A Study On The Productivity Of Korea's Industrial Sector With IT Technology Capital And R&D Stock's Variation.

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Abstract

This paper examines the effects of IT technology capital and R&D stock's variation on the growth of Korea's industries with time series approaches. In detail, we analyze the Granger causality and impulse response analysis among the Korea's industrial growth, IT technology capital, and R&D stocks. When it comes to this research conclusion, we know that IT technology capital and R&D stock's shocks affect the growth of Korea's industrial sector. However, the revere effect is ambiguous in each industrial sector. Also, the impulse response function analysis shows that the effect of IT technology capital and R&D stock's fluctuation in each industrial sector is presented with different time periods.

Introduction

As the importance of IT technology is staidly on the increase, a wide range of decision markers of company, industry and nation level must be driven to the bold investment decision marking, so that investment on IT is rapidly growing compared to most of traditional industries. This sort of trend emerging in a recent is not only limited to our country [1] regardless of developed country and developing country and it is carried out to anyplace, in which is concerned about acquiring the competitiveness in the near future.

What investment on IT technology is economically influenced is too much focused, however, it is a difficult situation to expect if it has the spreading effect throughout a wide range of economy and see if IT technology capital and R&D stocks are simply extended to different kind of industry sectors in quantity without being variable analysis. The relevance between IT technology capital and productivity [2] has been already reviewed in many developed countries, going on many researches in a recent.

On the economical outcome of IT technology capital and R&D stock at the level of enterprise [3], Sin and Song(1999), Lee(2000) emphasis on the concept of reshaping or conversion efficiency, and the fact that investment in IT technology capital can't be a requisite to guarantee outcome progress. Also, Gene M. Grossman and Carl Shapiro (1986) study the optimal pattern of outlays for a single firm pursuing an R&D program over time and assert that it is optimal to increase effort over time as the project nears completion.

Readers with comments or questions are encouraged to contact the authors via email.

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[1] IT industry has been playing an important role in Korea's economic development as it is rapidly growing in the middle of 1990.
[2] Investment on IT technology capital goods generates network externality or spreading effects by performing production, application and distribution of knowledge

[3] Research at the level of enterprise is focused on whether it improves infra –investment of information communication or economical outcome related expenditure in a standard of private company and plant

On the economical outcome of IT technology capital and R&D stock at the level of industry[4], Brynjolfee-son and Hitt (1998) stress that a positive effect is not certainly happened at the level of industry because industry that co-exist positive and negative effects in the tantalization process is supposed to be generating inter-offset effects. Hong and Youn (1998) classify levels of industry research and apply inter-industry table into IT technology showing production inducement coefficients, import inducement coefficients and value added coefficients are the main issue of analysis.

On the economical outcome of IT technology capital and R&D stock at the level of country, Kim (2000) bails out the guideline of national information policy by putting a comprehensive research together internationally, showing the main subject and latest analysis result, so that policy planners carrying out national information policy can be supposed to acquire implications from research.

By looking throughout the related works, we realize that no works has been done for the relationship among industrial sector's productivity, IT technology, and R&D stocks in terms of relative effectiveness among them. That is, are the IT technology capital and R&D stocks in the Korea's industrial sector have affected the growth of productivity? This research intends to answer the above question by analyzing the spreading effects cased by IT technology capital and R&D stocks on the growth of domestic industrial sectors through time series analysis. First of all, we look into the conception, increasing state of IT technology capital for each part of industry, and intend to consider reactions of the present or future between variables cased by error shocks of three variables after analyzing the Granger causality test among each industrial sector's growth, IT technology capital and R&D stocks. In addition, we make up for supplementation in the estimated conclusion, by identifying co-integration relation among variables due to annual data of low frequency.

This paper is organized as follows. Section 2 deals with general understanding of IT technology capital in each industrial sector presenting the average growth of IT technology capital. In chapter 3, we analyze the spreading effects cased by IT technology capital and R&D stocks on the growth of domestic industrial sectors through Granger causality test. Finally, chapter 4 shows implications and conclusions of the empirical analysis.

Understanding on Korea's IT technology capital stock in each industrial sector Definition and features of IT technology capital[5].

We will be able to define IT technology as the ability that can generate productivity and value added; manage complaints, information, and transmission, revelation, related manufacture, aerial and trolley and service. This involves the traditional electronic communication, data communication and allied industry, computer and computer related industry, broadcasting and contents industry, electronic processing related business - to detect, measure and control physical phenomenon. Whether the contents business is involved or not, "IT industry" which OECD defines is different from "information & telecommunication industry", which the ministry of information and communication defines. So far, the ministry of information and communication haven't yet involved the contents industry into information & communication industry.

The Increasing State Of IT Technology Capital Stock In Each Industrial Sector

Objections of analysis is classified into 8 sectors in domestic industry as below <Table 1>.

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[4] Research on R&D and information communication at the level of industry mainly deals with a case that information communication is regarded as a part of industry or industrial outcome that is considered as a input element field of information communication more than information communication industry itself.

[5] General capital, which is in opposition to IT technology capital could be defined as " total sum of asset to have the ability of creating production and incomes as the accumulated liability for future production.
Capital is narrowly defined as durable and reproducible tangible assets, with the exception of natural resources like land, intangible asset like human asset. In Korea, tangible asset is narrowly only regarded as asset by nation wealth statistic survey. This is classified into private capital stock, state capital stock, customer durables, and inventory asset. In wider sense, capital involves human asset, physical intangible asset by adding a narrow sense of capital.
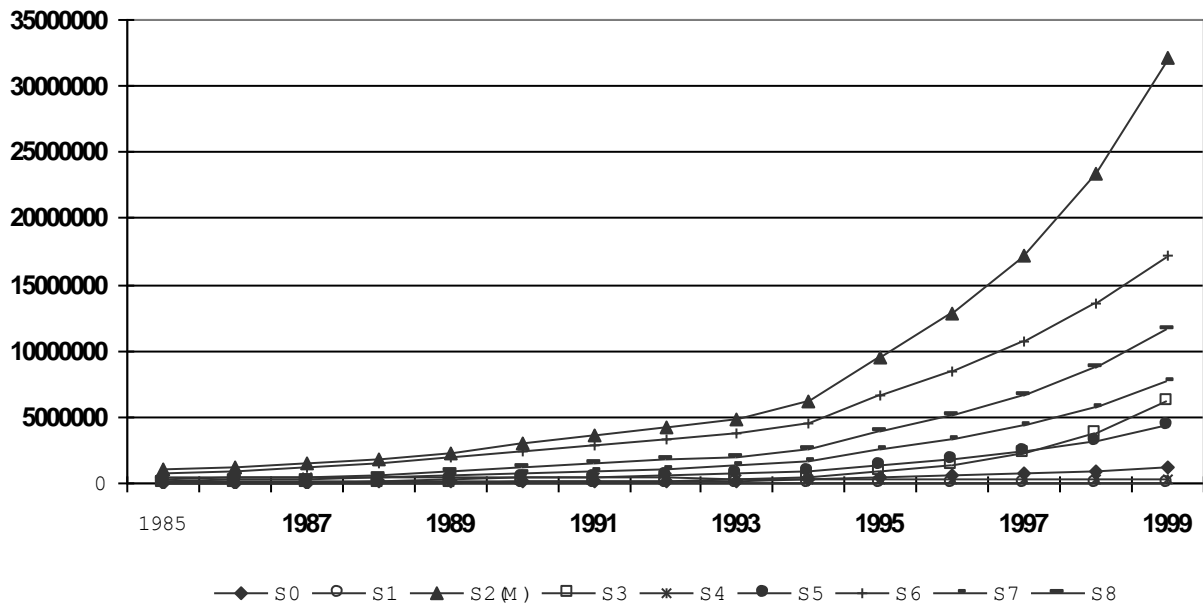
(Table 1) Domestic industry classification.

Inter Industry Table	Classification	1995*	1990**	1985**
1. Mines	S1	31~45	35~50	38~51
2. Manufacture	S2(M)	46~305	51~317	52~316
3. Electricity, Gas, Water-supply	S3	306~312	318~324	317~323
4. Construction	S4	313~329	325~341	324~342
5. Wholesale, Retail, Food, loading	S5	330~333	342~345	343~346
6. Transportation, Warehouse, Communication service	S6	334~351	346~360	347~363
7. Finance, Insurance, Real estate, Service	S7	352~369	361~375	364~375
8. Community or Personal service	S8	370~399	376~402	376~399
Total Industry	S	1~399	1~402	1~399

Note: *, **, *** are the classified number in Korea's Inter Industry Table.

See the increasing state of industrial IT technology capital stock as below in the Figure I. With reference to Figure 1, the manufacturing industry records the highest growth rate (43%). We can find out that the manufacturing industry takes a leading role in the growth rate of domestic IT technology capital stock, which would be sure that manufacture is given much weight on IT technology capital stock.

(Figure 1) The existing state of industrial IT technology capital stock.

Also, IT technology capital stock with computer system industry is rising up, but in terms of a scale of quantity, retail, food, and loading industry's (S5) IT technology capital stock drops behind relatively more than culture and personal service industries in 1997. From 1991 to 1994, ranking in a scale of quantity has been gradually changed. It could be a significant result that IT technology along with industrial centric IT has a special meaning. In other words, it proves that the differentiation could be happened to IT technology in demand or suitability across all of industrial sectors and provides a critical framework of policy in setting up industrial policy for IT.

The annual average growth rate of domestic industrial IT technology capital stock.

See Figure 2 to check out the annual average growth rate in advance. The annual average growth rate of IT technology capital records approximately 27.3%. Particularly, in 1995, it seems to be recognized that the annual average growth (after 1995, in which IT technology capital takes up the economic growth) has been much higher than that of the previous period (before 1995, accounting to 25%). Having been already mentioned, Investment on IT technology capital is moving sharply upward.

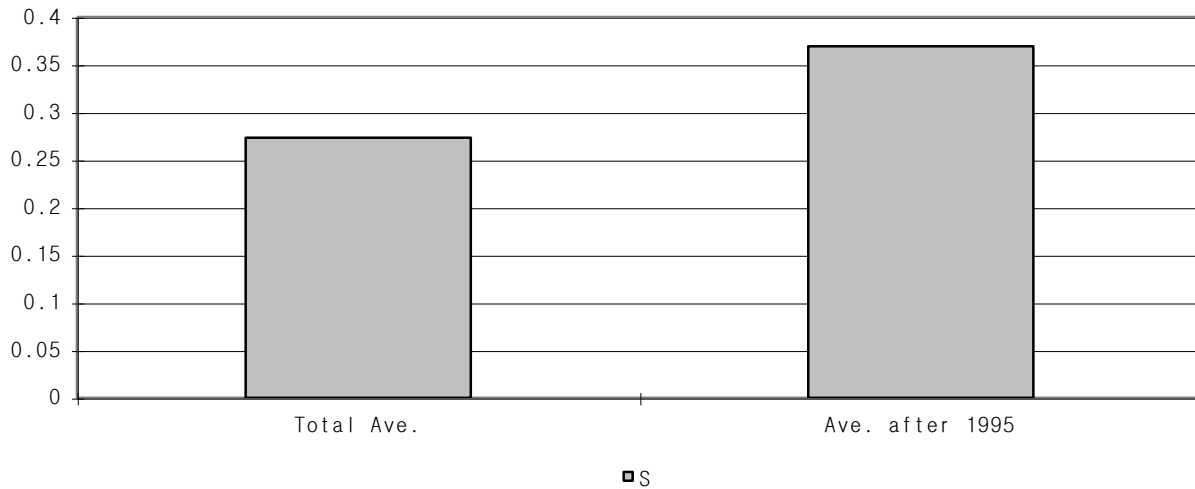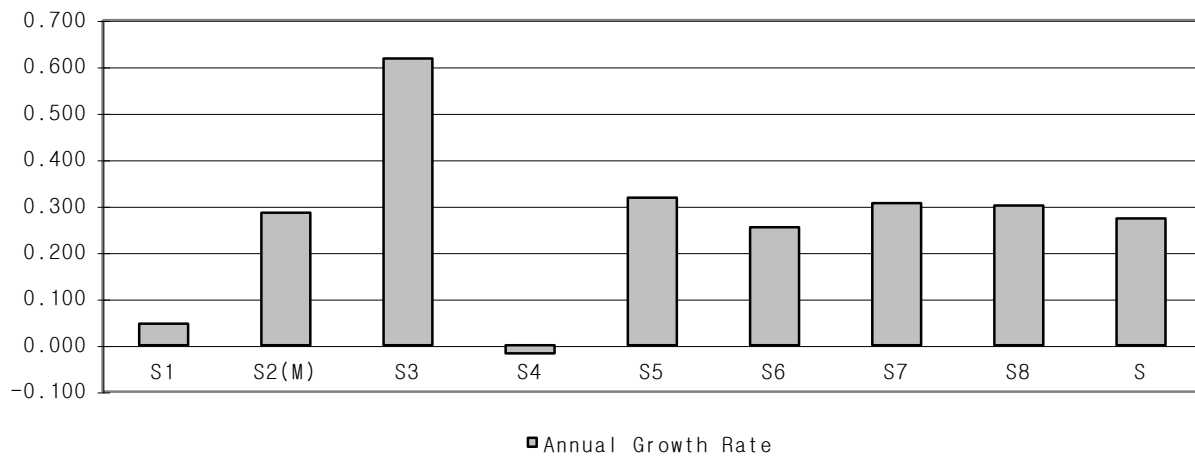**(Figure 2) Annual growth rate of information communication**

Figure 3 shows the annual growth rate of industrial IT technology capital stock. Electricity, gas, water supply industry (S3) hit the highest growth rate accounting for 61.8%, owing to employ a large scale of computer system for management.

(Figure 3) Annual growth rate of domestic IT technology capital stock.

Moreover, in the field of the mining and construction industry (S1), the annual growth rate on the average records each about 5%, 2%, which is the lowest in IT technology capital stocks. That results in low contiguity for IT technology of the mining (S1) and construction industry (S4). With the exception of these two industries we mentioned above, other industries in annual growth rate is equally ranged around 30%, which indicates that these two industries have a similar contiguity for information communication technology.

Demonstrative analysis by the VAR(vector auto-regression) model

The Methodology

Methodology that is used for analyzing the effectiveness of IT technology capital and R&D stocks in domestic industry development is VAR(vector auto-regression) model. A motive of using this model is easily able to grasp the relative importance of IT technology capital and R&D stocks respectively, in explaining the industrial growth via impulse response function and variances decomposition, and performs the intended analysis minimizing a priori restriction as much as it can. The model developed by Sims(1980) would be shaped as follows.

$$X_t = \mu + A(L)X_t + u_t \tag{1}$$

Define dependant variables for equation (1) as below:

TPS_i = log (value added quantity in each industrial sector)
ITS_i = log (each industrial IT technology capital stock)
RDS_i = log (each industrial R&D stock), i = S1, S2, S3, S4, S5, S6, S7, S8.

From equation (1)

$X_t = (TPS, ITS, RDS)'$
$u_t = (u_t^{TPS}, u_t^{ITS}, u_t^{RDS})'$
$\mu = (\mu_1, \mu_2, \mu_3)'$

X is 3×1 vector variable, L is lag operator, A(L) is 3×3 coefficient matrix, u is pure noisy disturbance terms.

Therefore, the VAR is composed of linear regression equation, and each of equation regards variables as dependent variables within this model, being formulated explanatory variables or lagged variables. However, a coefficient that is generated by the estimated result is not really meaningful because model itself doesn't identify a hypothesis, which is suggested from economic theories, and has a difficulty in interpreting coefficients.

MAR (Moving Average Representation) is commonly used for interpreting the estimated consequence.

$$X_t = B (L)u_t \tag{2}$$

In equation (2), B_i, i=0,1,2… which is Coefficient matrix of moving average representation informs how variables x^j in J is reacting with time passing whenever a unit of impulse happens to b_i^{jk}, i=0,1,2…that is variables x^k , in k. But, there is one problem coming out to interpret B_i by itself. Covariance matrix of is not diagonal matrix since the elements of U_t, for instance u_{1t} and u_{2t} is made up for correlation. In this case, it proves to be difficult that b_i^{12}, i=0, 1, 2… which is transformed by x^2, is simply interpreted as the response of x^1.

That is the main reason why a part of x^2 change forms a correlation with the transformation of x^1. Therefore, it is essential that this correlation is removed and it performs as following formula.

$$X_t = B (L)\Pi^{-1}\Pi U_t \tag{3}$$

In equation (3), Π matrix turns covariance matrix into diagonal matrix by eliminating correlation among

the elements of U_t

If B $(L)\Pi^{-1}$= C(L), ΠU_t= ε_t X_t is again

$$X_t = C\ (L)\ \varepsilon_t \tag{4}$$

Consequently, c_i^{jk} , a elements of C_i is able to interpret that a unit of impulse in k becomes the response of variables in j

Statistical data
<Table2> Contents and Source of statistic data

Variables	Statistic data	Source
TPS_i	An amount of value added output by each industry (1990 standard of 1 billion won) (1985-1998)	Annual economic statistic from Korea bank
ITS_i	Estimated result by domestic industry and asset capital stock(1985-1998)	Pyu (1998)
RDS_i	• R&D stock by domestic industry (in 1900, standard of thousand won (1985-1998) • Method of perpetual inventory to estimate R&D stock used in this research is presented as following. $RD_t =$ $RD_{it}+(1-\delta)RD_{it-1}$, RD_{it} shows new technology know-ledge supply in the year of t, and RD_t means R&D stock in the year, δ presents pure loading rate of R&D stock	'Science technology research activity survey report' by the ministry of science and technology.

Note: i= S1, S2, S3, S4, S5, S6, S7, S8

Preliminary Data Analysis by Unit Root Test

For time series analysis, the stability of time series data must be guaranteed, and unit root test [6] can confirm this. There are some sorts of unit root tests to time series analysis; in general, DF test presented by Dickey-Fuller (1979), informs that ADF test extends to DF test, and PP test revealed by Phillips-Person (1988). PP test, which is introduced by Phillips-Perron(1988), modifies and supplements DF test by introducing a case of hetero-phenomenon, even autocorrelation of error terms as well - that is a comprehensive situation which is not adequate to the assumption error terms should come to i.i.d(0,$\sum$). Accordingly, PP test have an advantage that is able to test a wide rage of variables compared to DF test or ADF test.

The following two models are used for ADF test. First of all, general AR model (1) is

$$\Delta Y_t = \mu + \rho Y_{t-1} + \varepsilon_t \tag{5}$$

In equation (5), AR (1) has a stable time series in terms of 1<ρ<1, but result in a unstable time series if any p=1. So, the model to ADF test is revised as below.

$$\Delta Y_t = \mu + \gamma Y_{t-1} + \varepsilon_t \tag{6}$$

where, $\gamma = \rho-1$, H_o: $\gamma=0$

If null hypothesis (H_o: $\gamma=0$) is not rejected above model (2), ΔY_t, a time series, is exceptional and have a unit. Table 3 indicates the result of unit root test.

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[6] In case that regression analysis is preformed among the unstable time series, which involves a unit root, it is possible that "spurious regression" (being not clear for statistical significance) is likely to be generated

<Table 3> Unit root test result of domestic industry sectors

Variable/ Classification	Domestic industry classification								
	S1	S2	S3	S4	S5	S6	S7	S8	S
Value added output (TPS)	-2.32 -7.19***	-1.97 -5.97***	-3.70** -3.05*	-2.42 -4.32**	-1.07 -4.89***	-2.15 -3.55**	-1.92 -2.96*	-1.02 -7.54***	-1.59 -5.04***
IT Technology capital(ITS)	-2.62 -3.49**	-2.79* -3.66**	-2.82* -3.71**	-2.54 -3.42**	-2.77* -3.64**	-2.75* -3.62**	-2.76* -3.64**	-3.20* -3.64**	-2.79* -3.65**
R&D stock (RDS)	-3.87** -4.50***	-3.77** -3.66**	-3.56** -3.30**	-2.59 -4.23**	-2.55 -3.84**	-5.57*** -4.07**	-2.82* -3.23**	-2.55 -3.84**	-3.97** -5.32***

Note: 1) apply lag number to '1' for model (2)

2)***(**, *) Stands for a significant level, 1%(5%, 10%)(upper low :1st difference, below low: 2nd difference)

3) Critical point at the level of significant 1%, 5%, 10%, is each −4.32, -3.219, and 2.75 in model (2)

With reference to Table 3, each Industrial TPS for unit test result from model (2), in case of first difference, takes a unit root except for electricity, gas, water supply industry (S3). However, when it comes to second difference, the existence of unit root test can be rejected to every industry. In each sector's IT technology capital stock, first difference takes the possession of a unit root at the significant level of 10%, but in case of second difference, a unit root can be generated to every industry. Besides, with the exception of construction industry (S4), wholesale and retail industry, food, loading (S5), and personal service industry (S8), the existence of a unit root is likely to be rejected for R&D stocks by industry, in first difference. With second difference, a unit root can be rejected to all industry.

Therefore, we can generally verify from Table 3 that a unit root exist in each industrial variable, so that by taking into account the fact which statistic data for this research is extremely   limited we use 2nd difference of each industrial variable for this research.

Analysis of Granger Causality Test

The Granger approach to the question whether X causes Y is to see how much of the current Y can be explained by past values of Y and then to see whether adding lagged values of X can improve the explanation. Y is said to be Granger-caused by X if X helps in the prediction of Y, or equivalently if the coefficients on the lagged Xs are statistically significant. Note that two-way causation is frequently the case; X Granger causes Y and Y Granger causes X. It is important to note that the statement "X Granger causes Y" does not imply that Y is the effect or the result of X. Granger causality test measures precedence and information content but does not by itself indicate causality in the more common use of term.

We, namely, can think of two-equation system that express it clearly such as the following or vector auto-regression by column vector of (X.Y).

$$X_t = \sum_{i=1} a_i X_{t-1} + \sum_{j=1} b_j Y_{t-j} + \varepsilon_{1t}$$

$$Y_t = \sum_{i=1} c_i Y_{t-i} + \sum_{j=1} d_j X_{t-j} + \varepsilon_{2t} \tag{7}$$

After presuming above formulas and thinking two null hypotheses, which is $H_o^1 : a_i = 0$ and $H_o^2 : d_j = 0$, we judge existence of causality by practicing F test[7] about each null hypothesis. If rejecting $H_o^1 : a_i = 0$ and $H_o^2 : d_j = 0$, causality exists, and if selecting those.

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[7] F Test is little different from the existing method like this. That is F=[(SSRR-SSRU)/q]/ [(SSRU)/(n-k)]. n,k,q is relatively total data number, the number of estimated parameter, and the number of constraints

In terms of rejecting $H_o^1:a_i=0$ and not rejecting $H_o^2:d_j=0$, Grander cause from X to Y exist. On the opposites side, it is estimated that Granger cause from Y to X exist.

(Table 4) Cause and Effect relation in domestic industry

Industrial mark	RDS$\Rightarrow$ TPS	TPS$\Rightarrow$ RDS	ITS$\Rightarrow$ TPS	TPS$\Rightarrow$ ITS	RDS$\Rightarrow$ ITS	ITS$\Rightarrow$ RDS
S1 (Mining)	0.00 (0.99)	3.25 (0.10)	0.44 (0.65)	6.08* (0.02)	20.44* (0.00)	3.63* (0.08)
S2	0.06 (0.94)	0.21 (0.81)	3.11 (0.10)	1.44 (0.30)	0.54 (0.60)	0.02 (0.98)
S3	0.10 (0.90)	2.95 (0.11)	2.62 (0.14)	1.01 (0.41)	1.83 (0.23)	0.27 (0.76)
S4	5.01* (0.04)	2.45 (0.15)	0.74 (0.51)	4.71* (0.05)	1.07 (0.39)	3.73* (0.07)
S5	0.97 (0.42)	2.60 (0.14)	6.24* (0.02)	2.73 (0.13)	13.76* (0.00)	1.47 (0.29)
S6	0.75 (0.50)	1.71 (0.24)	1.05 (0.40)	0.42 (0.67)	0.57 (0.58)	12.35* (0.00)
S7	1.24 (0.34)	2.73 (0.13)	9.08* (0.01)	0.68 (0.53)	5.66* (0.03)	7.59* (0.01)
S8	0.47 (0.64)	2.82 (0.12)	20.42* (0.00)	0.86 (0.46)	14.07* (0.00)	1.57 (0.27)
S	7.48* (0.01)	0.24 (0.63)	5.39* (0.03)	0.80 (0.48)	1.83 (0.22)	0.63 (0.55)

Note :() value of p to F Test.

As shown in table 4, if seeing domestic industry, the growth of mining industry Granger cause IT technology capital stock, and R&D stock Granger cause IT technology capital, and vice versa. Manufacture (S2), electricity, gas, and water supply industry (S3) never present Granger causality among variables. The increase of R&D stock in construction industry (S4) has Granger cause on the growth of construction sector, and vice versa. The rising of stock of IT technology in the whole sale and retail industry (S5) cause on the growth of S5, and increase of R&D stock leads to climb up IT technology capital. Although the growing of IT technology capital stock cause the increase of R&D stock in transportation, warehouse, communication industry (S6), other variables don't present Granger causality. The rising of IT technology capital stock in finance, warranty, and real estate industry (S7) has caused on the growth of S7, and R&D stock cause IT technology capital stock in private service industry (S8), which causes the growth of S8.

Conclusions

We could gain the following suggestion in analysis for understanding potential effects of domestic industrial information communication stock and R&D stock. In Unit test, which is to see whether data for time series analysis is stable or not, the result of unit test to model 2 can certify the existence of two-grade division variables, and we intend to make an argument that two-grade division variables is safety by considering that a number of statistic data are so limited for this research, so in this research develop will development an argument to the assumption that two grade division variable is safety.

In Granger Causality test for analyzing cause and effect relation among three variables like Table 4, it shows increase of value added product amount -> information communication stock -> increase of R&D stock in mining industry (S1). Manufacture (S2) and electricity, Gas, Water supply (S3) industry is not shown to mutual cause and effect relation. In case of the construction industry (S4), it has an effect in the increase of R&D stock -> value added product amount -> increase of information communication. In case of wholesale and retail sale industry (S5), it leads to the increase of information communication stock and R&D stock -> increase of value added product

amount. In case of transportation, warehouse and communication industry (S6), it has an effect that information communication stock -> R&D stock. In finance, insurance and real property industry (S7), it has a effect on increase of information communication stock and R&D stock -> increase of value added product amount, R&D stock -> increase of value added product amount.

In all portion of domestic industry, R&D stock and information communication drives the increase of value added product amount. With connection to cause and effect relation itself, we must consider that acquiring a decisive result would be limited to a temporary interpretation via more strict time series.

The importance of this research can be summarized for the following reasons. First, mutual cause and effect test among variables, through cause and effect test that domestic industrial information communication capital stock and R&D stock is affected by time series analysis, and Impulse Response Function among variables that is caused by variation of error variance are able to take a significant economic meaning of domestic industry. However, it is indicated that analysis is much limited, owing to restriction using annual data and must keep pace with panel data analysis additionally, which can sort out this kind of problems in the near future. 📖

References

1.   Brynolfsson, E. and L.M. Hitt (1998), Beyond the productivity paradox: Computer are the catalyst for bigger changes, Communications of the ACM 41(8), 49-55.
2.   Dickey, D.A & W.A. Fuller (1979), "Distribution of the Estimates for Autoregressive Time series with a Unit Root," *Journal of American Statistical Association*, 74, pp. 427-31.
3.   Grossman. G. M. & C.Shapiro(1986), "Optimal Dynamic R&D Programs," *RAND Journal of Economics*, Vol. 17(4), pp. 581-593.
4.   Hong, Dong Pyou and Jung, See Larn (1998), "Analysis on contribution of information technology to national economy with inter industry analysis form 1985 to 1995", *Korea Information Society Development Institute.*
5.   Hong, Dong Pyou and Park, Sung Jin (1997), "Analyzing Information & Communication Industry", *Korean Information Society Development Institute.*
6.   Jorgenson, D.W. & K. Stiroh (2000), Information Technology and Growth.
7.   Johansen, Soren (1991)., "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models," *Econometrica*, 59, pp 1551-1580.
8.   Korea Bank (2000), Quarterly National Accounts.
9.   Kim, Euo (2000), "Analysis on the factors of domestic manufacturer industry: centered on productivity analysis for R&D investment".
10.   Kim, Jung Sang (2000), "Analyzing relation between information communication investment and economic growth, performed: for cross-sectional analysis," a doctoral thesis of economy of Seoul university.
11.   Kim, Jun Young (1992), "Structure analysis on domestic capital stock and capital cost," Korea economy research center in the Korea chamber of Commerce and Industry.
12.   Korea bank (1987), Inter Industry analysis explanation.
13.   Lee, kye dong (1999), "Contribution of Information Technology Investment to the growth of Korea Economy", *Korea Industry Organization Academy*, spring academic conference in 1999, pp. 271-294.
14.   National Computerization Agency (1999), Information Technology statistical data.
15.   Oliner, S.D. & D.E. Sichel (2000), The Resurgence of Growth in the Late 1990s: Is Information Technology the Story? "Finance and Economics Discussion Series" # 2000-20 (Board of Governors of the Federal Reserve System (U.S.).
16.   Pyou, Hark Kil (1998), "Estimated result of capital stock in industry and asset," *Korea Institute of Public Finance.*
17.   Phillips. P.C. & P. Perron (1988), "Testing for a Unit Root in Time Series Regression," *Biometrika*, 75(2), pp. 335-346.
18.   Sin, ill soun and Song, jae gyung (1997), "Identification on several hypotheses that the growth of information technology affects productivity", *Korea Information Society Development Institute.*
19.   Sin, ill soun and Joung, byuo youn (1997), "Research the developing methodology with an index of infor-

mation policy: focused on the estimated result and analysis of information technology data", *Korea Information Society Development Institute.*

20.   Sims, Christoper A (1980), "Macroeconomics and Reality," *Econometrica*, 48, pp. 1-48.
21.   The Bureau of Statistic (1998), Information & Communication Statistical Report.

Notes