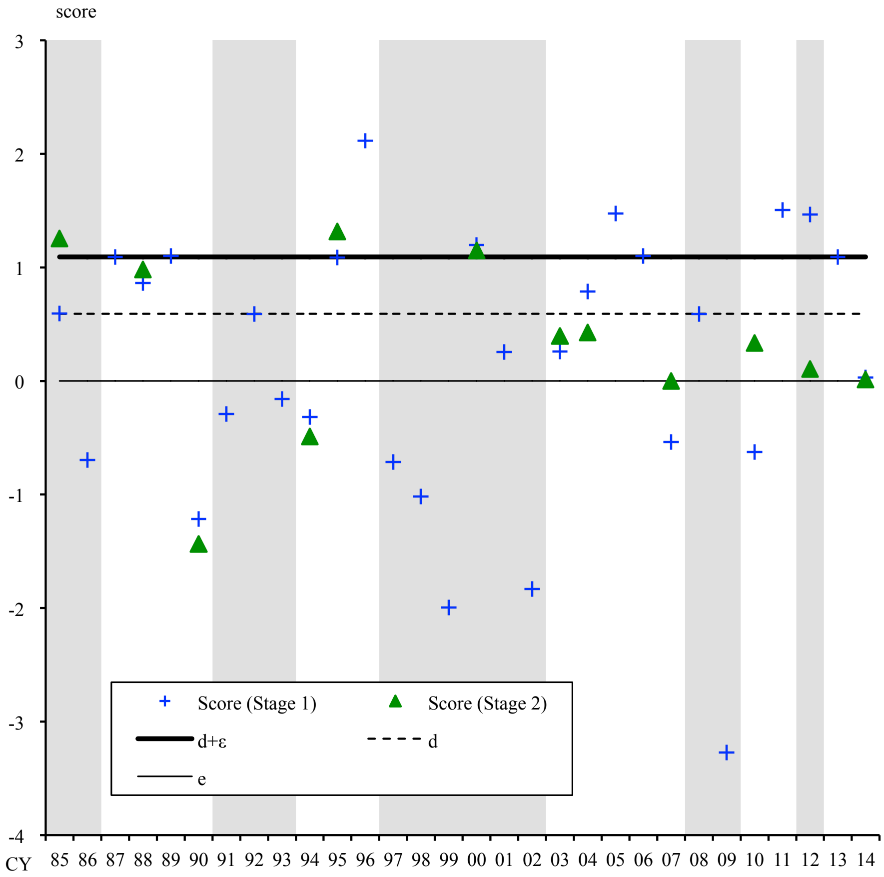
Table 4.1: Correlations of indicators in leading index

		L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
L1	Index of Producer's Inventory Ratio of Finished Goods (Final Demand Goods)(Inverted)	1.00	0.78	-0.54	-0.55	-0.55	-0.45	-0.48	-0.03	-0.52	-0.72
L2	Index of Producer's Inventory Ratio of Finished Goods (Producer Goods For Mining and Manufacturing)(Inverted)		1.00	-0.48	-0.42	-0.35	-0.55	-0.36	-0.14	-0.36	-0.69
L3	New Job offers (Excluding New School Graduates)			1.00	0.90	0.41	0.46	0.58	-0.15	0.48	0.61
L4	New Orders for Machinery at Constant Prices (Excluding Volatile Orders)				1.00	0.50	0.33	0.63	-0.17	0.53	0.57
L5	Total Floor Area of New Housing Construction Started					1.00	0.26	0.18	0.44	0.60	0.36
L6	Consumer Confidence Index						1.00	0.08	0.17	0.44	0.32
L7	Nikkei Commodity Price Index (42items)							1.00	-0.16	0.23	0.46
L8	Interest Rate Spread								1.00	0.10	-0.02
L9	Stock Prices(TOPIX)									1.00	0.43
L10	Index of Investment Climate (Manufacturing)										1.00

The estimated results and weights are indicated in Table 4.2, and the scores $\sum_{i=1}^{k} \alpha_i z_{ij}$ as well as $\sum_{i=1}^{k} \beta_i z_{ij}$ are in Figure 4.1. In the first stage, 60% of samples are accurately separated and 40% of samples are separated in overlap and incorrectly. In the second stage, 50% of samples are accurately separated. Thus, through these two stages, 80% of samples are successfully classified, and the ratio of precision of the model has improved by examing the stage 2.

Table 4.2: Estimated coefficients of leading index

		Stage 1 (α)	Stage 2 (β)
L1	Index of Producer's Inventory Ratio of Finished Goods (Final Demand Goods)(Inverted)	0.116	0.001
L2	Index of Producer's Inventory Ratio of Finished Goods (Producer Goods For Mining and Manufacturing)(Inverted)	0.066	0.135
L3	New Job offers (Excluding New School Graduates)	0.010	0.007
L4	New Orders for Machinery at Constant Prices (Excluding Volatile Orders)	0.019	0.031
L5	Total Floor Area of New Housing Construction Started	0.072	0.024
L6	Consumer Confidence Index	0.004	0.012
L7	Nikkei Commodity Price Index (42items)	0.065	0.038
L8	Interest Rate Spread	0.004	0.002
L9	Stock Prices(TOPIX)	0.000	0.000
L10	Index of Investment Climate (Manufacturing)	0.637	0.750
	d	0.500	—
	ε	0.591	—
	e	—	0.000
	Correct classification	60%	50%



Note: Shaded areas indicate recession periods (the same shall apply hereafter).

Figure 4.1: Business cycle and estimated score of leading index

As for weights of estimated samples, the coefficients are similar but there are a couple of small differences in two stages. These difference would mean the importance of variables has changed in detailed judgments. In Fugure 4.1, shadow areas indicate recession terms, which are decided as the turning point of business cycle by Cabinet Office, Government of Japan[1], and almost samples are put in accurate zones. In economic expanding periods, the points (estimated scores) are over $d + \epsilon$ or e. By contrast, in recession periods, the points are below d or e. In addition, this index is a leading one, and in 1990 and 2007, the recessions of the economy are expected in the model.

Secondly, the study uses the coincident index. Table 4.3 means correlations of indicators in the index. There are some indicators, which hold higher correlations and this study excludes such samples. Variables with higer correlation would lead to lower accu-

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[1] From 1997 to 2002, there were two business cycles: one held a peak on May 1997 and a trough on January 1999, as well as the other held a peak on November 2000 and a trough on January 2002. Figure 4.1 and 4.2 are drawn yearly base and these cycles look to be joined.

racy of the model. Then, the indicators in Table 4.4 are selected for making a model. The estimated results and weights are indicated in Table 4.4, and the scores are in Figure 2.

Table 4.3: Correlations of indicators in coincident index

		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	Index of Industrial Production (Mining and Manufacturing)	1.00	0.97	0.94	0.91	0.85	0.92	0.50	0.81	0.94	0.98	0.26
C2	Index of Producer's Shipments (Producer Goods for Mining and Manufacturing)		1.00	0.90	0.88	0.80	0.83	0.39	0.71	0.94	0.94	0.17
C3	Large Industrial Power Consumption			1.00	0.88	0.72	0.84	0.54	0.86	0.83	0.91	0.41
C4	Index of Producer's Shipment of Durable Consumer Goods				1.00	0.73	0.76	0.40	0.69	0.81	0.86	0.21
C5	Index of Non-Scheduled Worked Hours (Industries Covered)					1.00	0.82	0.29	0.62	0.85	0.84	-0.01
C6	Index of Producer's Shipment (Investment Goods Excluding Transport Equipments)						1.00	0.54	0.83	0.86	0.95	0.29
C7	Retail Sales Value (Change From Previous Year)							1.00	0.71	0.43	0.57	0.70
C8	Wholesale Sales Value (Change From Previous Year)								1.00	0.67	0.85	0.62
C9	Operating Profits (All Industries)									1.00	0.93	0.13
C10	Index of Shipment in Small and Medium Sized Enterprises										1.00	0.30
C11	Effective Job Offer Rate (Excluding New School Graduates)											1.00

In the first stage, 80% of samples are accurately separated and 20% of samples are separated in overlap and incorrectly. In the second stage, 83% of samples are accurately separated. Thus, through these two stages, 97% of samples are successfully classified. In economic expanding and recession periods, almost all points are put in accurate zones.

These two exercises show that the constructed DEA-DE model for estimating turning points of business cycle could separate samples with highly precision. The two stages built process is useful for improving the model. The model holds the non-parametric approach, and does not presume a specific parametric function. Therefore, it would be corresponded to large shocks which might change production functions. In addition, additional samples (future samples) can be distinguished in the constructed models.

Table 4.4: Estimated coefficients of coincident index

		Stage 1 (α)	Stage 2 (β)
C1	Index of Industrial Production (Mining and Manufacturing)	0.033	0.002
C5	Index of Non-Scheduled Worked Hours (Industries Covered)	0.378	0.449
C7	Retail Sales Value (Change From Previous Year)	0.193	0.310
C8	Wholesale Sales Value (Change From Previous Year)	0.009	0.240
C11	Effective Job Offer Rate (Excluding New School Graduates)	0.386	0.000
	d	0.500	—
	ε	0.373	—
	e	—	0.000
	Correct classification	80%	83%

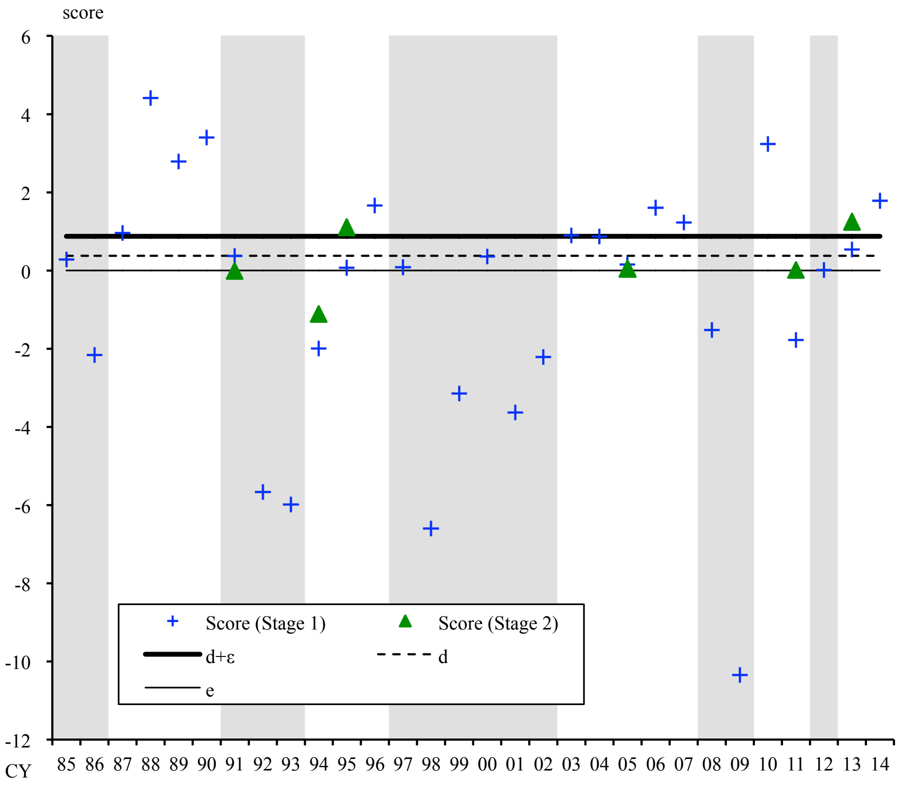


Figure 4.2: Business cycle and estimated score of coincident index

4.1.4 Discussion

The results in this study show that the non-parametric model, DEA-DA, can separate period in economic expanding and recession terms and judge the turning points in real time. The DEA-DA is two stages model and these processes are useful for rising accuracy of the model. In general, the judgments of economic turning points are done after a couple of years, but the constructed model would be helpful for the real time judgments. Additionally, the DEA is a non-parametric model and does not presume specific parametric functions, and then it would be able to correspond to sudden economic shocks, such as the global financial crisis in 2007-2008, and the Great East Japan Earthquake in 2011.

This study aims to propose a new non-parametric judgment model for economic turning points, and uses data in *Indexes of Business Conditions*, the Cabinet Office, Government of Japan. There are wide ranges of related data, and using other variables might advance the precision of the model. In the future studies, these trials and improvement of the model are expected.

4.2 Prediction model of bank failure based on DEA-discriminant analysis

4.2.1 Motivation

Recently, the business environment of Japanese banking sector has dramatically changed. Some Japanese commercial banks had faced to their bankruptcy from the mid 1990s, while Japanese banking system had changed, such as dealing with a large amount of bad debt after the corruption of Japanese bubble economy, deregulation of interest rates, and removal of deposit insurance. In addition, there are merger and reorganization of banks, including city banks and local banks. Under these changing situations, depositors have to consider risks of managing their money, and choose banks for deposits or securities investments.

This study aims to construct a model for predicting bankruptcy through analyzing the financial ratio of Japanese banks, which would help depositors to choose banks or other investment ways. We make not only a traditional model but also a new model, the DEA-DA, by using past bankruptcy data. Then, through these models, we try to put figures, which indicate the possibility of bankruptcy in the near future. In addition, through these processes, structures of Japanese banks would be analyzed.

The main study features are as follows. Chapter 4.2.2 mentions related studies and makes the definition of bankruptcy in this study. Chapter 4.2.3 indicates the data for the experiment tests. Chapter 4.2.4 shows the models and results. Chapter 4.2.5 concludes the study by summarizing the findings.

4.2.2 Related studies and definition of bankruptcy

Related studies

There are two approaches for analyzing corporate bankruptcy. Firstly, some studies use the non-financial analysis approach. Argenti (1976) analyzes the cause of bankruptcy and indicates that there are some processes for the way of bankruptcy. The approach is a qualitative analysis, which is related to causes and patterns of bankruptcy, and it would be difficult to show the quantitative possibility of bankruptcy in the future.

Secondly, there is the financial analysis approach. Altman (1969) makes a forecasting model and a lot of studies construct models based on the study, such as i) linear discriminant analysis and probability models, as well as ii) option pricing models. These studies hold a certain precision for forecasting. Our study aims to make a forecasting model for future failures of Japanese banks, and we use not option pricing models, which cannot expand the models for unlisted companies, but linear models, which can expand the models for many cases, using securities reports of banks. In addition, the study tries to make an aggregated analysis index. The index would help people without seeing all parts of security reports.

There are not plenty number of related studies using linear models for Japanese banks. Moridaira (1999) develops a logit model, a probit model, and discriminant analysis for Japanese credit unions, and estimates failure probabilities. The study seems to pick up not banks but credit unions for gathering more failure samples. Fujiwara (2002) calculates failure probabilities of Japanese banks by making a logit model and a probit model. The models hold higher performances. The study introduces dummy variables for bigger banks to arrange the size effect for estimations, but there is room for discussion to simply separate banks into two groups by using dummy variables.

This study tries to develop a failure prediction model for Japanese banks with using linear models, financial data and objective evidences.

Definition of bankruptcy

The word of bankruptcy is not strictly defined as a legal term. This study defines it as the situation that banks hold excessive debt and possibilities to stop returning deposits. In detail, the following timing is considered as bankruptcy. The first is the timing that the banks apply supports to the government (e.g. injecting public funds) for protecting depositors, keeping roles of banks, and dealing with bad debts, and the applications are admitted. The second is the timing that the banks decide to go out of their business because of excessive debt. The third is the timing that the banks apply the Corporate Rehabilitation Law in Japan to the courts and the applications are admitted. The fourth is the timing that the banks apply the Personal bankruptcy to the courts and the applications are admitted. The fifth is timing that the banks are ordered business stop instruction and are deprived their banking licenses.

4.2.3 The data

Samples of banks

This study picks up 18 banks as failure samples. These banks faced to bankruptcy between 1994 and 2004. We select the periods for the following reasons. Firstly, economic situations and accounting rules have changed, so financial data for too long periods are not suitable for analysis. Related studies also use periods for about 10 years. Secondly, after the collapse of Japanese bubble economy, Japanese government changed its stance for banks, and the environment of banks also changed. As for failure samples, the Ashikaga bank and the Risona bank, which had been controlled by the government for some years, are added in.

In terms of continuous samples, we pick up banks which hold their business at the timing, using the paired sampling method. The study considers the types of banks (e.g. city banks, regional banks, second-tier regional banks) and the scale of banks (total assets), then picks up about four continuous samples per one failure sample by the faired sampling method. The total number of continuous samples is 64.

Samples of periods

This study tries to make a forecasting model in the next fiscal period by using securities report data in the most recent fiscal period. Therefore, when we pick up data for bankruptcy, the data in the former fiscal period from the timing of failure. As for banks which bankrupted between April to June (before the timing to disclose the securities report), we use the data in the two periods before. Because, the data in the former period includes the information of bankruptcy. The total number of samples is 82 (Table 4.5).

Table 4.5: Samples

Failure samples	Picked up accounting period	Continuous samples
Hyogo	Mar-94	Nagoya, Fukuokacity, Tokyosouwa, Nishinihoncity
Taiheiyou	Mar-95	Kagawa, Kyushuu, Niigatachuou, Biwako
Hanwa	Mar-96	Sendai, Chubu, Yamagatashiawase, Takushoku
Kyotokyouei	Mar-97	Shizuokachuou, Nagasaki, Kanagawa, Okinawakaihou
Hokkaidotakusyoku	Mar-97	Asahi, Tokai, Sakura
Tokuyoucity	Mar-97	Minaminihon, Nagano, Fukushima, Sapporo
Midori	Mar-97	Momiji, Aichi, Keiyou, Nagoya
Long-Term Credit Bank of Japan	Mar-98	Industrial Bank of Japan
Nippon Credit Bank	Mar-98	Industrial Bank of Japan
Kokumin	Mar-98	Sendai, Chubu, Syokusan, Saikyou
Koufuku	Mar-98	Touwa, Tochigi, Yachiyo, Hokuyou
Tokyosouwa	Mar-98	Aichi, Kinki, Nagoya, Nishinihoncity
Namihaya	Mar-99	Touwa, Tochigi, Momiji, Aichi
Niigatachuou	Mar-99	Kitanihon, Kagawa, Kumamotofamily, Ehime
Ishikawa	Mar-01	Shokusan, Minaminihon, Saikyou, Yamagatashiawase
Chubu	Mar-01	Shizuokachuou, Okinawakaihou, Fukuhou, Houwa
Risona	Mar-02	Mizuho, UFJ, Tokyomitsubishi, Mitsuisumitomo
Ashikaga	Mar-03	Kyoto, Shichijyushichi, Chugoku, Hokuriku

Financial data

This study selects financial data from the three point of view; soundness, profitability and liquidity, for seeing credibility of banks. We use not financial indices themselves but financial ratio indices to exclude the effect of banking size. Based on analyzing related studies, the indices which indicate growth of banks are excluded.

The financial data is selected in financial data set of banks in *Nikkei NEEDS*. The Correlations of samples are shown in Table 4.5. Based on related studies, we pick up seven indices; capital-to-asset ratio, Tire 1 ratio, gross margin rate, expense ratio, commission rate of return, and loan-to-deposit ratio. Due to constraints in data availability in *Nikkel NEEDS*, some values are directly gathered by securities reports.

Modification of data

The capital-to-asset ratio of banks, which deal with international business, is calculated by the BIS standard, by contrast that of banks, which hold only domestic business, is calculated by the domestic standard. In the case that the ratio is under the standard value (8% for BIS standard and 4% for domestic standard), the government warnings to the banks. Thus, it is not suitable to compare the ratio of banks from the same viewpoint.

Table 4.6: Correlation

	soundness				profitability						liquidity	
	capital-to-asset ratio	Tire 1 ratio	fixed assets to equity capital ratio	debt ratio	gross margin rate	deposit yield	expense ratio	ROA	instant coverage ratio	commission rate of return	loan-to-deposit ratio	total asset turnover
capital-to-asset ratio	1.00	0.81 0.76 0.85	-0.13 -0.13 0.11	-0.20 -0.43 -0.41	-0.13 -0.54 -0.41	0.09 -0.03 0.54	-0.37 -0.27 -0.69	0.19 -0.19 0.05	0.18 0.16 0.19	0.56 0.58 0.70	0.16 0.28 0.16	-0.03 -0.39 0.41
Tire 1 ratio		1.00	-0.21 -0.53 0.31	-0.23 -0.68 0.52	0.09 0.22 0.52	-0.17 -0.32 0.34	-0.13 -0.07 -0.37	0.33 0.17 0.01	0.29 0.31 0.02	0.18 0.16 0.34	-0.18 -0.18 0.02	-0.16 -0.45 0.25
fixed assets to equity capital ratio			1.00	0.82 0.70 0.19	-0.13 0.10 0.19	0.08 0.24 -0.09	-0.01 0.16 0.07	-0.47 0.61 -0.29	-0.12 0.19 -0.12	0.09 0.35 -0.04	0.29 0.56 0.15	0.05 0.12 -0.05
debt ratio				1.00	-0.07 0.22 0.28	0.00 0.22 -0.20	0.05 0.01 0.09	-0.39 -0.33 -0.24	-0.13 -0.22 -0.16	0.00 0.13 -0.10	0.11 0.34 -0.07	0.03 0.25 -0.10
gross margin rate					1.00	-0.24 -0.04 -0.48	0.02 -0.27 0.43	0.25 -0.14 -0.42	0.12 0.09 -0.37	-0.30 -0.45 -0.31	-0.34 -0.27 -0.45	-0.09 0.24 -0.19
deposit yield						1.00	-0.44 -0.28 -0.64	-0.17 -0.01 -0.13	-0.09 -0.12 0.29	0.25 0.10 0.54	0.27 0.12 0.42	0.78 0.83 0.81
expense ratio							1.00	0.10 0.25 0.05	0.01 0.02 -0.21	-0.54 -0.41 -0.82	-0.19 -0.06 -0.37	-0.38 -0.14 -0.56
ROA								1.00	0.15 0.16 0.58	-0.14 -0.43 -0.02	-0.24 -0.49 -0.04	-0.28 0.25 -0.33
instant coverage ratio									1.00	-0.12 -0.15 0.19	-0.12 -0.14 0.08	-0.04 -0.06 0.17
commission rate of return										1.00	0.46 0.53 0.33	0.05 -0.25 0.33
loan-to-deposit ratio											1.00	0.15 -0.12 0.29
total asset turnover												1.00

Note: The upper, middle, and lower rows for each index indicate correlations of all samples, continuous samples, and default samples, respectively.

This study makes the modified capital-to-asset ratio, which is excluded 8% or 4% from the capital-to-asset ratio, and uses in the following analyses. This modification allows us to compare all banks under one model and the effect of bank size would be excluded.

Statistical hypothesis tests

Table 4.7 shows results of statistical hypothesis tests. These results indicate that the continuous samples and the failure samples hold statistical differences. Thus, this study considers that these samples have significance differences and develops failure prediction models.

Table 4.7: Statistical tests

	F-test	T-test (t value)	U-test (Z value)
modified capital-to-asset ratio	0.69	-4.64 ***	4.10 ***
Tire 1 ratio	0.73	-2.08 **	1.97 **
gross margin rate	0.61	-6.82 ***	5.59 ***
expense ratio	0.18	3.34 ***	3.33 ***
ROA	0.00 ***	-2.99 ***	4.67 ***
commission rate of return	0.00 ***	2.06	2.21 **
loan-to-deposit ratio	0.00 ***	-1.40	3.58 ***

Note: ** denotes significance at 5%; *** at 1%.

4.2.4 The model and estimation

The logit model

Firstly, the study uses a standard failure prediction model (logit model) and estimates failure probabilities of banks. The formula of logit model is:

$$p(x_i) = \left\{1 + exp(-\lambda_0 - \sum_{j=1}^{k} \lambda_j x_{ij})\right\}^{-1} \tag{4.3}$$

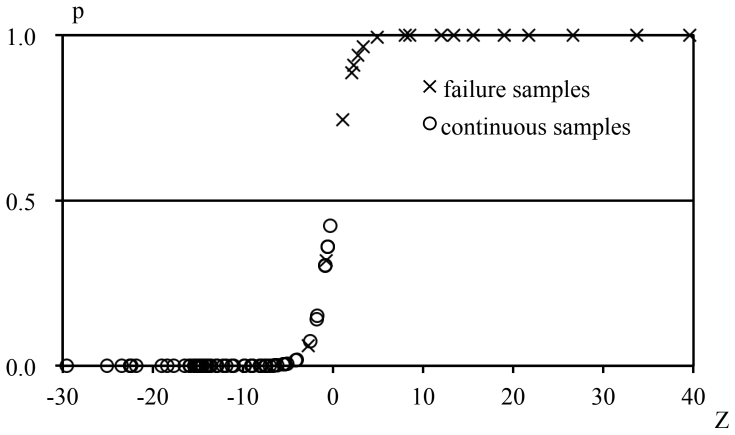
where p means probability of failure ($p \geq 0.5$: failure, $p < 0.5$: continuous). x_{ij} indicates bank $i(i = 1, 2, ..., n)$ and indices $j(j = 1, 2, ..., k)$.

The estimated result is shown in Table 4.8. The gross margin rate and the commission rate of return are excluded, because the model including these indices does not hold higher efficiency. The estimation uses JMP 5.2.

Table 4.8: Logit model: estimation result

	Weight: λ
modified capital-to-asset ratio	1.70
Tire 1 ratio	16.46
expense ratio	-63.50
ROA	7.34
loan-to-deposit ratio	6.84
Const.	29.72

The successful discrimination rate for the model is 97.6% (Figure 4.3), and the result of Wilcoxon rank sum test is significance at 1%. In addition, we try to input data in 2004 fiscal year to the model, which are constructed by data before 2003. Then, five banks are discriminated as failure, but there is no failure bank in 2005 and the successful discrimination rate is 95.6%.



Note: $Z = \lambda_0 + \sum_{j=1}^{k} \lambda_j x_{ij}$.

Figure 4.3: Logit model: distribution of sample

Therefore, the logit model has higher discrimination rate. However, there are strong prerequisites for estimations. For example, the model holds an assumption that samples follow logistic distribution. In addition, the estimated probabilities concentrates around zero or one, so it might be difficult to compare banks.

The DEA-DA model

Secondly, the study develops the DEA-DA model. The formula of the model is the equation (4.1) and (4.2). In this study, each index (x_{ij}) is divided by the mean of sample ($\sum x_{ij}/n$). The calculated values are named Z_{ij} and used as factors. Through these processes, the effects of data size are excluded and each estimated weight in the DEA-DA model means contribution for the results. As for ϵ, this study uses 0.5 in order to obtain higher successful discrimination rate. As for discrimination thresholds, d comes 0.012 and e comes 0.512. The successful discrimination rate is 98.8% (Figure 4.4). In stage 1, there are 18 overlapping samples and 2 misclassified samples.

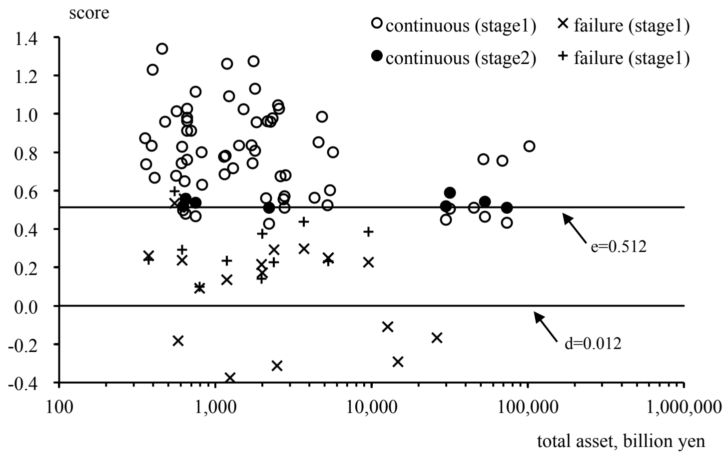


Figure 4.4: DEA-DA: probability of failure for samples

Table 4.9 shows the estimated weight. The gross margin and capital-to-asset ratio hold more weight and mainly affect on the result. The banks, which are inferior in business conditions, hold higher expense ratio. Comparing weights in Stage 1 and Stage 2, the weight of Tire 1 ratio is larger in Stage 2, and its importance comes to be larger around the threshold. In addition, we have a back test for failure banks after 1998 (9 samples). The result shows that the model can forecast the failure in the next financial period with higher probability (88.9%), although the number of sample for back test is limited.

Table 4.9: DEA-DA: score

	Stage1 (α)	Stage2 (β)
modified capital-to-asset ratio	0.160	0.180
Tire 1 ratio	0.001	0.083
gross margin rate	0.626	0.553
expense ratio	-0.153	-0.136
ROA	0.014	0.025
commission rate of return	-0.030	-0.007
loan-to-deposit ratio	0.016	0.016

We try to input data in 2004 fiscal year to the model, which is constructed using data prior to 2003. In this case, all banks are discriminated as “continuous” (Figure 4.5). There is no failure bank in 2005 and the successful discrimination rate is 100.0 %. As for data in 2005, one bank, which was ordered to modify its business by the government, is discriminated as failure (Figure 4.6).

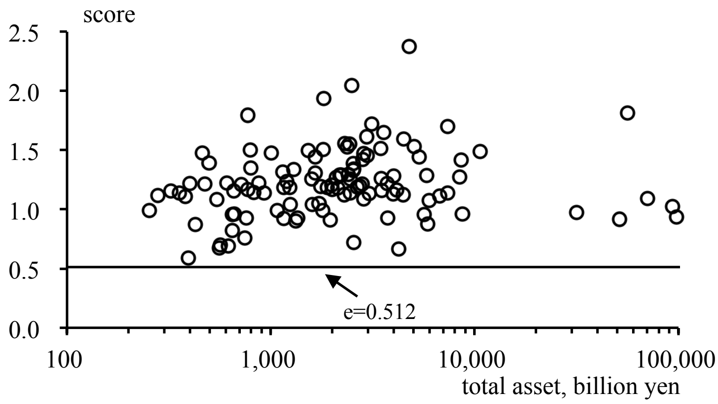


Figure 4.5: DEA-DA: probability of failure for data in 2004

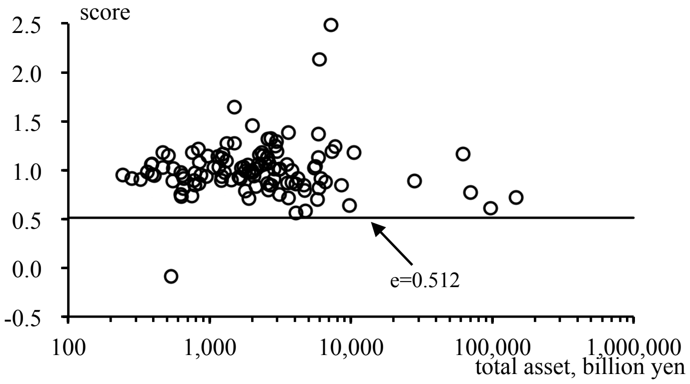


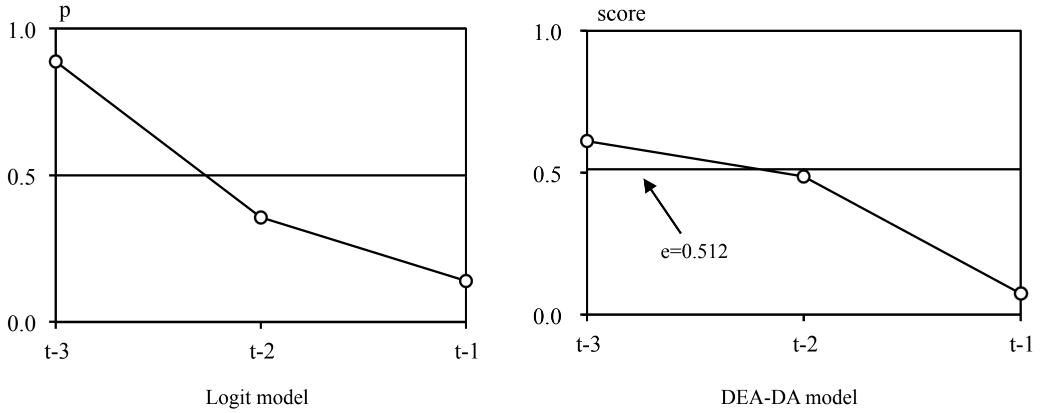
Figure 4.6: DEA-DA: probability of failure for data in 2005

4.2.5 Discussion

Both the logit model and the DEA-DA model hold highly successful discrimination rates for bank failure. These models show that the probability and the score of failure samples had declined for a couple of years before their failure timing (Figure 4.7). The results imply that there are signs for future bankruptcies.

The bank failure in Japan would be able to forecast by using our models. This study introduces a nonparametric model for the forecast and the model hold highly successful discrimination rate for bank failure. The model does not assume a specific distribution, and seems to be an objective one. This study suggests the DEA-DA model for forecasting model for Japanese bank failure.

Before concluding this part, attention should be paid to the following points concerning the analysis presented above. Firstly, the DEA-DA model can forecast the failure and pick up features of the industry through analyzing the weights. Through, developing



Note: The left figure shows the estimated results in the logit model, and the right figure shows the results in the DEA-DA model.

Figure 4.7: Probability of failure

the model for other sectors or foreign banks, we can compare the qualities. Secondly, the proposed DEA-DA model uses not real time data but annual data, so there are time lags for getting recent information. The model might be improved by introducing some real time data, such as stock prices. In the future studies, these points should be considered.

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Chapter 5

Concluding Remarks

This study mainly focuses on two points and tries to find keys for the future development in Japan. Firstly, the study clarifies the nonlinear transition mechanism of production. Chapter 2 makes an economic model and succeeds to provide a theoretical description about the nature of nonlinear transition mechanism in production, which has been widely acknowledged empirically but not been acknowledged theoretically. The findings in the study confirm the existence of nonlinear jumps in production implying changes in production functions over time. This leads to the need to develop methods that calculate the production and productivity using nonparametric approaches, which do not assume specific parametric production functions. To begin with, productivity is one of the main drivers of economic developments, and it needs to be evaluated from a wide perspective. However, related studies tend to mainly use the parametric approach (e.g. TFP method) for evaluating productivity.

Then, secondly, the study investigates a nonparametric model in order to grasp nonlinear jumps in productions and productivity in the real economy. Chapter 3 develops a new time series analysis method —DEA time series analysis— for estimating productivity using a nonparametric approach called the Data Envelopment Analysis (DEA). The DEA does not presume a specific parametric production function, and the new model is expected to be able to accurately grasp dramatic changes in the economy. The DEA approach tends to have disadvantages for time series analyses, but this study has overcome these weaknesses by combining it with ideas of the Kalman filter and the Markov switching to derive a new model. This study estimates Japanese productivity based on the new model, and succeeds in calculating it as technical and scale bases. The estimated results minutely grasp sudden and dramatic changes that would have knock-on effects on production mechanisms in the economy. The new model can be evaluated as being able to accurately calculate productivity in typical and atypical periods, compared to other traditional approaches. As this study discussed, productivity is one of the main drivers of economic developments and it must be evaluated from a wide perspective. Especially, in the case that economies face nonlinear changes which would put pressure on the shapes of production functions, productivity should be calculated based on a model corresponding to the changes like the proposed model in this study.

In Chapter 4, the study shows two practical application of the DEA model. As the previous chapter indicates the DEA model has potentials for the nonparametric estimation. The first study in this chapter is the estimation of turning points in business cycles using a DEA applied model (DEA-discriminant analysis). The second study is the prediction of bank failure using the same model. These studies show that DEA-discriminant analysis can separate samples (economic expansion and recession terms, as well as samples of banks that have remained in operation and samples of banks that have defaulted), hence it is useful for a forecasting model. The DEA is a nonparametric model and does not presume a specific parametric function, and then it would be able to correspond to sudden economic shocks for estimating data. Both results indicate the utility values and expansion possibilities of the DEA model.

Finally, the study tries to show keys for the future continuous development in Japan. Based on the results, Japanese economy and companies should focus on raising their technical efficiency. This study tries to separate efficiency into technical efficiency and scale efficiency. As a result, Japanese economy had been developed using scale efficiency in the past. However, these companies have shifted from being in a developing environment to a developed and mature period of development, and recently it seems to be difficult to dramatically raise their scale efficiency by the results. In other words, they already hold enough facilities. By contrast, it would be possible to keep and raise technical efficiency for Japanese companies. For example, the Japanese electronic industry succeeds to increase its technical efficiency after the collapse of the economic and dot-com bubbles. This is partly because, Japanese electronic companies increased their efficiency by making structural reforms, and proceeded scrap and build in their business. Considering the higher personnel cost, it would be difficult for focusing on making general-purpose products. The cost is clearly cheaper in developing countries. On the other hand, as the results in the study shows, Japanese companies hold technical efficiency, so by concentrating on making the most advanced products, they would keep their higher competitive power. Indeed, Japanese motor vehicle companies have maintained their higher technical efficiency, and kept their higher competitive power in the world, as the study shows. It would be a main driver for future development of the Japanese manufacturing sector to keep and raise its technical efficiency.

Before concluding this study, attention should be paid to the following points. Firstly, the study developes a new method of analysis –DEA time series analysis—, but there are some points with this model which might be able to improve it. The model uses the Markov switching process to incorporate business cycles. The estimated technical efficiencies and TFP have similar paths. Recent studies have tried to exclude the cycles from TFP. The new model would be improved by considering pure productivity without business cycles. Secondly, the study mainly uses annual data, and some of the estimated results contain extreme values. For instance, some results have values which are around zero. By using more data (e.g., quarterly or monthly data), the movements would be much smoother. Future researches would be expected to implement these ideas and apply the method to more exercises. Thirdly, the study makes models and applies them to explain the nature of Japanese economic development, but these models are general ones and can equally be applied to other economies. Substantial works based on the findings and the models in this study are expected in future studies for plentiful cases.

Acknowledgments

Connecting the Dots.

I believe economists and policy makers have a need to see both theory and practice. Through my work at the Bank of Japan for a decade, Japanese economy has faced several unprecedented events, such as the financial crisis, the Grate East Japan Earthquake, and non-traditional monetary policies by central banks including the Bank. The events were unparalleled in history, but there were precious lessons. We have to preview the events in practice, as well as we have to study and develop an academic theory which can account for these developments. By such a merging of theory and practice, a contribution would evolve as multiplier effects and we would be able to enjoy the sustainable developments in our ecnomy. This is the first motivation for my study in the doctorial program.

This study had supported by a lot of wisdom. Keio University provided me with the opportunity to carry out my research. I would like to thank Professor Masako Takahashi whose comments and suggestions were of inestimable value for my study. Special thanks go to Professor Norio Hibiki, Professor Yasushi Masuda, and Professor Atsuyuki Kogure whose meticulous comments were an enormous help to me. Emeritus Professor Tadaaki Fukukawa and Emeritus Professor Nobuo Shinozaki also encouraged me for the study. Without these help, I could not run the whole distance for the degree.

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