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Catch-up, Human Capital, and Technological Growth in Korean Manufacturing

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1. Introduction

The large volume of recent empirical studies on economic growth inspired by the new growth theory has been investigated mostly by using cross-country regressions, typically employing the Summers and Heston (1991) data and IMF data. There are two main issues in these cross-country analyses on economic growth, which provide further implications for explaining the sources of economic growth. First, the main concern is to verify the possibility of per capita income convergence among cross-countries. The Neoclassical growth models illustrates that the per capita growth rate tends to be inversely related to the initial level of output or income per person. If economies are similar with respect to preferences and technology, then poor economies grow faster than rich ones. Thus, there is a force which promotes convergence in levels of per capita income.(1) The second trend of cross-country analysis is to investigate the relationship between economic growth and macroeconomic policy indicators. It is widely accepted that a stable macroeconomic framework is necessary though not sufficient for sustainable growth. However, these cross-country studies could not provide a growth mechanism between economic growth and technological progress. Furthermore, none of the macroeconomic factor showed consistently robust relation with economic growth.

Current cross-country analyses have indicated that all the possible macro-economic factors including their policies could be considered as possible sources of economic growth. First, various measures of the level of financial

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development are strongly associated with real per capita GDP growth (King and Levine, 1993). Second, macroeconomic indicators and policies (i.e., fiscal structure, government's budget surplus or deficit, government's investment in transport and communication, inflation rate, foreign exchange rate, and etc) are consistently correlated with growth [e.g., Easterly and Rebelo (1993), Fisher (1993), and Barro (1991)]. Third, the export growth and trade openness is crucial for explaining the differential in income growth [e.g., Feder (1983) and Dollar (1992)]. Fourth, human capital is strongly and positively associated with convergence in per capita income growth (Barro, 1991). Almost all macroeconomic variables are weak in relation to per capita output growth, however, there is robust correlation between growth and the share of investment in GDP (Levine and Renelt, 1992). Thus, those cross-country analyses could not answer which macroeconomic factors are consistently related to income growth and failed to find a growth mechanism between income growth and technological progress. Furthermore, these analyses did not challenge to clarify what kinds of growth mechanism is existing between technological progress and macroeconomic factors. In this context, only Fisher (1993) tried to find a growth mechanism between income growth and total factor productivity growth by using growth accounting method.

The growth accounting method that decomposes output growth to three different parts (i.e., physical capital growth, labor input growth, and technological progress) is applied in order to calculate technological progress (i.e., Solow residual or total factor productivity growth). Neoclassical growth theory implies that the long-run growth can be achieved and continued by the exogenous technological progress. In addition, endogenous economic growth theory implies that technological progress has related with human capital, R&D activity, and international trade. In this context, cross-country analysis encounters serious problem of data limitation in calculating the rate of technological progress. However, these problems can be solved by using time-series analysis of a country. The necessity of time series analysis for a country deserves to be another motivation of this study.(2) First of all, we cast doubts on the results of cross-country analysis: whether or not these results conform well to those of time-series of single country. Secondly, there is little cross-country analysis, which investigates some linkages between technological growth and growth mechanism. Thus, the problem we have to pursue and solve is the sources of technological progress and the structure of growth mechanism.

Based on these motivations and current different cross-country regression results, the objectives of this study are to identify a growth mechanism and the sources of technological progress of Korean manufacturing during 1974-1993. To compare with the results of cross-country analyses, we also employ all the possible macroeconomic indicators considered in previous cross-country analyses- fiscal, monetary and financial, and trade sectors. In this respect, it is highly interesting to investigate the role of macroeconomic indicators on the technological progress of Korean economy if we recognize its government nature in economic growth. From the early 1960s, Korean government actively intervened private economy by using fiscal and financial tools in order to achieve rapid economic growth. However, there are no cross-country studies investigating the relationship between R&D indicators and technological progress even though endogenous growth theory places a great importance of R&D activity in economic growth (Grossman and Helpman, 1993). We think that the source of technological progress must be closely related with human capital and R&D capital rather than other macroeconomic variables. As a new feature of this study, we employ a variety of R&D indicators to examine its relationship with technological progress.

We use the econometric methodology of sensitivity analysis suggested by Levine and Renelt (1992). As Levine and Renelt indicated, we consider the relationship between technological progress and a particular variable of interest to be robust if it remains statistically significant and theoretically predicted sign when the conditioning set of variables in the regression changes. There are also several differences between Levine and Renelt (1992) and this study as follows. First, we employ the growth model of Benhabib and Spiegel (1994) as the base regression equation. Second, we focus on manufacturing industry not the whole economy. We choose manufacturing industry as our main concern because manufacturing industry has served as a main sector of economic growth and export growth. Another reason is that manufacturing sector can be easily separated from the effect of monetary and fiscal sector rather than whole economy. Third, small differences will be found on the composition of basic-variables positioned in the right hand side of regression equation. Particular difference is employing the catch up term in our regression, which is required by Benhabib and Spiegel's growth model (1994). Discrete descriptions will be shown in Section 3.

The next section of the paper introduces the overview of Korean macroeconomic policies and economic growth during 1960s-1990s. The growth model, econometric methodology, and data used will be described in Section 3. Our empirical investigation starts in Section 4, which uses macroeconomic policy indicators for the period 1974-1993. We summarize and conclude in Section 5.

2. Overview of Korean Macro-economic Policy and Economic Growth

This section describes the brief features of Korean macro-economic policy and manufacturing growth during 1960-1993. Korea in the 1950s, with a per capita of less than \$80 (nominal base) and more than two thirds of its population engaged in the primary sector, possessed all the familiar characteristics of an extremely underdeveloped economy. With the energetic execution of export-oriented growth strategy since the early 1960s, however, the Korean economy expanded at an average annual rate of nearly 9 percent during 1960-1993. Nominal per capita GNP grew from \$80 in 1960 to \$7513 in 1993. Most of all, commodity exports rose from \$33 million in 1960 to \$82.2 billion in 1993. During this era of rapid economic growth, Korean economy encountered serious problems in its economic system. As a result of large part of investment financed by foreign savings, Korea gradually became a major indebted developing nation and its economy became vulnerable to external shocks. Furthermore, government's drive for heavy and chemical industry during the 1970s distorted resource allocation by discretionary credit allocation. In addition, the undesirable side effect of this policy invoked the concentration of economic power in large business group or chebols, as opposed to small and medium- sized companies.(3) Needless to say, Korean manufacturing became vulnerable to external shocks by this heavy debt ratio. We present more detailed descriptions about macroeconomic policies and manufacturing sector during 1960-1993. Table 1 reports the main indices of Korean macro-economic developments during the period 1974-1993.

2.1 Export-led Growth Policy during 1961-72

After export-led growth (or government-led growth) strategy adopted in the early 1960s, Korean economy showed a successful transition to a newly industrializing economy from an agrarian economy in a relatively short period of time. In 1961, the new government of the Third Republic, headed by President Park Chung Hee, committed to growth first strategy through by export-led growth policy.(4) In the 1960s, the essence of this strategy was the promotion of labor-intensive manufacturing exports in which Korea had a comparative advantage. The government actively mobilized both policy tools of government and financial sectors to this end. The results of the comprehensive changes in Korea's growth strategy and institutional structure transformed Korea into one of the fastest-growing economies in the world. Average annual growth of real GNP for the 1961-72 periods was more than double the 1954-60 average, with an average annual rate of 8.2 percent. Corbo and Suh (1992) indicated that the share of total investment financed by national savings rose from less than 25 percent in 1962 to just under 61 percent in 1971, while the ratio of investment to GDP in current prices rose from 13 percent to 25 percent. The manufacturing sector increased its share of GDP from 13.6 percent in 1961 to 22.2 percent in 1972, while the share of the agricultural, forestry, and fisheries sector decreased from 37 percent to 26.8 percent. Most of all, Korea's rapid growth and structural change were largely the result of the surge in foreign trade. The ratio of total exports to GNP rose from 1.95 percent in 1961 to 15.9 in 1972, with an average growth rate of 27.8 percent.

2.2 Strong Drives for Heavy and Chemical Industries during 1973-1980

The development strategy of the 1970s was again characterized by continued government intervention. First of all, this period could be represented by government's strong drives for heavy and chemical industries (HCI): development of new strategic industries and promotion of intermediate materials and capital goods. The motivation of these polices was that there was concern of losing Korea's comparative advantage in light manufacturing industries compared with other developing countries and was to construct industrial structures toward higher value added products. In 1973, the government announced the heavy and chemical industry development plan, which favored such industries as shipbuilding, automobiles, steel products, nonferrous metals, and petrochemicals. Thus, expansionary fiscal and financial policies were directed to support this drive: better public services and administration, special tax incentives, preferential credit allocation, and negative real interest rates under a system of widespread credit rationing. In particular, a great effort was made to raise domestic savings, which fell far short of investment requirement. As a consequence, heavy foreign borrowing made up most of the shortage in the domestic saving. To make economies of scale possible in a limited domestic market, monopolistic production was permitted in a few industries. The administration also set up high protective barrier for these infant industries and maintained the protection until the industries became internationally competitive.(5)

The expansionary financial and fiscal policies aggravated the condition of foreign debt, which financed a sharp increase in total absorption and a current account deficit: the ratio of foreign debt to GDP reached 38.9 percent during 1973-1983. Nevertheless, Korean economy was left increasingly vulnerable to external shocks; this vulnerability was intensified by the government's extensive financing and subsidy schemes for agriculture and by an industrial structure of great dependence on crude oil. As a consequence, expansionary economic policies for HCI provided undesirable side-effects to Korean economy: excess capacity appeared in the HCI, government deficit and foreign debt were increasing, the financial sectors were accumulating non-performing loans, and these policies fostered the rapid growth of a few but large conglomerates, chebols. At the same time, an overheated labor market that caused real wages increases in manufacturing and export activities: an average annual rate of real wages was increased by 9.89 percent during 1974-1980. The overheated labor market and a sharp increase in total absorption followed by expansionary economic policies led to a high average annual inflation rate of 19.5 percent based on consumer price index during 1974-1980. Moreover, real effective exchange rate appreciated due to the domestic inflation: real effective exchange rate grew at an average annual rate of 0.4 percent during 1974-1983. Thus, it was clear that the rate of increase in wages and the appreciation of real effective exchange rate were outstripping the rise in productivity. Furthermore, the rise in wages and the lack of access to bank credit hit the profitability of labor-intensive exports particularly hard, and they rapidly lost competitiveness in the face of lower unit labor costs in other NICs.

2.3 Stabilization and Liberalization Policies during 1981-86

In the early 1980s, the Korean economy was characterized by very slow growth, rapidly expanding foreign debt, and high inflation. Despite its initial lack of success in 1979-80, the stabilization program did establish the basis for the reform efforts of the new government-Fifth Republic government (President Chun Doo-Hwan). In 1981 the reformers launched a development strategy directed toward achieving three related goals: (a) price stability, particularly for daily necessities; (b) market liberalization; and (c) balanced economic growth. Although the plan embodied the three areas of emphasis, price stabilization clearly took the highest priority. The plan was based on a package of restrictive monetary and fiscal measures that replaced the aggressive government spending of the late 1970s. In pursuit of price stability, the government introduced a series of tight monetary and fiscal measures to eliminate the destructive cycle of inflation. In 1983, public sector expenditures, which throughout the 1970s had been growing, resulting in a public sector deficit, were cut back sharply. In 1984, the government went so far as to freeze its nominal spending at 1983 levels. As a result, the share of government expenditure in GDP declined from 14.5 percent during 1974-80 to 12.3 percent during 1981-1986. A further measure designed to stabilize prices was a steady reduction in the rice subsidy to farmers. As a result, the share of government deficit in GDP dropped from minus 3.0 percent during 1974-1980 to minus –2.0 percent during 1981-1986. Another important component of the stabilization program was income policy, which played an essential role in breaking the inflationary trend of the economy. By issuing suggested guidelines for wages increases and setting low scheduled raises for the salaries of its own employees, the government made strenuous efforts to keep nominal wage increases at reasonable levels. Wage dropped sharply from 9.89 percent during 1974-80 to 5.5 percent during 1981-86.

During 1981-86, the Korean economy recovered its rapid economic growth and better macroeconomic conditions by these reforms and policy directions. In light of the minus GDP growth in 1980, Per capita GDP grew at an average annual of 3.04 percent during 1981-86, which was greater than 2.30 percent during 1974-80. The most significant achievement, however, was the success in curbing inflation. Inflation rate declined sharply from 16.9 percent during 1974-80 to 5.2 percent during 1981-1986. The success in curbing inflation and wage enhanced the international competitiveness in the export market. Real effective exchange rate depreciated considerably: the growth of real exchange rate declined from 0.4 percent during 1974-80 to minus 0.4 percent during 1981-86. As a consequence, Exports increased from 25.1 percent during 1974-80 to 28.9 percent during 1981-86 while imports showed stable pace of growth. In particular, Korean economy for the first time faced current account surplus in 1986: $4.2 billion of trade surplus accomplished. However, there exists still a large burden of foreign debt: Foreign debt increased to 47.1 percent during 1981-86 from 38.9 percent during 1974-83. Although Korean policy and its implementation were clearly dominant factors in the successful adjustment of the 1980s, it is also true that after 1982 Korea faced an increasing favorable external environment. World trade picked up once again, particularly in the United

States, commodity prices declined significantly, after 1983. The important point, however, is, that Korea took full advantage of these opportunities.

2.4 Deregulation and External Liberalization Policies during 1987-1993

In 1986, Korean economy faced a new phase of growth by realizing high economic growth, stable prices, and a trade surplus. The broad policy direction of this period was to enhance the efficiency and strengthen the international competitiveness of Korean economy in general by reforming the free enterprise market system. Thus, the major contents of policy reforms included the drastic reduction of various government regulations constraining the growth of the enterprises plus extensive promotion of liberalization of finance, imports, and foreign exchange. Korea has been taking a gradual approach to opening market and to external liberalization. However, since 1983, the process has been more rapid, as the government has accelerated the liberalization of imports, foreign direct investment, current and capital accounts transactions, and the reduction of tariffs. The pace of import liberalization was further accelerated by the surplus of balance of payments in 1986. The nation decided to eliminate the import surveillance system, which was introduced in 1977 to monitor imports of newly liberalized items for special treatment. The system was abolished in 1989. Furthermore, over 800 items restricted by 17 different special laws were liberalized as these laws were eliminated between 1987 and 1988 (Sakong, 1993). From 1986, regulations on foreign exchange transactions were also gradually introduced and accelerated, when the nation recorded a balance of payments. Korea formally announced the acceptance of full obligations of International Monetary Fund Article VIII in November 1988. At the same time, it also decided to give up privileges of quantitative import restrictions justified under the GATT Article XVIII Section B, effective as of January 1990. The government also continuously liberalized markets for technological and foreign direct investment in the 1980s. In addition, market liberalization for services was introduced, and intellectual property rights were to be protected according to international conventions.

During 1987-1993, most of the macroeconomic indicators showed high economic growth, increasing trade surplus, and decreasing foreign debt with the exception of real wages and inflation. Per capita GDP continued to grow at an average annual rate of 3.07 percent with the increased investment shares in GDP. The share of trade surplus in GDP reached 1.5 percent during 1987-1993 from minus 1.3 percent in 1981-1986. This trade surplus was made possible by the increase of exports while the decrease of imports: Imports declined largely to 25.8 percent during 1987-1993 from 30.2 percent during 1981-1986. However, there seemed to be an inflationary pressure on Korean economy, which showed different aspects as compared with those of the early 1980s. The share of government expenditure in GDP continued to reduce at 10.2 percent during 1987-1993 from 12.3 percent during 1981-1986. At the same time, the growth of monetary and financial sectors sustained its stable pace during 1987-1993 as compared with the period of 1981-1986. However, the booming economy and export growth overheated labor market: Unemployment declined from 4.1 percent during 1981-1986 to 2.6 percent during 1987-1993. A phenomenon of bubble economy happened on land and stock prices. Furthermore, labor unions reacted to this bubble economy by demanding wages that exceeded productivity gains. As a consequence, wage increased rapidly from 5.52 percent during 1981-1986 to 8.78 percent during 1987-1993. Inflation rate was 6.4 percent during 1987-1994 while it increased rapidly from 3.0 percent in 1987 to 9.3 percent 1991.

3. Growth Model, Econometric Methodology, and Data

3.1 Growth Model

We employ the human capital growth model of Benhabib and Spiegel (1994) as the basic model of our sensitivity analysis. This model represents that the level of human capital will affect directly the technological progress and indirectly with a catch up term. The model can be described as follows. Benhabib and Spiegel (1994) assume a Cobb-Douglas technology,
$Y_t = A_t(H_t)K_t^{\alpha}L_t^{\beta}$, where per capita income, Y_t, is dependent on two input

factors-labor, Y_t and physical capital, K_t, α and β represent factor shares, and the technological factor $A_t(H_t)$ is assumed as a function of human capital.[(6)] The standard growth accounting method further decomposes the relationship for long-term growth from time 0 to time T by taking log differences. The technological progress, total factor productivity growth, will be described as follows

$$\log A_t(H_t) - \log A_0(H_0) = (\log Y_t - \log Y_0) - \alpha (\log K_t - \log K_0) - \beta (\log L_t - \log L_0). \quad (1)$$

Furthermore, Benhabib and Spiegel (1994) revised the growth of technology by considering the technological growth model of Nelson and Phelps (1966). They devised a model of technological growth composed of two factors: the level of human capital that account for domestic endogenous innovation and a catch-up term that account for foreign technological inflow.

$$[\log A_t(H_t) - \log A_0(H_t)]_i = c + gH_i + mH_i[(Y_{\max} - Y_i) / Y_i], \quad (2)$$
$$= c + (g - m) H_i + mH_i Y_{\max}/Y_i,$$

where H_i, Y_i, and $Y_{\max}$ indicate the level of human capital of country I, the per capita of country I, and the per capita income of leader country, respectively. Therefore, c, the coefficient of constant term, represents the exogenous technological progress, gH_i represents endogenous technological progress associated with the ability of a country to innovate domestically, and $mH_i[(Y_{\max} - Y_i) / Y_i]$ represents the diffusion of technology from abroad. While the 'domestic innovation progress' term indicates that human capital stocks independently enhance technological progress, the 'catch-up' term suggests that holding human capital levels constant, countries with lower initial productivity levels will experience faster rates of growth of total factor productivity.

Furthermore, we expand the model of Benhabib and Spiegel (1995) by including two factors, the growth of labor input and the ratio of investment to GDP, in order to compare our results with those of previous research (i.e., Levine and Renelt, 1992). These two factors have been employed in most of the growth regressions. Thus, the base equation of technological progress will be estimated as follows

$$[\log A_t(H_t) - \log A_0(H_t)]_i = c + (g-m) H_i + mH_i(Y_{max}/Y_i) + pINV_t + sLAB_t, \quad (3)$$

where *INV* and *LAB* indicate the share of investment to GDP and the growth of labor input, respectively. These four numbers of variables in the right-hand side of equation (3) will become "basic variables" (termed I-variables) of sensitivity analysis in Section 4. In particular, it is one of our main interests to clarify the relationships between *INV* and TFP growth and between INV and per capita income growth. Levine and Renelt (1992) found that *INV* had a positive and robust relationship with per capita income growth.

3.2 The Econometric Methodology and Data used

We use a variant of extreme bound analysis (hereafter, sensitivity analysis) of Levine and Renelt (1992), which was firstly proposed by Leamer (1983, 1985) and Leamer and Herman (1983). Levine and Renelt (1992) used sensitivity analysis in order to investigate whether there exists a robust or fragile relationship between per capita income growth and a variety of macro-economic variables, even in the changes of conditioned information set. We briefly show the methodology of sensitivity analysis suggested by Levine and Renelt (1992). We use a following equation for sensitivity analysis

$$Y=\beta_i I+\beta_m M+\beta_z Z+u \qquad (4)$$

where *Y* is income growth (or TFP growth), *I* is a set of variables always included in the regression, *M* is a variable of interest, and *Z* is a subset of variables chosen from a pool of variables identified by past studies as potentially important explanatory variables of growth. The sensitivity analysis involves varying the subset of *Z*-variables included in the regression to find the range of coefficient estimates on the variable of interest, *M*, that standard hypothesis tests do not reject. Levine and Renelt (1992) first chose a variable that has been the focus of past empirical studies, *M*, and ran a "base" regression that includes only the I-variables and the variable of interest. Then they compute the regression results for all possible linear combinations of up to three Z-variables and identify the highest and lowest values for the coefficient on the variable of interest, β_m, that cannot be rejected at the 5 percent significance level.(7) Thus, the extreme upper bound is defined by the group of Z-variables which produces the maximum value of β_m. The degree of confidence that one can have in the partial correlation between the *Y* and *M* variables can be inferred from the extreme bounds on the coefficient βm.If βm remains significant and have the same sign at the extreme bounds, then, we can refer to the result as "robust." If the coefficient does not remain significant or if the coefficient changes sign, then one might feel less confident in the relationship between the *M* and *Y* variables, because alterations in the conditioning information set change the statistical inferences that one draws regarding the *M*-*Y* relationship. In this case, we can refer to the result as "fragile." Furthermore, Levine and Renelt (1992) stipulated a specific number of variables included in I and Z variables. They only allow the procedure to choose up to four I-variables, and three Z-variables from the pool of variables identified as potentially important for explaining cross-country growth differentials. Consequently, Levine and Renelt (1992) restricted total number of explanatory variables in any one regression to be eight or fewer. Although we examine the sensitivity of the relationship between growth and more variables that were considered by any other study, we restrict the pool of variables to only seven.

The data used are all annual data. All the growth rates of variables are calculated by differences in logarithms. The manufacturing GDP is used as a measure of aggregate output while the quantity of labor input is measured by the labor employed in manufacturing multiplied by average hours worked in manufacturing (i.e., man-hours worked). Manufacturing physical capital is acquired by deflating the nominal manufacturing capital of Pyo (1993) with 1990 constant GDP deflator during 1973-1990. Due to data unavailability, manufacturing investment is capitalized by using the program of CAPITAL in TSP software during 1991-1993. Both depreciation rate of capital and manufacturing operation rate are further considered in constructing manufacturing physical capital. We reformulate the compositions of I- and Z-variables of equation (4) in order to reflect the identification of Benhabib and Spiegel's growth model and the characteristics of Korean economic growth. As described in equation (3), I- variables are composed by the ratio of manufacturing investment to manufacturing GDP (MINV), high-school enrollment rate (HUM), catch-up term (CAT), and the growth of man-hours worked in manufacturing (LAB). The catch-up term is constructed by the multiple of HUM and the ratio of Korea's per capita GDP relative to United States' per capita GDP. Both of per capita GDP are nominal dollar base. The pool of Z-variables become the ratio of government expenditure to GDP (GOV), the ratio of government consolidated surplus or deficit to GDP (GDB), the inflation rate (PI), the growth rate of domestic credit (DCR), the ratio of total export to GDP (EX), the ratio of total import to GDP (IM), and the ratio of R&D expenditure to GDP (R&D). Full descriptions of macroeconomic indicators are described in the Appendix 1.

4. The Growth Mechanism and Human Capital of Korean Manufacturing

Before we investigate the fundamental sources of technological progress in Korean manufacturing,. we have to identify a growth mechanism (if existing) among the growth of manufacturing GDP per man-hours (GMH), the growth of capital per labor (GKL), and technological progress (GTFP). The growth accounting method provides a better way to find the transition mechanism of GTFP effect on GMH. For this purpose, we perform both regression analysis and sensitivity analysis on GMH, GKL, GTFP (as dependent variables) in respect to the I-variables (as independent variables), respectively. This section will also clarify differences on the sources of GTFP, GKL, and GMH.

Table 2 reports regression results of GKL and GTFP with I-variables over the 1974-1993. The estimated results are as follows.

$$GKL = -0.109 + 0.064\ HUM + 0.004\ CAT + 0.245\ INV - 0.614 LAB \quad (5)$$
$$\quad (0.169) \quad (0.133) \quad (0.007) \quad (0.084) \quad (0.204)$$

(R^2 = 0.46, number of obsrvation=20, values in the parenthesis are standard errors).

$$GTFP = -0.304 + 0.269\ HUM + 0.011\ CAT + 0.051\ INV - 0.321\ LAB \quad (6)$$
$$\quad (0.133) \quad (0.105) \quad (0.005) \quad (0.066) \quad (0.161)$$

(R^2=0.46, number of obsrvation=20, values in the parenthesis are standard errors).

The I-variables explain half of the time-series variance both in the regressions of GKL and GTFP. The regression results of GKL with I-variables show that the coefficients of INV and LAB are significant over the 5 percent level in relation to GKL. While the coefficient of INV is positive and significant at the 5 percent level, the coefficient of LAB is negative and significant at the 1 percent level. The regression results of GTFP with I-variables show something different from those of GKL. All three variables (HUM, CAT, and LAB) show significant over 10 percent level with GTFP. While the coefficient of LAB is negative and significant at 10 percent level, the coefficients of HUM and CAT show positive and significant at the 5 percent level with GTFP. However, the coefficient of INV is positive but not significant with GTFP.

In the next step, we examine whether these findings are robust or fragile to changes in information set. Thus, we do a sensitivity analysis in order to investigate the robustness of I-variables in correlation with GKL and GTFP, respectively. Table 3 represents the sensitivity analyses for each I-variables with GKL. The coefficient of INV is robust and positive and that of LAB is robust and negative. The signs and significances of sensitivity analyses well coincide with those of regressions in Table 2. Table 4 represents the sensitivity analyses for I-variables with GTFP. The coefficients of HUM and CAT have positive and robust relationship with GTFP. However, that of LAB does not show robust correlation with GTFP. Thus, we can summarize that GKL has been associated robustly and positively with INV but negatively with LAB, and GTFP has been associated robustly and positively with HUM and CAT.

In order to verify the growth mechanism existing among GMH, GKL, and GTFP, we perform both regression analysis and sensitivity analysis on GMH with I-variables. Table 2 presents regression results of GMH with I-variables: The regression results show

$$GMH = \underset{(0.168)}{-0.356} + \underset{(0.132)}{0.297}\,HUM + \underset{(0.006)}{0.014}\,CAT + \underset{(0.084)}{0.056}\,INV - \underset{(0.203)}{0.601}\,LAB \qquad (7)$$

(R^2=0.46, number of obsrvation=20, values in the parenthesis are standard errors).

All I-variables become significant over 5 percent level with GMH. The estimated signs of I-variables are coincide well with the ones estimated in relation with GKL and GTFP: the coefficients of three variables (HUM, CAT, and INV) are positive but that of LAB is negative. Table 5 represents the sensitivity analyses for each of I-variables in relation with GMH in order to check the robustness of regression results. Each of I-variables shows robust relation with GMH. It is interesting that each robust variable in relation with GKL and GTFP becomes robust in relation with GMH.

Considering all the results of regression and sensitivity analyses for each of I-variables with GMH, GKL, and GTFP, it is evident that there appears to be a growth mechanism among GMH, GKL and GTFP: both GKL and GTFP contribute to GMH by basic four variables but two different routes. One route is that investment share (INV) will give a positive effect on the labor productivity growth (GMH) by its positive effect on the growth of capital-labor ratio, while the growth of unskilled labor (LAB) will give a negative effect on labor productivity growth (GMH) by its effect on the growth of capital-labor ratio (GKL). The other is that both the level of human capital (HUM) and catch-up effect (CAT) will provide a positive effect on labor productivity growth by their positive effect on technological progress (GTFP). Therefore, investment share and the growth of unskilled labor do have a relationship with labor productivity growth by their effect on the growth of capital-labor ratio not by their effect on technological progress. In this context, Levine and Renelt (1992) also found the positive and robust relationship between the ratio of investment to GDP and the growth of per capita income based on the result of cross-country regression. However, they could not verify the existence of growth mechanism. Furthermore, we can infer the important economic implications about source of Korean manufacturing growth. As Benhabib and Spiegel (1993) interpreted, the positive effect of the level of human capital indicates that there exists the possibility of domestic innovation, and the positive catch-up effect indicates that there is the possibility of foreign technology inflow. Thus, technological progress of Korean manufacturing may be possible by both the effects of domestic innovation and foreign technology inflow.

There are also some criticisms on the use of secondary enrollment rate as a proxy of human capital.[8] Considering these criticisms, we re-estimate the relationship with GTFP and I-variables while we substitute other human capital proxies in the I-variables. The new proxies for human capital are the ratio of teacher per 10000 populations (TEM), the ratio of professional, technical and related workers to 1000 workers employed in all industry (AHC), and the ratio of teacher per student (TES).[9] At the same time, the catch-up term will also be reconstructed by using the different human capital proxy. The regression results in Table 6 indicate that the coefficients of catch-up term are all positive and significant in relation with GTFP. These results support the positive effect of catch-up terms on GTFP. However, none of the levels of human capital proxies shows positive and significant in relation with GTFP while HUM (high school enrolment rate) is still positive and significant.

5. Summary and Conclusions

The main objective of this study is to find the growth mechanism of Korean manufacturing growth and the source of its technological progress during 1974-1993. The growth accounting method was employed in order to calculate total factor productivity growth, which was used as technological progress. We used sensitivity analysis suggested by Levine and Renelt (1992) and employed a variety of all possible macroeconomic growth variables including R&D indicators. Firstly, we investigated the robustness of the four numbers of basic variables employed in the growth model of Benhabib and Spiegel (1995) in relation to technological progress: manufacturing investment shares, high school enrollment rate as a proxy of human capital (HUM), catch-up term, and labor input growth as a unskilled labor growth. Secondly, we examined the robustness of macroeconomic indicators with the technological progress.

We summarize main results of this study as follows. First, technological progress has a robust and positive relationship with human capital and catch-up term. Second, the growth of capital-labor ratio has a robust and positive relation with investment shares and a robust and negative relationship with the growth unskilled labor. Third, labor productivity growth has a robust relationship with all four of basic variables: positive with human capital, catch-up term, investment shares, and negative with the growth of unskilled labor.

Considering all the results of regressions and sensitivity analyses, it is evident that there appears to be a growth mechanism existing among labor productivity growth, the growth of capital-labor ratio, and technological progress. The growth of capital-labor ratio and technological progress contribute to labor productivity growth but by different route. While unskilled labor growth gives a negative effect on labor productivity growth by its effect the growth of capital-labor ratio, investment share will give a positive effect on labor productivity growth by its positive effect on the growth of capital-labor ratio. Both human capital and catch-up effect will provide a positive effect on labor productivity growth by their positive effect on technology progress. As Benhabib and Spiegel (1994) interpreted, the positive effect of the level of human capital indicates that there exists the possibility of domestic innovation, and that of the catch-up effect indicates that there is the possibility of foreign technology inflow. Thus, technological progress of Korean manufacturing seems to be possible by the effects of domestic innovation and foreign technology inflow. We may thus conclude that the fundamental sources of technological progress of Korean manufacturing appear to be investment share, human capital, and catch-up effect.

Notes

(1) There is common recognition about convergence hypothesis: conditional convergence can be found among countries, however, absolute convergence cannot.

(2) Fisher (1993) suggested that it would be necessary to undertake more detailed case studies of individual countries.

(3) A *cheabol* in Korea is a group of firms owned and controlled primarily by a single entrepreneur and usually his family members. Sakong (1993) reported that top 46 cheabols' share in GDP rose from 9.8 percent in 1973 to 17.1 percent in 1978.

(4) Hwang (1997) indicated that an outward oriented policy regime change in 1961 was not subject to the Lucas critique.

(5) World Bank (1987) indicated that Korea's trade regime was both "outward-looking on the export side and restrictive on the import side" during this period.

(6) Factor shares of α and β are employed by total employee compensation and operating surplus, respectively. Furthermore, annual data of factor shares are used in order to calculate annual total factor productivity growth.

(7) However, 10 percent significant level will be used by our sensitivity analysis in Section 4.

(8) School enrollment rate could be a proxy for the flow of investment in human capital rather than for stock [e.g., Barro (1991) and Benhabib and Spiegel (1994)]. Barro (1991) suggested another measures of human capital such as student-teacher ratio.

(9) AHC was used also a proxy of human capital in Hwang (1998). TEM includes all teachers and students in elementary school, middle school, high school, and university.

Table 1
The Macro-economic Indicators of Korean Economy: 1974-1993

	PGDP	UMP	WAGE	TINV	MAF	AGR	GOV	GDB	PI	MIR	GM2	DCR	REX	EX	IM	FDB	TRSR	R&D
1974-1980	2.30	4.0	9.89	25.0	26.9	21.4	14.5	-3.0	19.5	3.35	11.4	13.4	0.5	25.1	30.7	35.0	-5.5	0.6
1981-1986	3.04	4.1	5.52	27.4	29.3	13.2	12.3	-2.0	6.6	9.61	7.5	7.83	-2.0	28.9	30.2	47.1	-1.3	1.2
1987-1993	3.07	2.6	8.78	34.0	29.6	8.66	10.2	-0.2	6.4	8.84	7.5	6.80	0.7	27.3	25.8	15.6	1.5	4.9

Notes: PGDP indicates the growth rate of per capita GDP, UM-unemployment rate, WAGE-real wage increasing rate, MAF-the share of manufacturing in GDP, TINV-the ratio of total investment to GDP, AGR-the share of agriculture in GDP, GOV-the share of government consumption expenditure to GDP, GDB-the share of government consolidated debt to GDP, PI-inflation rate based on 1990 constant consumer price index, MIR-average real interest rate as computed by the averages of yields of guaranteed corporate bonds with maturity 3 years minus PI, GM2-the growth rate of M2, DCR-the growth rate of domestic credit, REX-the growth rate of real effective exchange rate, EX-the ratio of total exports to GDP, IM-the ratio of total imports to GDP, FDB-the ratio of foreign debt to GDP, TRSR-the ratio of trade deficit or surplus to GDP, and R&D-the ratio of R&D expenditure to GDP.

Table 2: Results of Regression between Basic Variables

	Dependent Variables														
	GTFP					GMH					GKL				
CONS	-0.304**	-0.348**	-0.256	-0.388*	-0.329*	-0.356*	-0.246	-0.014	-0.291	-0.459**	-0.109	0.231	0.598**	0.202*	-0.286
	(-0.133)	(-0.132)	(0.254)	(0.194)	(0.169)	(0.168)	(0.170)	(0.306)	(0.198)	(0.211)	(0.169)	(0.163)	(0.237)	(0.095)	(0.172)
HUM	0.269**	0.144**	0.246	0.340*	0.285**	0.297**	0.219	0.074	0.288	0.365**	0.064	-0.293	-0.412**	-0.764	0.181
	(0.105)	(0.144)	(0.171)	(0.171)	(0.128)	(0.132)	(0.187)	(0.191)	(0.184)	(0.153)	(0.133)	(0.169)	(0.149)	(0.105)	(0.122)
CAT	0.011**	0.012*	0.011*	0.013*	0.125*	0.014*	0.013	0.012	0.015*	0.018*	0.004	0.000	-0.000	0.004	0.012
	(0.005)	(0.006)	(0.006)	(0.007)	(0.007)	(0.006)	(0.008)	(0.007)	(0.008)	(0.009)	(0.007)	(0.006)	(0.005)	(0.004)	(0.007)
INV	0.051	0.036	0.053	0.072	0.062	0.156*	0.141	0.109	0.122	0.201	0.245**	0.256**	0.134	0.120*	0.324*
	(0.066)	(0.068)	(0.084)	(0.067)	(0.086)	(0.084)	(0.089)	(0.131)	(0.087)	(0.123)	(0.084)	(0.075)	(0.109)	(0.057)	(0.009)
LAB	-0.321*	-0.333	-0.299	-0.265	-0.335	-0.601**	-0.746*	-0.613**	-0.619**	-0.658**	-0.614***	-0.871***	-0.678**	-0.754***	-0.712**
	(0.161)	(0.286)	(0.199)	(0.196)	(0.191)	(0.203)	(0.351)	(0.225)	(0.257)	(0.222)	(0.204)	(0.174)	(0.172)	(0.244)	(0.198)
PI		0.018					-0.091					-0.231**			
		(0.091)					(0.105)					(0.051)			
GDC		-0.052					-0.044					0.054			
		(0.153)					(0.187)					(0.113)			
GDB			-0.240					-1.033					-1.929**		
			(0.338)					(0.867)					(0.721)		
GOV			-0.259					-0.346					-0.375		
			(0.654)					(0.434)					(0.404)		
EX				-0.078					-0.051					-0.007	
				(0.118)					(0.143)					(0.138)	
IM				0.096					-0.134					-0.514**	
				(0.194)					(0.199)					(0.114)	
R&D					0.027					0.107					0.184
					(0.042)					(0.062)					(0.065)
Obs.	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
F-stat.	2.88	2.06	3.14	1.98	2.19	4.85	4.36	9.70	5.98	13.72	8.96	18.54	17.99	27.89	25.42
R^2	0.43	0.44	0.44	0.45	0.44	0.56	0.60	0.60	0.59	0.60	0.70	0.88	0.83	0.84	0.78

Notes: *, **, and *** indicate significant at 10, 5, and 1 percents, respectively.

Table 3
Sensitivity Results for Basic Variables (Dependent Variable: Growth of Physical Capital Per Man-hours, 1974-1993)

M-Variable	β	Standard error	p-value	R^2	Other variables	Robust/fragile
HUM	High:-0.248	0.110	0.044	0.90	*PI, IM, GDB*	fragile
	Base:0.064	0.132	0.637	0.70		
	Low:-0.389	0.155	0.027	0.89	*PI, GOV, GDB*	
CAT	High:0.014	0.008	0.117	0.81	*GDC, EX, R&D*	fragile
	Base:0.004	0.007	0.551	0.70		
	Low:0.007	0.005	0.148	0.91	*PI, EX, R&D*	
INV	High:0.315	0.095	0.006	0.81	*GDC, EX, R&D*	robust
	Base:0.244	0.084	0.011	0.70		
	Low:0.157	0.066	0.034	0.91	*PI, GOV, IM*	
LAB	High:-0.580	0.221	0.022	0.82	*GDC, EX, GDB*	robust
	Base:-0.614	0.204	0.009	0.70		
	Low:-0.934	0.148	0.000	0.90	*PI, R&D, GDB*	

Notes: The base β is the estimated coefficient from the regressions with the variable of interest (M-variable) and the always include variables (I-variables). The I-variables are INV, HUM, CAT, and LAB. The high β is the estimated coefficient from the regression with the extreme high bound; the low β is the coefficient from the regression with the extreme lower bound. The "other variables" are the Z-variables included in the base regressions that produce the extreme bounds. The robust/fragile designation indicates whether the variable of interest is robust or fragile.

Table 4
Sensitivity Results for Basic Variables (Dependent Variable:
Total Factor Productivity Growth, 1974-1993)

M-Variable	β	Standard error	p-value	R^2	Other variables	Robust/fragile
HUM	high:0.540	0.257	0.058	0.49	*EX, IM, R&D*	robust
	base:0.269	0.105	0.022	0.43		
	low:0.383	0.154	0.069	0.40	*PI, IM, GDB*	
CAT	high:0.019	0.008	0.048	0.49	*EX, IM, R&D*	robust
	base:0.011	0.005	0.045	0.43		
	low:0.011	0.006	0.093	0.45	*GOV, IM, GDB*	
INV	high:0.186	0.135	0.196	0.49	*EX, IM, R&D*	fragile
	base:0.051	0.066	0.458	0.43		
	low:-0.019	0.124	0.882	0.47	*GDC, GOV, GDB*	
LAB	high:-0.236	0.201	0.262	0.49	*EX, IM, R&D*	fragile
	base:-0.321	0.161	0.064	0.43		
	low:-0.415	0.236	0.104	0.47	*GOV, EX, R&D*	

Notes: The base β is the estimated coefficient from the regressions with the variable of interest (M-variable) and the always include variables (I-variables). The I-variables are INV, HUM, CAT, and LAB. The high β is the estimated coefficient from the regression with the extreme high bound; the low β is the coefficient from the regression with the extreme lower bound. The “other variables” are the Z-variables included in the base regressions that produce the extreme bounds. The robust/fragile designation indicates whether the variable of interest is robust or fragile.

Table 5
Sensitivity Results for Basic Variables (Dependent Variable: Growth of GDP per Man-hours, 1974-1993)

M-Variable	β	Standard error	p-value	R^2	Other variables	Robust/fragile
HUM	High:0.469	0.187	0.028	0.63	*EX, R&D, GDB*	robust
	Base:0.279	0.132	0.040	0.56		
	Low:0.362	0.189	0.079	0.61	*EX, IM, GDB*	
CAT	High:0.021	0.011	0.074	0.61	*EX, IM, R&D*	robust
	Base:0.014	0.007	0.053	0.56		
	Low:0.013	0.007	0.096	0.60	*PI, IM, GDB*	
INV	High:0.213	0.117	0.093	0.62	*PI, R&D, GDB*	robust
	Base:0.156	0.083	0.084	0.56		
	Low:0.187	0.098	0.082	0.62	*PI, EX, R&D*	
LAB	High:-0.589	0.253	0.038	0.61	*EX, IM, R&D*	robust
	Base:-0.601	0.203	0.010	0.56		
	Low:-0.805	0.280	0.014	0.64	*GDC, GOV, GDB*	

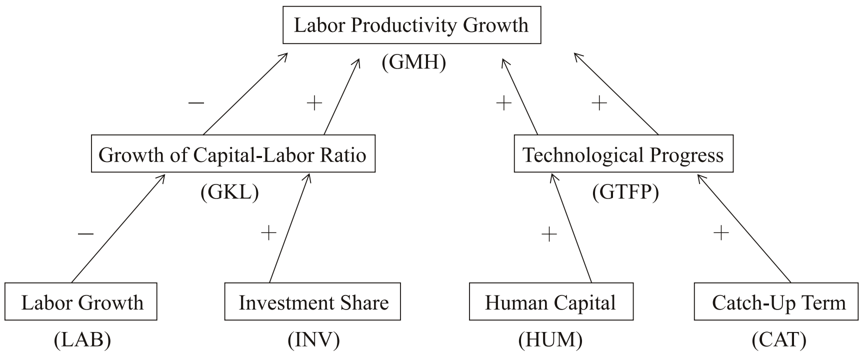
Notes: The base β is the estimated coefficient from the regressions with the variable of interest (M-variable) and the always include variables (I-variables). The I-variables are INV, HUM, CAT, and LAB. The high β is the estimated coefficient from the regression with the extreme high bound; the low β is the coefficient from the regression with the extreme lower bound. The “other variables” are the Z-variables included in the base regressions that produce the extreme bounds. The robust/fragile designation indicates whether the variable of interest is robust or fragile.

Table 6
Regressions between TFP growth and Other Human Capital Proxies

	Eq.(1)	Eq.(2)	Eq.(3)
		Dependent Variable	GTFP
Variable	GTFP	GTFP	0.033 (0.067)
INV	0.046 (0.073)	0.044 (0.068)	-0.270 (0.158)
LAB	-0.196 (0.155)	-0.286 (0.160)*	0.279 (0.049)**
HUM	0.175 (0.084)*	0.289 (0.162)*	
AHC	-0.043 (0.136)		
CATAHC	0.032 (0.017)*		
TEM		-5.654 (10.864)	
CATTEM		1.237 (0.605)*	-1.478 (1.499)
TES			0.289 (0.149)*
CATTES			20
Obs.	20	20	37
R-squared	42	41	

Notes: INV indicates the share of manufacturing investment to manufacturing GDP, LAB- the growth of labor inputs, HUM-high school enrollment rate, AHC-the ratio of professional, technical and related workers to 1000 workers in all industries, CATACH-AHC multiplied by increasing rate of Korean per capita with relation to USA per capita, TEM-the ratio of researcher per 1000 populations, CATTEM-TEM multiplied by increasing rate of Korean per capita with relation to USA per capita, TES-the ratio of student per teacher, and CATTES-TES multiplied by the increasing rate of Korean per capita with relation to USA per capita. * and ** indicate significance level of 10 and 5 percents, respectively.

Figure 1
The Growth Mechanism of Korean Manufacturing



Note: + (or -) means positive (or negative) effect on each growth rates.

Appendix 1

Variables and Sources

Variable	Definitions and Sources
INV	The share of manufacturing investment in manufacturing GDP, 1990 constant value [Source: The Bank of Korea's National Account, 1994)
HUM	High school enrollment rate [Source: National Statistical Office's Major Statistics of Korean Economy, 1993, 1995)
CAT	Catch up term processed by the product of HUM and the increasing rate of per capita Korean GDP from per capita US GDP. Per capita GDP is nominal value [Source: International Financial Statistical Yearbook, 1994).
LAB	Per man-hours growth rate of manufacturing [Source: National Statistical Office's Major Statistics of Korean Economy, 1993,1995)
GOV	The ratio of government expenditure to GDP, 1990 constant value [Source: The Bank of Korea's National Account, 1994]
GDB	The ratio of consolidated budget deficit or surplus to GDP, nominal value [Source: National Statistical Office's Major Statistics of Korean Economy, 1995]
PI	The consumer price increasing rate, 1990 constant price [Source: National Statistical Office's Major Statistics of Korean Economy, 1993, 1995]
GDC	The growth rate of domestic credit, [Source: National Statistical Office's Major Statistics of Korean Economy, 1993, 1995]
MIR	Real interest rates: the averages of yields of guaranteed corporate bonds with maturity 3 years minus PI. [Source: The Bank of Korea]
PGDP	The growth rate of per capita GDP
UMP	Unemployment rate
WAGE	Real wage increasing rate
GM2	The growth rate of M2 [Source: The Bank of Korea's The Statistics of Korea (written by Korean), 1995]
TINV	The ratio of total investment to GDP
AGR	The share of agricultural in GDP
REX	The growth rate of real effective exchange rate
FDB	The ratio of gross foreign liabilities to GDP, nominal value [Source: National Statistical Office's Major Statistics of Korean Economy, 1993, 1995]
MAF	The share of manufacturing in GDP
EX	The ratio of gross export to GDP, nominal value [Source: The Bank of Korea's National Account, 1994]
IM	The ratio of gross import to GDP, nominal value [Source: The Bank of Korea's National Account, 1994]
TRSR	The ratio of trade surplus or deficit to GDP [Source: The Bank of Korea's National Account, 1994]
R&D	The ratio of R&D expenditure to GDP [Source: Korea Industrial Technology Association's Major Indicators of Industrial Technology, 1994, 1995]
AHC	The ratio of professional, technical and related workers to 1000 workers in all industries
TEM	The ratio of researcher per 1000 populations
TES	The ratio of student per teacher

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キャッチアップ、人的資本、技術進歩の韓国製造業に対する寄与

< 要 約 >

黄　仁相

この研究の目的は、1974 年から 1993 年における韓国製造業の技術進歩の要因と成長過程を特定することである。成長会計からの Solow 残差が技術進歩率として計算された。この研究に使われた計量経済学的分析方法は Sensitivity 分析方法である。主な研究成果は、労働生産性成長率、資本 - 労働比率成長率、そして技術進歩率との間にある成長プロセスが発見されたことである。すなわち、次のような二つのプロセスである。投資 シェアは、資本・労働比率の成長率を変化させた、労働生産性成長に正の影響を与えた。また、人的資本と Catch-up 効果は、技術進歩率に正の影響を与え、労働生産性成長に正の影響を与えたことである。これらの結果を踏まえて、韓国製造業の技術進歩の要因は、人的資本と Catch-up 効果であったように思われる。