Input-Output Analysis Of The Effect Of Education And Research On The Korean Economic Structure

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Abstract

The purpose of this paper is to study the effect of economic policy such as subsidy or tax reduction by the government on education and research activities. The data to be utilized are the input-output tables reported by the Bank of Korea for 1980 and 1990. Using an input-output tables, we found a growing effect of education cost reduction on economic development. Unlike the traditional analysis by Leontief, input substitution is possible in the model we have used in this paper. As a result, we could predict the economy's response to cost variation. A surfeit of fervent passion on education among Koreans has been criticized as the source of a negative effect on the economy. However, the structural capability to accept these highly educated human resources must have grown for the past ten years. From the evidence of this trend, we can deduce a positive effect of education and research on the economy in the future.

I. Introduction

Education cultivates human intellect individually and makes society a better place to live in. It is known to be the stimulus needed to enhance the productivity of an economy. It helps the work forces improve their skills and productivities, which ultimately will affect the economy positively.

The purpose of this paper is to study this economic effect from the view point of economic policy such as subsidy or tax reduction by the government on education and research activities.

Readers with comments or questions are encouraged to contact the authors via e-mail.

The data to be utilized are the input-output tables reported by the Bank of Korea for 1980 and 1990. Using these data, we are going to find where the Korean economy is heading, and conclude whether the subsidy on education and research is effective in improving the economy.

The matter to be considered is a cause-effect relationship of the economy such as the change in output due to the change in education cost. The economy's output resulting from the education cost reduction should increase as time passes due to improvement in skills and technology. The hypothesis in this paper is that the sensitivity factor will become larger over time.

II. Educational Effect on Korean Industries

The educational investment and its rate of return have a close relationship with demand for labor at various levels of academic background. Korean economy has changed its structure through governmental initiative.(1) In the 1960s, the agricultural or light industry using cheap labor was the main portion of Korean economic structure. In the 1970s, the developmental strategy of industrialization was implemented by an intensive drive in the heavy and chemical industries. In the 1980s, the export drive policy was changed into technology drive policy. The emphasis on technological development was to let Korean industries be equipped with competitiveness not only in domestic but also in overseas markets.

The structural change of Korean economy has moved from a labor-intensive aspect to a capital-intensive aspect. This movement was guided by government policy especially in mid 1980s. The rate of return to junior high school education was the highest in 1960s and early 1970s while that to college education was the lowest. Since then, there has been a trend to accelerate the rate of return to the higher level of education. This trend reflects a developmental feature of the structure of Korean economy: that it has acquired a facet of intellectual industry after experiencing agricultural and manufacturing stages of industry. This structural change implies a change in the demand for labor at a higher education level.(2)

The purpose of this paper is to test if the cost reduction of education and research will improve the economy. The sensitivity of cost reduction for 2 years will be compared with the analysis of economic structure related to education. The data to be utilized are the 1980 and 1990 input-output tables(3) reported by the Bank of Korea.

III. Models

The model to be used here is different from the traditionally accepted input-output model introduced by Leontief. Because Leontief's model contains a defect of incapacity for input substitution, an explanation of output change due to cost variation is impossible. It also lacks the capacity to explain consumers behavior during periods of substitution of one good for another.

1. Leontief Model

The Leontief input-output system is a summary of interindustry relations within an economy. The commodity flow between industries is denoted by the matrix

$X=(x_{ij})$

where $i,j=1,2,3,\text{-----},n.$

where x_{ij} implies that industry i sells its product as an intermediate good to industry j. Usually the commodity flows are expressed in dollar value (monetary terms). The coefficient matrix, that is the technological coefficient, is the ratio of the each required input to the output of an industry. The term "technological coefficient" is made possible only by the assumption that each industry or sector produces a single type of output. The matrix form of the coefficient is denoted as;

$A=(a_{ij})=X\hat{x}^{-1}$

where x is the vector of each industry's total output, $x=(x_1,x_2,\ldots,x_n)$, and the hat (^) implies diagonalization of row vector, x. This technical coefficient indicates the structure of the economy in a Leontief I-O system. The accounting balance equation for output x_i is formed as

$$x_i = \Sigma^n_{j=1}\ x_{ij} + F_i \qquad (3.1)$$

$i=1, 2,\ldots\ldots,n,$

where x_i is total output of industry i, and F_i is the final demand for commodity i. Equation (3.1) can be written as follows by substituting $x_{ij} = a_{ij} x_j$ and thus expanding horizontally on the I-O table:

$$x_i = \Sigma^n_{j=1} \; a_{ij} \, x_j + F_i. \qquad (3.2)$$

In matrix form,

$$x = Ax + F \text{ or } x = (I-A)^{-1} F. \qquad (3.3)$$

The term ,$(I-A)^{-1}$, is called ' Leontief Inverse.' When A and F are given, the n linear equations can be solved for x.

By expanding vertically on the I-O table, we can solve for the equilibrium prices of commodities and services. In equilibrium, the revenue function for each industry is

$$p_j x_j = \Sigma^n_{i=1} \, p_i x_{ij} + w_j L_j \qquad (3.4)$$

i=1----,n,

where p_j is the price of commodity j and w_j is the input price of primary input (L) used by industry j. By dividing equation (3.4) by x_j , we have

$$p_j = \Sigma^n_{i=1} \, p_i a_{ij} + v_j \,, \qquad (3.5)$$

where $v_j = w_j L_j / x_j$ is value added per unit of commodity j. In matrix notation equation (3.5) can be p=pA+v or

$$p = (I-A')^{-1} \, v \qquad (3.6)$$

Since equations (3.3) and (3.6) were introduced, there have been criticisms of the Leontief Model because the two equations contain no relationship between price and output. The defect of the Leontief model is that cost variation or price cannot affect the output level. In equation (3.6) a change in the costs of production (a change in v) will affect the prices of commodities. However, neither cost nor price can affect output because we cannot observe any variable except final demand (F) in equation (3.3). In the real world, a change in price (p) always affects output, yet in this model this change does not occur because of the dichotomy of price and output in equations (3.3) and (3.6).

The criticism of the Leontief's two equations centers around the issue that the dichotomy generates a misbelief in the disconnection of cost and price with output. One can pass Samuelson's citation unnoticed. Based on the assumption that each industry produces only a single type of commodity, Samuelson interprets technological structures in two ways. If we look at this system as a linear production function with a fixed proportion among factors, the system does not allow for input substitution. This view leads to a disconnection between price and output. On the other hand, if we look at this as production functions, homogeneous of degree one, the system allows input substitution. This input substitution allows changes in technological coefficients and will lead to the connection with price and output.

2. VIO model

VIO has the capacity to incorporate another type of production function, such as CES functions, in addition to the Cobb-Douglas production function. It begins with equation (3.4), which is the equation of revenue and cost. In addition to this equation, the subject issue, the education and research cost variable is exogenously treated.

$$p_j x_j = \Sigma^n_{i=1} \, p_i x_{ij} + w_j L_j + e_j E_j \,, \qquad (3.4)'^{(4)}$$

where e_j is the price of education and research and E_j is the input of education and research used by industry j.

Production side

Equation (3.4) is changed to a profit maximizing function subject to a production function.

$$\text{Max } F = \Sigma_j \, (p_j x_j - \Sigma_i p_i x_{ij} - \Sigma_k w_{kj} \, L_{kj} - \Sigma_m e_{mj} \, E_{mj}) + \Sigma_j \, \lambda(\ln x_j - \alpha_{0j} - \Sigma_i \alpha_{ij} \ln x_{ij} - \Sigma_k \beta_{kj} \ln L_{kj} - \Sigma_m \gamma_{mj} \ln E_{mj}) \qquad (3.7)$$

This model has the same homogeneous condition as the Leontief model. Thus, $\Sigma_i \alpha_{ij} + \Sigma_k \beta_{kj} + \Sigma_m \gamma_{mj} = 1$ is from the Cobb-Douglas function. Unlike equation (3.4), equation (3.7) categorizes the primary inputs with k and education and research inputs with m. L_{kj} implies primary input k used by j industry.

The Lagrangian equation of this optimization function leads to the first order condition;

$$dF/dx_j = p_j + \lambda / x_j = 0$$
$$dF/dx_{ij} = -p_i - \lambda \alpha_{ij} / x_{ij} = 0$$
$$dF/dL_{kj} = -w_{kj} - \lambda \beta_{kj} / L_{kj} = 0$$
$$dF/dE_{mj} = -e_{mj} - \lambda \gamma_{mj} / E_{mj} = 0$$
$$dF/d\lambda = \ln xj - \alpha_{0j} - \Sigma_i \alpha_{ij} \ln x_{ij} - \Sigma_k \beta_{kj} \ln L_{kj} - \Sigma_m \gamma_{mj} \ln E_{mj} = 0$$

The first equation gives the result; $\lambda = -p_j x_j$. The profit maximizing optimal input demand is;

$$x_{ij} = \alpha_{ij} p_j x_j / p_i, \quad L_{kj} = \beta_{kj} p_j x_j / w_{kj}, \quad E_{mj} = \gamma_{mj} p_j x_j / e_{mj} \qquad (3.8)$$

When we substitute the values, $\alpha_{ij} p_j x_j / p_i$, $\beta_{kj} p_j x_j / w_{kj}$, and $\gamma_{mj} p_j x_j / e_{mj}$ into the production equation, the following price frontier equation is obtained:

$$\ln p = (I - S')^{-1} [\Sigma_k \beta_k \ln w_k + \Sigma_m \gamma_m \ln e_{mj}] \qquad (3.9)$$

When education and research costs change, with primary input prices remaining constant, the prices of j-m industries will be affected. With these affected prices, the exogenously changed education and research prices form a complete (j=n by j=n) diagonal price matrix $\hat{p}$ which we use in a matrix form:

$$x = \hat{p}^{-1} (I-A)^{-1} \hat{p} F, \qquad (3.10)$$

where x is an n component column vector of x_i;

A is an n by n square matrix of α_{ij};
$\hat{p}$ is an n component diagonal matrix of p_j;
F is an n component column vector of F_i;

This equation resolves the problem of the inability of the Leontief model to explain an output effect from cost variation. We then can use equation (3.10) to estimate the change in the output of each commodity of the economy even if we deal with a single I-O table for a certain year.

If we use more than two years' tables, we can compare results, and we can determine and measure changes in the economic structure. Based on the assumption that input substitution exists within a single year, we can estimate the possible change of the output (dx) for that year. By comparing the change rates in output(dx/x) between years, we can measure the structural change of the economy. This paper will address the output effect of education and research cost changes.

Consumption side

We assume utility maximization for consumers with constrained expenditure, and we use that convention for consumption. We consider the Cobb-Douglas form of utility function for the simple case of two commodities as follows.

$$\text{Max } U = A c_1^{\tau 1} c_2^{\tau 2}$$

$$\text{subject to } E = p_1 c_1 + p_2 c_2 \qquad (3.11)$$

The Lagrangian equation of this optimization function is

$$Z = A c_1^{\tau 1} c_2^{\tau 2} + \mu (E - p_1 c_1 - p_2 c_2)$$

The first order condition:

$$dz/dc_1 = \tau_1 A c_1^{\tau 1-1} c_2^{\tau 2} - \mu p_1 = 0$$
$$dz/dc_2 = \tau_2 A c_1^{\tau 1} c_2^{\tau 2-1} - \mu p_2 = 0$$
$$dz/d\mu = E - p_1 c_1 - p_2 c_2 = 0$$

The optimal levels of consumption of c_1 and c_2 are:

$$c_1 = \tau_1 E/((\tau_1+\tau_2)p_1), \quad c_2 = \tau_2 E/((\tau_1+\tau_2)p_2)$$

When we use these values in the utility function, we obtain the indirect utility function (V).

$$V = (A\Omega E(\tau_1+\tau_2))/(p_1^{\tau 1} p_2^{\tau 2}) = (A\Omega E)/(p_1^{\tau 1} p_2^{\tau 2})$$

where $\Omega = (\tau_1)^{\tau 1} (\tau_2)^{\tau 2}$ and $\tau_1 + \tau_2 = 1 = \Sigma \tau_i$.

This indirect utility function is assumed to be homogeneous of degree zero in p's and E. Some proportional change in p's and E will not change the utility and consumption of commodities.

If the V equation is extended to the multi-commodities case, the indirect utility function is as follows;

$$V = (A\Omega E)/\Pi_i(p_i^{\tau i})$$

where $\Omega = \Pi_i(\tau_i)^{\tau i}$, $E = \Sigma_i p_i c_i$, and $\Sigma_i \tau_i = 1$ $(i = 1,2,3,.......,n)$.

Taking the natural log on both sides;

$$\ln V = \ln A\Omega + \ln E - \Sigma_i \tau_i \ln p_i$$

$\ln A\Omega$ can be ignored because it is a constant value.

$$\ln V = \ln E - \Sigma_i \tau_i \ln p_i \qquad (3.12)$$

Roy's identity will give a utility maximizing consumer demand as follows.

$$c_i = -(dV/dp_i)/(dv/dE) = \tau_i E/p_i, \qquad (3.13)$$

where τ_i is commodity i's share of consumption expenditures. Household aggregate consumption expenditure, E, is defined to be a fraction of national income, $Y = \Sigma_j \Sigma_k w_{kj} L_{kj}$;

$$E = \delta Y = \delta(\Sigma_j \Sigma_k w_{kj} L_{kj}), \qquad (3.14)$$

where d is a fractional value of consumption rate which is derived from dividing the total amount of personal consumption expenditure by the amount of value added, in other words, GNP (Gross National Product). When we substitute $L_{kj} = \beta_{kj} p_j x_j / w_{kj}$ in equation (3.14), the expenditure equation becomes

$$E = \delta Y = \delta(\Sigma_k \beta_k \Sigma_j p_j x_j).$$

Thus, the utility maximizing consumption level of each commodity is:

$$c_i = \tau_i E/p_i = \tau_i \delta(\Sigma_k \beta_k \Sigma_j p_j x_j)/p_i$$

<u>Combination of Production and Consumption side</u>

In addition to eq.(3.10) from the producers' behavior, we substitute (3.8) condition in equation (3.1) for consumers' behavior.

$$x_i = \Sigma_j \alpha_{ij} (p_j/p_i) x_j + ci + f_i$$

$$= \Sigma_j a_{ij} (p_j/p_i) x_j + t_i \delta(\Sigma_k \beta_k \Sigma_j p_j x_j)/p_i + f_i,$$

where f_i is an n component column vector of final demand excluding consumption by households. When expressed as a matrix form, the technology coefficient matrix, A, is changed into Λ.

$$\Lambda = \begin{bmatrix} \alpha_{11}+\delta\tau_1\beta_1 & ...\alpha_{1n}+\delta\tau_1\beta_n \\ : \quad X & : \\ \alpha_{n1}+\delta\tau_n\beta_1 & ...\alpha_{nn}+\delta\tau_n\beta_n \end{bmatrix}$$

As a result, the accounting balance equation will be changed into

$$x = \hat{p}^{-1} \Lambda \hat{p} x + f,$$

where x is an n component column vector of x_i; Λ is an n by n square matrix; $\hat{p}$ is an n component diagonal matrix of p_j; f is an n component column vector of final demand. The output vector x is expressed as

$$x = \hat{p}^{-1} (I-\Lambda)^{-1} \hat{p} f. \qquad (3.15)$$

In the equation above, price affects the output. This result cannot be observed in the Leontief model. This is the VIO model's contribution in the amelioration of a traditional I-O model.

The output equation (3.15) can proceed to a differential form, namely

$$x = \hat{p}^{-1} (I-\Lambda)^{-1} \hat{p} f = (I-h)^{-1} f, \quad \text{where } h = \hat{p}^{-1} \Lambda \hat{p}$$

Multiplying by (I-h) on both sides and conducting the total differentiation, then we have:

$$(I-h)x = x - hx = f$$
$$dx - h\,dx - dh\,x = df$$

$$(I - h)dx = dh\,x + df$$
$$dx = (I-h)^{-1}\,dh\,x + (I-h)^{-1}\,df \qquad (3.16)$$

The term h in the above equation involves p (prices of commodities) which is affected by the input cost variation. As a result, the output effect of the relative price change due to cost variation is described by $(I-h)^{-1}dh\,x$ which is often referred to as 'substitution effect'. The output effect of final demand change $(I-h)^{-1}dF$ is referred to as 'income effect'. The substitution effect will only be considered in this paper.

V. Hypothesis and Empirical Results

1. Hypothesis

Since the goal of the analysis is to find if the I-O table can show trends of the structural changes in the Korean economy in response to education cost decreases, the arbitrary constant benefit of 10% cost reduction is assumed in each of these years.(5) Since it is assumed that our I-O table involves the input substitution with a production function homogeneous of degree one, each one-year table will show a changed output in response to the education cost reduction. By comparing the rate of output change for two years, we can successfully trace the structural changes if the response to the education cost reduction stimulates the economy as time passes.

It was expected that in the first year (1980) of the analysis, the rate of change in output would have been smaller than in later years because the highly educated labor force would not have been very useful in an industrial structure of low-skilled labor intensiveness. In other words, output elasticity with respect to education cost reduction should have been smaller in 1980 than in 1990. It is hypothesized that the rate of change in output of the economy due to cost variation should increase as time progresses:

$\mu_{1980} < \mu_{1990}$.(6)

Paired observation method was used for the empirical test.

2. Empirical Results

The results of the output changes and the difference between two years of each of 29 industries in response to the education cost reduction of 10% are in Appendix 1.

The mean percent change in output of 1980 and 1990 of Appendix 1 is as follows:

Mean	% change in output
1980	-0.25889%
1990	-0.11236%

The test for the paired observations is as follows:

Mean difference	Std. Dev.	t	Prob. > |t|
0.14653%	0.00186	4.25	0.0002

The comparison of the production sensitivities between 1980 and 1990 indicates an overall increase in output due to cost reduction in education and research. In both years, however, we have negative reactions in output even if there is assumed a beneficial phenomenon of cost reduction. We have to interpret these results as an indication that Korean education level is still too high for its economic structural level.

The passion for high education in Korea has been a negative aspect for economic development because the economic structure has required unskilled labor without high education. The change in output response for ten years indicates that economic structure is slowly changing in the direction of requiring a highly educated labor force. Even if the response in 1990 shows a negative change in output, the negativity has decreased, which means highly educated people contributed to an enhancement of economic structure.

The t value(4.25) for the difference between two years reveals that there has been a growing effect of cost reduction in education on output. The P value is so low that we can deduce the existence of a significant structural change in the economy. There was the large increase from 170.1 college students per 10,000 people in 1980 to 389.8 college students per 10,000 people in 1990.[7] Despite this surplus of highly educated resources, the output has decreased less than that of 1980. We can conclude that the Korean economic structure has changed in the direction of an increased demand for highly educated people.

VI. Summary

We have analyzed Korean economic structural change from labor to capital intensiveness. Using an input-output table, we found a growing effect of education cost reduction on economic development. Unlike the traditional analysis by Leontief, input substitution is possible in the model we have used in this paper. As a result, we could predict the economy's response to cost variation.

A surfeit of fervent passion on education among Koreans has been criticized as the source of a negative effect on the economy. However, the structural capability to accept these highly educated human resources must have grown for the past ten years. From the evidence of this trend, we can deduce a positive effect of education and research on the economy in the future.

VII. Suggestions For Future Research

We have had a difficulties in finding statistical data concerning more detailed I-O tables classifying the education and the research separately. The test for more detailed classification would have been more satisfactory. If we could find the data we wanted, the cost-benefit analyses of education and research, respectively, would have been possible.

The future plan for our research will be with the more detailed and recent data based on multiregional I-O tables. The multiregional I-O table will help us analyze the Korean industries' competitiveness assisted by education and research in the international trade. Because it seems to us that the comparison of the social passsions for education and research is the key factor for finding out nations' competitiveness. 🕮

Footnotes

1. For example, the share of agriculture fell from 40 percent in 1963 to only 9 percent in 1990. Manufacturing's share was only 14.7 percent in 1963, and rose to a maximum share of 28 percent in 1990. Finance, insurance & real estate share were increased from 7.0 percent in 1973 to 14.4 percent in 1990. Source: Bank of Korea, National Income in Korea 1975, Seoul, 1976; Bank of Korea, National Accounts 1990, Seoul, 1990; National Statistical Office, Korea Statistical Yearbook 1992, Seoul, 1992.
2. Kong used Becker's model for finding the rate of return to education and applied it to the Korean situation and concluded this. Kong(1988), pp. 176-77.
3. The Bank of Korea has issued the I-O table on a constant industry basis since 1980. To compare the two years' sensitivity, we had no alternative to choose 1980 and 1990.
4. From now on, for simplicity's sake, we are about to use Σ_i for $\Sigma^n_{i=1}$.
5. As the model used here is based on the assumption of a production function which is homogeneous of degree one, the statistical value is always the same regardless of the size of the change in the cost. Thus we set up an arbitrary but realistic reduction rate of 10%.
6. This μ is a population mean which is different from the symbol of the consumption side Lagrangian equation.
7. Source: Korean educational Development Institute, 1994, pp. 76-77.

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Appendix 1
Changes in output (1980, 1990)

Industry classification	Rate of output change (1980)	Rate of output change(1990)	Difference of rate of change
1. Agriculture/ forestry /fisheries	-0.14563	-0.006730	0.0078338
2. Mining /quarrying	0.012796	0.010485	-0.0023113
3. Food /kindred /product /tobacco	-0.008401	-0.005071	0.0033300
4. Textile mill product /apparel /leather	-0.001578	-0.000825	0.0007532
5. Paper/ wood product	-0.003902	-0.003416	0.0004866
6. Printing/ publication	-0.009879	-0.006203	0.0036764
7. Petrochemical basic products	-0.006783	-0.003436	0.0033466
8. Rubber/plastics products	-0.005663	-0.004895	0.0007677
9. Petroleum/coal products	-0.002094	-0.001309	0.0007855
10. Stone/clay products	-0.001028	-0.000821	0.0002066
11. Primary metal products	-0.001791	-0.000985	0.0008065
12. Fabricated metal products	-0.001821	-0.000873	0.0009484
13. General machinery/equipment	-0.003418	-0.000631	0.0027873
14. Electronic/other electric equipment	-0.001158	-0.000930	0.0002278
15. Precision instruments	-0.006141	-0.005632	0.0005091
16. Transportation equipment	-0.001097	-0.001142	-0.0000455
17. Miscellaneous manufacturing products	-0.002552	-0.001535	0.0010174
18. Electric/ gas/water services	-0.005094	-0.004206	0.0010671
19. Construction	-0.000385	-0.000264	0.0001214
20. Wholesale/retail trade	-0.003567	-0.002186	0.0013813
21. Eating/drinking place/hotels/lodging places	-0.007612	-0.004328	0.0032841
22. Transportation/warehousing	-0.003074	-0.002314	0.0007599
23. Communication	-0.004960	-0.003408	0.0015525
24. Finance / insurance	-0.003680	-0.002623	0.0010575
25. Real estate/business services	-0.004967	-0.003109	0.0018582
26. Public administration/defense	-0.000049	-0.000119	-0.0000700
27. Education/research	0.031640	0.032106	0.0004668
28. Medical/health services/social security	-0.005581	-0.004129	0.0014522
29. Social services	-0.008673	-0.004237	0.0044356

*. Difference of rate of change = Rate of output change (1980) - Rate of output change (1990)