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Nakanishi, Yasuo

Senshu University

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Department of Economics

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Abstract

This article presents an empirical investigation of the role of IT (Information Technology) capital in the Japanese macroeconomy, with a particular focus on the adjustment of IT capital stock. We use the Translog model in this study and treat IT capital as the only quasi-fixed factor. We found that the shadow price of IT capital was largely decreased, and that there was a significant difference in the shadow prices between the beginning of the measurement periods and in recent years. There was also a high investment incentive in most periods. We found evidence for the contribution of IT capital to labor productivity, and our findings are consistent with the proposition that IT capital contributes to output growth.

JEL classification number: D21, D24, J23, O33

Key word: IT capital, Translog model, productivity

Yasuo Nakanishi

Department of Economics, Senshu University,

2-1-1 Higashimita, Tamaku, Kawasaki,

214-8580, Japan

tel +81-44-900-7981,

Fax +81-44-900-7849,

Email nakanisi@isc.senshu-u.ac.jp

1 Introduction

We made an empirical investigation of the role of IT capital[1] on the economic growth of Japan, with particular focus on the adjustment of capital for measurement. The appropriation of the IT capital price index and the efficiency of IT investment are analyzed as well as the impact of IT capital on economic growth.

Recently, there have been many studies that support a positive correlation between productivity and IT capital(Siegel (1997), Oliner and Siegel(2000), Brynjolfson and Hitt(2000), Gordon(2000) and Jorgenson(2001)). Jorgenson, in particular, has developed this case in detail and, overall, there is a strong consensus for a positive correlation between productivity and IT capital.

There have been few studies on IT capital in Japan, since it emerged several years later than that in the USA. Shinosaki (1998) did pioneering research in this area, in addition to similar studies by Shinjo and Cho (1997) and Nakanishi(2002)[2]. Their studies support the case for the contribution of IT capital and its positive correlation to high productivity and output in Japan.

Most of the previous studies, except that by Nakanishi(2002), are based on the approach of growth accounting, using the Cobb-Douglas function. Therefore, this leads to the problem of the functional form. The obtained value of measurement is only one among all sample periods. Furthermore, all studies assumed a long-run equilibrium. It is natural that with IT capital the emergence is early is not adjusted instantaneously. Thus, a new model that considers the adjustment of IT capital is needed.

Morrison(1997) used a variable cost function approach to consider the adjustment of IT capital. The variable cost function approach incorporates the efficiency of investment and the shadow value of IT capital, but does not consider the impact on economic growth.

The efficiency of IT investment is key in verifying the contribution of IT capital to productivity and economic growth. Morrison (1997) constructs a model in which both IT capital and general capital are treated as quasi-fixed factors and measures the Tobin's Q. It was concluded that investment was low. Morrison also found that the incentive to invest in IT capital was relatively low and that there was little difference between the value of IT capital and general capital. Shinjo and Cho (1997) used the same approach with similar results. In particular, there was very little difference between the value of IT capital and general capital. The value of Q of all industries was low and there were cases in which the value of Q of general capital was higher than that of IT capital. Therefore, the results of both Morrison(1997) and Shinjo and Cho (1997) were not natural.

While the generalized Leontief cost function was adopted in studies by Morrison (1997) and Shinjo and Cho (1997), we used the Translog model in the present study. Since we treated IT capital as the only quasi-fixed factor, our study was not as broad as that of Morrison (1997) and Shinjo and Cho (1997). However, since the impact of IT capital and its correlation to productivity, economic growth, and investment incentive are measured using the same model, the consistency of the impact of IT capital is maintained.

This study is organized as follows: the model is presented in Chapter 2. In Chapter 3, the data is described, with the estimation results presented and discussed in Chapter 4. In Chapter 5, we present the conclusion and issues for further discussion.

2 Structure of the Model

In this study, a so-called dual approach utilizing a cost function was used. The following variable cost function is obtained by:

$$VC = VC(P_K, P_N, X_H, y, t) \tag{1}$$

Where P_i denotes the price for i input. Where y denotes the output, X_i denotes the input i where i is capital stock (K), labor (N), and IT capital (H), and t denotes the time trend.

The cost is the function of each input price, output, IT capital, and its time trend (t).

The shadow price of IT(SPIT) is obtained by

$$SPIT = -\frac{\partial VC(P_K, P_N, X_H, y, t)}{\partial X_H}. \tag{2}$$

The Tobin's Q is defined as follows.

$$Q = SPIT/P_H \tag{3}$$

The output growth is obtained after manipulating the above equation as follows.

$$\dot{y} = S_{X_N}\dot{X_N} + S_{X_K}\dot{X_K} - VC_{X_H}\dot{X_H} + T\dot{F}P \tag{4}$$

where S_{X_i} is the share of i input in variable cost. The growth rate of the labor productivity (LP) is defined by

$$\dot{y} = S_{X_N}\dot{X_N} + S_{X_K}\dot{X_K} - VC_{X_H}\dot{X_H} + T\dot{F}P \tag{5}$$

While the cost function can be presented theoretically, it cannot be applied directly to empirical studies and, thus, the functional form of the cost function must be determined. The Translog functional form has been applied to the cost function in the present study. The Translog cost function can be written as (Diewert(1974)):

$$\begin{aligned} \ln\ C = \alpha_0 + \sum_i \alpha_i \ln P_i + \frac{1}{2}\sum_i\sum_j \alpha_{ij}\ln P_i \ln P_j \\ + \sum_i \alpha_{i\,Y} \ln P_i \ln Y + \alpha_{H\,Y}\ln X_H \ln Y + \alpha_Y \ln Y + \frac{1}{2}\alpha_{Y\,Y}(\ln Y)^2 \\ + \sum_i \beta_{i\,H}\ln P_i \ln X_H + \beta_H \ln X_H + \frac{1}{2}\beta_{H\,H}(\ln X_H)^2 \\ + \sum_i \beta_{i\,t}\ln P_i t + \beta_{Y\,t}\ln Y\,t + \beta_{H\,t}\ln X_H\,t + \beta_t\,t \end{aligned} \tag{6}$$

The above Translog cost function is generalized for the more recent cost function analyses. There are no a priori restrictions to the model. In particular, the elasticity of substitution is not restricted. Moreover, several indices obtained by the observation allow us to compare each value. This cost function is derived under maximization behavior, and the function requires the restriction of first degree homogeneity for the input prices. Therefore, the following condition is provided by:

$$\begin{aligned} \sum_i \alpha_i = 1, \sum_i \alpha_{ij} = 0, \sum_j \alpha_{ij} = 0 \\ \sum_i \beta_{i\,H} = 0, \sum_i \alpha_{i\,Y} = 0, \sum_i \beta_{i\,t} = 0, \alpha_{ij} = \alpha_{ji} \end{aligned} \tag{7}$$

The following share function for each input is obtained by utilizing Sheferd's lemma is(Varian, 1982):

$$S_i = \frac{P_i X_i}{C} = \frac{\partial \ln C}{\partial \ln P_i} \tag{8}$$

where S_i indicates the cost share of the i input. Two inputs are used in this study and one share function is obtained. Each input price and its time trend determine each share function.

The variable cost function (eq. 6) and one of the share functions (eq. 8) are estimated by 3SLS[3]. Since this model is a simultaneous equation model, the system estimation methods are applied.

3 Data

The definition of IT capital has yet to be precisely determined , and we will attempt such a definition here[4]. Several types of investment can be collected and aggregated to one variable named IT capital. Our definition generally follows that of Berndt and Morrison (1994) and that in Survey of Current Business. It encompasses investment in the following: (1) electric computing equipment, (2) telephones and telegraph equipment, (3) new telephone and telegraph facilities, (4) maintenance and repair of telephone and telegraph facilities, (5) communications (except radio and TV), (6) calculating and accounting machines, and (7) office machines (including typewriters). Based on the Input-Output Table (MITI), categories are selected and the amount of investment is aggregated. The nominal IT investment can thus be obtained. The depreciation rate in the USA is then applied to develop data on the real capital stock[5]. The deflator is the domestic final demand for each category of definition of IT capital, also from the Input-Output Table (MITI).

4 Results

[Table 1]

The estimated results of the parameters are shown in Table 1. Of the 18 parameters, 12 are significant. The Translog cost function can be applied to the model including that with IT capital.

[Table 2]

Table 2 presents the results of measuring the shadow price of IT capital. This shadow price is identical to the marginal productivity of the IT capital. The shadow price showed a decrease from the initial period up to 1992. The shadow price was at its lowest in 1992, but showed a slight increase in 1993 and 1994. The variation after 1989 was smaller than that prior to 1989.

There was a significant difference between the shadow price in the early measurement periods and in recent years. In reality, IT equipment was not affordable for individual consumers before 1985. The personal computer was created in the early 1980s, during a period when many businesses were still using mainframe computers. By contrast, personal computers are now seen in many households, as well as in businesses, as a result of the advent of Microsoft Windows after 1990. Mobile and cellular telephones are also widely used today. The reduction of the shadow price of IT capital can be attributed to such rapid changes in the availability of IT equipment, and this is clearly evident in our calculations for the shadow price.

The marginal productivity of IT capital was identical to the actual price of IT capital in the long-run equilibrium. In the short-run, the marginal productivity of IT capital was not identical to the actual price of IT capital. The ratio of the shadow value of IT capital to the actual price of IT capital indicates the efficiency in IT capital's investment. This value is generally the value of Tobin's Q, in spite of the difference of the model in the case of IT capital. There are many studies on the measurement of Tobin's Q in general capital. The value is ordinarily between 0.5 and 2 in general capital. In the USA, Morrison (1997) has conducted the only study to measure the Tobin ' s Q of IT capital. The results show that the value is low and is located in a narrower range around 1. In Japan, Shinjo and Cho (1998) applied Morrison's strategy with similar results to those of Morrison (1997). The increase of investment of IT capital is actually stronger than that of general capital; hence the low Q value is not natural. Our results differ from those of previous studies: our results for the measurement periods except 1990 and 1991 are significantly larger than those of Morrison (1997) and Shinjo and Cho(1998). Therefore, there is high investment incentive in most periods.

[Table 3]

We also analyzed the growth of labor productivity. The tables show the contribution of each input resulting in the growth of labor productivity. The growth of labor productivity is was analyzed to show the contribution of each input, technical progress, and TFP. The contribution of IT capital was the largest amount among all inputs prior to 1987. The contribution of both general capital and TFP growth were the largest among all inputs between 1988 and 1991. However, in recent years, it has been difficult to rank input. The contribution of labor has always been negative. Hence, the increase of the labor input leads to deterioration in labor productivity.

The years between 1988 and 1991 span the period of the so-called bubble economy in Japan. One of the characteristics of this bubble economy was aggressive investment among businesses in equipment and land. Therefore, the growth of the economy in this period depended on general capital. The output likewise showed a tremendous increase. Hence, the scale economy was evident during the bubble economy. The contribution of the TFP growth is a result of the scale economy. The contribution of IT capital was not as strong as these other factors. Further, with regard to the paradox between IT and productivity, we also identified the contribution of IT capital to labor productivity.

[Table 4]

We also sought to determine the contribution of inputs for the growth of output. The principle difference between methods that measure the contribution of output growth and those that measure labor productivity concerns the treatment of labor. The impact of IT capital is strongest in all factors before 1987.By contrast, the impact of IT capital is weakest in all factors in the bubble economy. The impact of both general capital and TFP are strongest. The contribution of labor is stronger than that of IT capital and weaker than that of both general capital and TFP. It is often said that IT capital plays a major role in the growth of output, and the results of this study prove IT capital's contribution to output growth. However, the contribution of IT capital is especially strong before 1987. It is important to note the contribution of other factors, and both general capital and TFP had a strong impact on output growth after 1989.

5 Concluding Remarks

We constructed a Translog cost function model, which included IT capital. Since the estimation result of the Translog cost function model is not problematic, it could be applied to a model that includes IT capital.

The shadow prices of IT capital decreased from the initial period up to 1991. The shadow price was at its lowest in 1991, and showed a slight increase in 1993 and 1994. There was a significant difference in the shadow prices between the beginning of the measurement periods and in recent years. There was a high investment incentive in most periods, and we determined the contribution of IT capital to labor productivity. Moreover, our results are consistent with the proposition that IT capital contributes to output growth.

Our future studies will employ a dynamic model to examine the interaction between IT capital, overall capital, and investment behavior. In addition, since these data are macro data, each industry will be analyzed in detail.

Footnote

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1) IT capital is defined to include computers, peripheral equipment, communications equipment, and other related equipment. The definition is essentially identical to that of high-tech capital in Berndt and Morrison(1992). Berndt and Morrison (1995) referred to information technology equipment as high-tech capital. The strict definition is explained here .

2) The impact of IT capital to labor is also investigated in Nakanishi(2002) using a Translog cost function.

3) The instrumental variables are two periods lagged variable of each variable.

4) See Nakanishi(2002).

5) An attempt was made to apply the depreciation rate of the electric machinery industry. That depreciation rate was the same as that used in Shinjo and Cho(1998). However, there was no difference.

References

[1] Brynjolfsson, E. and Hitt, L. M. (1998) "Beyond the Productivity Paradox: Computers are the Catalyst for Bigger Changes." *mimeo.*

[2] Brynjolfsson, E. and Hitt, L. M. (2000) "Beyond Computation: Information Technology, OrganizationalTransformation and Business Performance." *Journal of Economic Perspectives.* 14,23-48.

[3] Berndt, E. R. and Christensen, L. R. (1973) "The Translog Function and the Substitution of Equipment, structures and labor in U.S. Manufacturing 1929-68." *Journal of Econometrics* 1,81-113.

[4] Berndt, E. R. and Morrison, C. J. (1995) "High-tech Capital Formation and Economic Performance in U.S. Manufacturing Industries An Exploratory Analysis." *Journal of Econometrics* 65, 9-43.

[5] Denny, M., Fuss, M. and Waverman, L. (1981) "The Measurement and Interpretation of Total Factor Productivity in Regulated Industries, with an Application to Canadian Telecommunications." In *Productivity Measurement in Regulated Industries* edited by Thomas G. Cowing and Rodoney E. Stevenson. New York: Academic Press.

[6] Diewert, E. W. (1974) "Applications of Duality Theory." In *Frontiers of Quantitative Economics, vol. 2.* edited by Michel D. Intriligator and David A. Kendrics. Amsterdam: North-Holland.

[7] Gordon, R. J. (2000) " "New Economy" Measure up to the Great Innovations Past." *Journal of Economic Perspectives* 14, 49-74.

[8] Jorgenson, D. W. and Stiroh, K. (1995) "Computers and Growth." *Economics of Innovation and New Technology* 3, 295-316.

[9] Jorgenson, D. W. (2001) "Information Technology and the U.S. Economy." *American Economic Review* 91, 1-32.

[10] Kuroda, Y. (1995) "The Production Structure and Demand for Labor in Postwar Japanese Agriculture." *American Journal of Agricultural Economics* 69, 328-337.

[11] Lichtenberg, F. R. (1997) "The Output Contribution of Computer Equipment and Personal: A Firm-Level Analysis." *Review of Economics and Statistics* 79, 471-481.

[12] Morrison, C. J. (1997) "Assessing the Productivity of Information Technology Equipment in U.S. Manufacturing Industries." *Review of Economics and Statistics* 79,471-481.

[13] Nakanishi, Y. (2002) "Employment and IT Capital in Japan." *Applied Economics Letters* 13, 865-867.

[14] Oliner, S. D. and Sichel, D. E. (1994) "Computers and Output Growth Revised: How Big Is the Puzzle." *Brookings Papers on Economic Activity* 2,273-334.

[15] Reenen, J. V. (1997) "Employment and Technological Innovation: Evidence from U.K. Manufacturing Firm." *Journal of Labor Economics* 15,255-284.

[16] Seigel, D. (1997) "The Impact of Computers on Manufacturing Productivity Growth: A Multiple-Indicators, Multiple-Causes Approach." *Review of Economics and Statistics* 79, 66-78.

[17] Siegel, D. and Grilicches, Z. (1992) "Purchased Services, Outsourcing, Computers, and Productivity in Manufacturing." In *Output Measurement in the Service Sectors* edited by Zvi Grilicches. Chicago: University of Chicago Press.

[18] Shinjo, K. and Cho, S. (1988) "The Analysis of Productivity Effects of Information Capital: Comparison between Japan and US.." *Discussion Paper No.9811, Kobe University* (in Japanese)

[19] Shinosaki, A. (1998) "The Empirical Analysis of Information Investment in Japan." *National Economy* 161, 1-25. (in Japanese)

[20] USDC. (1998) "The Emergence of Digital Economy." *Washington, USDC*

[21] USDC. (1999) "The Emergence of Digital Economy II." *Washington, USDC*

[22] Varian, H. R. (1984) *Microeconomic Analysis: Second Edition.* New York: W.W. Norton.

Table 1: Paramete Estimates

Parameter	*Estimate*	*t-statistic*
α_0	-71.822	-0.265
α_N	4.617	6.752
α_K	-3.617	-5.290
α_{KN}	-0.160	-24.424
α_{KK}	0.160	24.424
α_{NN}	0.160	24.424
α_{NY}	-0.339	-4.121
α_{KY}	0.339	4.121
α_{HY}	0.688	0.358
α_Y	23.712	0.369
α_{YY}	-2.776	-0.363
β_{NH}	0.038	1.788
β_{KH}	-0.038	-1.788
β_H	-6.715	-0.419
β_{HH}	-0.120	-0.244
β_{Ht}	0.000	-1.673
t	0.013	7.363
Dummy	-0.016	-3.485

Note:Dummy 0 75-85, 1 86-95

Table 2: Shadow price and q

year	*shadow price*	*q*
78	39.931	36.324
79	30.714	23.630
80	24.779	16.725
81	20.196	11.352
82	17.518	14.727
83	15.243	13.198
84	12.198	11.694
85	8.988	9.212
86	7.739	9.054
87	5.605	7.158
88	3.584	4.807
89	2.411	2.911
90	1.874	1.912
91	0.936	1.371
92	0.794	1.278
93	1.243	2.147
94	1.227	2.211

Table 3: labor productivity

year	N	K	IT	TFP
78	-2%	26%	71%	5%
79	-3%	37%	54%	12%
80	-3%	37%	74%	-8%
81	-6%	16%	113%	-23%
82	-11%	46%	111%	-45%
83	-14%	67%	70%	-23%
84	-2%	64%	35%	3%
85	-4%	35%	31%	38%
86	-2%	8%	85%	9%
87	-1%	20%	46%	35%
88	-4%	35%	27%	41%
89	-8%	37%	22%	49%
90	-11%	51%	19%	42%
91	-22%	51%	16%	55%
92	46%	69%	-38%	22%
93	13%	-19%	-49%	155%
94	0%	96%	34%	-30%

Table 4: GDP

year	N	K	IT	TFP
78	9%	24%	64%	4%
79	9%	33%	48%	10%
80	7%	33%	67%	-7%
81	14%	13%	91%	-19%
82	24%	31%	76%	-31%
83	29%	41%	44%	-14%
84	5%	60%	32%	3%
85	12%	30%	26%	32%
86	10%	7%	75%	8%
87	6%	19%	42%	33%
88	13%	29%	23%	34%
89	20%	28%	16%	36%
90	21%	36%	13%	30%
91	34%	28%	9%	30%
92	158%	-76%	41%	-24%
93	-106%	-45%	-117%	368%
94	-1%	97%	35%	-31%