An Endogenous Growth Model Approach to the Korean Economic Growth Factors

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The rapid growth of the Korean economy since 1960s is generally regarded as a miraculous event. The growth strategies of the Korean economy have been evaluated as a successful development model imitated and pursued by other countries. But pessimistic views on the Korean economy as a growth model have been raised, especially when Korea faced the foreign exchange crisis in 1997. One of these pessimistic views is that Korean economic growth was just the result of an expansive input of production factors. Therefore it argues that the Korean economy lacks further potential of rapid growth. But these debatable arguments have not been properly analyzed yet. To evaluate the future growth potential of Asian countries including Korea, these pessimistic views should be examined thoroughly.

The aim of this paper is to evaluate empirically the pessimistic views on the Korean economy. In other words, this paper analyzes what factors caused the growth of

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the Korean economy so far from a new viewpoint. This paper analyzes the growth factors of the Korean economy based on the new economic growth theory that regards technological change and human capital as endogenous core factors of economic growth. The main results of this paper show that the Korean economy has achieved endogenous growth depending not only on an extensive increase in capital input but also on its own technology development. Therefore we conclude that the popular pessimistic views on the future of the Korean economy are quite inappropriate. (O11, O40, O53)

Ⅰ. Introduction

Skeptical views on the future of Korean economy have been raised among economists inside and outside Korea since Korea entered into the IMF bail-out package program. One of the most significant arguments supporting these negative views is that the ability of economic growth of Korea has reached its limit, since Korean economic development has depended excessively on increases of labor and physical capital inputs[1].

Capitalistic economy has been developed not only through an extensive expansion process, that combines huge capital accumulation and labor inputs, but also through an intensive expansion process, that develops high quality technology and human capital. Therefore, we can infer that continuous economic development of an economy is quite improbable if the economy cannot achieve continuous productivity improvement through technological development. In this regard, we can raise the following question: Has economic development of Korea largely depended on employment of more later and physical capital? To answer this question, this paper tries to analyze mostly in the first place the major causes of Korean economic growth since

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[1] This controversy on this issue was initiated by Paul Krugman's article, "The Myth of Asia's Miracle,"(1994, *Foreign Affairs*). This has been developed into a controversy on the 'Asian Value', since Asian countries faced the financial crisis in 1997.

1960s, and to figure out in due course how technological factor has affected Korean economic growth.

There are two major approaches dealing with the relationship between technology and economic growth[2]. One is the `Growth Accounting Analysis approach(GAA, hereafter)' of Neo-Classical tradition which was developed by Solow(1956) and Griliches(1973). With this method we can determine a sort of contribution ratio of major inputs. In this approach, however, the contribution ratio of technology is computed by simply extracting the contribution ratios of labor and capital from the total output growth rate. In addition, the GAA simply depends on arithmetic calculation, and neglects a dynamic economic aspect in consequence. Thus, although we can measure how much the technological factor contributed to economic growth relatively, we cannot examine in what ways the technology made contribution to economic growth[3]. Denison and Chung(1976), Young(1995), Kim and Hong(1997) and Kim(1998) analyzed the Korean economic growth using this GAA approach.

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[2] As another method for analizing relationship between technology and economic growth, the Theory of Technological Innovation System, that is suggested by New Schumpeterists based on Schumpeter's economic growth theory, could be brought in here. It can serve as an useful method to examine the pattern of technological development in an economy or a firm. But it is not introduced here since it concentrates only on the direct relationship between technological development and economic growth.

[3] Barro and Sala-I-Martin(1995), pp. 330-381.

The other approach is based on a New Economic Growth Theory(NEG, hereafter), which has been popular among many economists since mid-1980s. It emphasizes technology as one of the most important factors in economic growth. The NEG Theory was developed to overcome the limitations of Neo-Classical Economic Growth Theory, regarding technology as an endogenous factor in economic growth. The NEG Theory examines how technological development causes influences other factors' productivity in a production function. In fact, The NEG Theory is a new theory to analyze how technological development affects economic growth in a dynamic context. It is obvious that the NEG will overcome major drawbacks of traditional approaches, since it can examine the relationship between technological development and economic growth, based on an endogenous growth model.

Some economists have analyzed the major causes of Korean economic growth using the NEG approach since 1990. Sengupta(1991), Pyo(1995) and Jang(1995) are good examples. However, most of these researches have focused simply on emphasizing export or human capital as a major growth factor, and thus neglected the role of technological change for economic development.

Romer(1990)'s Endogenous Technological Change Model(ETCM, hereafter) is employed in this study in order to overcome the weaknesses of GAA and some limitations of previous NEG based studies[4]. We adopted Romer's ETCM in this study for the following reasons: First, this model emphasizes technological development, a core source for development of capitalistic economy, as an endogenous factor for economic growth. Since Romer's ETCM makes technological factor as an endogenous variable in a production function, it can analyze the process of intensive growth of capitalistic economic system more specifically. Second, production function type of ETCM is convenient for empirical analysis.

II. Specification of an Analytical Model

According to the core theory and policy implications of Romer-type ETCM, there are four basic factors in production, capital(K,x_i)[5], labor(L), human capital(H) and the level of

[4] The term, 'technological development', in this study, means not only improvements of production methods but also the improvements of human capital that can be associated with new production methods. With the adoption of associated endogenous technological change model, this study is to analyze the sources of economic growth, based on the fundamental mechanism of capitalistic economic development: Capitalistic economic system has been developed through advancement of technology and accumulation of human and physical capital.(see Lee and Yu(1998), Yu(1998))

[5] x_i is an intermediate good, and K represents the total sum of x_i

technology(A). Since it assumes an one-sector production model, a final good can be used as an intermediate good or a consumption good. Labor supply(L) is simply defined as labor force or the size of population. Human capital(H) is represented by the cumulative effects of learning activities such as institutional education and knowledge acquisition or on-the-job training. A special feature of this model is that it separates the non-contestable, physical technological factor A, from the competitive technological factor, H. That is, it distinguishes technology level and human capital that utilizes technology. Furthermore, since A can be independent of any specific individual, A can be increased without limit. Romer assumes the technology level A can be measured by the number of designs in order to solve the measurement problem[6].

Romer's model(1990) assumes that the economy is composed of three sectors. First one is the research sector. The research sector combines human capital and technology that have been accumulated so far to develop a new technology. This sector makes designs for new durable goods. Second one is the intermediate-goods sector. This sector uses previous products and designs that the research sector made, to produce durable goods. Works for creation of designs can be carried out by both a corporation

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[6] Design means a state variable that includes not only changes in the shape of goods but also changes in the qualities of goods and innovation in production methods.

itself and other corporations that attempt to sell patent rights to final-goods-producing corporations. Since the creation of a unique design can exercise monopolistic power, intermediate-goods leads to a monopolistic equilibrium. Third one is the final goods sector. This sector uses labor, human capital and durable goods to produce final goods. In this sector, perfect competitive equilibrium prevails.

By all these assumptions, we can specify a Romer-type model, in Which final goods are produced in a perfectly competitive market with a transformed Cobb-Douglas type production function.

$$Y = H_Y{}^{\alpha} L^{\beta} \sum_{i=1}^{\infty} x_i{}^{1-\alpha-\beta} \tag{1}$$

Where $0 < \alpha, \beta < 1$, $0 < \alpha + \beta < 1$, H_Y is human capital devoted to final output, L is labor, x_i is input of intermediate good.

Accumulation of capital can be measured as the unconsumed part of total output. We assume that η units of products(x_i) must be used to produce a unit of capital good(intermediate good) and the production of intermediate good is constrained by A(the number of designs). That is,

$$\dot{K}(t) = Y(t) - C(t)$$

$$K = \eta \sum_{i=1}^{\infty} x_i = \eta \sum_{i=1}^{A} x_i \qquad (2)$$

A general equlibrium solution can be derived in the following form, in which dynamic characteristics of the model can be examined.

$$\begin{aligned} Y(H_A, L, x) &= H_Y{}^{\alpha} L^{\beta} \int_0^{\infty} x(i)^{1-\alpha-\beta} di \\ &= H_Y{}^{\alpha} L^{\beta} A \bar{x}^{1-\alpha-\beta} \\ &= H_Y{}^{\alpha} L^{\beta} A \left(\frac{K}{\eta A}\right)^{1-\alpha-\beta} \\ &= (H_Y A)^{\alpha} (LA)^{\beta} K^{1-\alpha-\beta} \eta^{\alpha+\beta-1} \qquad (3) \end{aligned}$$

Technological development function can be set for the endogeneity of technology as in the following. That is, technology is developed by existing technology level of present and human capital.

$$\dot{A}_T = \delta H_A A_T \qquad (4)$$

(A_T : technology level(=A), H_A : human capital employed in research,

δ : productivity coefficient)

Combining this with partial equilibrium solutions, we can get the following general equilibrium solution:

$$g = \frac{\delta H - \Lambda\rho}{\sigma\Lambda + 1} \qquad (5)$$

$$(\Lambda = \frac{\alpha}{(1-\alpha-\beta)(\alpha+\beta)},\ H = H_A + H_Y)$$

From these general equilibrium solutions we can derive the following economic implications.

First of all, on the basis of the production function and technology function, we can finally derive an the growth rate:

$$g = \delta H_A = \delta H - \frac{\alpha}{(1-\alpha-\beta)(\alpha+\beta)} r \qquad (6)$$

(r = interest rate)

Equation (6) gives the notion that economic growth is determined by human capital H_A. That is, with H_A we can achieve technological-development-oriented growth in terms of the equation (4), $\dot{A}_T = \delta H_A A_T$.

And it allows us to accomplish economic growth in the form of increasing return to scale. In the production function of the Romer's ETCM, the technology(A), which is an increasing-returns-to-scale factor, is to be an endogenous variable. In this aspect, Romer's ETCM is different from the Neo-Classical-type Growth Model, which assumes decreasing-returns-to-scale. Therefore, the most fundamental factor for economic growth, in Romer's ETCM, is not labor L or physical capital K, but human capital H, which causes technological change(A) in the end.

This model also provides some useful economic implications for the relationship between economic growth and international trade(via human capital). We can easily see the correlation between these two by comparing economic growth rates of the two independant closed economies and that of the integrated economy of these two. For example, we assume that common economic growth rate of these two is given as g, (see equ.(5), where $g = \frac{\delta H - \Lambda\rho}{\sigma\Lambda + 1}$), and that each economy has the same quantity of human capital H. Therefore, if these two economies are integrated, the new joint economic growth rate of the newly integrated economy will be the sum of each H (that is, 2H). This economic growth rate of the newly integrated economy will be higher than the previous individual growth rate. This argument eloquently speaks of the importance of an opening policy in international trade. In other words, this implies that free international trade can accelerate economic growth of each country through common utilization of human capital of participating.

By all these, we can summarize three major findings based on the implications of this model: First, it is human capital that plays a more important role than physical capital in the continuous economic development of capitalism. The accumulation of human capital can be a cause for technological change and it can improve the efficiency of physical capital. Second, the role of capital and labor is quite limited in the ETCM, due to this characteristics of diminishing-returns-to-scale. Third, accumulation of human capital and technological change can be accelerated by the expansion of international trade. In other words, expansion of international trade can have positive effects on the accumulation of human capital and technology and thereby on the economic development through importation of the advanced technologies from abroad. This model in a way argues for the export-led growth strategy.

III. Empirical Analysis

1. Specification of Estimation Model

In order to analyze major causes of productivity improvements in Korean economy, We can specify an estimation model in the following way on the basis of the production function, which was drived from ETCM in the previous section. In other words, we set the estimation equation by differentiating equation (3).

$Y(H_y, L, K) = (H_Y A)^{\alpha} (LA)^{\beta} K^{1-\alpha-\beta} \eta^{\alpha+\beta-1}$ with respect to time t. Actually we estimated two different production fuctions, one with a international trade term in it, the other without it.

So, the first equation to be estimated becomes: .

$$\dot{Y} = f(\dot{L}, \dot{H}, \dot{K}, \dot{A})$$

(where, $\dot{Y}$: growth rate of GDP, $\dot{L}$: growth rate of labor, $\dot{H}$: growth rate of human capital, $\dot{K}$: growth rate of physical capital, $\dot{A}$: growth rate of technology level)

The second estimation equation is specified so as to test whether the expansion of international trade makes positive effects on the economic growth through improvement of human capital and technological advancement. So, the second estimation equation becomes:

$$\dot{Y} = f(\dot{L}, \dot{H}, \dot{K}, \dot{A}, \dot{T})$$

(where, $\dot{T}$: degree of international trade expansion)

2. Data

Annual data for the period of 1975-1997 was used for the empirical study of Korean economic growth. We employ the real per-capita GDP growth rate(PRGDPR) as a dependent variable[7]. Explanatory variables are separated into five groups: physical capital, labor, human capital, technology, and degree of international trade expansion.

Table 1

Major Variable Lists

	Variable Names	Definition of Variables
Output	PRGDPR	real GDP per capita growth rate(%)
Physicsl Capital	RGKSR	total fixed capital growth rate (%)
Labor	POPR WPLR	total population growth rate (%) labor force growth rate (%)
Human Capital	HY	weight of professional, technical workers in labor force(%)

[7] The estimation period was limited to the 1975-1996 period due to the availability of data, regarding the number of professional, technical workers for the human capital variable, and severe structural change caused by the financial crisis since the end of 1997.

	HYLR RSEW OJTR	growth rate of the number of professional, technical workers (%) the relative ratio of the number of scientists and engineers in R&D activities to labor force growth rate of the workers on-the-job training(%)
Technology	RRNDNR	real R&D investments growth rate (%)
Degree of International Trade Expansion	TAR	effective rate of tariffs (%)

Data Sources:

Bank of Korea, *National Accounts*, *Annual Statistics*, each volume.

Bureau of Science and Technology, *Year Book of Statistics of Science and Technology*, each volume.

Bureau of Statistics, *Year Book of Statistics*, each volume.

Department of Labor, *Yearly Labor Statistics*, each volume

ILO, *Year Book of Labor Statistics*, each volume.

Korea Association of Promotion of Industry and Technology, *Statistics of Industry and Technology*, each volume.

Growth rate of the total fixed capital(RGKSR) is used for the total physical capital variable. In case of human capital, the weight of professional, technical workers in labor force(HY), the relative ratio of scientists and technicians related to R&D activities to labor force(RSEW) and the growth rate of the workers on-the-job training(OJTR) are used by turns. For labor, labor force growth rate(WPLR) is used. For technology, real R&D investments growth rate in the nation(RRNDNR) is used. In case of the degree of international trade expansion, effective rate of tariffs(TAR) is used.

3. Estimation Results

We carried out an empirical study to test whether three major implications drawn from the ETCM model can be straightforwardly applied to the process of Korean economic development. In other words, we tried to analyze the major factors of Korean economic growth, the influence of the labor input on Korean economic growth, and the impact of international trade expansion on Korean economic growth.

First, of all, let's look at the estimation results on the major causes of productivity increase in Korean economy, using basic four production factors: physical capital, human capital, technology and labor. (see estimation equations (1) in <table 2>). In short, the estimation result showed that Korean economic growth was highly related to the increase rate of real total fixed capital(RGKSR), the weight of professional and technical workers in the total population(HY) and the growth rate of the total R&D investments of the nation(RRNDPR). But, it was not so much related to the population growth rate. The growth rate of the labor force was turned out to be positively related with economic growth. The significance level was however quite low. This means that the influence of this variable is still weaker than those of other variables. This result implies that high and rapid Korean economic growth has been accomplished rather through accumulation of human capital and improvement of technology than through increase of labor inputs.

To examine what type of human capital has contributed to Korean economic growth most, we made estimations by using three variables(HY, RSEW and OJTR) as alternatives(see est. equations (2)~(6)). And we found out that the OJTR variable was consistently inferior to others in terms of the size of t-values. The result implies that the technology effect of on-the-job training made positive effects on Korean economic growth, but with less significant impact on economic growth in Korea.

Table 2

Estimation Results of the ETCM without a Foreign sector

Dependent Variable: Real GDP Per Capita Growth Rate (RPGDPR)						
Estimation Period: 1975~1993						
Estimation method: OLS						
Explanatory Variables	Estimation Results					
	(1)	(2)	(3)	(4)	(5)	(6)
Constant Term	9.652	9.876	9.362	9.696	9.923	9.356

	(33.031)	(33.396)	(30.630)	(35.430)	(33.977)	(37.870)
Total Fixed Capital (RGKSR)	0.318	0.332	0.336	0.308	0.317	0.337
	(6.311)	(7.862)	(5.818)	(6.710)	(8.040)	(7.076)
Professional,technical Workers (HY)	0.012	–	–	0.012	–	–
	(2.704)	–	–	(2.709)	–	–
Scientists and Egineers (RSEW)	–	0.401	–	–	0.372	–
	–	(3.025)	–	–	(2.874)	–
Workers on-the-job Training (OJTR)	–	–	0.000	–	–	0.000
	–	–	(0.648)	–	–	(0.725)
Total R&D (RRNDNR)	0.189	0.146	0.208	0.196	0.159	0.208
	(6.269)	(4.807)	(6.286)	(7.296)	(5.868)	(7.479)
Labor Force (WPLR)	0.002	0.003	-0.000	–	–	–
	(0.518)	(1.002)	(-0.036)	–	–	–
R^2	0.996	0.997	0.996	0.996	0.997	0.996
D/W	1.168	1.321	0.892	1.087	1.078	0.896

note: Values in parentheses are t values.

The second group equations are estimated in order to examine the role of international trade in Korean economic growth. As shown in <table3>, tariff variable was found to strongly and negatively influence economic growth in each estimation equation. This implies the decrease of tariff rates or expansion of international trade has played a very strong role in economic growth in Korea.

Table 3

Estimation Results of the ETCM with a Foreign sector

Dependent Variable: Real GDP Per Capita Growth Rate (RPGDPR)						
Estimation Period: 1975 ~ 1993						
Estimation method: OLS						
Explanatory Variables	Estimation Results					
	(1)	(2)	(3)	(4)	(5)	(6)
Constant Term	9.762	9.794	9.734	9.842	9.885	9.833
	(37.970)	(36.132)	(40.184)	(37.861)	(35.056)	(43.324)
Total Fixed Capital	0.316	0.332	0.310	0.294	0.309	0.288
(RGKSR)	(7.230)	(8.664)	(7.275)	(6.911)	(8.096)	(7.526)
Professional,technical Workers (HY)	0.008	–	–	0.008	–	–
Scientists and Engineers (RSEW)	(1.790)	–	–	(1.719)	–	–

Workers on-the-job Training (OJTR)	-	0.212	-	-	0.219	-
	-	(1.413)	-	-	(1.376)	-
	-	-	0.000	-	-	0.000
	-	-	(1.487)	-	-	(2.020)
Total R&D	0.191	0.167	0.209	0.206	0.182	0.221
(RRNDNR)	(7.300)	(5.703)	(8.641)	(8.225)	(6.082)	(10.382)
Tariff	-0.016	-0.013	-0.020	-0.013	-0.010	-0.018
(TAR)	(-2.567)	(-2.110)	(-3.894)	(-2.112)	(-1.541)	(-3.704)
Labor Force	0.005	0.005	0.003	-	-	-
(WPLR)	(1.475)	(1.732)	(1.114)	-	-	-
R^2	0.997	0.998	0.998	0.997	0.997	0.998
D/W	1.596	1.787	1.688	1.204	1.194	1.369

note: Values in parentheses are t values.

IV. Summary and Conclusion

This study employed a Romer-type ETC model to analyze major factors for Korean economic development. Estimation results showed that the ETC model explains the characteristics of the Korean development experience very well. In other words, we could find out that Korean economic growth was achieved by technological development, human capital accumulation as well as accumulation of physical capital: i.e., Korean economic development was achieved not merely through more inputs, but through human capital and technological development as well.

Further we derive the following three concluding notes. First, it turns out to be that human capital plays a very important role together with physical capital in the continuous economic development of Korea. The accumulation of human capital is believed to surely induce technological progress and improve the efficiency of physical capital as well. Second, the role of labor turned out to be quite limited due to their characteristics of diminishing return to scale. Third, the international trade expansion variable was found to play a strong and positive role for economic growth in Korea. It is a natural result when we consider the fact that accumulation of human capital and technological change could be accelerated by expansion of international trade. Increase of international trade through expansion of opening domestic markets certainly provided positive effects on accumulation of human capital by absorbing advanced technologies from abroad. This result in part proves the efficiency of the export-led growth strategy in LDC's.

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