The Impacts of IT Industry on the Economy: The Income and Substitution Effects Analysis Using VIO Model

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Abstract

This paper analyzes how the production behavior of the IT industry itself and other allied industries can be changed based on the input substitution and income effects resulting from changes made in IT industries being classified by a VIO model. By developing IT industries in Korea, income effect increases a production activity of a majority of other industries rather than an industrial production structure favorable for IT induced by substitution effect for production elements. That is, the income effect, such that an IT commodity and service is in an increasing demand while prices of information communication commodity have come down, is to be a main factor generating affirmative results for a majority of industries. On the other hand, it is observed that the substitution effect itself, a modification to an industrial production structure favorable for IT, cannot result in the affirmative effects extended to other industries. At the same time, it was found that a development of IT industries has not been a great help for increased employment overall in industries in Korea.

Keywords: IT Industry, production, VIO Model, substitution effect, income effect

I. Introduction

New information technology (denoted, "IT" hereafter) has developed rapidly and been applied recently because investment in IT will reduce expenses and promote

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efficiency in an individual firm or industry, thereby increasing competitiveness in the near future. Accordingly, there has been a great deal of research on IT investment and its extended influence on the economy in a variety of aspects[1]. However, they have mostly focused on the verification of assumptions about correlations among corresponding data variables under a significant level utilizing an econometric model. As a result, there is relatively insufficient information on how IT investment affects inter-connected industries that have an influence on one another interacting together to give a new output.

A number of domestic and international studies have examined this issue. The most representative works are by Hong et al. (1999), Wong (2001), etc. These studies compare inductive effects of data in a variety of years through “Input-Output (IO)” analysis and indicate changes of IT industries made so far. But, they can hardly explain the origins of such changes to identify the economical relationships.

This paper describes how production behavior of IT industry itself and other allied industries, can be changed on the basis of the substitution and income effects resulting from any change made in IT industries being classified by a Variable Input-Output (denoted, “VIO” hereafter) model, a supplemented and modified model in place of existing Input-Output analysis model. In particular, it analyzes how a fall in the price of IT commodity effects production activities of other industries while production techniques have been changed in IT industries. Moreover, based on the results above mentioned, it indicates whether IT industries as a foundation of knowledge-based society does or does not contribute to changes of industrial production activity and employment enlargements, a main subject discussed in the Department of Commerce (U.S.A.) in 1998 & 2000.

As production techniques develop for IT industries with relatively less production expense, the price of IT commodity declines, possessing a higher competitiveness, as compared to that of other industrial commodities. Also, an IT commodity will be in greater demand by other industries that take it as an intermediate input. Subsequently, a change in production activity of IT industry has a significant influence on production activities and employments of other industries. In order to explain such economical relationships, it is necessary to be familiar with price changes in IT industry, which reveals substitution effect, an increasing number of

1. A variety of publications by Pohjola, Matti, 2001 / Kraemer and Dedrick, 1994 and 2001 / Oliner and Sichel, 1994 / Morrison and Berndt, 1990 / Niininen, 2001 / Berndt et al., 1992 / Brynjolfsson, 1996 / Hitt and Brynjolfsson, 1996 deal with results of this type of research or study related to “Productivity Paradox”

IT applications as the input being substituted for others in overall industries, followed by an income effect through changes of value added. In addition, the changes of production activity affect an employment rate to be changed implying that the rate change comes from an expense change of IT industrial.

To summarize the main results in this study, although development of the IT industry increases production activities for a majority of other industries in Korea, this results from income effects rather than production structures of industry favorable for IT induced by substitution effects. A fall in the price of an IT commodity generates such positive effects, followed by increasing demands for the commodity in the industries (income effects). On the other hand, there is no positive effect extended to other industries by substitution effects establishing an industrial structure favorable for IT. At the same time, a development of production techniques in Korean IT industry does not contribute to an overall employment enlargement.

This paper utilizes an IO table released by The Bank of Korea (1995) and reduces 402 fundamental industries in the table down to 31 industries. Classification of IT industry is made on the basis of classification system of IT industry arranged by Ministry of Information and Communication. It consists of 4 chapters: Chapter 2, 3, and 4 describe a basic model in this analysis using a VIO model, empirical results, and suggestions for main and significant data revealed in this research, respectively.

II. Basic Model and Data

Leontief's Input-Output (IO) analysis is a well-known IO model. However, it cannot analyze effects extended to other industries as production expense changes for a certain industry[2]. Thus, this study utilizes a supplementary VIO model[3] to Leontief's.

The model was established by transforming a Cobb Douglass' production model into log-linear type and including an intermediate input (production factor),

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2. It was processed by a previous IO analysis on the assumption that a production method is fixed for each industry. As an output model, a reciprocal matrix, $(I-A)^{-1}$, is fixed in $x=(I-A)^{-1}F$ while the only final demand, F, is treated as an external variable. In other words, it is assumed that there is only one production method for each commodity ignoring changes of production techniques. As a result, it is impossible to substitute production factors for one another due to a production function of such fixed input coefficient.
In addition, in aspect of input, a price model is $P=(I-A')^{-1}V$, where prices of total industries change as a price (V) of the original factors changes. However, in application of existing Leontief's model, the price change in aspect of input have no influence on that in aspect of output. That is, a dichotomy exists, such that a price cannot be connected to a production.

3. Refer to researches by Liew, C. K., and C. J. Liew (1979) for the details

employee pay (labor), business surplus, depreciation of fixed capital, and indirect tax (capital) as a part of primary production inputs.

$$\ln x_j = a_{oj} + \Sigma_i a_{ij} \ln x_{ij} + \Sigma_k ß_{kj} \ln L_{kj} \quad (1)$$

-x_j: Output of j industry

-x_{ij}: Commodity (intermediate medium) of i industry purchased by j industry

-L_{kj}: Amount of original production elements (k: labor & capital) employed in j industry

-$S_i a_{ij} + S_k ß_{kj} = 1$: Condition of linear homogeneity

Profit equation:

$$p_j x_j - \Sigma_i p_i x_{ij} - \Sigma_k w_{kj} L_{kj} = 0 \quad (2)$$

p_j: commodity price of j industry,

p_i: commodity price of i industry,

w_{kj}: unit price of primary production factors (k) purchased by j industry

In consideration of eqn. (1) as a constraint condition, Lagrangian function of profit maximization model is described below:

$$\text{Max } \prod = \Sigma_j (p_j x_j - \Sigma_i p_i x_{ij} - \Sigma_k w_{kj} L_{kj}) + \Sigma_j \lambda (\ln x_j - a_{oj} - \Sigma_i a_{ij} \ln x_{ij} - \Sigma_k ß_{kj} \ln L_{kj})$$

It is to calculate a profit maximization factor of employment level by applying the given production function as a constraint condition.

$$x_{ij} = a_{ij} p_j x_j / p_i \quad , \quad Lkj = ß_{kj} p_j x_j / w_{kj} \quad (3)$$

Then, apply optimum values of intermediate medium, labor, and capital in (3) into eqn. (1) in order to obtain a following price function.

$$\ln p = (I - A')^{-1} [\Sigma_k ß_k \ln w_k] \quad (4)$$

In addition, apply xij value in (3) into a basic equation of IO table, $x_j = S_j x_{ij} + F_i$.

x_i : total output

$S_j x_{ij}$: summation of intermediate demands of all j firms

F_i : total final demands of households, firms, government, and international sectors

This procedure is to transform a production equality on output side into the matrix form, as shown below.

x = (I- h)-1F , h = p-1Ap, where p is a diagonal matrix (5)[4].

By differentiating[5] eqn. (5), we get eqn.(6).

$$dx = (I - h)^{-1} dh\, x + (I - h)^{-1} dF \qquad (6)$$

It is to estimate production changes of total industries (total effects) from eqn.(6) with price changes of total industries, caused by a price change of a certain industry due to cost(wk) change of primary production factor, exogenous variables, in eqn. (4). The eqn. (6) representing the change in output, dx, comprised of two terms. The former term, $(I - h)^{-1}dh\, x$, is input substitution effects[6] through changes of production techniques and the latter term, $(I-h)^{-1}dF$, is income effects[7] through changes of the final demand. If prices have no influence on matrix h, it becomes to be $(I-A)^{-1}dF$ as A matrix in existing Leontief's model. After all, it is to say that Leontief's IO analysis deals only with such income effects. On the other hand, dF, changes of the final demand as a variable, F, of income effects, can be obtained from effects of increasing IT on the final demand.

A regression model reveals relationships between VA[8] and IT expenses and between F and VA, respectively, providing dF[9] through changes of the expenses in

4. In stead of matrix, h = p-1Ap can be expressed as a general eqn of aijpj/pi in eqn. (3). Technique fixed coefficient of technique aij, an element of A matrix, changes by relative price (pj/pi) of commodity implying that intermediate medium is to be replaced.

5. x = (I- h)-1F becomes (I- h)x=F. Express it as x-h*x=F and start a differentiation:
dx-dh*x-h*dx=dF, dx-h*dx=dh*x + dF, (I-h)dx=dh*x + dF,
dx = (I- h)-1dh*x + (I- h)-1dF

6. (I -h)-1dh x: Changes of dh, a coefficient of technique, cause a substitution effect of the factors increasing demands for IT commodity in virtue of a fall in its price and reducing application ratios of other factors to change previous production method. The substitution effects explain production changes by the ratio changes whereas Hicks' substitution effects refer to the replacement of factors with a fixed output. So be aware that they are not in accord with each other.

7. (I-h)-1dF: When IT commodities or services are applied to an industry, it costs human and material resources increasing national GDP, followed by increasing demands for each industry. In other words, income effects result from dF, changes of a final demand.

8. VA: According to the IO table of the Bank of Korea, value added = employee pay + operating surplus + depreciation of fixed capital + indirect tax

9. VA=g(IT cost) expresses the relationship with the expense for increasing IT share and the benefit paid to production factors involved in IT applications while F=f(VA) with the final demand for commodities and the benefit paid to production factors participated in production

each industry as a price of IT commodity changes.

As mentioned previously, this paper utilizes the data from manufacture's price evaluation table of the IO table released by The Bank of Korea (1995). It reduces 402 basic industries in the table down to a valid 28 industries[10] close to a large consolidating classification. Then, it added an IT industry into the valid industries making 28 to 31, where a classification of the industry was adjusted by its classification system[11].

III. Empirical Result

1. Effects of development of production techniques in an IT industry on other industries

This paper assumes 1% decrease in the capital cost due to technological improvement in the IT industry. Thereby, the IT industry becomes most competitive over other industries. <Appendix Table 1> shows substitution effects of production factors in each industry with IT industry's increase in production by 0.06%, the highest degree of change among others[12]. At the same time, household

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activities. VA=10926739+1.18 IT cost, b=1.18 counts when t=2.057 at 5% of significant level. Increasing 1won in a certain industry induces a value added 1.18 won.

F=-985262+1.08 VA, b=1.08 counts when t=5.791 at 5% of significant level. 1.08 won of final demand for increasing value induces a commodity in a certain industry added 1 won in the industry. (1.08)(1.18)d(IT cost) generates dF value.

10. It takes electric/electronic device, video/audio, computer, and office device industries as information & communication industries from the basic large scale of 28 industries categorized by the Bank of Korea. Actually, they belong to the industry (#13). Then, a household electric appliance industry is treated as a single independent industry classifying the industry(#13) into 3 parts. Also, the information & communication industry is to involve communication & broadcasting industry (#22) and real estate & computer services of business service industry (#24). In addition, it treats an education & health (#26) and health & social security industries as education/research/medical industries and other single industry, respectively. Social & other service industries (#27) are classified into cultural & recreational services and other services establishing a total of 31 industries.

11. The Ministry of Information and Communication defined a basic communication service, broadcasting service, communication device, and software industries as IT industries. In order to approach such systems, it is to carry out analysis on electric appliance, video/audio & communication device, computer & office device, and communication, broadcasting, and computer service industries regarded as an IT industry. Furthermore, this paper seems to have a relatively wider classification range of IT industries than that found in previous IT industry studies. For example, the most of international papers by Morrison(1991), Lichtenberg(1993), Gurmukh(1997), Beede(1997), etc. treated electronic computer, communication device, scientific equipment, and copy machine industries as IT capital.

12. As a research scenario for IT industry, it processes the analysis on the assumption that capital expenses fall by 1% based on a development of IT industry

electric appliances (#14) and precision instruments (#15) are the only industries prosperous to changes of the IT industry. For this reason, we may think the following main factors about these two industries. They are very sensitive to a fall in a price of production factors in IT commodity because of changes in IT industry, and their outputs are proportional to competitiveness induced by a huge fall in a price of their products, as compared to that of other industries. In general, this happens for industries with a high portion of IT commodity as intermediate mediums.

Although the range of Korean IT industry is set up to be wider than that found in international researches, there are only two industries with increasing production activities through substitution effects, which implies that the domestic IT industry has the opposite effects on changes of production techniques in other industries. In other words, production activities of other industries tend to be atrophied by the prosperity of IT industry in Korea.

Yet, as depicted in <Appendix Table 1> showing total effects (substitution + income effects) for 15 other industries such as Food & kindred products(#3), textile mill products & leather (#4), General machinery & equipment(#12), Transportation equipment(#16), Furniture & other manufacturing products(#17), Construction (#19), Wholesale & retail trade(#20), Restaurant & lodging places & hotel(#21), Finance & insurance (#22), Real estate & business services(#25), Education & research (#27), Medical, health, & social security (#28), Cultural & recreational services(#29), Other services (#30), and Non-classifiable services(#31) changed from negative to positive rates. However, public administration & defense (#26) is not influenced by substitution effects whereas proportional to income effect.

Summing-up the results in <Appendix Table 1>, a development of an IT industry has not an affirmative influence extended to changes of production techniques in other overall industries by substitution effects only. It is suggested that positive effects of total effects are observed over a majority of industries because IT commodity and services are in increasing demands due to a fall in a price of the IT industry. As IT commodity is in increasing demands by industries, a value added also increases being paid to production factors in association with each industry using IT commodity. Consequently, as the value added increases and its inducing increase in GDP, other industrial commodity becomes in increasing demands as well. In conclusion, a development of IT industry in Korea increases production activities of other industries through income effects rather than an industrial production structure favorable for IT[13] established by substitution effects.

As for total effects of service industries, negative effects are exhibited in Transportation & warehousing(#22) and Education & research (#27) industries. In contrast to Korea, the U.S. increased productivity of transportation industry by using computerized systems. Besides, Korea has industrial structures of education and research unfavorable for IT industries. In order to be familiar with how effective a development of IT industry is on economic structure, it is necessary to divide an industry into 3 different sections, a primary industry (Agriculture, forest & fisheries(#1) + Mining & quarrying(#2)), manufacturing industry (Food & kindred products(#3)~Construction (#19)) and service industry (Wholesale & retail trade(#20)~Non-classifiable services(#31) except Information & communication(#29) regarded as a single independent industry in the table), and compare them to one another. <Table 1> compares total effects in virtue of changes in IT industry with the data (1995) utilizing the ratio of each industry.

According to <Table 1>, a production percentage of IT industry increases from 7.5987 to 7.6031 of total production in an industry due to 1% fall in production expenses of IT industry while that of the primary, manufacturing, and service industries decreases. Classifying in industry into the three parts, Korean IT industry tends to developed by itself and absorb other industries, instead of providing a positive effects on them. Just by considering outputs, the primary and manufacturing industries have decreasing amount of outputs (35,197,190 to 35,195,758.3 and 449,657,885 to 449,652,762, respectively) while the service industry has increasing amount of outputs (292,719,130 to 292,731,382.9) implying that an industrial structure of service industries might increase. Yet, it seems more reasonable to compare the portion of production activities for an analysis of industrial changes and to conclude service industry's contraction because of the decreased portion.

13. As an example of a production structure of industry favorable for IT, airline industry in U.S. removed related regulations in the late1970s accelerating a Hub & Spoke System (HSS)-airport as a center of wheel (hub) from which air lines forms a shape of spoke. There was a strict restriction on economy for a point-to-point routing system before the late 1970s. But, thereafter, airlines utilizes computer systems for such data as pilot schedules, flight plan, estimation of fuel consumption, weather changes, air route, service fee, reservation, etc. managing them in their data base systems. In other words, they promoted and developed a transportation industry very quickly through rich economy systems by changes of techniques.

<Table 1> The Contribution of IT Industry

	Primary industry	Manufacturing industry	Service industry	IT industry	Total amount
Industry share in 1995	35,197,190 (4.1826%)	449,657,885 (53.4341%)	292,719,130 (34.7846%)	63,944,358 (7.5987%)	841,518,563 (100%)
Later share after change	35,195,758.3 (4.1821%)	449,652,762 (53.4305%)	292,731,382.9 (34.7842%)	63,985,490 (7.6031%)	841,565,312.2 (100%)

*Unit: one million won

In summary of the <Table 1> above, the contribution of IT industry is to make the economic pie bigger judging from the increase in total amount even if it cannot give a positive impact on other industries.

2. Effect of development of production techniques in IT industry on employment

As stated before, in the Korean economic system, the development of IT industry does not result in an industrial structure favorable for IT industry with the substitution effects only. This section will show what kind of changes the development causes to employment structure. It analyzes whether an employment over total economic systems is or is not increased as each industry enables IT commodities and services to be in increasing demands. That is, it reveals if IT commodity takes the place of employees, or is a supplement to them through a test of hypothesis.
<eqn. 3> gives an employment rate, where $L_{kj} = ß_{kj}p_jx_j/w_{kj}$ is expressed to $L_{kj} = ß_{kj}(p_j/w_{kj})x_j$, and the rate ($L_{kj}$) of j industry changes as its output changes (?x_j). Accordingly, it comes up with an equation, ?L_{kj} =$ß_{kj}(p_j/w_{kj})$?x_j , where L: variables of value added; k: number of value added (1~4); 1: employee pay(labor), 2: business surplus, 3: depreciation of fixed capital, 4: indirect tax.

The third column in <Appendix Table 2> shows the changes in labor use(?L_{kj}) due to the industries' changes in production activity(?x_j) under the condition where unit labor cost(w_{kj}) is fixed and all the prices(p_j) of commodities are changed. In <Appendix Table 2>, the first column shows the original data on labor cost and the second one shows the changed labor cost influenced by the change in IT industry. In order to process Paired Observations Test with values in the table, it is to setup following hypotheses.

Ho: $\mu_d \leq 0$; IT 's incapability of creation of labor employment
Ha: $\mu_d > 0$: IT 's capability of creation of labor employment

After all, a null hypothesis is rejected if two data has different values to each other admitting that the development of IT industry increases employment of each industry. However, in <Table 2>, although the mean of the labor cost is positive implying increases in employment, t value is not significant even at the significance level of 10 %, under which the null hypothesis cannot be rejected. That is, if a price of IT commodity comes down in virtue of a development of IT, the commodity will be in increasing demand for an intermediate medium in other industries. Moreover, the mean value in <Table 2> shows that IT commodities and employments seem to be complement to each other in regard to the positive value (1508.04) obtained by increasing employment pay as the application of IT commodity increases. But, the value is too small to say that IT has an influence on an employ enlargement.

<Table 2> The Impact of IT Indusutry on Employment

N	Mean	Std Dev	T	Prob>∣T∣
31	1508.04	7641.97	1.0987224	0.2806

*Prob>∣T∣: Probability of making a mistake on the consideration of t as a significant value.

IV Conclusion

Analyzing substitution effects of development of production techniques in IT industry, they increase a productivity of household electric appliance and precision instrument industries only rather than that of overall industries with improved production techniques gives a negative effect on the rest of industries decreasing their outputs. With the given total effects, it is concluded that outputs increase for a majority of industries in this study, resulted from a fall in a price of IT commodity, instead of a industrial structure favorable for IT, followed by increasing demands for the commodity. In general, it is also revealed that a development of production techniques in Korean IT industry does not contribute to an employment enlargement.

Although IT industry is to be a strategic industry in Korea in the near future, it is very disappointing for the fact that a current (1995) industrial structure is not inter-connected with IT industry. In particular, advanced countries develop IT industries by expanding service sector while reducing manufacturing industries. In Korea, as an IT industry develops, primary, manufacturing, and service industries have a reduced portion of the economy. Therefore, it is urgent to study industrial policies that inter-connect them with the IT industry. At the same time, a labor structure should be favorable for IT considering that advanced countries support IT industries with human resources on the basis of development of the education and research industries.

Footnotes:

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<Appendix Table 1> Change Rate in Production Activity

Industry	Substitution effect	Total effect
1. Agriculture, forestry, and fishery	-0.005048	-0.000437
2. Mining and quarrying	-0.084533	-0.039678
3. Food and kindred products	-0.004392	0.0001155
4. Textile mill products and leather	-0.001675	0.001238
5. Paper and wood products	-0.017297	-0.004547
6. Printing and publishing	-0.012895	-0.000289
7. Petroleum and coal products	-0.014452	-0.005739
8. Chemicals and allied products	-0.018121	-0.009905
9. Stone, clay, and glass products	-0.023736	-0.016652
10. Primary metal products	-0.021548	-0.007365
11 .Fabricated metal products	-0.00713	-0.002116
12. General machinery and equipment	-0.005039	0.0031658
13. Electrical machinery and equipment	-0.028596	-0.006326
14. Household electric appliances	0.0006833	0.0316116
15. Precision instruments	0.0019948	0.0423851
16. Transportation equipment	-0.000531	0.0075292
17. Furniture and other material products	-0.00286	0.0034603
18. Electric, gas, and water	-0.017192	-0.008469
19. Construction	-0.001105	0.0013128
20. Wholesale and retail trade	-0.004256	0.0139147
21. Restaurant, lodging places, and hotel	-0.010705	0.0038253
22. Transportation and warehousing	-0.008048	-0.002103
23. Finance and insurance	-0.00983	0.0057864
24. Information and communication	0.0600991	0.0641977
25. Real estate and business services	-0.010155	0.0037551
26. Public administration and defence	0	0.0064652
27. Education and research	-0.014195	-0.006627
28. Medical, health, social security	-0.001336	0.0020942
29. Cultural and recreational services	-0.004047	0.0021053
30. Other services	-0.001555	0.0047678
31. Nonclassfiable services	-0.01169	0.0027812

● numbers are presented in %

<Appendix Table 2> Change in Labor Cost

Industry	labor cost	labor cost I	change
1. Agriculture, forestry, and fishery	2800445	2800432.751	-12.24864
2. Mining and quarrying	818988	818663.0568	-324.9432
3. Food and kindred products	3878279	3878283.48	4.4800015
4. Textile mill products and leather	6284875	6284952.805	77.80476
5. Paper and wood products	1833314	1833230.647	-83.35259
6. Printing and publishing	2113284	2113277.893	-6.107376
7. Petroleum and coal products	721148	721106.6166	-41.38344
8. Chemicals and allied products	6503099	6502454.878	-644.1217
9. Stone, clay, and glass products	2879809	2879329.488	-479.5122
10. Primary metal products	3233789	3233550.837	-238.1628
11 .Fabricated metal products	3375508	3375436.585	-71.41474
12. General machinery and equipment	5365540	5365709.848	169.84801
13. Electrical machinery and equipment	2214779	2214638.917	-140.0828
14. Household electric appliances	566179	566357.9187	178.91874
15. Precision instruments	787633	787966.7178	333.71776
16. Transportation equipment	6961229	6961753.07	524.06978
17. Furniture and other material products	1674907	1674964.953	57.953106
18. Electric, gas, and water	1631592	1631453.819	-138.1807
19. Construction	20354621	20354888.19	267.19493
20. Wholesale and retail trade	13390903	13392766.02	1863.0165
21. Restaurant, lodging places, and hotel	2043051	2043129.147	78.146991
22. Transportation and warehousing	9720144	9719939.624	-204.3758
23. Finance and insurance	16063008	16063937.38	929.38056
24. Information and communication	9579144	9585279.009	6135.0092
25. Real estate and business services	9896652	9897023.599	371.5986
26. Public administration and defence	14797057	14798013.58	956.57621
27. Education and research	19684098	19682793.61	-1304.393
28. Medical, health, social security	6186093	6186222.545	129.54462
29. Cultural and recreational services	1769842	1769879.258	37.258498
30. Other services	2766878	2767009.908	131.90787
31. Nonclassfiable services	0	0	0

Unit:1 million won; labor cost: wage payment in original data; labor costI: wage payment after the change in IT industry; change: labor costI-labor cost