

THE IT PARADOX AND ITS ECONOMIC IMPACTS ON JAPAN

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ABBREVIATIONS

CRM	Customer Relationship Management
ERP	Enterprise Resource Planning
IS workers	IT-related workers
IT	Information technology
IT investment	Investment pertaining to the introduction of IT
IT paradox	Productivity paradox of IT
METI	Ministry of Economy, Trade and Industry
MIS	Management Information System
SCM	Supply Chain Management
SIS	Strategic Information System
VA	Value added

INTRODUCTION

The progress and diffusion of information technology (IT) in recent years have been remarkable. In corporate management, methods of efficiently and effectively utilizing IT are of critical importance for a firm's survival and success. Establishment of an intranet system and database-sharing within a firm can result in a more efficient business operation. At the same time, the diffusion of the Internet is contributing to developments of various new business models, such as by electronic trading. Such effective and efficient application of IT has become an extremely important factor that determines market performance not only of large corporations, but of venture companies as well.

Nevertheless, no concrete empirical evidence that proves IT's contribution to a productivity increase had been offered until the early 1990's. Instead, it had been widely argued that investment pertaining to the introduction of IT (hereinafter "IT investment") had a negative impact upon economic growth or remained minimally beneficial at best. This state of affairs is to called a productivity paradox of IT (hereinafter "IT paradox") and has been the subject of lengthy academic discussions (Loveman: 1988; Berndt, Morrison and Rosenblum: 1992; Morrison and Berndt: 1991).

Such discussions entered into a new stage in the early 1990's. A few empirical research studies based on economic data in the United States confirmed the positive economic effect of IT investment, proving the complete resolution of the IT paradox (Brynjolfsson and Hitt: 1995 and 1996; Lichtenberg: 1995). These earlier findings were well supported by additional empirical studies (Oliner and Sichel: 2000; Jorgenson and Stiroh: 2000). Given this evidence, it seems that a general consensus had emerged among U.S. scholars that the IT paradox had been already settled.

We may need to treat such optimism on IT with caution, however, because the end of the IT paradox is a matter that not only pertains to the U.S. economy, and that of Japan is another story. In fact, no conclusion has yet been reached as to whether the IT paradox has been resolved in Japan. In addition, few empirical analyses have been made in the past on the economic effects of IT investment in Japan. If any, arguments for the importance of IT depend heavily on U.S. precedents or cases studies of specific Japanese firms. While acknowledging the importance of these case studies, I find it imperative to conduct a more comprehensive quantitative analysis to demonstrate a general trend that covers a wider range of Japanese businesses.

This study aims at providing a quantitative evaluation of the economic effects of IT investment in Japan, using data on the firm level. As will be noted below, existing quantitative analyses of the subject matter in the Japanese economy of the past were based on either macro-data or specific company data that were rather biased in sampling. In either case, it can hardly be said that these studies established many facts about IT's economic effects in Japan. In order to address and correct such methodological weakness, I intend to conduct an empirical analysis by using more systematic data on the firm level, while trying to lessen sampling bias. I will estimate the production function and growth accounting on the firm level, and, based on this, I will examine whether the economic effects of the IT investment can be found to be statistically significant.

This paper is organized as follows. A brief overview of past empirical research on the IT paradox will be provided in Chapter 1. I will define what the IT paradox is and examine how earlier analysts came to the conclusion that the paradox was overcome. Chapter 2 explains the basic empirical model to be used in this paper, the estimation methods, and the data to be

collected, as well as the methods of building this data. In Chapter 3, I will provide empirical results and my interpretations of them.

CHAPTER 1

AN OVERVIEW OF RELATED RESEARCH

In general, the IT paradox describes a phenomenon in which the popular recognition of the diffusion of computers and their benefits is not reflected in the macro-productivity statistics.¹ Such negative research results were mainly based on the U.S. economy in the 1980's. Loveman's empirical study in 1988 was a pioneer in the field. He chose samples of about 60 business operations in some 20 companies chosen from the Fortune 500. Based on the samples, he established a model based on the Cobb-Douglas production function of such factors as labor, non-IT capital, and IT capital. In the model, the estimated value of the IT capital coefficient was found to be extremely low, sometimes even recording a negative value.

Berndt, Morrison, and Rosenblum (1992) estimated the ratio of high-tech-related capital stocks (such as PCs, communication-related equipment, scientific instruments, and copying machines) to the total capital stocks by industry (an industry that belongs to the category of "manufacturing industries" on the two-digit level of the Standard Industrial Classification) during the period between 1968 and 1986. They found that, in general, there was a negative correlation between this ratio and labor productivity. Using similar data, Morrison and Berndt (1991) came to the conclusion that the marginal productivity falls below the marginal cost, which in return resulted in over-investment.

In this way, a large body of the empirical research related to the IT paradox conducted in the United States from the 1980's to the early 1990's reported that the high-tech capital

¹Solow (1987) succinctly summarizes this phenomenon as "we see the computers everywhere but in the productivity statistics."

investment represented by IT made little contribution to a productivity increase, or even caused a negative impact, such as overinvestment.

Nevertheless, once the U.S. economy entered into a growth stage in the 1990's, more researchers argued that the economic growth was decisively attributable to IT investment. Brynjolfsson and Hitt (1996), for example, provided empirical proof of such an argument. They collected IT-investment-related data from 367 U.S. companies between 1987 and 1991 and estimated the firm-level production function based on these data. According to their findings, IT investment had a positive and substantial effect on the company outputs, with the marginal productivity of IT capital as high as 81 percent. Its marginal productivity scored at least at the same, or higher, than that of other capital. In the comparison of IT-related workers (IS workers) and other workers (non-IS workers), the former productivity was found to be higher than the latter's. With this evidence, Brynjolfsson and Hitt concluded that the IT paradox had disappeared by 1991.

Their study conveys their argument as to whether the IT paradox exists or not based on estimated marginal productivity, which was obtained mainly by a projection of production function. Lichtenberg (1995) conducted follow-up research using the same data as Brynjolfsson and Hitt in order to give more thorough scrutiny to the hypothesis. He examined statistically whether IT capital's marginal productivity exceeds that of other capital, and concluded that the IT paradox was completely resolved on the grounds that the excess return was evident.

Other scholars tackled the same hypothesis by taking various other approaches. Among them, Oliner and Sichel (2000) and Jorgenson and Stiroh (2000) applied the growth accounting approach based on macro-data from the U.S. economy during the late 1990's. Oliner and Sichel calculated the degree of contribution of an increase in IT capital to the growth of labor

productivity as 0.96 percent. Jorgenson and Stiroh calculated the IT capital contribution to the output growth rate as 0.80 percent.² In both cases, the positive, albeit limited, contribution of IT capital to productivity was confirmed. Meanwhile, Kiley's study (1999) based on the growth account model during the period between 1985 and 1998 estimated that the numerical contribution of computer hardware to the output growth rate was -0.27 percent. This research result, which is different from the other two studies, presumably comes from the fact that Kiley employed a new growth accounting model, which included the adjustment cost related to IT investment. Despite such discrepancies, it could be concluded that IT capital has a positive, albeit limited, impact upon labor productivity and the output growth rate, at least within the framework of conventional growth accounting.

Similarly, some Japanese scholars, such as Ito (2001), Miyagawa et al. (2002), and Motohashi (2002), while using a different measurement method of production factors, but a similar growth accounting method, have confirmed the positive contribution, albeit partial, of IT capital in Japanese corporations. Ito found that the IT capital contribution to the output growth rate was the largest during the first half of the 1980's, at 0.5 percent annually, but slowed down to 0.2 percent in the 1990's. Miyagawa et al. demonstrated a similar trend: the impact of the increase of IT capital on labor productivity was the largest in the 1980's (0.9 percent annually in the first half of the decade and 1.0 percent in the second half), but declined in the next decade (0.3 percent each year in both the first and second halves of the decade).³ The degree of contribution in Motohashi's study amounted to 0.3 percent and 0.4 percent per year in the first

²Oliner and Sichel (2000) report that the contribution of IT hardware to the output growth was 0.63, while Jorgenson and Stiroh (2000) measure the value as 0.49 percent.

³Miyagawa et al. (2002) measure the contribution of IT capital increase in terms of intra-sectoral capital deepening and efficiency effects of capital deepening, respectively. My study treats both as one value.

and second half of the 1980's, respectively. In the first half of the 1990's, this figure declined to 0.2 percent, but showed a positive growth of 0.5 percent in the latter part of the decade.

These previous studies conducted in Japan share common views: (1) the IT capital contribution in Japan was low in the 1990's compared to that of the United States, but (2) it remained positive overall throughout the research period, and (3) the contribution in the late 1990's amounted to about half of that in the United States or less. That is, the economic impact of IT investment in Japan in the late 1990's was smaller than that in the United States; but the IT paradox can be said to have disappeared, given the positive contribution of IT investment.

In sum, past empirical studies on the issue of the IT paradox took the following two major research approaches: (1) statistical evaluation of excess returns based on estimates of marginal productivity of production function, and (2) estimation of IT capital contribution based on growth accounting. In this study, I employ these two approaches simultaneously. In particular, I examine whether the IT capital contribution is statistically viable by conducting a regression analysis of the growth accounting model, as opposed to the numerical calculation in the previous studies.

CHAPTER 2

BASIC MODEL

In this section, I will explain the basic model and the estimation method, the data to be used for empirical analysis, and the way to construct variables in order to examine the existence of the IT paradox in Japan.

Basic Model

Cobb-Douglas Production Function

First of all, I apply the production function approach to an evaluation of the economic effects of IT in order to make an effective comparison with past empirical studies on the IT paradox. The Cobb-Douglas production function is defined here as:

$$(1) \quad Y_{i,t} = A \exp\left(\sum_j \delta_j J_j + \gamma T\right) K_{i,t}^{\beta_1} C_{i,t}^{\beta_2} L_{0i,t}^{\beta_3} L_{1i,t}^{\beta_4} e^{\varepsilon_{i,t}},$$

where A , $Y_{i,t}$, $K_{i,t}$, $C_{i,t}$, $L_{0i,t}$, $L_{1i,t}$ are scale factor, added value, capital, IT capital, labor, and IT labor of the i th firm at time t , respectively. J_j and $\varepsilon_{i,t}$ mean a dummy variable that indicates a type of industry of the i th firm and a measurement error, respectively. T means a time trend and its coefficient indicates the rate of technological progress.

Taking a log of both sides of the equation, we obtain

$$(2) \ln Y_{i,t} = \ln A + \sum_j \delta_j J_j + \gamma T + \beta_1 \ln K_{i,t} + \beta_2 \ln C_{i,t} + \beta_3 \ln L_{0,i,t} + \beta_4 \ln L_{1,i,t} + \varepsilon_{i,t}.$$

By making a regression analysis of this production function, we can estimate the elasticity of each explanatory variable. In particular, elasticity estimates of IT capital and IT labor are our main concerns in this paper.

Growth Accounting Model

Next, I explain the growth accounting model used to measure the contribution of IT investment to labor productivity growth. Equation (2) can be differentiated with respect to time as:

$$\hat{Y}_{i,t} = \hat{A} + \beta_1 \hat{K}_{i,t} + \beta_2 \hat{C}_{i,t} + \beta_3 \hat{L}_{0,i,t} + \beta_4 \hat{L}_{1,i,t} + \hat{\varepsilon}_{i,t},$$

where $\hat{\varepsilon} \equiv \partial \varepsilon / \partial t$, $\hat{Y} \equiv \dot{Y}/Y$. The same is true of other variables. Assuming a linear homogeneity of production function, this equation can be expressed as:

$$(3) \quad \hat{Y}_{i,t} - \hat{L}_{0,i,t} = \hat{A} + \beta_1 (\hat{K}_{i,t} - \hat{L}_{0,i,t}) + \beta_2 (\hat{C}_{i,t} - \hat{L}_{0,i,t}) + \beta_4 (\hat{L}_{1,i,t} - \hat{L}_{0,i,t}) + \hat{\varepsilon}_{i,t}.$$

The left side of this equation signifies the growth of labor productivity, which, in turn, is composed of per capita growth of capital, IT capital, and IT labor. In typical growth accounting, the growth rate of each production factor is calculated first, and, then, by multiplying the corresponding coefficient (usually, factor share is used), IT's contribution to labor productivity is

numerically calculated. Thus, the contribution of each production factor to labor productivity growth is not evaluated statistically at all. If the assumption of the linear homogeneity of production function or that of perfect competition in the factor markets is vindicated, there would not be a problem in this calculation. In reality, however, there is no guarantee that each coefficient is identical to the factor share.

In addition, when equations (2) and (3) are estimated separately, there is no way to assure that the coefficients in both equations can be identical, because an actual production function is not always compatible with a Cobb-Douglas production function. In this study, therefore, I make a separate estimate for equations (2) and (3).

Estimation Methods

Since this study deals with data on the firm level, it is necessary to control for firm-specific effects in estimating the above regression equations. In this respect, there are mainly two approaches to dealing with such effects. One is called the “fixed effect model”; the other is called the “random effect model.” The appropriateness of either approach can be determined by the Hausman test.

In the following, by applying these two estimation models to (2) and (3), I will try to explain the economic effects of IT capital and labor. Since there is a possibility of serial correlation of error terms, especially in (2), however, I will also estimate the models assuming that error terms follow ARI, not iid.

Data

Data Set

In this study, the economic effects of IT investment will be examined based on the data in the “Survey on Information Processing Activities” published by the Ministry of Economy, Trade and Industry (METI). This survey has been conducted every year since 1969 for the purpose of understanding the actual state of information processing at Japanese firms. This official survey is considered the most comprehensive and systematic of all such surveys conducted in Japan.

This study uses the unbalanced panel data of this survey from 296 firms in the manufacturing and non-manufacturing sectors between 1996 and 1999.⁴ I decided to narrow down the data obtained from about 3,500 companies each year to 296 firms for the following two reasons. First of all, the longest possible time series data could be obtained only for these 296 firms. Second, these firms are all listed companies and financial data are disclosed. Therefore, this study may be also subject to some selection bias, but I believe this bias is less severe than in the previous studies, because the METI survey on information processing activities randomly analyzes selected companies.

Another problem to be mentioned here is that our data deal only with listed companies, which may somewhat inflate the level of IT investment in comparison with that of non-listed firms. As a result, the data set used in this study may not be representative of all Japanese enterprises, especially non-listed ones. It may be fair to assume, however, this study best describes the most typical listed companies in Japan.

⁴The reason why the time period is limited is that the firms under study did not provide the data/information annually during the period prior to 1995 and I was unable to construct the panel data. In contrast, during the period after 1996, I was able to collect the annual data for each company up to 1999.

Variables related to IT investment were obtained from this METI survey on information processing activities; the other variables were constructed by obtaining data from financial statements of the corresponding firms. In the following, I describe the concrete procedure for constructing each variable in this study.

Calculation of Variables

The dependent variable in this study is value added (VA), which is calculated by summing up ordinary profits, personnel expenses, rents, financial expenses, depreciation expenses, and taxes. In order to calculate the real VA, I employ the 1995 GDP deflator from the “Annual Report on the National Economics Calculation” issued by the Economic Planning Agency.

Previous studies by Bryonjolfsson and Hitt (1995) and Matsudaira (2000) define capital as a company’s tangible fixed assets. To get a deflator, they first calculate the average vintage of capital based on the ratio of the accumulated depreciation to the current depreciation expenses. Following this, they use the deflator for the initial year of capital. This method is based on the assumption that each company adopts the straight-line method, and it is flawed in that it does not use the average year in which capital is used in a more strict economic sense. Thus, I follow the alternative method presented by Tokutsu and Hagiwara (1992) given below:

$$TA_t = \frac{\ln \{ Knn_t / (Knn_t + CDep) \}}{\ln \{ 1 - Dep_t / (Knn_t + CDep) \}}.$$

In this equation, $K_{nt,t}$ equals the tangible fixed assets at time t , $CDep$ is the accumulated depreciation, and Dep_t is the depreciation cost at the time t . Here, net capital stock S_t can be calculated by deflating the tangible fixed asset with the deflator at time $t - TA_t$. For the deflator, I use the above-mentioned 1995 GDP deflator.

While the capital that is calculated in this method equals capital stock in a strict sense, the factor input in production function is not in “stock” terms, but in “flow” terms that emanate therefrom. Therefore, following Jorgenson and Stiroh (2000), I express the capital service input K_t at time t as:

$$K_t = \frac{S_t + S_{t-1}}{2}$$

Regarding IT, I use the data indicated in the expenses related to information processing in the “Survey on Information Processing Activities.” The data in this survey do not indicate the asset value of computers owned by each firm, but the IT-related budget for each fiscal year. Therefore, I do not follow the method that Bryonjolfsson and Hitt (1995) and Lichtenberg (1995) use to calculate IT capital (i.e., to calculate the real value of the total assets of computers owned by a firm). Nevertheless, it is also true that the service input flow of IT capital cannot be accurately measured by the total amount of computers alone. For example, according to Lichtenberg (1995), two American journals – *Information Week* and *Computerworld* – separately conducted surveys on computer assets and IT budgets in American companies. When comparing these two independent surveys, he finds that the correlation for the computer assets between them was as low as 55 percent, while that for the IT budgets scored 85–94 percent. Given this, it

follows that the IT budget more accurately measures the IT capital input flow than the computer assets, which is flawed in terms of data credibility. Thus, the IT capital input flow can be calculated by deflating the IT budget with the rental price of IT capital. The IT capital rental price is formulated as follows.⁵

$$(4) \quad p_t = r_t q_{t-1} + \mu q_t - (q_t - q_{t-1}),$$

where p_t indicates the rental price of IT capital, r_t is the interest rate at time t , μ is the depreciation rate, and q_t is the IT capital price.⁶

If this IT capital service consists of “s” kinds of different capital service, the input flow of each service is expressed as:

$$(5) \quad C_{h,t} = B_{h,t} / P_{h,t} \quad (h = 1, \dots, s),$$

where $C_{h,t}$ means the input flow of IT capital of type h at time t , $B_{h,t}$ is the amount paid for IT capital of type h at time t , and $P_{h,t}$ is the rental price of IT capital of type h at time t .

To measure the IT capital input flow, I have taken the following steps. First, in the METI survey, the IT budget includes such items as hardware-, software-, and communications-related expenses. Therefore, in this study, I use the price indices of computers themselves and peripherals in the Bank of Japan’s “Wholesale Price Index” for the hardware-related budget, and

⁵Regarding this equation, refer to Christensen and Jorgenson (1970) for example.

⁶In the empirical analysis below, I use the average yield of a 10-year government bond for each year in terms of “ r .” For the depreciation rate of IT capital, I use “0.2” based on the Lau and Tokutsu formula (1992).

the price indices in software development and those in data transmission (both come from the “Service Price Index for Companies”) for the software-related budget and the communication-related budget, respectively. All these indices are based on the 1995 value. They are used to calculate the rental price in (4), and the service input flow of each IT capital item is measured by (5).

I also measure the IT capital input flow, which is the sum of the three classes of services: hardware-related, software-related, and communications-related as:

$$(6) \quad C_t = \sum_{h=1}^s s_{h,t} C_{h,t},$$

where $s_{h,t}$ means the share of type h factor.

To measure IT labor, I use the figures of the total number of company personnel, both full-time and part-time employees, who engage in work related to information processing in an information systems department or elsewhere. Such personnel include data-handlers, operators, programmers, system engineers, and network administrators. Total labor is the number of total employees of a firm after deducting these IT-related personnel.

Among other explanatory variables, I use time trend and dummy variables by industry in order to control for time and industry-specific factors. For a time trend variable, the year 1996 is set as “1.” Dummy variables by industry follow the Japan Standard Industry Classification. The average data and standard deviation of each variable to be used in this paper are indicated in Table 1. VA for 1997-1999 and the distribution of each factor of production are shown in Figures 1-3. These figures demonstrate the general trend in which both capital and labor increases along with VA. But it can also be noted that increases in IT capital and IT labor are rather moderate as

VA increases. Also, IT capital and IT labor fluctuate more than total capital and labor. That is, there is a trend that both IT capital and IT labor do not show a steady increase compared with other factors of production.

CHAPTER 3

EMPIRICAL ANALYSIS

In this section, I will describe the results of estimation of production functions (2), followed by the results of the growth accounting model (3), as well as my interpretation of these results.

Results

Estimation of Cobb-Douglas Production Function

Table 2 shows the estimation results of the AR1 in terms of Cobb-Douglas production function. The Hausman test rejects all the fixed effect models in favor of the random effect model.

In the models estimated here, the coefficient of determination amounts to about 30 percent, which indicates a certain explanatory power of the models. In addition, Chi square statistics also show high values. The sum of the coefficients for all factors of production is about 0.8, which indicates that production functions result in diminishing returns. In fact, this total sum in all the models rejected the null hypotheses that the sum is equal to 0 or 1.

According to the results, the coefficients of both capital and labor are positive and significant, while that of IT labor is negative, but not statistically significant. Regarding IT capital, no substantial effects are observed. Furthermore, I also attempted to ascertain the existence of excessive returns on IT capital and IT labor. No such excessive returns on IT capital,

however, were confirmed, while negative returns on IT labor, that is excessive returns on the labor force, were verified.⁷⁸

Table 3 summarizes the results of panel estimation based on the hypothesis that measurement error follows iid. It is clear that the results here are similar to those in Table 2. The same results were obtained in terms of excessive returns. Given this evidence, I conclude that the IT paradox has not yet been resolved in terms of the elasticity of production functions.

Estimation in the Growth Accounting Model

Next, let me evaluate the contribution of IT labor and IT capital to labor productivity growth based on the growth accounting model. As I described above, typically such a contribution is numerically calculated by multiplying the factor share by the corresponding factor growth. This calculation is valid only if production function shows linear homogeneity and there is perfect competition in factor markets. Of course, even if such conditions are not met, this growth accounting procedure would be useful as the first approximation. It is also important, however, to evaluate the contribution of each factor of production by alternative approaches. Here, I employ a regression analysis to measure the contribution of each factor of production and test its statistical significance. Table 4 shows the results of the regression analysis.⁸⁹

⁷For the calculation method of excessive returns, refer to Lichtenberg (1995). The rates for IT capital and IT labor were measured as -0.015 and -0.0466 , respectively. The result for the former was not significant, while for the latter it was significant at the 1 percent level.

⁸I also attempted the ARI panel estimation, but the result was almost identical to the panel estimation with an assumption of iid. In the growth accounting model, since I took the first order difference, I was able to control for the ARI impact to a certain extent. For these reasons, I decided to omit the estimation result of ARI in Table 4.

Table 4 indicates that there is a positive effect in the growth of communication service, but I could not find any substantial impact of other IT capital services, including the aggregate IT capital. Regarding IT labor, while its contribution was negative in the Cobb-Douglas production function, its contribution to labor productivity growth is positive and significant in this table. This result fundamentally questions the validity of the use of factor share values in the typical growth accounting model.

In explaining the labor productivity growth, a positive effect of IT labor is observed, but almost no impact whatsoever of IT capital can be noted. Therefore, I came to the same conclusion that the IT paradox has hardly been resolved in Japan.

Implications of the Estimation Results

The Existence of the IT Paradox

My above results diverge from previous studies conducted in Japan, suggesting that the IT paradox in Japanese corporations is far from being completely resolved. Then, why does the IT paradox still persist in Japan? This puzzle will be analyzed in the following.

To my best knowledge, there are no previous empirical studies on production function that clearly distinguish IT labor and IT capital and simultaneously estimate each factor's impact.⁹ In these previous studies, IT labor as personnel expenses was added to IT capital. This approach is faulty because labor and capital are, in essence, totally different factors of production and, thus, should be measured separately.

⁹As I explain below, refer to Nishimura et al. (2000) for an empirical study of the substitutability among IT capital, ordinary capital, productive and non-productive labor.

Another methodological problem of the previous studies is that they depend on factor shares for measuring the contribution of IT capital in the growth accounting model. According to these studies, the deepening of Japanese IT capital significantly contributed to growth of output and labor productivity, although the extent of this process remains modest compared to its U.S. counterpart. We must, however, more carefully examine the analytical validity of the very value of factor share here. By definition, factor share always takes a positive value. In addition, when IT investment is on the increase, it always leads to a certain degree of contribution to labor productivity growth. The test results above, though, show that there is no statistically significant impact when each coefficient is estimated for factors of production, instead of using factor shares from the beginning.

Of course, I cannot make a simple comparison between the results of this paper and those of previous studies since this paper uses firm-level as opposed to macro-level aggregated data. It can be conjectured, however, that when a regression analysis using macro-level data can be conducted, the analysis may reach results that are different from the numerical calculation in typical growth accounting. And no previous studies have attempted a regression analysis. For that reason, in the past, it was impossible to obtain a large enough sample size of the relevant macro-data. In comparison, this study uses firm-level data, which allowed me to obtain a sufficient sample size even in the late 1990's.

In any event, it is fair to say that we can "declare" the end of the IT paradox only when a positive impact of both IT labor and IT capital is confirmed in regression analysis in the micro-level data as well as the growth accounting analysis in the macro-level data. Therefore, based upon the above results, we can hardly confirm the end of the IT paradox in Japan.

The Impact of Labor

In contrast, our analysis demonstrates an interesting result regarding IT labor, that is, a negative impact in production function and a positive one in growth accounting. In general, these two values should be identical if the Cobb-Douglas production function is linear homogeneous. But without linear homogeneity, these two take different values. Since none of the above estimation results of the Cobb-Douglas production functions showed linear homogeneity, it is not contradictory at all to have different estimation results between production functions and growth accounting.

It would be more useful, however, to discuss the implications of such contrasting results, rather than theoretical consistency in these two approaches. The above results suggest that: (1) the marginal productivity of IT labor ended in the negative, but (2) IT labor growth contributes to an increase in labor productivity. That further implies that: (1) IT labor is utilized more actively in small and/or medium-sized firms and (2) such firms that continue to accumulate IT labor enjoy relatively higher growth rates in general.¹⁰

For example, while the correlation between IT labor and VA amounts to 18.8 percent, the correlation between VA and the ratio of IT to total labor remains at no more than 4.2 percent, which is not statistically significant. That is, there is no significant correlation between VA and IT labor relative to total labor. This suggests that IT labor is utilized not only in large firms, but in small ones as well. Also, there is a tendency in which the labor productivity growth scores relatively higher when more IT labor is employed. Therefore, it could be inferred that IT labor was actively employed in small and medium-sized firms in the late 1990's and that these firms indeed achieved relatively higher growth.

¹⁰Small and medium-sized here mean here "somewhat relative," not small or medium-sized firms as defined by the basic law of small and medium-sized companies in Japan.

The Role of IT Labor

Based on these results, the question arises as to how IT labor contributes to labor productivity growth. First of all, it is important to note that the complementary capability to make full use of IT plays a crucial role in rendering the existing IT investment in a way that has a significant effect. In this context, Nishimura et al. (2000) conducted an empirical analysis about the factor substitutability between IT capital and other factors of production based on industry-level data. The study shows a substantial substitutability between IT capital and productive labor. Moreover, in the electric machinery industry, one of suppliers for IT, IT capital began to substitute even for non-productive labor throughout the 1990's.

With the higher marginal productivity of IT capital, one can presume that IT can increasingly substitute for both productive and non-productive labor, especially lower-skilled labor. The role of IT labor, such as highly skilled and general IT labor, however, becomes more significant in accordance with the higher marginal productivity of such labor. To support this, Sakurai (2000) reports that the ratio of computer investment significantly affects a change in the share of non-productive labor's wages. That is, computer investment stimulates demand for non-productive workers, which, in turn, leads to increases in their wages. This also indicates the important role of an IT-literate staff in the general economic environment of technological progress toward IT. In this study, I did not differentiate workers who use IT among (non-IT) labor.¹¹

¹¹In this respect, the previous studies referred to here did not distinguish IT labor. For example, Nishimura et al. (2000) classify labor into productive and non-productive labor. Sakurai (2000) uses the variable called "professional and technical employee" in calculating the correlation between computer use and the employment of engineers.

Nevertheless, I conjecture that the role of IT labor is now becoming more important than that of IT-user personnel, especially in the period covered by this study, i.e., the late 1990's. This period was called era of the "IT Revolution" in Japan, with a widespread diffusion of the Internet. In Japan, application of IT in the field of production in the manufacturing industries and marketing in the service industries had already been attempted for a long time (e.g., CAD, CAM, and POS). These technologies proved useful in cost reduction in these fields. Also, large-scale investment in the Management Information System (MIS) and Strategic Information System (SIS) that emerged in the 1980's attempted a unified management of various information utilized in production, logistics, marketing, and so forth. Unfortunately, not all of these efforts bore fruit. But the diffusion of Internet and package software in the late 1990's made possible low-cost integration of various types of information within a firm and across different firms in the form of Enterprise Resource Planning (ERP) or Supply Chain Management (SCM).

Partly due to the fact that almost all major Japanese firms began using ERP and/or SCM in this period, however, IT investment itself was not soon translated into productivity increases that differentiated one firm from another. Also, in ERP and SCM, what matters is not only information and expertise in each field, but also architecture and technology as a whole system in general. Thus, IT labor plays a crucial role here, more so than the IT-user personnel in each field.

Moreover, Customer Relationship Management (CRM) and online shopping, emerging in the late 1990's, aim not at cost reduction, but at providing new values to customers. That is, they try to increase VA by providing new goods and services or convenience to online customers. What is important here is not so much conventional labor skills or expertise as a system design capability from a new perspective. Accordingly, the capacity of IT labor has a large impact upon economic performance.

Taking these factors into consideration, I assume that the importance of IT labor increased more than that of highly skilled labor in the late 1990's. Nevertheless, Japan still has relatively few system engineers, and their skills probably have not reached the level of their American counterparts. Although the presence/absence of such IT labor is not necessarily reflected in the size of VA, it does help to increase labor productivity growth. And IT labor is not concentrated in large firms, but some medium-sized and small firms make full use of such personnel as well. It follows that these firms enjoyed a relatively higher labor productivity growth in the late 1990's.

Impact and Role of Communication

Among IT capital services, "communication" showed relatively similar results with those of IT labor in this analysis. While the estimate of marginal productivity was not significant, it had a positive impact upon labor productivity growth. Hence, this result can be interpreted in a similar manner to the case of IT labor. Of course, since the estimate for marginal productivity was not significantly negative, it cannot simply be assumed that the most frequent users of IT-related communication services were medium-sized and small firms. But we can confirm that such services do contribute to labor productivity growth. The spread of the Internet during this period played a key role in accounting for these results. Therefore, in evaluating the economic impacts of IT investment, it is imperative to extend our attention beyond hardware and software to communications services.

CONCLUSION

I conclude that the economic effects of IT investment have not been identified with full confidence in the Japanese economy. Regarding IT labor, while its marginal productivity remains negative, an increase in IT labor has a positive impact on the growth of labor productivity. It also suggests that small and medium-sized firms are fairly active in making use of IT labor, which, in turn, results in rapid growth of labor productivity in such firms. It follows that the high performance of these firms in the late 1990's is attributable to the active use of IT labor.

My conclusion in this study is consistent with the main message of David (1990): it takes decades for IT investment to have a significant impact on economic growth. In this context, the IT revolution as a boom has not resulted in a miraculous economic impact to the extent that it is reflected in production function. But we can expect that the real results of a genuine IT revolution will emerge rather gradually.

Figure 1. Value Added and Factors of Production (1997)

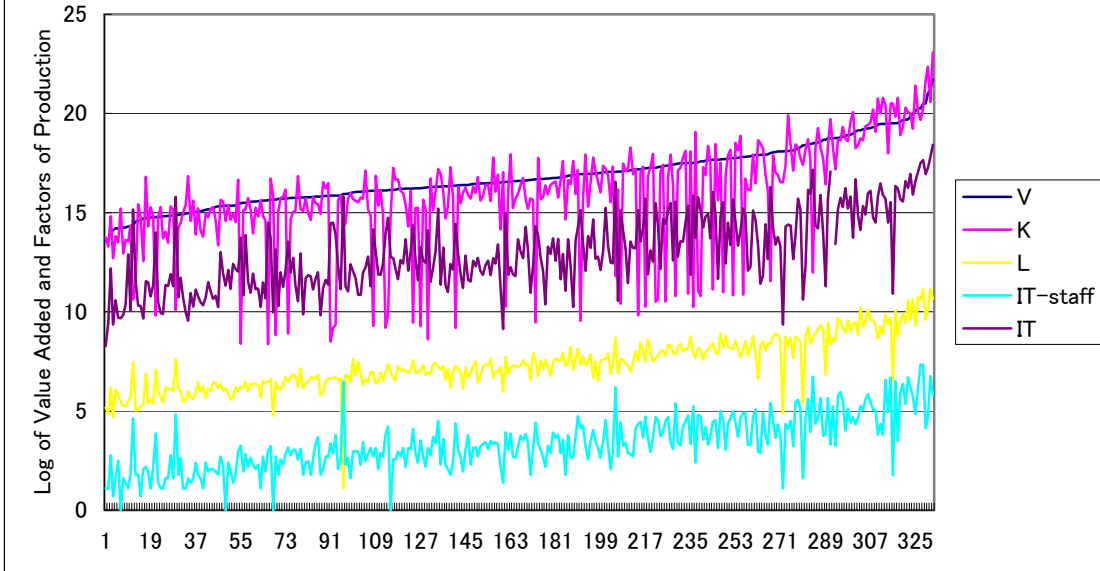
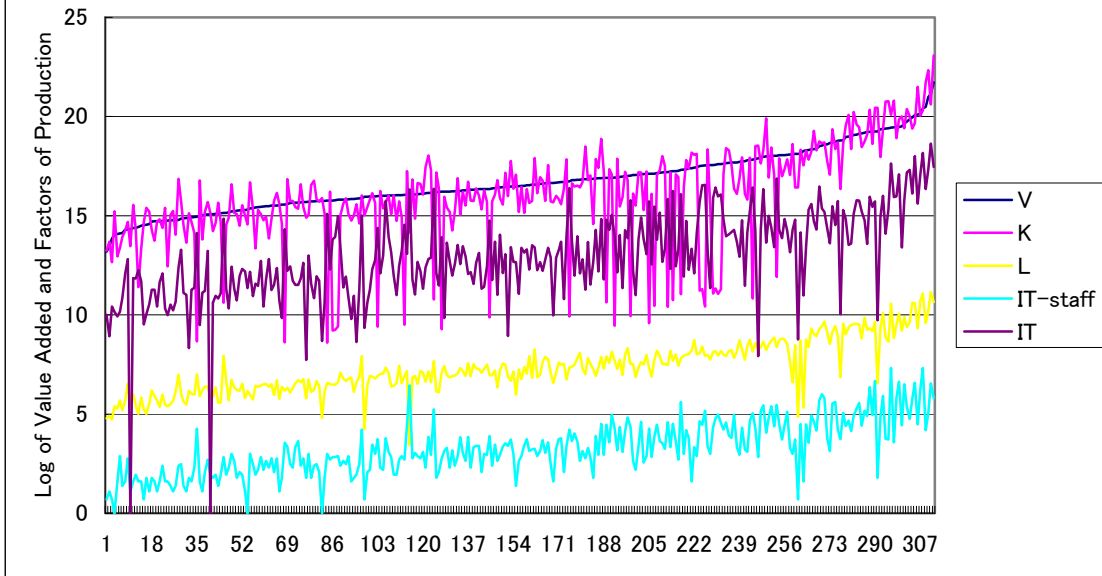


Figure 2. Value Added and Factors of Production (1998)



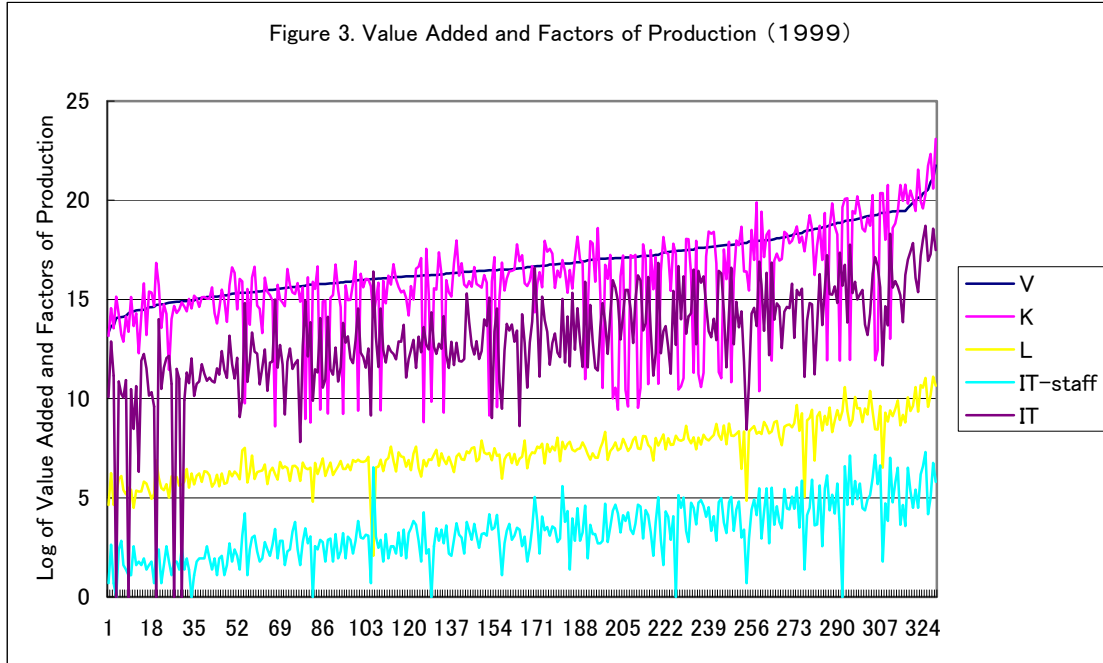


Table 1. Mean and Standard Deviation (1997~1999)

Variable	All Industry	Manufacturing	Non-manufacturing
Value Added (Y)	70235.4 (206019)	57688.1 (144049)	125885.0 (343012)
Capital (K)	91616.9 (585046)	49580.6 (126289)	253018.0 (1159920)
Labor (L_0)	4001.5 (8017)	4231.9 (9316)	4197.5 (6386)
IT Labor (L_1)	88.1 (192)	76.9 (184)	65.4 (139)
IT Capital (C)	3297.4 (9075)	2168.5 (7442)	5139.3 (11000)
Hardware	3329.0 (10095)	2252.5 (10122)	2705.6 (6955)
Software	3094.9 (9698)	2003.9 (6062)	4622.2 (15151)
Communication	794.9 (2653)	617.8 (2858)	789.8 (2337)

Note: Standard errors are in the parenthesis.

The units of Labor and IT Labor are the number of respective employees.

All other variables are evaluated using the 1995 GDP deflator with the unit of million yens.

Table 2. Regression Results of Cobb-Douglas Production Function (AR1)

	(1)	(2)	(3)	(4)	(5)
Capital (K)	0.598*** (0.071)	0.597*** (0.071)	0.596*** (0.071)	0.496*** (0.075)	0.599*** (0.071)
Labor (L ₀)	0.517*** (0.164)	0.539*** (0.166)	0.527*** (0.165)	0.591*** (0.187)	0.533*** (0.166)
IT Labor (L ₁)	-0.358*** (0.139)	-0.319** (0.137)	-0.331** (0.137)	-0.454*** (0.151)	-0.345** (0.140)
(IT Capital)					
Hardware	0.028 (0.037)				0.037 (0.040)
Software		-0.014 (0.027)			-0.020 (0.029)
Communication			-0.001 (0.032)		-0.004 (0.034)
IT Capital (C)				0.115 (0.114)	
Sum of Estimates	0.785	0.801	0.790	0.747	0.800
Hausman Test	9.43	9.57	9.46	9.22	9.63
P value	0.093	0.088	0.092	0.101	0.211
Fixed or Random	Random	Random	Random	Random	Random
R ²	0.309	0.309	0.309	0.296	0.310
χ ²	327.03	326.91	326.1	304.68	327.94
Baltagi-Wu LBI	2.737	2.737	2.737	2.734	2.737

Note: The dependent variables are the log of value added.

Standard errors are in the parenthesis.

The Hausman test is made at the 5 % significant level.

* p<0.1 ** p<0.05 *** p<0.01

N=1032.

Table 3. Regression Results of Cobb-Douglas Production Function (iid)

	(1)	(2)	(3)	(4)	(5)
Capital (K)	0.606*** (0.073)	0.605*** (0.073)	0.605*** (0.074)	0.500*** (0.079)	0.608*** (0.074)
Labor (L ₀)	0.519*** (0.169)	0.539*** (0.170)	0.528*** (0.169)	0.593*** (0.193)	0.534*** (0.171)
IT Labor (L ₁)	-0.370*** (0.142)	-0.333** (0.139)	-0.344** (0.140)	-0.462*** (0.153)	-0.358** (0.143)
(IT Capital)					
Hardware	0.028 (0.038)				0.036 (0.040)
Software		-0.013 (0.027)			-0.019 (0.029)
Communication			-5.21E-05 (0.032)		-0.003 (0.035)
IT Capital (C)				0.115 (0.116)	
Sum of Estimates	0.783	0.799	0.788	0.746	0.797
Hausman Test	4.5	4.97	4.54	5.28	5.17
P value	0.480	0.419	0.474	0.3825	0.6396
Fixed or Random	Random	Random	Random	Random	Random
R ²	0.309	0.309	0.309	0.296	0.310
χ ²	309.49	309.24	308.57	283.72	309.58

Note: The dependent variables are the log of value added.

Standard errors are in the parenthesis.

The Hausman test is made at the 5 percent significant level.

* p<0.1 ** p<0.05 *** p<0.01

N=1032.

Table 4. Regression Results of Growth Accounting

	(1)	(2)
Capital Growth	0.045*** (0.016)	0.527*** (0.050)
IT Labor Growth	0.111*** (0.022)	0.061*** (0.022)
(IT Capital)		
Hardware Growth	-0.014 (0.013)	
Software Growth	0.014 (0.011)	
Communication Growth	0.060*** (0.016)	
IT Capital Growth		0.015 (0.014)
Hausman Test	2.69	5.17
P value	0.748	0.6396
Fixed or Random	Random	Random
R ²	0.079	0.310
χ^2	58.63	309.58

Note: Standard errors are in the parenthesis.

The Hausman test is made at the 5 percent significant level.

* p<0.1 ** p<0.05 *** p<0.01

N=688.

BIBLIOGRAPHY

- Berndt, E., C. Morrison, et al. (1992). "High-Tech Capital Formation and Labor Composition in U.S. Manufacturing Industries: An Exploratory Analysis." NBER Working Paper No. 4010.
- Brynjolfsson, E., and L. Hitt (1995). "Information Technology as a Factor of Production: The Role of Differences Among Firms." *Economics of Innovation and New Technology* 3: 183-200.
- . (1996). "Paradox Lost? Firm-level Evidence on the Returns to Information Systems Spending." *Management Science* 42: 541-558.
- Christensen, L. R., and D. W. Jorgenson (1970). "The Measurement of U.S. Real Capital Input, 1929-1967." *The Review of Income and Wealth* 16: 293-320.
- David, P. A. (1990). "The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox." *American Economic Review* 80: 355-361.
- Griliches, Z. (1994). "Productivity, R&D and the Data Constraint." *American Economic Review* 84: 1-23.
- Hsiao, C. (1986). *Analysis of Panel Data*. Cambridge and New York: Cambridge University Press.
- Itoh, Y. (2001). "IT Revolution and Vitalization of the Japanese Economy."
- Jorgenson, D. E., and K. J. Stiroh (2000). "Raising the Speed Limit: U.S. Economic Growth in the Information Age." *Brookings Papers on Economic Activity* I: 125-235.
- Kiley, M. T. (1999). "Computers and Growth with Costs of Adjustment: Will the Future Look Like the Past?" Federal Reserve Board, Finance and Economics Discussion Series Paper 1999-36 (July).
- Lau, L. J., and I. Tokutsu (1992). "The Impact of Computer Technology on the Aggregate Productivity of the United States: An Indirect Approach." Mimeo.
- Lichtenberg, F. R. (1995). "The Output Contribution of Computer Equipment and Personnel: A Firm-level Analysis." *Economics of Innovation and New Technology* 3: 201-217.
- Loveman, G. (1994). "An Assessment of the Productivity Impact of Information Technologies." T. J. Allen and M. S. S. Morton. *Information Technology and the Corporation of the 1990s*. Cambridge, MA: MIT Press: 84-110.

- Matsudaira, J. (2000). "Information Technology, Performance and Productivity." Fujitsu Research Institute Discussion Paper No. 2000-01.
- Miyagawa, T., Ito Y., and Harada N. (2002). "Does the IT Revolution Contribute to Japanese Economic Growth?" JCER Discussion Paper No. 75.
- Morrison, C. (1997). "Assessing the Productivity of Information Technology Equipment in U.S. Manufacturing Industries." *Review of Economics and Statistics* 79: 471-481.
- Motohashi, I. (2002). "Comparative Analysis of IT Productivity Between U.S. and Japanese Economies." RIETI Discussion Paper Series 02-J-018 (unpublished report; in Japanese).
- Nishimura K. G., M. Shirai, K. Minetaki, and F. Kurokawa (2001) "The Effects of Information Technology on Demand for Labor and Technological Progress in Japanese Manufacturing: 1980-1998." Mimeo.
- Oliner, S. D. and D. E. Sichel (2000). "The Resurgence of Growth in the Late 1990's: Is Information Technology the Story?" *Journal of Economic Perspectives* 14: 3-22.
- Sakurai K. (2000) "Biased Technological Change and Employment: the Case of the Japanese Manufacturing Industries." H. Yoshikawa and M. Otaki. *Macroeconomics of Cycle and Growth*. Tokyo: University of Tokyo Press.
- Tokutsu I., and Hagiwara Y. (1992) "On the Estimation of Gross Capital at the Firm Level." A. Mori. *Issues in Corporate Finance and Accounting*. Kobe: RIEB: 37-65.