E C O N O M I C S   B U L L E T I N

Empirical evidence of externalities of IT capital in Japan

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Abstract

We tested for the presence of IT capital externalities, based on a translog cost function framework applied to 10 Japanese manufacturing industries for the years 1974 to 1993. This framework allows us to test whether investment in IT capital in other industries reduces costs in a given industry. Our findings strongly suggest that externalities are prevalent in these manufacturing industries.

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1 Introduction

We empirically studied the externalities of Information Technology (IT) capital by analyzing whether an industry's IT capital contributes to the production of other industries and whether it contributes to the production of the IT industry itself.

Investment in information technology as we know it today is a recent phenomenon, starting only in the late 1960s and early 1970s in most industries and increasing in the 1990s as technology progresses in leaps and bounds. Berndt and Morrison's 1995 study did not verify the contribution of IT capital to output or productivity. More recent studies (Brynjolfson and Hitt (2000) and Jorgenson (2001)) have empirically supported the contribution of IT capital to output. Other studies have shown that investment in general capital is known to contribute to output and productivity growth (Jorgenson (2001)). However, the impact of IT capital may be different from that of general capital. One of the essential differences between general capital and IT capital brings about positive externalities (Shapiro and Varian (1998)).

Examples of externalities can be found in studies of research and development (R&D) stock (Bernstein and Nadiri (1989), Morrison and Siegel (1995), and Nakanishi (2002)). While externalities have been in general analyzed previously, no other study, except that by Morrison and Siegel (1997), has investigated the externalities of IT capital.

One reason for this lack of research is the unavailability of data. It is necessary to gather unaggregated instead of aggregated data to conduct empirical studies on the externalities of IT capital. The availability of such data is low because IT capital has a relatively short history.

A study by Morrison and Siegel (1997) is the only one that measures the externalities of IT capital empirically. In their report, they analyzed R&D capital, human resource capital, and IT capital and measured the elasticity of cost with respect to IT capital externalities at -0.1. Their preliminary study of the externalities of IT capital has made them pioneers in this field. However, they were not able to make a clear distinction between the effects of investment in an industry's own IT capital and the externalities of investment in IT capital in general. Our study constructs models in which both an industry's own IT capital and the externalities of IT capital are independently incorporated, which allows us to consider their different impacts. Our analysis focuses on ten different manufacturing industries.

In the present study, we construct IT capital data by industry, and the translog cost function model is applied to analyze the data. Thus, we preserve theoretical consistency preserved in this empirical analysis. The measurement results on all sample periods are also obtained. Because existing studies have investigated R&D capital externalities, we are able to make comparisons with such studies as well as with that of Morrison and Siegel (1997).

Our presentation is organized as follows. A description of the model is presented in Section 2. Data and the estimation methods are presented in Section 3. Empirical results are presented and discussed in Section 4. The conclusion is presented in Section 5.

2 Model

We employ a duality approach using a cost function. The following variable cost function is employed here.

$$C = C(P_K, P_N, P_{IT}, X_{ITE}, Y, t) \tag{1}$$

where Y denotes output; P_i is the price of input i, with i representing capital stock (K), labor (N) and IT stock (IT), respectively; X_{ITE} is input of IT capital externalities and C is the cost. Cost is the sum of capital, labor, and IT capital costs and also a function of each input price, IT capital externalities, and a time trend. Because a theoretically derived cost function cannot be estimated directly, the functional form of the cost function is determined. A translog function for the cost function is employed as follows:

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

The above translog cost function is the most generalized of several cost functions that have been presented in recent years. There are no a priori restrictions on the model and in particular, the elasticity of substitution is not restricted. Several indices have also been obtained by observation, so all values can be compared.

This cost function is derived under maximization behavior, and thus the cost function requires a homogeneous degree-of-one restriction on input prices. Thus, the following condition applies:

$$\sum_i \alpha_i = 1, \sum_i \alpha_{ij} = 0, \sum_j \alpha_{ij} = 0,$$
$$\sum_i \beta_{i\,ITE} = 0, \sum_i \alpha_{i\,Y} = 0, \sum_i \beta_{i\,t} = 0, \alpha_{ij} = \alpha_{ji}.$$

Using Shepherd's lemma, the following share function for each input is obtained.

$$S_i = \frac{P_i X_i}{C} = \frac{\partial \ln C}{\partial \ln P_i} \tag{3}$$

where S_i is the cost share of input i. In this article, four inputs are employed. Three share functions are obtained, each of which is determined by the relevant input price and time trend.

3 Data

The cost function (2) and two share functions (3) are estimated by Seemingly unrelated regression (SUR). In this simultaneous equations model, system estimation methods are applied. Data from ten Japanese manufacturing industries between 1974 and 1996 have been used as panel data for the estimation[1].

The definition of IT capital has yet to be precisely specified, and we will attempt such a definition here. Several types of investment can be collected and aggregated into one variable named IT capital. Our definition generally follows that of Berndt and Morrison (1994) and that in the Survey of Current Business. It encompasses investment in the following: (1) electronic 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 (Ministry of International Trade and Industry (MITI)), categories are selected and the amount of investment in each of the enumerated areas is aggregated. Nominal IT investment can thus be obtained. The depreciation rate in the United State

[1] See Nakanishi (2002)

is then applied to develop data on real capital stock. An attempt was made to apply the depreciation rate of the electric machinery industry. The depreciation rate was the same as that used in Shinjo and Cho (1998). The deflator is the domestic final demand for each category of IT capital, also from the Input-Output Table (MITI). Statistics for Order Received for Machinery (Cabinet Office) were applied to convert the IT data by industry. Our research uses total IT capital from all other industries to represent IT externalities; thus, we identify the existence of IT externalities not for particular industries but for manufacturing industries as a whole[2].

The manufacturing industry categories are as follows: food, apparel, pulp and paper, chemical products, petroleum refining and related industries, iron and steel, metals, general and electric machinery, transport equipment, and miscellaneous manufacturing.

4 Results

Table 1 shows the estimation results of parameters of the manufacturing industries. Twenty-one of 27 parameters are significant at a level of 10 percent. Compared with the results of previous analyses, our translog cost function is well suited for this application. While various analytical results emerged, all are based on this model parameter, which demonstrates the reliability of the results. All seven parameters that are related to the IT externalities[3] are significant in the manufacturing industries, thus reflecting the existence of IT externalities in Japanese manufacturing industries.

Table 2 shows the values of the elasticity of cost with respect to IT externalities, which are examined as follows. The sign of the elasticities must remain negative according to microeconomic theory. Furthermore, if the externalities of IT capital increase costs, it would be rational not to invest in any IT capital. All values of elasticity of cost with respect to IT externalities show a negative sign and are thus consistent with the tenets of microeconomic theory.

The following six industries had nearly identical values of elasticity of cost with respect to IT externalities: petroleum, food, chemicals, metals, transport equipment, and miscellaneous, and can be referred to as industries with high elasticities. The following four industries also had similar values: apparel, pulp, iron and steel and machinery, all showing low elasticities. The differences between

[2] See Nakanishi (2002)

[3] Those are β_{ITE},β_{ITEITE},β_{NITE},β_{KITE},β_{ITITE},β_{ITET} and β_{ITEY}

high and low elasticity ranges among the examined industries is large. The elasticities of cost of with respect to IT externalities all industries grew, peaking in 1988 and 1989. However, their elasticities have shown little growth since 1990. The decreased growth in IT externalities corresponds to a recession in the macro economy.

We compared our results with those of previous studies. Our values of elasticity of cost with respect to IT externalities are apparently higher than those of the study by Morrison and Siegel (1997). All of the values in the results from Morrison and Siegel (1997), including the R&D externalities as well as IT capital, are low, and they may reflect an underestimation. There are several previous studies on the measurement of elasticity of cost with respect to R&D externalities. The results are mostly impacted by one specific industry that has a strong influence. The elasticity of cost with respect to R&D externalities is -0.5 or -0.6 in a study by Odagiri and Kinukawa (1997). Our results are a measurement of not one specific industry but of all other industries, with figures from the examined industry being excluded. Thus, our results are stronger than those for R&D externalities alone.

Table 3 shows the elasticity of labor with respect to IT externality. Since all of the values are negative, an increase in the IT externality brings about a decrease in labor usage. The progressive substitution of IT capital for labor is becoming more apparent. The elasticity of the machinery industry is the highest. Elasticities of both the food and apparel industries are also high. However, the elasticity of both the petroleum and chemical industries are rather low. Three categories can be identified. The first is the food, apparel, petroleum and iron and steel industries, in which the elasticity is increasing over the period examined. The second is relatively consistent, despite some fluctuations; it includes the pulp and paper, metals, transport equipment and miscellaneous industries. The third is the chemical and machinery industries, in which the elasticity is decreasing.

Table 4 shows the elasticity of an industry's own IT capital with respect to IT externality. All values are positive. This means that an increase in IT externalities brings about an increase of its own IT capital. The elasticity scenario is highest in the metals industry. The elasticity of both pulp and iron are also high. The elasticity of the miscellaneous industry is the lowest, and likewise, the elasticity of the chemical and petroleum industries are also low. Each industry showed consistent characteristics over the period examined. While their elasticity is decreasing, the elasticity increased slightly between 1990 and 1996.

5 Concluding Remarks

We investigated the effects of IT externalities in Japanese manufacturing industries. The main method of analysis employed a translog cost function model under duality, with the following main findings.

The parameters for the IT externalities were significant in all cases, demonstrating their contribution. All values of elasticity of cost with respect to IT externalities show the negative sign, which is consistent with microeconomic theory. IT externalities reduced costs in all industries during most of the observation period. The elasticity of all industries showed an increase, peaking in 1988 and 1989. The values in our results are clearly higher than those of Morrison and Siegel (1997). All of the values for elasticity of labor with respect to IT externalities are negative. Therefore, the increase in the IT externalities results in a decrease in the use of labor, and a progressive substitution of IT capital for labor is clearly evident.

This is a static model, but given the focus on investments behavior, an expansion to a dynamic model is natural. Of course, government policies are also important to consider in these analyses. Such expansions of this model will be investigated in future studies.

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Table 1: Parameter Estimates

Parameters	*Estimates*	*t-statistics*	*Parameters*	*Estimates*	*t-statistics*
α_0	-186.272	-2.533	β_{ITE}	-28.1304	-2.08296
α_N	-.450582	-.900568	β_{ITEITE}	-2.43390	-1.91075
α_K	1.39434	2.86234	β_{NITE}	-.135591	-2.78372
α_{IT}	.056245	1.60093	β_{KITE}	.121833	2.56976
α_{KN}	-.875586E-02	-.964124	β_{ITITE}	.013758	4.37457
α_{ITN}	.692797E-03	.767806	β_T	6.04111	2.44918
α_{ITK}	-.306892E-02	-1.82333	β_{ITET}	.460808	2.00914
α_{NN}	.806307E-02	.863854	β_{NT}	.020372	2.38215
α_{KK}	.011825	1.30962	β_{KT}	-.018788	-2.25708
α_{ITIT}	.237612E-02	1.62013	β_{ITT}	-.158407E-02	-2.12717
β_{YT}	.075653	2.34586	α_{YY}	.116379	.696430
β_{TT}	-.096566	-2.31934	α_{NY}	.026833	1.83774
α_{KY}	-.032538	-2.28823	β_{ITEY}	-.349390	-1.83654
α_{ITY}	.570493E-02	5.75282			

Table 2: Elasticities of Cost with respect to IT Externalities

year	*Food*	*Apparel*	*Pulp*	*Chemical*	*Petroleum*
1980	-2.570	-2.133	-2.109	-2.321	-2.409
1985	-2.602	-2.051	-2.098	-2.439	-2.458
1990	-2.621	-2.066	-2.196	-2.556	-2.485
1995	-1.325	-0.767	-0.874	-1.295	-1.156
year	*Iron and Steel*	*Metals*	*Machinery*	*Transport Equipment*	*Miscellaneous*
1980	-2.205	-2.495	-2.064	-2.460	-2.475
1985	-2.235	-2.486	-2.048	-2.471	-2.463
1990	-2.326	-2.594	-2.235	-2.565	-2.526
1995	-1.032	-1.293	-0.987	-1.288	-1.168

Table 3: Elasticities of Labor with respect to IT Externalities

year	*Food*	*Apparel*	*Pulp*	*Chemical*	*Petroleum*
1980	-1.228	-1.722	-1.153	-1.171	-0.791
1985	-1.811	-1.887	-1.123	-1.117	-0.787
1990	-1.680	-1.893	-1.052	-0.939	-0.839
1995	-1.803	-2.011	-1.137	-0.926	-0.898
year	*Iron and Steel*	*Metals*	*Machinery*	*Transport Equipment*	*Miscellaneous*
1980	-1.287	-1.629	-5.790	-1.626	-1.682
1985	-1.366	-2.014	-3.322	-1.855	-1.620
1990	-1.381	-1.924	-2.564	-1.431	-1.465
1995	-1.507	-1.715	-2.640	-1.572	-1.721

Table 4: Elasticities of Own IT Capital with respect to IT Externalities

year	*Food*	*Apparel*	*Pulp*	*Chemical*	*Petroleum*
1980	1.617	2.069	3.141	1.114	0.641
1985	1.222	0.932	1.855	0.587	0.500
1990	0.842	0.547	1.147	0.345	0.330
1995	1.423	0.734	1.955	0.515	0.650
year	*Iron and Steel*	*Metals*	*Machinery*	*Transport Equipment*	*Miscellaneous*
1980	3.366	2.770	3.013	1.395	1.136
1985	1.920	1.601	1.328	0.754	0.620
1990	1.272	1.252	0.717	0.403	0.334
1995	1.869	1.922	1.005	0.638	0.468