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한국 제조산업의 IT투자 대비 경제적 효과 실증분석

고중걸* · 한현수**

Empirical Analysis for Korean Manufacturing Firm's IT Investment Effect to Economic Performance

Joong-Gul Ko* · Hyun-Soo Han**

■ Abstract ■

As implied by the terms of IT productivity paradox, measuring the information technology contribution to economic performance has been one of the challenging issues to both policy makers and business professionals. As such, diverse attempts with sophisticate analyses have been reported in the literature to analyze the effect of IT contributions. In this paper, we follow Growth Accounting Method to measure the IT contribution effect to manufacturing firm's economic performance in Korea. Various regression methods and statistical analyses are applied with fourteen years of industry panel data. Using the Cobb-Douglas function, time lag analysis is made to understand IT effect to economic growth. Instead of capturing data from individual firm, industry level data from the National Statistics Bureau is used for IT capital, non-IT capital, and so on. Statistical analysis following the panel unit test and panel co-integration test was performed to reveal the exact effect of IT contribution to economic performance. Empirical testing results for non-stationary nature of IT investment effect are reported as well as IT contribution to manufacturing industry's economic performance.

Keyword : IT Productivity Paradox, Growth Accounting Method, Manufacturing Industry

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* KT마케팅연구소 마케팅전략연구팀
** 한양대학교 정보통신대학 정보기술경영전공(교신저자)

1. Introduction

With the rapid development of information technologies along with the growth of information technology industries, opportunities and challenges are given to the firms in the senses of exploiting IT as a critical means to improve productivity. While old industrial society started with the mechanical technology using power, the power of knowledge-information society comes from information technology that brings about innovative changes in all sectors of a country. Recently, Korean information technology industries (IT industries) have taken an increasingly large portion in our national economy in terms of GDP, facility investment, and export-import volumes. Also, all the other industries such as manufacturing, finance, and service areas have been their investment in IT to capturing competitive advantages through BPR, strategic information system development, and so on.

Many managers and researchers have been interested in determining the validity of the belief that IT has a significant positive on organizational performance. Many managers and researchers have been interested in determining the validity of this belief, and various studies have been conducted. Some previous ones have attempted to examine the contributions of IT to output but have failed to show any evidence of IT impact on productivity in spite of the increased IT investment [13], and so the "IT productivity paradox" has been the issue debated by IS researchers for the past decade [1, 2, 5, 9, 16, 19].

The primary focus of this study is to measure IT contributions to the productivity improvement in domestic industry, especially in domestic manufacturing industry. As has been addressed in numerous literatures on IT productivity paradox, the measurement of IT contribution to firm performance has been known to be very difficult. Since the financial performance of the firm is affected by many managerial and environmental factors, we used macro level data such as IT capital stock, non-IT capital stock, and so on. Using various statistical methods from the literatures, theoretical rationale and causal links are developed to explain the effects of IT on the manufacturing industry. Growth Accounting Method is followed to verify if IT have positive or negative effects on the manufacturing industry.

One of the distinguishing features of our study compared to other IT productivity paradox research is that we approached the issue from macro economic perspective. As has been comprehensively reviewed in Osei-Bryson K & M. Ko [16], most literatures used firm level data sampling, for example, Weill [20] used the data set of 33 valve manufacturing firms during 1982 ~1987, and Loveman [13] collected the data from 60 manufacturing business units during 1978~1984. Those research focuses are made to the organizational level performance enhancement gained from IT system development and process restructuring. In this paper, we used macro level industry data refined from large data set of National Statistical Bureau. The advantage of using industry level data is that various effects blurring the IT contribution effect to performance can be minimal trough large data aggregation. Internal and external environmental factors as well as measurement correctness, can more significantly bias the causal effect in limited sample cases. Our analysis also put more rigorous attention on time lag effects in measuring causal relationship between IT investment and economic growth.

In the next section, we briefly reviewed IT productivity literatures that are related to our macro level approach. In section 3, our research model is suggested with various statistical techniques in detail. The data capturing procedures and statistical testing results are reported in section 4. And wrap-up comments are made in section 5.

2. Literature survey

Oliner and Sichel [15] tries to estimate the contribution of IT industries to the labor productivity of whole economy by using an approach on the basis of the growth of the capital deepening of computer hardware, software, telecom equipment, other capitals, plus the growth of labor quality and MFP (Multi-Factor Productivity). Also, they divided the MFP of whole economy into that of each sector in the IT and non-IT industries to draw the indirect effects of IT in the industries using IT. The work of Oliner and Sichel [15] is worthwhile in that they quantify the contribution of IT industries to the whole economy and approach the labor productivity growth in terms of capital deepening, labor quality and MFP growth. They argue that about 70% portion of labor productivity growth was resulted from IT industries and remaining 30% portion was created by other industries.

Jorgenson and Stiroh [8] put forward their arguments on the two fronts. First, they showed that recent increase of the growth rate of labor productivity at the aggregate level is mainly resulting from the growth of MFP rather than that of capital deepening. Second, they break down the growth of MFP into each industry and examine the contribution of each industry to the MFP of whole economy including far-reaching impact from the expansion of IT. Similar to their approach, Jorgenson and Stiroh attempted to analyze MFP and to investigate the contribution of each industry and overall economy. The existence of partial spreading effects was proved. However, they do not provide any explanation on the labor productivity growth caused by cyclical factors, which is the most basic argument by Gordon while Oliner and Sichel [15] does not.

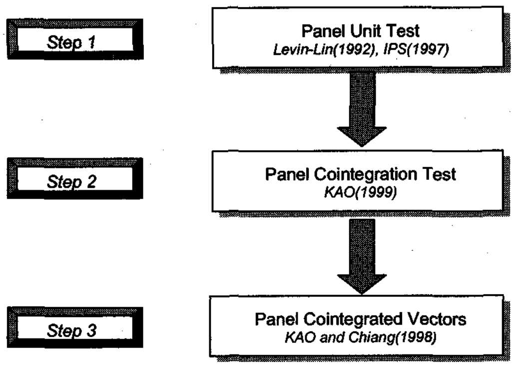
On the other hand, Gordon [4] expressed negative attitude toward the far-reaching impact of IT to the economic growth. His argument is that present US economy is standing at the starting point of the golden age of long-term prosperity stemming from the fundamental change of economic paradigm. Explaining the various contribution factors like cyclical economic upturn, acceleration of the technologies producing computer hardware and technological changes in the factories producing durable goods, he concludes that use of computer has made unexpectedly low contributions to economy. In other words, he proves that the effect of IT on productivity is small, i.e. boosting of US economy has been made entirely by the durables manufacturing industry [4]. He pointed out that recent labor productivity enhancement in the whole US economy is mainly effected only by the labor productivity of the IT industries. And, the growth of labor productivity in other industries is mainly due to the cyclical factors. The weakness of this approach is that other industries are regarded as one sector. There can be a sector showing productivity growth effected by IT or cyclical factors, and vice versa. Other literatures, for instance, Loveman [13] conducted micro-level study to show that return on investment from IT is significantly lower than that of old economy. Morrison and Berndt [14] report that USD 1 invested in IT produces only a return of USD 0.8 [21].

3. Methodology

In order to test the IT investment effect to firm performance, we used the following Cobb-Douglas production function that has been used as a standard economic production model. Our model distinguishes the capital as IT-capital and non-IT capital. The notation is defined as follows ; Y=output, k=capital inputs other than IT related capital, L=labor input, IT=IT related capital input, A=total factor productivity (TFP), and α and β =parameters showing partial efficiency of each factor.

$$Y_{it}=f(k_{it}, L_{it}, IT_{it})$$
$$Y_{it}/L_{it}=Ak_{it}^{\alpha}IT_{it}^{\beta}$$
$$\ln y_{it}=\ln A+\alpha\ln k_{it}+\beta\ln IT_{it}$$

Traditional GAM (Growth Accounting Method) is employed as the fundamental framework, which measures the quantitative effect of IT to firm's performance from the volume-based perspective such as economic growth rate, capital stock, etc. Since GAM lacks to reflect the qualitative nature of the IT contributions to firm's economic performances, we complement the GAM approach using DOLS (Dynamic OLS) and FM-OLS (Fully Modified OLS), as well as classical OLS used from GAM. In case the causal relationship among the economic variables are non-stationary, then simple OLS based GAM will always cause the bias on the parameters. Since traditional OLS applications to the model will make α and β biased because it works only for non-stationary case, traditional OLS must not be used if Y_{it} & k_{it} & IT_{it} equals I(1). As such, as illustrated in the [Figure 1], we perform three step analyses to correctly adjust the parameters consisting the model. The panel test in the [Figure 1] is essential in this regard.



[Figure 1] Statistical analysis procedure

3.1 Panel unit test

Panel unit test is performed to verify the stationary of panel data. It has been used recently in the empirical testing the contribution of IT capital to national economy. If the empirical testing result shows non-stationary nature of the model, successive panel cointegration test and panel cointegration coefficient estimation is followed. The empirical analysis methods for panel unit test used in this study are LL Test [12] and IPS Test [6].

3.1.1 LL panel unit root test(Levin and Lin Test)

With the assumption that each panel has identical primary autocorrelation coefficient, the following formula (1) examines the non-stationary of the data. It is known to increase the Test of Power complementing traditional ADF unit root test, which is the traditional test method to verify panel data.

$$\Delta w_{i,t} = \mu_i + \beta_i w_{i,t-1} + \sum_{k=1}^{p} \theta_{i,k} \Delta w_{i,t-k} + \gamma_i t + \varepsilon_{i,t}$$
$$i = 1, 2, \cdots, N, \ t = 1, 2, \cdots, T \quad (1)$$

In formula (1), w_{it} represents the output and traditional capital stock of each industry, labor input and IT capital stock. In the above model, the null hypothesis and alternative hypothesis in the LL panel unit root test are set as following (2). In these hypotheses, normal OLS $\hat{\beta}$ has the asymptotic distribution of (3). In case of equation (3), the convergence speed of OLS coefficient to true parameters is known to be more efficient.

$$H_0: \beta = 0, \ H_a: \beta_i \exists i \ \ s.t \ \ \beta_i < 0 \quad (2)$$
$$T\sqrt{N}\hat{\beta} \Rightarrow N(0,2), \ T, N \rightarrow \infty$$
$$t_\beta \Rightarrow N(0,1) \quad (3)$$

3.1.2 Panel unit root test (Im, Pesaran and Shin Test: IPS Test)

While LL test enhances the Test of Power with the assumption of each cross-sectional analysis unit's homogeneity, IPS test begins with acknowledging their heterogeneity. IPS test analyzes the non-stationary of data by verifying average panel unit test values. The testing formula is expressed as the same formula (1) in the LL test. The null hypothesis and alternative hypothesis are set differently as the following (4).

$$H_0: \beta_i = 0, \ \forall i, \ H_a: \exists i \ \ s.t \ \ \beta_i < 0. \quad (4)$$

Statistics used for verifying hypotheses are IPS t-bar estimators. They are expressed as the average of normal Dickey-Fuller τ statistics.

$$\bar{t} = \frac{1}{N} \sum_{i=1}^{N} \tau_i, \ \tau_i = \frac{\hat{\beta}}{\hat{\sigma}_{\beta_i}} \quad (5)$$

If the t statistics are independent each other, IPS statistics have following theoretical standards t-bar statistics as (6) in large sample. Using Monte Carlo simulation, Im, et. al [6] proved that $\Gamma_{\bar{t}}$ has the following variances of distribution (7) if the average and distribution of the above statistics are adjusted.

$$\Gamma_{\bar{t}} = \frac{\sqrt{N}(\bar{t} - E(\tau_i | \beta_i = 0))}{\sqrt{var(\tau_i)|\beta_i = 0}} \quad (6)$$

$$\lim_{n\rightarrow\infty, \ t\rightarrow\infty} \Gamma_{\bar{t}} \Rightarrow N(0,1) \quad (7)$$

3.2 Panel cointegration test

Since the nature of the model will necessarily shows non-stationary, we test Engle and Granger [3] cointegration relation. In our study, panel ADF (Augmented Dickey-Fuller) test posed by Kao [10] is used. This test model is formalized as the following formula (8), where, Y_{it} is a non-stationary variable of invariable output of each industry, and X_{it} is a vector variable for input factor. Note that all variables are logarithmic transformation.

$$Y_{i,t} = \alpha_i + X_{i,t}\beta_i + \omega_{i,t} \quad (8)$$

$$\hat{\omega}_{i,t} = \rho \hat{\omega}_{i,t-1} + \sum_{j=1}^{p} \eta_i \Delta \hat{\omega} + \upsilon_{i,t} \quad (9)$$

The error term of the equation (8) is used to test the panel ADF unit root against error terms. In this case, test statistics ADF-t is obtained as the following formula (10).

$$ADF_t = \frac{t_{adf} + (\sqrt{6N}\hat{\sigma}_\upsilon / 2\sigma_\upsilon)}{\sqrt{(\hat{\sigma}_{0,\upsilon}/2\hat{\sigma}_\upsilon^2) + (2\sigma_\upsilon^2/10\sigma_{0,\upsilon}^2)}} \quad (10)$$

Using the equation (8), long-term efficient covariance estimations of $\hat{\sigma}_v^2$ and $\hat{\sigma}_{0v}^2$ are calculated. The test statistics will follow standard normal distribution in case of large sample. If null hypothesis is rejected, we can conclude that the above equation has long-term cointegration relation.

We also used Pedroni's cointegration test [17], which assumes observation data heterogeneity. For this test, we use Phillips and Ouliaries [18] statistics represented in formula (11), where $\lambda_i = \frac{1}{2}(\hat{w}_i^2 - \hat{s}_i^2)$, $\hat{w}_i^2$ and $\hat{s}_i^2$ uses the covariance of the equation (9). It uses average value of the statistics of cointegration test of each cross-sectional unit.

$$\hat{Z}_\rho = \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \frac{\hat{\omega}_{i,t-1}\Delta\hat{\omega}_{it} - \lambda_i}{\sum_{t=1}^{T} \hat{\omega}_{i,t-1}^2} \right) \tag{11}$$

3.3 Panel cointegration vectors

After passing through the above procedures, Panel Cointegration Vector is obtained for DOLS and FM-OLS estimation. To find the panel cointegration coefficient, we followed Kao and Chiang [11] method. The method suggests the following three panel estimation procedures to analyze cointegration relation for non-stationary panel data. From the equation (8), OLS-bias-adjusted estimator is calculated as (12).

$$\beta_{OLS} = \left[\sum_{i=1}^{N} \sum_{t=1}^{T} (x_{i,t} - \bar{x}_i)(x_{i,t} - \bar{x}_i)' \right]^{-1} \left[\sum_{i=1}^{N} \sum_{t=1}^{T} (x_{i,t} - \bar{x}_i)(y_{i,t} - \bar{y}_i)' \right] \tag{12}$$

The equation (12) can correct the bias caused by the small sample size of the OLS model. Further the following FM-OLS of equation (13) can more effectively correct the possible bias from small sample size, which has been improved from the equation (12). In equation (13), $\bar{y}_{it}^+$ represents the modified variable to correct time series endogeneity of variable y, and, $\Delta_{\varepsilon\mu}^+$ is the variable introduced for correcting serial correlation.

$$\beta_{FM-OLS} = \left[\sum_{i=1}^{N} \sum_{t=1}^{T} (x_{it} - \bar{x}_i)'(x_{it} - \bar{x}_i)' \right]^{-1} \left[\sum_{i=1}^{N} (\sum_{t=1}^{T} (x_{it} - \bar{x}_i)'\bar{y}^+ - T\Delta_{\varepsilon\mu}^+) \right]^{-1} \tag{13}$$

By normal panel method, and the formula (14) shows using DOLS estimator for analyzing the stationary data. Kao and Chiang [11] show that it is possible to obtain cointegration estimation coefficient by estimating the equation (8). The t value for testing significance of cointegration coefficient under DOLS method has the following asymptotic distribution (15). In this case, cointegration estimation coefficient t has the normal distribution, as (16), in the null hypothesis on β (i.e. $\beta_i = 0$).

$$y_{i,t} = \alpha_i + x_{i,t}\beta + \sum_{j=-q_1}^{q_2} c_{i,j}\Delta x_{i,t+j} + \varepsilon_{i,t} \tag{14}$$

$$t_{DOLS} = \frac{\sqrt{N}T}{s}(\bar{\beta} - 1) \tag{15}$$

$$t_{DOLS} \Rightarrow N(0,1) \tag{16}$$

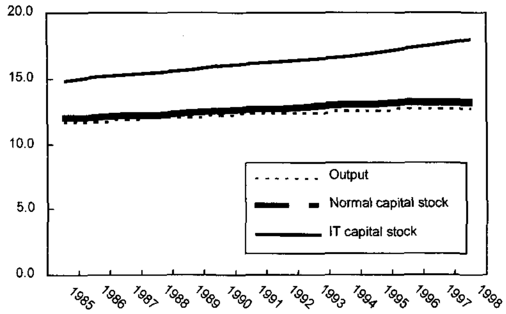
There are differences in adjusting bias among three estimation methods of OLS, DOLS, and FM-OLS. While the error terms of those three follows standard normal distribution, the average error term from large sample is not 0 in case of panel OLS method. DOLS and FM-OLS can correct it using panel cointegration vector.

4. Empirical analysis

4.1 Data collection

We used the Korea National Statistics data of Manufacturing Sector for the number of employees, capital stock, IT capital stock, output in sales amount. The period used for this research is collected from 1985 and 1998. To get the most correct figure of IT stock investment data, tangible fixed IT assets are categorized as per the IT industry stock classification standards of IT equipment, IT services, and software. The data for sub-category stocks are calculated through aggregation of investment data organized in detail level subcategories in Informatization Statistics from KNCA (Korea National Computing Agency), Inter-industry Analysis Table from Korea Bank, and IT industry Statistics from Korea Statistics Bureau. IT equipment stock data are aggregated from subcategories of computer and peripherals, network, and signal processing. IT services stock include the telecommunications investment, and software investment includes the items of data processing and databases.

The regression periods are covering from 1985 to 1999, which is set as prior and posterior 5 years from the base period of 1990 and 1995 during which inter-industry analysis fixed asset tables are formalized. [Figure 2] illustrates aggregated data for tree core variables of output, IT capital stock, and non-IT stock. All variables used are real prices translated by constant prices in 1990, and all data is natural logarithmically transformed. In [Figure 2], we note that three core variables are increasing with consistent trend for the period.



[Figure 2] Long-term trends curve for the variables

4.2 Statistical testing result

As illustrated in the <Table 1> and <Table 2>, the differences are revealed between LL test and IPS test in the sense of stationary characteristics of LL test and non-stationary characteristics of IPS test. It explains that the Test of Power is stronger in IPS test compared to LL test. The analysis is performed for two scenarios, the one is to assume the existence of common trend curve, and the other is not. For each scenario, those three rows show the testing results for the variables of output, non-IT stock, and IT-stock, each respectively. The overall p values for the common trend curve existence scenario is far less than non-trend curve assumptions, and that the further analysis is continued with common trend curve.

<Table 3> reports a long-term cointegration relation between the three independent variables, IT capital stock, non-IT capital stock, and labor. It shows that there is a long-term cointegration relation between dependent variable and independent variables. In case of Kao ADF-t test, 2Lag case shows the relation, and 1Lag case from Pedroni estimation method. As a result, there exist a long-term common trend between

the independent variables and dependent variables, while those three independent variable are non-stationary variables (i.e. I(1)). It means that regression analysis of independent variables against dependent variables has no risk of spurious regression problem.

〈Table 1〉 LL test results

Period	Scenario	1Lag	2Lag	3Lag
1985-1998	With common trend curve	20.11765 (0.00000)	47.49630 (0.00000)	65.10970 (0.00000)
		21.73331 (0.00000)	29.90721 (0.00000)	231.86359 (0.00000)
		17.44159 (0.00000)	22.96411 (0.00000)	42.38387 (0.00000)
	Without common trend curve	1.25961 (0.10391)	1.43220 (0.07604)	0.48656 (0.31329)
		-1.02043 (0.15376)	-6.33302 (0.00)	2.68112 (0.00367)
		4.76011 (0.00000)	3.74008 (0.00009)	2.19015 (0.01426)

Note) ( ) : p-value

〈Table 2〉 IPS test results

Period	Scenario	1Lag	2Lag	3Lag
1985~1998	With common trend curve	-1.25124 (0.10542)	-2.16989 (0.01501)	-1.60395 (0.05436)
		0.79746 (0.21259)	-2.03366 (0.02099)	-2.06940 (0.01925)
		4.14273 (0.00002)	4.08421 (0.00002)	0.10428 (0.45847)
	Without common trend curve	1.99616 (0.02296)	1.79544 (0.03629)	1.96807 (0.02453)
		3.12796 (0.00088)	1.49925 (0.06690)	2.02647 (0.02136)
		8.30734 (0.00000)	6.94114 (0.00000)	6.12888 (0.00000)

Note) ( ) : p-value

〈Table 3〉 Cointegration relation test result

Period	Estimation method	1Lag	2Lag	3Lag
1985~1998	Kao ADF t test	-0.6223 (0.2669)	-0.9842 (0.1125)	0.4680 (0.3199)
	Pedroni t_rho_NT	-43.3568 (0.00)	-	-

Note) ( ) : p-value

〈Table 4〉 Contribution testing results

Estimation period		Normal capital goods	IT capital goods
1985~1998	OLS	0.4343 (9.5819)	0.0844 (3.8830)
	DOLS	0.6465 (5.7428)	0.033 (0.6204)
	FM-OLS	1.0691 (13.7168)	-0.1022 (-2.7736)

Note) ( ) : coefficient estimate

Using the statistics from the above tests, three estimations methods of OLS, DOLS, and FM-OLS are applied to measure the contribution of input factors to industry output. The testing results are illustrated in <Table 4>. We distinguish between contribution percentage to output growth, and the regression coefficient of the independent variables. For OLS and DOLS cases, the non-IT capital stock's contribution percentage to growth is between 43.43% and 64.65%, and non-IT stock's contribution also ranges between 8.44% and 3.3%. These statistics falls within the acceptance range to justify the both the capital and non-IT capital stock contribute to growth rate. We also noted that there is no significant difference between the estimation methods. Normal OLS bias-adjusted estimators are 0.0844 in case of IT capital goods and 0.033 in case of DOLS, both of them shows consistent positive (+) result. However, for FM-OLS testing result shows no significant relationship between the IT capital stock contributes to manufacturing industry growth. It implies that the IT productivity paradox can exist in Korean manufacturing sector.

5. Conclusion and Discussion

In this paper, we applied three stage statistical testing methods of panel unit test, cointegration test, and cointegration vector finding, for empirical testing of IT contribution to economic growth. The scope of the testing is limited to Korean manufacturing sector with 14 years of data. The multi-step approach is effective to correct the bias of stationary characteristics of IT investment and the time lag of contribution effects. From the testing results, the statistical method applied in this paper is proved to be significant, and IT contribution to manufacturing industry growth is effective for OLS and DOLS cases. However, FM-DOLS testing results shows contradictory result for the contribution of IT to growth. We think that there can be IT productivity paradox in this case. One testing effect statistical methods being introduced recently are used to examine the contribution of IT capital stock to national economy from the standpoint of Korea.

We have limitations in capturing data for longer period, and the correctness of the data. It is obtained from National Statistics data and that some inconsistencies can exits in classifying stocks. Also, the variations across the sub-categories among the manufacturing sector cannot be controlled. Despite of the limitations of the data, we expect that the proposed approach could be effective to be exploited for similar type of problems such as e-commerce contributions to economic growth. Also for the firm level analysis of IT investment to organizational performance evaluations, the approach can be applicable to reflect the non-stationary nature of economic gains obtained from IT.

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