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Measuring the Impact of Human Capital on the Economic Growth of South Korea*

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The aim of this paper is to measure total factor productivity (TFP) growth in Korea without taking into account quality differences in the labor factor. Therefore, assuming that Lucas (1988) theory of endogenous growth is correct, the standard TFP measure will be overestimated and will include the contribution of human capital to economic growth. Hence, regressing the TFP growth against a proxy of human capital (average years of schooling) will estimate the impact of education on the economic growth of Korea. The main result of the study shows that between 1980 and 2004 the Korean economy grew at an annual rate of 6.7% and human capital accumulation accounted for 1.3 percentage points of that rate.

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1. INTRODUCTION

For the last 20 years, most of the macroeconomic work has centered its attention on the determinants of long-term economic growth, as Barro (2001) points out, but there is still no consensus on the causes of growth and development, and the research on this topic is far from over. Since the works of Lucas (1988) and Mankiw, Romer and Weil (1992), the contribution of human capital to economic growth has been the subject of many studies that emphasize the important role of education in the economic development of a country. Nonetheless, De la Fuente and Domenech (2000, p. 1) find that "Recent empirical investigations of the contribution of human capital accumulation to economic growth have often produced discouraging results. [...] The accumulation of such negative results in the recent literature has fueled a growing skepticism on the role of schooling in the growth process." In the same paper, the authors conclude that these results can be partially explained by the poor quality of data and the misspecification of the econometric models. So this paper will attempt to contribute some evidence to the ongoing debate about the importance of human capital as an engine of economic growth by studying the impact of education on the Korean economy using a time series approach instead of the cross-section approach, more commonly used in international studies.

The theoretical framework on which the paper is based is the theories of endogenous economic growth. In particular, the model is the one developed by Lucas in 1988 where education as a producer of human capital is the engine of long-term per capita economic growth. The methodology used will be "growth accounting" as portrayed by Barro and Sala-i-Martin (2004) to obtain total factor productivity growth (TFP or Solow residual). The computed standard TFP growth rate which contains the spillover effects from human capital resulting from the Lucas' (1988) model, will then be regressed against a human capital variable (average years of schooling) to estimate the impact of human capital (education) on economic growth. This is similar to the work done by Griliches in 1973 and Singh and Hung (1996a and 1996b) to asses the effect of R&D on TFP.

Human capital theory explains how education is a significant source of human capital, which in time is an important component in the economic growth of any country. In the particular case of South Korea, education is expected to play a very important role as a source of growth due to the traditional importance of education in the history of the country. Lee (2005) finds that the contribution of human capital to Korea's growth of output per worker in the period 1970 to 2001 was 0.9 percentage points out of the 4.9% GDP per worker growth. In his work Lee (2005) uses growth accounting and a Cobb-Douglas production function, which includes the growth rate of human capital as one of the inputs. This paper, however, uses a different approach; human capital is not introduced as an input in the production function, hence overstating the estimate of TFP. Then the TFP estimate is regressed against a human capital variable to decompose TFP growth into technological progress and human capital. The difference in methodology and data explain some differences in the results between Lee's work and the ones obtained in this paper.

The rest of the paper is structured in four sections: section 2 introduces the concept of growth accounting within the neoclassical theory of economic growth and the effects of introducing human capital; section 3 calculates total factor productivity for Korea between 1970 and 2004; section 4 uses the TFP estimates of the previous section to measure the impact of education on Korea's growth between 1980 and 2004[1]; and finally, section 5 presents the main conclusions from this paper.

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[1] There is a difference in the periods studied in sections 3 and 4, because the data used to construct the proxy variable of human capital (average years of schooling of the labor force) was only available for the 1980-2004 period.

2. GROWTH ACCOUNTING IN THE NEOCLASSICAL THEORY OF GROWTH

This subsection mainly draws on chapter 10 of Barro and Sala-i-Martin (2004). The analysis starts from a standard production function where Y is the level of output, T is the level of technology, K is the capital stock, and L is the quantity of labor. The model can be written as

$$Y = F(T, K, L). \tag{1}$$

Like Barro and Sala-i-Martin (2004) explain, output growth can be understood as a combination of factor accumulation and technological progress, where the latter cannot be measured directly and hence has to be computed as the difference between the growth rate of GDP and the growth rate of capital and labor. Now, the standard growth accounting equation results in[2)]

$$\hat{g} = \dot{Y}/Y - s_K \cdot \left(\dot{K}/K\right) - \left(1 - s_K\right) \cdot \left(\dot{L}/L\right), \tag{2}$$

where $\hat{g}$ is the estimate of TFP or the Solow residual, s_K is the capital share, that is, the part of GDP that is used to rent capital, and $1 - s_K = s_L$ is the labor share, assuming that all the income associated with GDP corresponds to capital and labor. Notice that, equation (2) shows that technological growth consists of the difference between output growth rate and the growth of capital and labor weighed by their contributions to GDP.

Equation (2) is formulated in continuous-time, and needs to be adapted to fit discrete-time data. In order to solve this Barro and Sala-i-Martin (2004, p. 435), propose to take logarithmic differences between two points in time, t and t+1, to measure the growth rate using the arithmetic averages of the

2) See Barro and Sala-i-Martin (2004, pp. 433-435) for a detailed analysis on how this equation is obtained. Here, as in growth literature, a dot over a variable denotes differentiation with respect to time.

factor shares at times t and t+1 as weights. Then, the TFP growth rate is approximated by

$$\log\left[T(t+1)/T(t)\right] \approx \log\left[Y(t+1)/Y(t)\right] - \bar{s}_K(t)\cdot\log\left[K(t+1)/K(t)\right] - \left[1-\bar{s}_K(t)\right]\cdot\log\left[L(t+1)/L(t)\right], \quad (3)$$

where $\bar{s}_K(t) \equiv \left[s_K(t)+s_K(t+1)\right]/2$ is the average share of capital for periods t and t+1. This last equation is the one used to estimate TFP in the third section of this paper, where the empirical estimation of each component will be explained in detail.

2.1. Model of Endogenous Growth with Human Capital

In the 1970s and 1980s, several authors created models of economic growth, which included increasing returns and spillovers. Of particular interest for this paper and the focus of attention is the model of endogenous economic growth created by Lucas in 1988. In this model, Lucas (1988) included human capital as a factor of production in the economy, which generates spillovers derived from the beneficial interaction with smart people. In his model, human capital is defined as the general level of qualification that each individual possesses, and is created through education. Therefore, the time invested by each individual in his own education will affect his productivity.[3)] Also, human capital has a spillover effect produced by the interaction of well-educated people with other well-educated people. This spillover effect in Lucas' (1988) model positively affects the long run economic growth of the economy. Hence, the larger the human capital stock in a country the higher the economic growth and that is why education becames

3) There is an opposing theory which states that education does not need to increase productivity, and that the purpose of education is to function as a signal for employers to distinguish between different levels of productive labor, see Spence (1973). Nonetheless, we will assume that Lucas' model holds, and that education does indeed increase labor productivity.

a central component of growth.

To analyze the effect that the introduction of human capital has over growth accounting we follow Barro and Sala-i-Martin (2004, p. 445). Let's represent the idea of an education spillover at the firm level with a Cobb-Douglas production function of the form

$$Y_i = AK_i^{\alpha} K^{\beta} L_i^{1-\alpha}, \tag{4}$$

where $0 < \alpha < 1$, $\beta \geq 0$, and the subindex i represents firm i in the economy. The output, Y_i, of firm i is a function of L_i the labor input, K_i the firm's employment of human capital, and K the aggregate (or average) level of human capital in a country.

The economy-wide production function can be derived from the firm's production function[4)]

$$Y = AK^{\alpha+\beta} L^{1-\alpha}, \tag{5}$$

where $s_K = \alpha$ and $s_L = 1 - \alpha$ are the factor-income shares. If $\beta > 0$, increasing returns to scale emerge economy wide due to the introduction of human capital in the production function.

Growth accounting in this context should be estimated as

$$\hat{g} = \dot{T}/T = \dot{Y}/Y - (\alpha + \beta) \cdot (\dot{K}/K) - (1 - \alpha) \cdot (\dot{L}/L). \tag{6}$$

Consequently, $s_L = 1 - \alpha$ is the correct weight for $\dot{L}/L$, but $s_K = \alpha$ understates the contribution of $\dot{K}/K$ by $\beta \geq 0$. It is also important to note that if $\beta > 0$ then there are increasing returns to scale.

Estimating equation (6) is difficult since income shares no longer can be used to calculate the weights of the factor growth rates. In particular there is no estimate for β. However, we can rewrite equation (6) as

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4) See Barro and Sala-i-Martin (2004, pp. 445-446) for a detailed presentation.

$$g(Solow) = \dot{T}/T + \beta \cdot \left(\dot{K}/K\right) = \dot{Y}/Y - \alpha \cdot \left(\dot{K}/K\right) - \left(1-\alpha\right) \cdot \left(\dot{L}/L\right), \quad (7)$$

notice, that the left side of equation (7) is exactly the standard growth accounting equation just as in (2), but if we compute the standard Solow residual within the endogenous growth model of Lucas (1988), it would be overestimated, because it includes the growth effect from human capital spillovers and increasing returns, $\beta \cdot \left(\dot{K}/K\right)$, as well as the technological progress growth rate $\dot{T}/T$.

Since it is not possible to estimate equation (6), but it is possible to estimate equation (7), one alternative to obtain the contribution from human capital to economic growth (β), would be to calculate the Solow residual $g(Solow)$ from equation (7) and then separate the technological progress $\dot{T}/T$ from the human capital effects $\beta \cdot \left(\dot{K}/K\right)$ by regressing the TFP estimate against the growth rate from human capital. That is exactly what is going to be calculated in section 4, where the estimates of TFP obtained in section 3 will be regressed on the growth rates of a proxy of human capital to estimate β.

3. ESTIMATING TOTAL FACTOR PRODUCTIVITY IN KOREA

To calculate TFP growth using equation (3), data on output, capital, labor, and factor shares are needed for the aggregate economy in Korea. The present section draws information from different sources including: the Bank of Korea, the OECD, and Korea National Statistical Office (NSO). The gross domestic product at market prices (GDP) comes from the National Accounts of the Bank of Korea; GDP is expressed in constant prices of 2000. The labor input is measured as the number of hours worked by persons employed. The data on average hours worked was found on the NSO KOSIS online database, while the data on total employment (which includes the self-employed) was obtained from the OECD Annual National Accounts.

Labor and capital shares estimations are based on the information from the GDP income approach, and employment found in the OECD Annual National Accounts. The compensation of employees only includes the wages paid to employees; therefore, the wage compensation of the self-employed must be estimated. This paper follows the recommendations of the OECD (2001, p. 45) assuming that average compensation per hour of the self-employed and the employees is the same. After calculating the total compensation of persons employed, the labor share is computed as the ratio of total compensation to GDP (income approach), and then the capital share is obtained as $s_K = 1 - s_L$.

The capital stock is net fixed capital stock taken from Pyo (1998) and updated in this paper using information on gross capital formation by types of assets provided by the Bank of Korea in the National Accounts. In his work, Pyo (1998) uses National Wealth Surveys of Korea as benchmark years to construct the capital stock series using the perpetual inventory method to link the series between the different years of the National Wealth Surveys. After 1987, the latest survey of that kind, Pyo (1998) estimates the capital stock by using the perpetual inventory method. This method is very simple and "considers that the capital stock in period t+1, $K(t+1)$, is the sum of the capital stock left over from period t — which is the capital from the previous period minus depreciation, $K(t) - \delta \cdot K(t)$ — plus the capital purchased during the period or investment, $I(t)$" (Barro and Sala-i-Martin, 2004, p. 436), where δ is the constant depreciation rate. Pyo (1998) estimates that the depreciation rate for the period 1977-1987 is 6.6, and then uses this result to estimate the rest of the series until 1996.

This paper applies the same technique used by Pyo (1998) to update his estimates of capital stock using the same depreciation rate[5] of 6.6 and the

[5] A larger (smaller) depreciation rate would have decreased (increased) the growth rate of the net capital stock, thus increasing (decreasing) the TFP estimate. However, the impact of such a variation on an eight year period (1997-2004) is rather small; with an 8.6 depreciation rate the average TFP growth between 1997 and 2004 would have been 0.88% while with a 4.6 depreciation rate it would have been 0.83%. The sensitivity of the TFP results to the

gross fixed capital formation from 1997 to 2004 in the National Accounts of Korea. Since Pyo's work presented the figures in current and 1990 constant prices, the first task was to deflate Pyo's (1998) net capital stock in current prices to figures in 2000 constant prices. In order to do this, the gross fixed capital formation deflator of the Bank of Korea was used. Then the capital stock series in 2000 constant prices was updated until 2004.

Table A1 in the appendix presents the results from growth accounting using equation (3). The first column shows the output, while in the second and third columns are the inputs (capital and labor). The last five columns present all the components of equation (3) required to calculate TFP growth, which is presented in the last column of the table.

Between 1970 and 2004, the Korean economy grew at an average of 6.8% with a clearly decelerating trend after 1995, which can be attributed to the financial crisis of the late 1990s. The growth of the factors of production, as seen in table 1, for the same period were 11.1% for the capital stock, and 2.2% for labor. The capital average share was estimated to be 23.7% and the labor share was 76.3%. The growth of total factor productivity calculated for the 35 years was of 2.2% fluctuating from 4.5% in the late 1980s to 0.4% in the second half of the 1970s. This last result is explained by the economic slowdown in 1980 that entailed a negative productivity growth in that year that reduced the average for the period 1975-1980.

Table 1 also shows the contribution of each input to GDP growth. There, it is clear that TFP growth effect over output is not negligible at all; quite the contrary, TFP growth is responsible for 39%[6)] of the growth of Korea over the past 35 years, while capital accumulation and labor contributed in the order of 34.9% and 26%, respectively.

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depreciation rate in a short period (eight years) is then small, so a different depreciation rate than the one found in Pyo (1998) would not imply a considerable change in the results.

[6)] It is important to note that the contribution of TFP to growth is overstated because it also includes the contribution of human capital. The next section will present the real contribution of TFP to GDP.

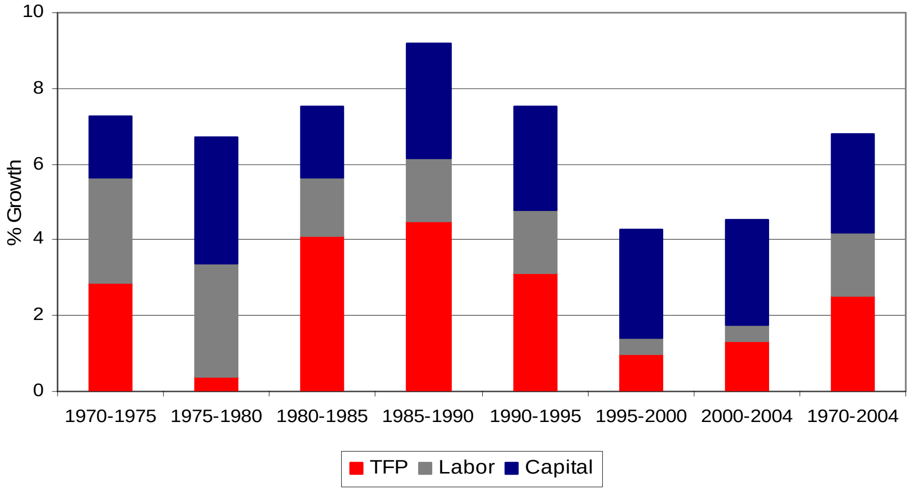
Table 1 Decomposition of Growth

Year	Average Growth of				Average		% Contribution of		
	GDP	Capital	Labor	TFP	Capital Share	Labor Share	Capital	Labor	TFP
1970-1975	7.3	11.0	3.3	2.8	14.7	85.3	24.7	43.5	31.8
1975-1980	6.7	15.5	3.8	0.4	21.4	78.6	42.4[a)]	32.9[a)]	24.7[a)]
1980-1985	7.5	9.8	1.9	4.0	19.4	80.6	25.9	22.4	51.6
1985-1990	9.2	11.4	2.3	4.5	26.6	73.4	33.9	16.9	49.2
1990-1995	7.5	10.5	2.2	3.1	26.2	73.8	37.8	20.8	41.4
1995-2000	4.3	10.6	0.6	1.0	27.1	72.9	20.7	35.9	43.4
2000-2004	4.5	8.6	0.6	1.3	32.1	67.9	66.9	7.6	25.5
1970-2004	6.8	11.1	2.2	2.5	23.7	76.3	34.9[a)]	26.0[a)]	39.0[a)]

Note: a) Excluding 1980 because the unusually large contribution of TFP to growth that year distorts the average presented in the table. In 1980 the contribution of TFP surpassed 100% and explained 408.2% of the growth, since in that particular year Korea experienced a recession (GDP declined –1.5%), while the capital stock and the labor input grew 11.9% and 2.7% respectively, hence leaving the explanation of the decline in output to TFP.

Sources: Bank of Korea (2005); Korea National Statistical Office (2005); OECD (2005).

Figure 1 Contribution of Inputs to GDP Growth



To analyze the contribution of TFP growth to GDP in more detail, it is useful to depict how much each factor (capital, labor and TFP) adds up to the total output growth. Figure 1 presents the GDP growth in five years intervals divided by the portion that each input contributes to it; the total height of the bar represents the average GDP growth of each period, while the different colors illustrate the importance of capital, labor and TFP to the growth rate of the economy. The low contribution of TFP to GDP in the second half of the 1970s and 1990s is explained by the recession of 1980 and the financial crisis that started at the end of 1997.

On average, 2.5 percentage points of GDP growth are attributed to productivity growth. In table 2 there is a summary of different studies done in Korea to estimate TFP growth. The table comes from Young (1995, p. 666) and is updated to include the studies of Singh and Trieu (1996b) and Lee (2005). While the rest of the studies presented in table 2 cover the entire economy, Lee (2005) focuses only on the non-agricultural sector. Nonetheless, the study is included since the period covered is almost the same as the one used in this paper, which is of interest for comparison purposes.

Table 2 Studies of Total Factor Productivity Growth in Korea

Study	Period	TFP Growth
This study	1970-2004	2.5
Lee (2005)[a]	1970-2001	2.0
Singh and Trieu (1996b)	1965-1990	2.4
Young (1995)	1966-1990	1.7
Pyo, Kong, Kwon, and Kim (1993)	1970-1990	1.3
Pyo and Kwon (1991)	1960-1989	1.6
Kim and Park (1985)	1963-1982	2.7
Christensen and Cummings (1981)	1960-1973	4.1

Note: a) The TFP estimate is only for the non agricultural sector.
Source: Updated from Young (1995, p. 666), table XI.

Besides the obvious differences in the periods studied, the differences in the TFP estimates come mainly from the estimation methods used by the authors. For a careful explanation of the particularities of each study, see Young (1995). However, the main difference between the earlier studies and this one is that here the labor input was not adjusted for changes in quality (education).[7] That explains why the estimate in this paper is higher than most of the other studies; the TFP growth of 2.5% includes the change in Korea's human capital, and the next section seeks to separate the technological change from the effect of human capital to determine the impact of education in Korea's economic growth. The studies of Christensen and Cummings (1981) and Kim and Park (1985) reveal higher measures of TFP since they include agriculture and measures of inventories in their capital stocks, which the rest of the studies,[8] including this one, do not.

[7] This was done expressly in this paper so that TFP estimation would include the effect of human capital, thus it then could be separated from the technological progress using the methodology shown in the next section.

[8] Pyo and Kwon (1991) include agriculture and a measure of land input in their estimates of capital stock, however their estimates of TFP are lower than those of Christensen and Cummings (1981) and Kim and Park (1985), because of the use of very early estimates of hours of work (Young, 1995, p. 667).

4. MEASURING THE IMPACT OF EDUCATION ON THE ECONOMIC GROWTH OF SOUTH KOREA

This section uses the TFP estimate obtained in the previous section to calculate the impact of education in Korea's economic growth. The section is divided in two major parts; the first one presents the methodology used to construct the variable that proxies the stock of human capital and the method of estimation. In the second part, the estimation results are presented and interpreted.

4.1. Methodology

As presented in section two in equation (7), the TFP estimate called *g*(*Solow*) not only includes the technological progress growth rate $\dot{T}/T$, but also incorporates the growth effect of human capital. Thus in order to separate these two effects, the following equation is estimated

$$g\left(Solow\right) = \dot{T}/T + \beta \cdot \left(\dot{K}/K\right) + \varepsilon_t, \tag{8}$$

where *g*(*Solow*) is the standard TFP computed in the previous section, $\dot{T}/T$ is a constant term, $\dot{K}/K$ is the growth rate of human capital, and ε_t is a random error term. It is important to note that the purpose of estimating equation (8) is to separate the contribution of human capital to economic growth from the technological progress. Both effects got tied together in the standard TFP estimate since there were spillover and increasing returns effects from human capital because of the underlying Lucas (1988) model. Since equation (8) is not seeking to explain the forces behind technological progress, there are no other exogenous variables included in the equation.

The variable used as a measure of human capital is the average years of schooling of the economically active population. The paper employs this more restricted measure of human capital, instead of the more commonly used average years of schooling of the population 15 and over, adhering to

Mulligan and Sala-i-Martin's (1995b, p. 4) definition of human capital: "Human capital is related to the aggregate stock of productive human bodies available in an economy. That is, the concept of human capital is related to the labor force."

The National Statistical Office of Korea provides data on the economically active population discriminated by educational attainment since 1980. The NSO data specify four categories of educational attainment: primary school graduates and under; middle school graduates; high school graduates; and college, university graduates and over. The average years of schooling of the labor force are calculated using the same methodology as Barro and Lee (2001). According to the Office of the Prime Minister (2005), the duration of each stage of the education system in Korea is as follows: six years of elementary school, three years of middle school and four years of college and university; this information is used later to compute the years of schooling.

The first group, primary school graduates and under, is rather large, so it is necessary to divide it into three different groups to increase the accuracy of the human capital variable to be constructed. The three subgroups are: no schooling, primary school incomplete, and primary school graduates. To do so, the data compiled for Korea by Barro and Lee (2001) is used. The authors calculate the population with no schooling, with primary school total (includes persons with incomplete primary), and with primary school complete, as a percentage of the total population over 15 years. The first task is to calculate the ratio of students that have completed primary out of the total ones with primary studies. Once this is done, since the data are presented in five-year intervals from 1960 to 2000, we estimate the portion of the population over 15 with no schooling, and the ratio of complete to total primary for the years in-between by assuming linear growth rates.[9] Table A2 in the appendix exhibits the labor force discriminated by educational attainment and also presents the measure of average years of schooling which will be used as the measure of human capital in the regressions.

[9] To estimate the portion of the population over 15 with no schooling after 2000, the same growth rate from the previous five years is used. It was not necessary to calculate the ratio of complete to total students with primary since Korea has achieved a ratio of 1 since 1989.

4.2. Estimation Results and Interpretation

Before the variables TFP and Average Years of Schooling (AYS)[10] are used in the empirical analysis, Augmented Dickey-Fuller (ADF) and Phillips-Peron (PP) tests are carried out to examine if the time series of the variables are stationary. Table A3 in the appendix shows that both tests confirm that the variables do not have a unit root, thus they are stationary and the decomposition of TFP into technological progress and human capital can be done using OLS. The results studying the contribution of human capital to the economic growth of Korea are summarized in table 3.

Table 3 also presents residual tests for normality, serial correlation and heteroskedasticity. The estimation of equation (8) uses the TFP growth as a dependant variable, and the growth of the average years of schooling of the labor force as the explanatory variable.[11] It is important to note that the number of observations is limited by the data availability of the explanatory variable (AYS), which could only be constructed for the period 1980-2004. Nonetheless, 24 observations are enough for an OLS regression with only one explanatory variable.[12]

To facilitate the understanding of the results it is important to explain how the second regression was obtained. After running Regression (1) (see table 3) and performing the usual tests on the residuals a problem appeared, the residuals did not fulfill the condition of normality, which can make the *p*-values of the coefficients unreliable. A careful analysis of the residuals showed that the problem was located in 1998, the year of the financial crisis, as can be seen conspicuously in figure 2. The significant decrease in GDP growth in 1998 (–7.1%) consequently produced an important decline in TFP growth (–5.1%) in the same year. This decline in TFP growth turned out to be an outlier, as can be seen in figure 2, distorting the results of the regression.

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[10] Both variables are growth rates calculated as logarithmic differences.

[11] Growth in both cases is calculated as the logarithmic differences of the variables.

[12] Singh and Trieu (1996) in a similar paper, use only 7 observations to estimate the effect of R&D in the TFP of Korea.

Table 3 Results of Regression to Estimate the Contribution of Human Capital to Growth

Dependant Variable is TFP Growth	Regression (1)	Regression (2)
Constant	0.0181 (0.0542)	0.0195 (0.0030)
Average Years of Schooling Growth	0.5383 (0.1828)	0.6536 (0.0183)
Dummy 1998		–0.0861 (0.0000)
Adjusted R^2 [*s.e*]	0.04 [0.0232]	0.59 [0.0151]
# of Observations	24	24
Normality Test[a)] Jarque-Bera Probability	 41.1574 (0.0000)	 0.3786 (0.8276)
Breusch-Godfrey Serial Correlation LM Test[b)] Obs*R-squared Probability	 0.5304 (0.7671)	 0.5104 (0.7748)
White Heteroskedasticity Test[c)] Obs*R-squared Probability	 1.4504 (0.4842)	 3.7328 (0.2918)

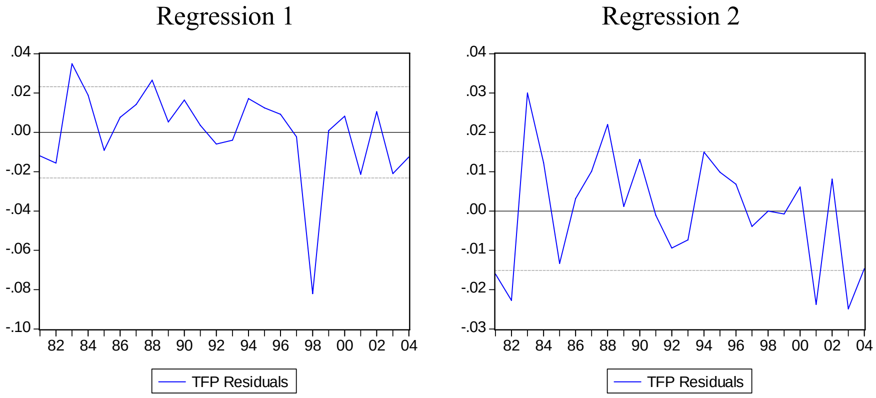
Notes: The p-value of the coefficients is presented in parentheses below each coefficient. The coefficients are significance at the 5% level if the p-value < 0.05. The standard error of the regression is presented in brackets.

a) Test under the null hypothesis of a normal distribution, hence if the probability > 0.05 we accept the hypothesis of normal distribution at the 5% level.

b) Test under the null hypothesis that there is no serial correlation of order 2, hence if the probability > 0.05 we accept the hypothesis of no serial correlation at the 5% level.

c) Test under the null hypothesis of no heteroskedasticity against heteroskedasticity of some unknown general form, hence if the probability > 0.05 we accept the hypothesis of no heteroskedasticity.

Figure 2 Residual Graph of Regressions 1 and 2



To examine the stability of the regression in 1998; a Chow stability test was conducted (see table A4 in the appendix). Both statistics of the Chow Breakpoint Test show that there is a structural change in 1998 at the 5% level, although if the test is performed for 1999 the result show there was no structural break. The analysis of the residuals and the Chow test indicates that the change in 1998 was an isolated incident that did not affect the structure of the regression. Therefore, in order to correct the distorting effect of the outlier in 1998, we decided to include a dummy variable for that year that would render a regression result controlling for the outlier. That is how Regression (2) in table 3 was obtained. The second regression has three main advantages over the first one; first the coefficients are statistically significant, second the adjusted R^2 improves considerably, and third all the residual tests are satisfactory (see table 3 and figure 2).

A Granger Causality Test was implemented to verify that the relationship between TFP and human capital runs in the direction expressed in equation (8). The test probabilities presented in table 4 confirm that human capital measured as the average years of schooling Granger-cause TFP and not the other way around. For almost all the different lag specifications used (except when 3 lags were included) the Granger test showed that human capital Granger-cause TFP at the 5% level, while the hypothesis that TFP Granger-cause

Table 4 Granger Causality Tests for TFP Growth and AYS Growth in Korea 1980-2004

Lags	Null Hypothesis	
	AYS does not Granger Cause TFP	TFP does not Granger Cause AYS
1	0.01456	0.05855
2	0.01262	0.25772
3	0.22033	0.46613
4	0.02177	0.64662

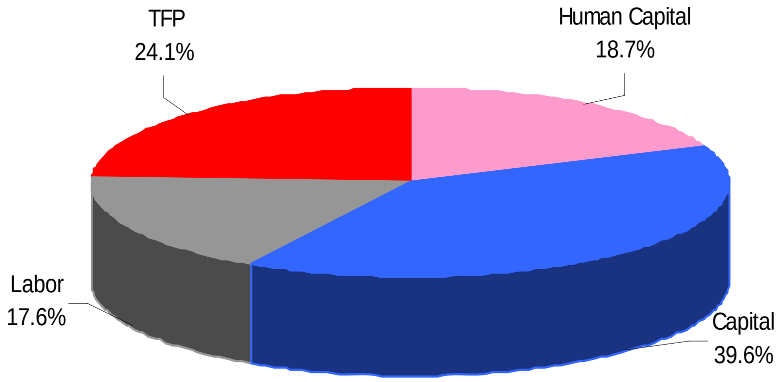
Note: The table presents the probabilities of the Granger Causality Tests. If the probability < 0.05 we reject the hypothesis of no Granger causality at the 5% level.

human capital was rejected for all the different lags tested. Therefore, the procedures applied here to measure the contribution of human capital to GDP growth in Korea are reliable. The regression of TFP against human capital is not reflecting a bidirectional relationship of the variables; it is extracting the component of human capital embedded in the overestimation of TFP.

Now, it is important to note that in both regressions the coefficient of human capital is positive and statistically significant. However, since the *p*-value of Regression (1) may be unreliable due to the non-normality of the residuals, the analysis of the results will be centered on the second regression. Also, it is important to note that since the estimate of $\beta = 0.65 > 0$, there are increasing returns to scale in the Korean economy thanks to the role played by education and its positive spillover effects in the economy. This coefficient is the elasticity of human capital to growth, indicating that a 1% increase in the growth of human capital entails a 0.65% increase in the growth rate of the economy, which is not an insignificant amount.

Finally, the coefficient estimate also encloses the answer that this paper proposed to address from the beginning: What is the impact of human capital on the economic growth of Korea? Since β is the factor share of human capital, it is possible to use it to compute the contribution of human capital to

Figure 3 Contribution to GDP Growth in Korea 1980-2004



the growth of output in Korea. The average annual growth rate of human capital in Korea between 1980 and 2004 was 1.9%, and multiplying this rate by the factor share of human capital, the growth rate of GDP attributable to human capital in the last 25 years is obtained; the result is 1.3 percentage points. Over the same period the economy grew at a rate of 6.7%, and the contribution of capital and labor to GDP growth amounted to 2.7 and 1.2 percentage points, respectively. The TFP contribution to output growth was estimated in 2.9 percentage points, but since it is now known that 1.3 points actually belong to human capital, it is possible to affirm that the real contribution of technological progress to growth is 1.6 percentage points.

Disaggregating the contribution of each input to economic growth since 1980, the results show that human capital was responsible for 18.7% of the GDP growth in Korea; while capital and labor contributed to 39.6% and 17.6%, respectively, and technological progress participated with 24.1%, see figure 3. These results are similar to those of Lee (2005), where the author calculates the contribution of human capital growth as 0.9 percentage points of the 4.9% of the average GDP growth per worker between 1970 and 2001, that is, 18.4% of GDP per worker growth was explained by human capital.

Temple (2000) in a paper that surveys the literature on the effects of human capital on economic growth, presents some evidence that might give some perspective to the results presented in this paper. Temple (2000, p. 14) points out that in a study done by Griliches (1997)[13] he estimates that increases in educational attainment in the 1950s and 1960s "would [have] an effect on the annual growth rate of aggregate output of around 0.5 percentage points; during the 1970s productivity slowdown the effect of educational improvement will have been lower, perhaps raising the growth rate by 0.2 or 0.3 percentage points." In the same paper, the author shows evidence of a paper by Englander and Gurney (1994),[14] which summarizes different studies for the G7 finding that "[…] the growth of human capital (sometimes including demographic effects […]) typically accounts for 10 to 20 percent of growth in total output." Comparing those results to the ones obtained in this paper, it is evident that human capital has a somewhat bigger effect in Korea than in the US or the G7 countries.

5. CONCLUSION

The paper constructed the TFP and AYS variables and analyzed the time series properties of the data, finding that both series are stationary, hence OLS could be employed. A Chow test was used to confirm 1998 as an outlier after the financial crisis, finding that the behavior of the data in 1998 was an isolated incident and not a fundamental change in the regression. Finally a Granger causality test was implemented to assess the directionality of the relation between TFP and human capital; the results showed that the relation flowed in the expected direction, that is, that human capital Granger-caused TFP and not the other way.

The results presented here suggest that human capital (education) played a very important role in the economic progress of Korea in the last 25 years. A contribution of 18.7% to output growth is considerable, and improves the welfare of a country like Korea, especially when the spillover effects are

[13] See Zvi Griliches (1997).

[14] See Steven Englander and Andrew Gurney (1994), p. 14.

taken into account, because this implies that the Korean economy exhibits increasing returns to scale. This is of particular interest since the increasing returns to scale help explain Korea's accelerated growth over the past three decades, having the accumulation of human capital as one of the engines behind Korea's success.

This paper also shows that there is still much to be done to fully explore the effects of human capital on economic growth. More country specific studies are needed; unfortunately, the literature on cross-country studies dominates the field. It is also of vital importance to improve the measures of human capital, since as pointed out in the introduction, the quality of the data affects the results. More research is needed to further explore these issues and hence, improve the knowledge about human capital accumulation, and economic growth and its determinants.

Finally, this study is important because it appears to be the first attempt to econometrically examine the effects of human capital accumulation on Korea's GDP growth by decomposing the estimate of TFP growth into the contributions of education and that of technological progress. This paper also contributes to the stock of knowledge on the economic growth literature, in particular to the studies that focus on the analysis of human capital.

APPENDIX

Table A1 Estimate of TFP Growth in Korea (1970-2004)

Years	GDP (in millions)	Net Capital Stock (in millions)	Total Hours Worked (in millions)	Capital Share	$\bar{s}_K(t)$	GDP Growth	Capital Growth	Labor Growth	TFP Growth
1970	69,046,000	55,203,478	25,861	0.134					
1971	74,737,500	61,443,562	26,227	0.147	0.141	0.079	0.107	0.014	0.052
1972	78,076,700	67,388,537	27,532	0.142	0.145	0.044	0.092	0.049	–0.011
1973	87,472,700	75,850,947	28,911	0.121	0.131	0.114	0.118	0.049	0.056
1974	93,755,100	84,896,090	29,522	0.189	0.155	0.069	0.113	0.021	0.034
1975	99,331,300	95,909,383	30,463	0.214	0.201	0.058	0.122	0.031	0.008
1976	109,832,900	107,883,239	32,795	0.209	0.211	0.100	0.118	0.074	0.017
1977	120,810,500	127,020,725	34,319	0.228	0.218	0.095	0.163	0.045	0.024
1978	132,040,000	154,853,784	35,856	0.218	0.223	0.089	0.198	0.044	0.011
1979	140,996,200	184,549,888	35,797	0.204	0.211	0.066	0.175	–0.002	0.030
1980	138,897,900	207,905,817	36,795	0.174	0.189	–0.015	0.119	0.027	–0.060
1981	147,458,200	227,523,342	37,928	0.186	0.180	0.060	0.090	0.030	0.019
1982	158,259,700	251,068,599	39,041	0.182	0.184	0.071	0.098	0.029	0.029
1983	175,312,000	278,807,734	39,686	0.189	0.185	0.102	0.105	0.016	0.070
1984	189,516,200	309,503,089	39,403	0.241	0.215	0.078	0.104	–0.007	0.061
1985	202,408,000	339,273,559	40,490	0.261	0.251	0.066	0.092	0.027	0.022
1986	223,901,500	374,587,342	42,422	0.269	0.265	0.101	0.099	0.047	0.040
1987	248,763,900	418,095,679	44,233	0.280	0.274	0.105	0.110	0.042	0.045
1988	275,235,300	467,720,077	44,923	0.265	0.272	0.101	0.112	0.015	0.059
1989	293,798,500	519,966,225	45,024	0.253	0.259	0.065	0.106	0.002	0.036
1990	320,696,400	601,269,252	45,428	0.258	0.256	0.088	0.145	0.009	0.044
1991	350,819,900	686,564,446	46,553	0.265	0.262	0.090	0.133	0.024	0.037
1992	371,433,000	760,898,315	47,055	0.265	0.265	0.057	0.103	0.011	0.022
1993	394,215,800	845,762,078	47,612	0.256	0.261	0.060	0.106	0.012	0.023
1994	427,868,200	918,740,647	49,029	0.265	0.261	0.082	0.083	0.029	0.039
1995	467,099,200	1,015,933,544	50,746	0.258	0.262	0.088	0.101	0.034	0.036
1996	499,789,800	1,126,782,886	51,403	0.245	0.251	0.068	0.104	0.013	0.032
1997	523,034,700	1,243,092,515	51,629	0.270	0.257	0.045	0.098	0.004	0.017
1998	487,183,500	1,428,877,815	47,693	0.273	0.272	–0.071	0.139	–0.079	–0.051
1999	533,399,300	1,570,660,815	50,652	0.310	0.292	0.091	0.095	0.060	0.020
2000	578,664,500	1,723,577,515	52,370	0.321	0.316	0.081	0.093	0.033	0.029
2001	600,865,900	1,894,414,515	52,838	0.313	0.317	0.038	0.095	0.009	0.002
2002	642,748,100	2,064,340,515	53,376	0.327	0.320	0.067	0.086	0.010	0.033
2003	662,654,800	2,244,779,715	52,957	0.321	0.324	0.031	0.084	–0.008	0.009
2004	693,424,000	2,432,896,315	53,723	0.334	0.328	0.045	0.080	0.014	0.009

Note: GDP and Net Capital Stocks are expressed in 2000 constant prices. All growth rates are computed as logarithmic differences.

Source: Bank of Korea (2005); Korea National Statistical Office (2005); OECD (2005b).

Table A2 Economically Active Population by Educational Attainment (in thousand), and Average Years of Schooling

Years	Total	No Schooling	Primary School Incomplete	Primary School Graduates	Middle School Graduates	High School Graduates	College, Univ. Graduates & over	Average Years of Schooling
1980	14,431	960	3,129	3,129	2,946	3,292	974	7.6
1981	14,683	915	2,862	3,360	3,024	3,500	1,022	7.8
1982	15,032	826	2,441	3,415	3,269	3,903	1,180	8.2
1983	15,118	760	2,080	3,539	3,293	4,185	1,262	8.4
1984	14,997	667	1,643	3,496	3,216	4,536	1,439	8.8
1985	15,592	625	1,534	3,578	3,299	4,912	1,644	9.0
1986	16,116	579	1,168	3,862	3,378	5,343	1,786	9.3
1987	16,873	545	794	4,234	3,559	5,797	1,945	9.5
1988	17,305	498	374	4,511	3,575	6,183	2,164	9.8
1989	18,023	470		4,961	3,608	6,638	2,409	10.0
1990	18,539	424		5,064	3,597	7,054	2,589	10.2
1991	19,109	369		4,573	3,629	7,792	2,916	10.5
1992	19,499	343		4,404	3,496	8,128	3,293	10.7
1993	19,806	315		4,188	3,341	8,513	3,605	10.9
1994	20,353	303		4,169	3,396	8,859	3,782	10.9
1995	20,845	282		4,084	3,382	9,200	4,048	11.0
1996	21,288	274		3,990	3,417	9,435	4,322	11.1
1997	21,782	273		4,000	3,599	9,563	4,495	11.2
1998	21,428	246		3,621	3,119	9,531	5,046	11.4
1999	21,666	243		3,606	3,153	9,626	5,171	11.5
2000	22,069	239		3,573	3,170	9,796	5,425	11.5
2001	22,417	232		3,490	3,064	10,005	5,756	11.6
2002	22,877	225		3,407	3,049	10,204	6,119	11.7
2003	22,916	207		3,146	2,757	9,986	6,938	12.0
2004	23,370	199		3,056	2,760	10,184	7,284	12.1

Note: The group primary school incomplete is assumed to have on average 3 years of schooling, and the group college, univ. graduates and over are assumed to have only 16 years of schooling since it is impossible to estimate the portion of the group that pursued a graduate degree and what kind of degree (master or doctorate) they attained.

Source: Korea National Statistical Office (2005); Robert J. Barro and Jong-Wha Lee (2001), pp. 541-563.

Table A3 Unit Root Tests for TFP and Average Years of Schooling for Korea between 1981 and 2004

	ADF	PP
Average Years of Schooling	0.0007	0.0009
TFP	0.0064	0.0008

Note: The table presents the probabilities of the Augmented Dickey-Fuller and the Phillips-Perron tests. Test regressions contain a constant and a linear time trend, and lags of the dependent variable are chosen by SIC in the ADF Test. Both tests work under the null hypothesis that a unit root exists for the series, hence if the probability < 0.05 we reject the hypothesis of the existence of a unit root at the 5% level.

Table A4 Stability Test for Regression (1)

	Chow Breakpoint Test: 1998	Chow Breakpoint Test: 1999
F-Statistic	12.7997	0.5862
Probability	(0.00026)	(0.56572)
Log Likelihood Ratio	19.7799	1.36719
Probability	(0.00005)	(0.50480)

Note: Test under the null hypothesis of no structural change, hence if the probability < 0.05 we reject the hypothesis of no structural change at the 5% level.

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