

Capital-Skill Complementarity and Economic Development*

Yongsung Chang[†] and Andreas Hornstein[‡]

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Abstract

Capital deepening has played an important role for the economic development of many countries, especially for the East Asian ‘Growth Miracles.’ At the same time the fraction of output invested in capital increased gradually over time. These growth characteristics appear to be at odds with the standard growth model which predicts that investment rates should start out high and then decline over time. We argue that the neoclassical growth model is still consistent with a hump-shaped investment rate if one takes into account that capital and skilled labor are complementary in production and that the relative supply of skilled labor increases only gradually over time. Based on the model calibrated to the observed population, TFP, employment, and skilled labor ratios in Korea for the last 40 years, we reproduce a hump-shape pattern of investment and savings rates.

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[†] Seoul National University

[‡] Federal Reserve Bank of Richmond

1. Introduction

From 1960 to 2000 per capita GDP in South Korea grew at an average annual rate close to 6%, more than twice the U.S. growth rate. An important source of Korean GDP growth during this time period is capital deepening. From 1960 to 1995 Korea's investment rate quadruples and consequently its capital-GDP ratio triples, Figure 1.¹ Korea's capital-accumulation driven growth dynamics is not an exception. Other developing countries, in particular other Asian 'growth miracles,' exhibit similar capital deepening and investment dynamics. These long-run growth facts appear to be at odds with neoclassical growth theory which predicts that increasing capital-output ratios should be accompanied by declining investment rates. We argue that, quite to the contrary, neoclassical growth theory is consistent with these observations if one allows for the possibility that capital is more complimentary to skilled labor than it is to unskilled labor, and if one takes into account the fact that the relative supply of skilled labor has been increasing substantially in these countries.

[Figure 1. Korea's Capital Accumulation Dynamics]

The standard growth model embodies balanced growth, that is, in the long run per capita growth is determined by total factor productivity growth. On this balanced growth path per capita capital and output grow at the rate of productivity growth, and the rate of return on capital is constant. The capital-output ratio therefore remains constant on the balanced growth path. Capital deepening occurs only during the transition to the balanced growth path if the economy starts out with a capital stock that is below its long-run capital stock. Given the relatively low initial capital stock, the rate of return to capital is high, and the economy is accumulating capital rapidly, that is, the investment rate is high. Over time the economy converges to the long-run growth path and during this transition period the capital-output ratio increases and the investment rate declines.

We modify the standard growth model and assume that capital is relatively more complementarity to skilled labor than it is to unskilled labor. Different from the standard growth model, there no longer exists an aggregate index for labor input, and the long-run growth path depends on the relative size of the skilled labor force. In particular, the long-run capital-output ratio and investment rate increase with the relative supply of skilled labor. To the extent that we take the relative supply of skilled labor as exogenous, we then interpret capital deepening not as a feature of the transition to the long-run growth path, but rather as the consequence of changes in the long-run growth path itself.

¹Figure 1 is based on National Income Accounts data from the Penn World Table. We describe the construction of capital stock series in section 2.2. The dashed lines are actual data and the solid lines are trend lines based on Hodrick-Prescott filtered data..

Our argument is easily formalized as follows. In the standard growth model per capita output y is a constant-returns-to-scale function of the per capita capital stock, k , and per capita labor supply, l . We assume that there is an aggregate labor input index, that captures changes in labor quality. For example, the labor input index captures changes in the relative supply of skilled and unskilled labor, s and $u = 1 - s$, $l = g(s, u)$. For concreteness, assume that technical change, A , is labor augmenting and that production is Cobb-Douglas,

$$y = f(k, Al) = k^\alpha (Al)^{1-\alpha}. \quad (1.1)$$

In equilibrium, the marginal product of capital is equated to the sum of interest, r , and depreciation, δ ,

$$r + \delta = f_k(k/Al, 1) = \alpha(k/y)^{-1}. \quad (1.2)$$

Clearly, on a balanced growth path with constant return to capital, the capital-output ratio is constant and there is no capital-deepening.

Barro and Sala-i-Martin (1995) characterize the transition dynamics of capital and investment in the optimal growth model with Cobb-Douglas production. They show that if the economy starts out with a capital stock that is below its balanced growth path value, then the investment rates decline during the transition if the capital income share is not too large, and the intertemporal rate of substitution is not too low.² If we parameterize the model to match empirically reasonable values of factor income shares and preferences, the model predicts a fast transition that is attained through high initial investment which then declines over time. Mankiw et al. (1992) show that the model can predict a prolonged transition path if one assumes large capital income shares, much larger than measured in the data. One can argue for such large capital income shares based on a broad concept of capital that also includes human capital and other kinds of intangible capital. But even with the large capital income shares of Mankiw et al (1992) the standard growth model predicts that the investment rate declines along the transition path.

Griliches (1967) and more recently Krusell, Ohanian, Rios-Rull, and Violante (2000) have argued that capital is relatively more complementary to skilled labor than it is to unskilled labor. In terms of the aggregate production function this means that skilled and unskilled labor have to be treated as different and distinct inputs to production. The following example illustrates that this property of the production function significantly affects the analysis of long-run growth. Suppose aggregate production is Cobb-Douglas in unskilled labor and a capital-skill aggregate, and the latter aggregate is a Leontief function of capital and skilled

²Smetters (2003) characterizes the transition dynamics for a general CES production function and shows that

labor,

$$y = f [g (k, As) , Au] = \min \{k, As\}^\alpha (Au)^{1-\alpha} . \quad (1.3)$$

Technical change, A , is labor augmenting. Given the strict complementarity between capital and skilled labor, capital accumulation on the balanced growth path is limited by the exogenous supply of skilled labor, $k = As$. Consequently, the capital-output ratio on the balanced growth path is an increasing function of the relative supply of skilled labor,

$$k/y = \left(\frac{s}{1-s} \right)^{1-\alpha} . \quad (1.4)$$

Furthermore, on the balanced growth path the investment rate increases with the capital-output ratio

$$x/y = \left(\delta + \hat{A} + \hat{N} \right) k/y. \quad (1.5)$$

In the first part of this paper we document the interaction of physical capital accumulation (capital deepening and investment rates) and human capital accumulation for a large number of developing and developed countries from the Penn World Table (2006). We find that for a majority of the fastest growing economies capital deepening is an important source of output growth. We also find that capital deepening is often accompanied by increasing investment rates, a pattern that is very pronounced for most of the Asian ‘growth miracles.’ Using the Barro and Lee (2000) data on educational attainment we find that in most countries capital deepening proceeds in parallel with the accumulation of human capital. Among the group of successful developing countries we find an especially strong positive relation between investment rates on the one hand and capital-output ratios and educational attainment. On the other hand, among the group of developed countries we only find weak evidence for this relation between investment rates and capital stocks.

In the second part, we provide a more detailed analysis of the South Korean economy which displays the most pronounced and persistent increase of the investment rate in our sample. We take Korea’s post-1960 development of demographic factors (population growth, labor participation rate, and skilled labor share) and productivity as exogenous and solve for the perfect-foresight path of a calibrated model of the economy. The substantial increase of the relative supply of skilled labor in Korea together with a reasonable degree of capital-skill complementarity then accounts for an increasing investment rate. Furthermore, in the early stage of economic development due to the scarcity of skilled labor, the marginal product of capital is relatively low despite a low capital-output ratio. Capital-skill complementarity may thus explain why capital does not flow from rich to poor countries, Lucas (1990). While the scarcity of skilled labor bounds the return on capital it does imply a high wage premium for skilled labor. The high skill premium in turn may induce an investment boom in human

capital, but the magnitude of this boom is likely to be limited by demographic factors. Finally, even though the skill premium is high initially, the level of wages is low due to the low capital stock. Therefore the incentives for skilled labor to move from developed countries to the Korean economy are weak.

An important part of Korea's development is the transition from a predominantly agricultural economy to an industrial economy. Since Korean agriculture is much less capital intensive than the rest of the economy, one might expect that the transition from an essentially capital-free economy to a capital-intensive economy also contributes to the observed capital accumulation dynamics. We investigate this issue in a two-sector version of the economy along the lines of Gollin, Parente, and Rogerson (2002). Taking into account the transition from an agricultural sector in and of itself does not account for the observed increasing investment rate, but it does improve the 'fit' of the economy with capital-skill complementarity.

Our work complements earlier quantitative research on the role of capital accumulation for growth. Young (1994, 1995) documents increasing investment rates and the important contribution of factor input accumulation to growth in the Asian 'growth miracles.' Hayashi (1986) documents the hump-shaped savings rate for the Japan of the 1950s and 1960s. Christiano (1989) shows that a time-varying intertemporal elasticity of substitution due to subsistence consumption may explain a low savings rate during the early phase of the growth transition. At low capital/income levels subsistence consumption can make the intertemporal elasticity of substitution extremely low and reduce the incentives for capital accumulation despite high rates of return. However, the subsistence consumption only explains why savings are low in a closed economy, but not why the investment rate is low if the return on capital is high and capital is mobile across countries. Chen, İmrohoroğlu and İmrohoroğlu (2006) show that the observed hump-shaped savings rate in Japan can be accounted for by the outcome of economic agents who perfectly foresee a high TFP growth in the early 1970's: that is, Japanese households delay their savings and investment in the 1960s. Our model also features delayed savings and investment as agents anticipate an increasing relative supply of skilled labor, but savings and investment rates increase even if the increase of skilled labor is unanticipated. King and Rebelo (1993) provide a comprehensive quantitative analysis of the transition dynamics in the standard growth model. They show that accounting for observed post-WWII growth in the United States solely based on capital deepening implies either extremely high real interest rates or extraordinarily high values of installed capital in the early stages of development; neither prediction appears to hold in developed or developing economies. Our model predicts that the rate of return to capital in less developed economies are not excessively high because of low supply of skilled labor. Gilchrist and Williams (2004) show that the putty-clay model of production and investment can generate a rising rate of

investment and moderate rates of return to capital that is consistent with the transition period in Japan and Germany. Closest to our work is Papageorgiou and Perez-Sebastian (2006) who present an endogenous growth model with embodied technology where the lack of human capital delays an adoption of new technology.

2. Economic development and investment rates

Based on a simple growth accounting exercise we establish that capital deepening is a significant source of long-run economic growth. In particular, many of the Asian growth miracles tend to exhibit rapid capital deepening. Capital accumulation in these countries, however, does not proceed as predicted by the standard growth model: we observe investment rates that start low, then increase over time and finally decline. We also observe that investment in physical capital tends to be associated with the stock of human capital (as measured by educational attainment). For the years 1960-2000, we find that in a panel of 56 countries the non-linearity in the path of investment rates is associated with an interaction between educational attainment and capital-output ratios.

2.1. The data

We study a set of countries for which we have National Income Account (NIA) data from the Penn World Table 6.2 (PWT) and educational attainment data from Barro and Lee (2000). We only consider PWT countries with at least 30 years of NIA data and data quality level “C” or better. We then restrict the sample to the countries with (i) an average annual per capita GDP growth rate of one percent or higher, and (ii) non-negative total factor productivity growth.³ Applying these criteria leaves us with a sample of 56 countries.⁴ The complete list of countries and a detailed description of the data can be found in the Appendix.

For each country we obtain the data on working age population N_t , real GDP per capita, y_t , real investment per capita, x_t , and the employment rate, e_t , that is, workers per capita, from the Penn World Table. For most countries we have data from 1960 on and for some countries even before 1960. We construct the per capita capital stock series using the real per capita investment series as an input to the perpetual inventory model with geometric

³We exclude countries with less than 1% average per capita growth for two reasons. First, countries with low or negative average growth rates often suffer political turmoil that is beyond the scope of our analysis. Second, a close to zero per capita GDP growth rate can exaggerate the relative contributions of TFP growth or capital deepening.

⁴We also exclude Ghana because it has capital-output ratios in excess of five, which is almost three times the sample average.

depreciation

$$k_{t+1} = \frac{N_t}{N_{t+1}} [(1 - \delta) k_t + x_t], \quad (2.1)$$

with a common depreciation rate for all countries, $\delta = 0.06$. For the construction of the capital stock series we use all available data points of a country. For the initial per capita capital stock we assume that the investment-capital ratio is near the steady state, $k_0 = x_0 / (\bar{g}_{X,0,9} + \delta)$, where $\bar{g}_{X,0,9}$ equals the average growth rate of real investment during the first ten years of available data. While this is a crude approximation, it works well for most countries.

Our measures of educational attainment are from Barro and Lee (2000). Primarily we use average years of schooling in the population aged 25 and over. The data on educational attainment are available at five year intervals for the years 1960 to 2000. We use a spline interpolation to generate annual schooling date. As an alternative measure of educational attainment we occasionally use the fraction of people with a completed secondary education in the population aged 25 and over. For the growth accounting exercise we use the labor income shares from Bernanke and Gürkaynak (2001) when available, otherwise we set the labor income share to two thirds.

2.2. Growth contributions of capital deepening

We calculate the contributions of capital deepening and labor-augmenting technical change to per capita output growth for a standard Cobb-Douglas production structure, (1.1). Per-capita output growth is

$$\Delta \ln y = \alpha \Delta \ln k + (1 - \alpha) [\Delta \ln A + \Delta \ln e]. \quad (2.2)$$

Here $\Delta \ln z$ denotes the first difference of the log of z , that is, the growth rate of z . Note that our measure of the aggregate labor input, the number of workers per capita, e , is independent of the available capital stock in the economy.⁵ Conditional on our measures of output and input growth and the labor income share we can solve (2.2) for productivity growth, $\Delta \ln A$.

In the standard growth model exogenous productivity growth induces capital accumulation on the BGP, but the capital-output ratio remains constant. Thus capital-deepening is not a source of long-run output growth. In order to separate out the growth contributions

⁵Since we do not correct for changes in the quality of labor inputs, our measure of labor-augmenting technical change conflates changes in human capital with changes in productivity. Following Hall and Jones (1999) and using the Barro and Lee (2000) data on educational attainment, we could have allowed for quality changes in labor input. We have not done so for two reasons. First, we are interested in the relative contribution of capital deepening to growth, and this variable is not affected by the treatment of the labor input. Second, using the data on educational attainment shortens the sample period for several countries.

of productivity growth and capital deepening during transitional periods we rewrite (2.2) as follows

$$\Delta \ln y = \Delta \ln A + \Delta \ln e + \frac{\alpha}{1 - \alpha} \Delta \ln (k/y). \quad (2.3)$$

In Table 1 we list the results from our growth accounting exercise for the ten countries with the highest per capita GDP growth rates and for an average of all countries, population or per capita GDP weighted.⁶ Even though technical change accounts for the biggest part of output growth, capital deepening does make a substantial contribution to output growth. Depending on the weighting scheme capital deepening can account for up to one third of output growth. Furthermore, high output growth and capital deepening go together. For seven of the ten fastest growing countries capital deepening accounts for more than 17 percent and up to forty percent of output growth. This group includes some of the Asian ‘miracle growth’ countries: Taiwan, Korea, and Japan. Among the ten fastest growing countries only in Hongkong, Singapore, and Swaziland does capital deepening not contribute to output growth. This pattern is confirmed in the full sample: the correlation between capital deepening and output growth is 0.37, and the rank-order correlation is 0.31.

2.3. Investment Rates in the ‘Miracle Growth’ Countries

In many of the fast growing Asian economies capital-deepening is accompanied by increasing investment rates. Countries with increasing investment rate trends include Japan, Korea, Taiwan, Thailand, Malaysia, and Indonesia, Figure 2.⁷ Korea is an extreme case in that the investment rate steadily increases from less than ten percent in the 1950s to reach a peak of forty percent in the mid 1990s. In all of these countries the increasing investment rates were accompanied by a substantial increase of educational attainment.⁸

[Figure 2. Asian Economies with Increasing Investment Rates]

We have argued that capital deepening accompanied by increasing investment rates is consistent with the neoclassical growth model if skilled labor is relatively more complementary to capital than is unskilled labor. Given that skilled labor is usually identified with that part of the population that has attained a critical level of education, the size of the skilled labor force will be positively correlated with the education level as measured in average years of schooling. In Figure 3 we graph average years of schooling from Barro and Lee (2000), investment rates, and capital-output ratios for the six Asian economies with increasing investment rates. For each country we normalize each variable to one in 1960. In each of the

⁶The growth accounting results for the complete sample are available on request.

⁷For all time series we calculate the trend as the HP-filtered series with a smoothing parameter of 100.

⁸We should note that not all Asian economies show the same increasing trend for investment rates. The investment rates for Singapore, Hongkong, the Philippines, and India are essentially flat or declining.

six countries the capital-output ratio and the investment rate are increasing over time with educational attainment. Admittedly the positive relationship between the three variables is not equally tight for all countries.

[Figure 3. Capital Accumulation in Asian Economies]

There is an alternative explanation that can potentially account for increasing real investment rates in the growth model. If technical progress is investment-specific, that is, the productivity of the investment-goods producing sector is increasing relative to the productivity of the consumption-goods producing sector, then an increasing real investment-output ratio may be consistent with a balanced growth path, e.g., Greenwood, Hercowitz, and Krusell (1997). In a simple version of investment-specific technical change with the same Cobb-Douglas production structure in the investment and consumption goods producing sectors the relative price of investment goods is the inverse relative productivity of the investment goods sector. Furthermore, on the balanced growth path the relative price of investment goods is falling at the same rate as the relative production of investment is increasing such that the expenditure share of investment goods remains constant.

In Figure 4 we graph the real and nominal investment rates and the relative price of investment goods in the six Asian economies with increasing real investment rates. We make two observations. First, there is no uniform pattern to the behavior of the relative price of investment goods across countries. The relative price of investment goods has been increasing in Indonesia and Malaysia, has been falling in Japan and Taiwan, and has been essentially flat in Korea and Thailand. Second, for almost all countries the nominal investment rate follows the real investment rate. The only exception is Japan where the nominal investment rate was essentially flat, whereas the real investment rate was increasing. This suggests that investment-specific technical change might have contributed to the observed increase of Japan's investment rate in the late 50s and 60s.

[Figure 4. Investment Rates and Relative Prices]

Our explanation for the increasing investment rate is based on the static capital-skill complementarity and as such does not necessarily have implications for savings rates. In particular, whether a country is open or closed to international capital markets need not affect the behavior of the investment rate. In Figure 5 we graph the trend investment rate and savings rate for the six Asian economies. In all countries but one savings rates follow investment rates. The exception to this pattern is Indonesia which starts out with a high savings rate that declines and a low investment rate that increases. The fact that savings rates follow investment rates suggests that a closed economy interpretation of increasing investment rates

might be a reasonable first approximation. Furthermore, the case of Indonesia suggests that explanations for increasing investment rates that are based on subsistence-consumption, e.g. Christiano (1989), do not necessarily apply to all countries.

[Figure 5. Savings and Investment Rates]

2.4. Investment Rates in the World

Increasing investment rates during times when countries are building up their capital stock are not specific to Asia. Investment rates were also increasing in some of the Western European countries during the 1950s and 1960s when these countries were rebuilding their capital stock after World War II, Figure 6. Although the qualitative features of investment rates in these European economies are similar to the ones of the above mentioned Asian economies, changes in the European investment rates tend to be of smaller magnitude. We now investigate how investment rates are related to capital-output ratios and education in our complete set of 56 countries which encompasses both developing and developed countries.

[Figure 6. Investment Rates in Europe]

We are interested in the properties of countries' transitions to long-run growth. Since we view these transitions as medium-term fluctuations, we eliminate the effects of high frequency business cycles in the data. For this purpose we consider non-overlapping five year sub-samples starting in 1960, $\bar{t} \in \{1960, 1965, \dots, 1995\}$, that is, observation $\bar{t} = 1960$ covers the time period 1960-1964, etc. For each country we calculate the average investment rate, $\overline{(x/y)}_{i,\bar{t}}$, and the beginning-of-period capital-output ratio, $(k/y)_{i,\bar{t}}$. As a proxy of the beginning-of-period relative supply of skilled labor we use either average years of schooling in the population aged 25 and over, $h_{i,\bar{t}}$, or the high-school completion ratio in the population aged 25 and over, $s_{i,\bar{t}}$.⁹ Summary statistics for the complete sample and country group sub-samples are in Table 2.

Investment rates tend to increase with capital-output ratios, the unconditional correlation coefficient is 0.59. If the data points in the scatter plot of Figure 7, Panel A, represented cross-country averages this positive correlation would not be very surprising: with similar depreciation rates higher capital-output ratios imply higher investment rates, and capital-output ratios can vary across countries because of differences in tax policies, preferences, etc. Our sample is, however, a panel and contains time series elements. To isolate the dynamic characteristics of the investment rate we regress the investment rate on country and time dummies, and the lagged capital-output ratio and its square. The country dummies pick

⁹We use the Barro and Lee (2000) data on educational attainment.

up cross-country differences in average investment rates, whereas the capital-output ratio proxies for deviations from a country’s average state. Figure 7, Panel B, plots the investment rate net of time-specific and country-specific effects against the capital-output ratio. The estimated relationship (solid line) clearly shows a hump-shaped relation between investment rates and capital-output ratios: as capital-output ratios increase the marginal effect of a higher capital-output ratio on investment rates switches from positive to negative.

[Figure 7. Investment Rates and Development]

The hump-shaped relation between capital-output ratios and investment rates seems to reflect economic development. Note that capital-output ratios are positively correlated with per capita GDP, the correlation coefficient is 0.66.¹⁰ In developed economies with high capital-output ratios investment rates decline as the capital-output ratios increase. This pattern is consistent with the transition dynamics of the standard growth model where investment rates are below trend and increasing when the capital-output ratio is initially above trend. On the other hand, in developing economies with low capital-output ratios investment rates increase with capital-output ratios. This pattern is consistent with the growth model if (1) capital is relatively more complementary to skilled labor than it is to unskilled labor and (2) the share of skilled labor is increasing over time. In Table 3 we characterize the change in human capital for a country by the max-min ratio of the educational attainment variable (years of schooling or skilled labor share) for that country. Comparing country sub-samples in Table 3 it is clear that the average increase of human capital in developing countries, especially in the Asian countries, was significantly bigger than in developed countries.

Educational attainment is more closely correlated with economic development, measured as per capita GDP, than is the capital-output ratio. In order to separate out the effects of education and capital-output ratios we now run a panel regression of investment rates on country and time dummies, lagged capital-output ratios, average years of schooling, and an interaction term between the last two. We find a significant non-linear relationship between investment rates, capital-output ratios, and schooling levels, Table 4, column (1). For low capital-output ratios, these are the less developed economies, the investment rate is increasing with average years of schooling and the capital-output ratio. According to the estimates, the threshold capital-output ratio is 2.25, that is, if the capital-output ratio is less than (greater than) 2.25 then the investment rate increases (decreases) with average years of schooling. About 60 percent of all observations in the panel regressions have capital-output ratios below

¹⁰See also Table 2A for the difference in average capital-output ratios across country sub-samples. The average capital-output ratio in developed economies is 2.4, versus capital-output ratios of 1.5 for the Asian and Latin American economies, and 1.2 for the African economies.

this critical level. This feature of the data is consistent with our proposed explanation, in that with capital-skill complementarity higher human capital increases the capital-output ratio.

The Asian economies play an important role for this result, but we also find evidence for the same non-linear relationship for the sub-sample of Latin-American countries, Table 4, columns (2) and (3). There is no statistically significant relationship for the sub-sample of African and Middle Eastern Economies and the Developed Economies, Table 4, column (4) and (5). For the African and Middle Eastern countries we do not have many observations and most of these countries cannot be called growth successes. For the developed economies the coefficients are not statistically significant, but they are of the correct sign. Furthermore, based on the estimated coefficients higher capital-output ratios have a negative impact on the investment rate for almost all observations. Again, the behavior of the developed countries is consistent with the standard growth model.¹¹

To check the robustness of our analysis we have replaced (1) average years of schooling with the share of skilled labor, and we have replaced the real investment rate with the (2) nominal investment rate or (3) the savings rate. Neither of these substitutions affects the qualitative features of the estimated relationship between investment rates and capital-output ratios and educational attainment, but it does affect the statistical significance of our results in the case of savings rates.¹²

3. Capital-Skill Complementarity and Economic Development: The Case of South Korea

Our empirical analysis suggests that (1) capital-deepening contributes significantly to economic growth, (2) investment rates tend to start low and rises over time for less developed countries, and (3) investment rates tend to increase with educational attainment. We argue that these features of economic growth is consistent with the neoclassical model once we differentiate between skilled and unskilled labor and account for the increasing share of skilled labor in population. We evaluate this hypothesis quantitatively by studying the South Korean economy in more detail.

¹¹We replicate this analysis with the share of skilled labor in place of average years of schooling. The results are essentially the same and available on request.

¹²The results are available on request.

3.1. The Model

The model consists of a minor modification of the standard neoclassical growth model. First, we differentiate between skilled and unskilled labor, and second, we replace the Cobb-Douglas production function with a composite CES production function as used in Krusell, Ohanian, Rios-Rull, and Violante (2000).

There is a representative household with constant intertemporal elasticity of substitution preferences for per capita consumption, c_t , and utility is proportional to population size, n_t ,

$$\sum_{t=0}^{\infty} \beta^t n_t \frac{c_t^{1-\nu} - 1}{1-\nu}, \quad (3.1)$$

with $0 < \beta < 1$ and $\nu > 0$. The household inelastically supplies skilled and unskilled labor, s_t and u_t , and work effort e_t . Aggregate (per capita) output, y_t , is a CES aggregate of unskilled labor and another CES aggregate of capital and skilled labor

$$y_t = \left\{ (1-\omega) [(1-\lambda) (A_t e_t s_t)^\rho + \lambda (A_k k_t)^\rho]^{\sigma/\rho} + \omega (A_t e_t u_t)^\sigma \right\}^{1/\sigma}, \quad (3.2)$$

with $\rho, \sigma \leq 1$. There is labor-augmenting technical change, A_t , only. The absence of skill-biased technical change will allow us to construct a balanced growth path despite the absence of unit substitution elasticities in production. The output is used for consumption and investment

$$y_t = c_t + x_t. \quad (3.3)$$

Investment augments the capital stock after depreciation

$$k_{t+1} = \frac{N_t}{N_{t+1}} [(1-\delta) k_t + x_t]. \quad (3.4)$$

3.2. Calibration: South Korea's Growth 1960-2000

We now calibrate the model to the Korean economy. A crucial part of the calibration is the parameterization of the CES production structure (3.2), which in turn provides an alternative growth accounting for the Korean economy. For the CES production structure we do not use average years of schooling as a measure of aggregate human capital, rather we distinguish between two types of labor, skilled and unskilled, based on educational attainment. We construct two measures of the skilled labor force in South Korea using Barro and Lee (2000)'s data on educational attainment. The first measure, Type 1 skilled labor, defines workers as skilled if they have completed primary schooling. According to this measure, the share of the skilled labor force in Korea increased from 50 percent in 1960 to about 90 percent in 2000. The second measure, Type 2 skilled labor, defines workers as skilled if they have completed

secondary schooling. Based on this second measure, the share of the skilled labor force in Korea increased from 10 percent in 1960 to about 60 percent in 2000. According to the first definition, today almost all of the labor force in Korea would have to be considered skilled. We find that too extreme an outcome, and therefore consider the second definition to be a more reasonable description of the skilled labor force in Korea.

The parameters of the CES production structure (3.2) are $(\rho, \sigma, \lambda, \omega, A_k)$. We use Krusell et al (2000)'s substitution elasticity estimates for the United States and make capital and skilled labor complementary, $\rho = -0.4$, and the capital-skill aggregate and unskilled labor substitutes, $\sigma = 0.5$.¹³ We choose the share parameters (λ, ω, A_k) to match the steady state skill premium and capital income share of the economy. According to Bernanke and Gürkaynak (2001) capital income shares are relatively stable over time, and the average capital income share for Korea is 0.35. We follow Caselli and Coleman (2006) and construct the skill premium from the schooling coefficients in Mincer regressions for Korea, $\gamma = 0.106$, Bils and Klenow (2000). When skilled labor represents completed primary schooling we set the skill premium at $w_s/w_u = \exp(4\gamma)$, and when skilled labor represents completed secondary schooling we set the skill premium at $w_s/w_u = \exp(9\gamma)$. From the skill premium, the capital income share, and the relative supply of skilled labor we obtain income shares for skilled and unskilled labor. Using the first order conditions for profit maximization, the labor income shares, and the relative supply of skilled labor, we can derive the production function parameters (λ, ω, A_k) .

Given a complete parameterization of the CES production function we can construct the time path for labor augmenting technical change $\{A_t\}$ using equation (3.2) and data on output, capital, and employment. Figure 8 displays the time paths for labor-augmenting technical change for the two skill definitions. The qualitative features of the different measures of technical change are very similar. Since Type 2 skilled labor increases by a factor of six, productivity implied by Type 2 skilled labor increases the least. The average growth rate of labor augmenting technical change is 1.4 percent and 0.7 percent, when skilled is defined as primary and secondary education completed, respectively. To provide some perspective on our CES function based productivity measures, we have also constructed a measure of labor-augmenting technical change based on the procedure used by Hall and Jones (1999). This procedure assumes that the substitution elasticities between capital and different types of labor are the same. In particular, effective labor input is the product of employment and average human capital per worker, and average human capital is a non-linear function of average schooling.¹⁴ This alternative productivity measure behaves very much like our Type 1 CES-based productivity measure.

¹³Some references to other estimates of substitution elasticities for capital and labor, e.g. Antras (2004).

¹⁴We use the Barro and Lee (2000) data on average schooling in Korea.

[Figure 8. Productivity in Korea, 1960-2000]

In Figure 9 we display the time paths for the skill premium, capital income share, and capital rental rate implied by the share parameters and the TFP time path. Since the relative supply of Type-2 skilled labor increases much more than that of Type-1 skilled labor, the implied skill premium declines more for Type-2 skilled labor. For the same reason, the capital income share and the rental rate of capital are more stable for Type-2 skilled labor. From now on, we use the Type 2 definition of skilled labor, that is, the skilled labor force includes all workers with completed secondary schooling. We complete the calibration by assuming that the steady state annual real interest rate is 6 percent, capital depreciation is $\delta = 0.06$, and preferences are logarithmic, $\nu = 1$.

[Figure 9. Implicit Factor Prices in Korea, 1960-2000]

3.3. Simulation Exercise

We now ask whether the observed path of the skilled labor force together with capital-skill complementarity in production can account for the investment pattern in the Korean economy for 1960-2000. For this purpose we solve the perfect foresight equilibrium given the exogenous time path for population growth ($g_{n,t}$), normalized employment rate (e_t), labor-augmenting productivity growth ($g_{A,t}$), and the share of skilled labor force (s_t). For the period of 1960-2000 we use the trend components (HP-filtered), dashed lines in Figure 10. From year 2000 on, these variables continue at their steady state values, indicated by the solid red lines: $g_n = 1.01$, $e = 1$, $g_A = 1.0074$, and $s = 0.6$. For 1960-2000, the capital-output ratio tripled in Korea. We assume that the initial (normalized) capital stock is just 15 percent of its steady state value. Since the model economy is far way from the steady state in the early periods, errors from the log-linear approximation of the optimality conditions (i.e., Euler equation) can be large. We therefore use a shooting algorithm to solve the non-linear Euler equations.

[Figure 10. Time Path for Exogenous Variables]

In order to highlight the role of skilled labor, we first keep the skilled labor share constant at the steady state level and allow for only three exogenous forcing variables—population growth, employment rate, and labor-augmenting technological change—to vary over time. Given the time paths for these three variables and the initially low capital stock, the qualitative properties of the transition to the steady state are similar to that of the standard neoclassical growth model. In Figure 11 we display the time paths of per capita output, investment rate, and capital-output ratio for the model simulation (solid lines) and for the

actual values from the Korean economy (dashed lines). Note that the investment rate starts out high, close to 50%, and then declines over time. This high investment rate in the beginning implies a fast convergence of the capital-output ratio to its steady state. Despite the high investment rate and fast capital accumulation, per capita output is far below that of the actual Korean economy because there is no human capital growth in this simulation exercise.

[Figure 11. Transition with constant share of skilled labor]

We now add changes in the share of skilled labor to our simulation. With the same parameter values and the same initial capital stock, the model now generates an increasing investment rate, Figure 12. While the investment rate rises in the beginning, the peak comes much earlier than in the data. Also, a small amount of skilled labor makes the aggregate output very small and results in a too high capital-output ratio.

[Figure 12. Transition with increasing share of skilled labor]

According to the standard growth model, a very low level of capital per worker should generate excessive returns to capital and thereby induce capital inflows. Capital-skill complementarity, however, implies that the return on capital is moderate even when skilled labor is scarce (see Figure 13). There is then no reason for capital to flow into the capital-poor economy. Here the crucial feature is the relative initial endowment of physical capital and human capital. In our exercise, both physical and human capital stocks start out at low levels, and human capital imposes a binding constraint on production. Given the substantial increase of the relative supply of skilled labor, the predicted skill-premium declines over time. The fact that the skill premium is very high initially need not imply that skilled labor should move from, say the United States to Korea. With a low capital stock, the absolute wage of skilled labor is much lower in Korea. For example, in the early sixties Korean per capita GDP was one tenth of U.S. per capita GDP.

[Figure 13. Factor Rentals and Changes in the Skilled Labor Share]

We find some support for the declining rate of return on capital and the skill premium in the Korean data. Although we do not match the levels of these variables, we do match their qualitative features. In the upper panel of Figure 14 we graph a measure of the real interest rate in Korea: the nominal rate of a National Housing Bond less ex-post consumer price inflation. From the mid-1980s on, the real rate of return in Korea has been declining.¹⁵ In

¹⁵The low real rates in the mid-1970s and 1980 are due to high inflation rates (25 to 30 percent). Presumably, rates of return on real assets did not suffer as much from inflation. It is well known that the official lending rate was kept low by government regulation in 1960s and 1970s. This policy of low interest rates effectively subsidized the Korean business sector. The fact that such a low loan rate is often needed might imply a low rate of return to capital at that time.

the lower panel of Figure 14 we graph the skill premium of a college educated worker relative to a worker with high school education. Clearly, the skill premium has been declining from the mid-1970s on.

[Figure 14. Actual Factor Prices in Korea, 1960-2000]

4. Industrialization as an Alternative Explanation?

One might argue that the increasing investment rate in the Korean economy, or developing economies in general, simply reflects the process of industrialization, that is, the transition from an agricultural to a capital-intensive industrial economy. In 1963 Korea was a predominantly agricultural economy, sixty three percent of Korea's labor force was employed in the agricultural sector.¹⁶ Furthermore, land represents most of the capital input in Korea's agricultural sector, about 87% of all fixed assets in agriculture, Young (1995). Today Korea is an industrialized economy with a small agricultural sector. For example, in 2000 less than ten percent of the Korean labor force is employed in the agricultural sector. Associated with being an industrialized economy is the fact that reproducible capital goods, structures and equipment, now make up most of Korea's capital stock. Thus one might be tempted to conclude that Korea's transition from a predominantly agricultural economy to an industrialized economy accounts for the observed increasing investment share. While we cannot provide an exhaustive analysis of this alternative explanation, we want to argue that the implications of industrialization for investment rates are not as straightforward as one might think.

Gollin, Parente, and Rogerson (2002) propose a simple model, that they argue accounts well for the transition from a traditional agricultural economy to an industrialized economy. We simplify the model of Gollin et al (2002) even more, and ignore the transition from a stagnating traditional agriculture sector to a modern agriculture sector with increasing productivity. This is justified since by 1960 Korea was well on its way to an industrialized economy. We now assume that the representative household has preferences over the per capita consumption of a manufactured good c and an agricultural good a . For simplicity we assume that the household consumes a fixed amount \bar{a} of the agricultural good,

$$\sum_{t=0}^{\infty} \beta^t n_t (\log c_t + \bar{a}). \quad (4.1)$$

¹⁶Our data on sectoral employment are from the South Korean Statistical Office. We measure employment in agriculture relative to the total non-institutional labor force.

Labor is the only input to the production of the agricultural good,

$$a_t = A_{at}e_{at}, \quad (4.2)$$

and the manufactured good is produced using capital and labor,

$$y_t = f(k_t, A_{yt}e_{yt}). \quad (4.3)$$

Total labor effort is exogenous and effort is allocated between the production of agricultural goods and manufactured goods,

$$e_{at} + e_{yt} = e_t. \quad (4.4)$$

We assume that the agricultural sector is productive enough to provide the fixed consumption amount \bar{a} if all labor is allocated to agriculture, $A_{at}e_t \geq \bar{a}$.¹⁷ The manufactured good can be used for consumption or investment, (3.3), and investment augments the capital stock, (3.4).

Production in both sectors is constant returns to scale, and as usual we assume that all markets are competitive. We can define aggregate GDP in terms of the manufactured good as

$$q = y + p_a a \quad (4.5)$$

where p_a is the relative price of the agricultural good. With competitive agricultural markets the price of the agricultural good is $p_a = w/A_a$, and the value of agricultural production is

$$p_a \bar{a} = (w/A_a) (A_a e_a) = w e_a = w \bar{a} / A_a. \quad (4.6)$$

The model we have described is essentially the standard neoclassical growth model. Exogenous employment in the manufacturing sector is now determined in part by the rate at which productivity improvements in the agricultural sector release labor to the manufacturing sector. As agricultural productivity increases over time, the agricultural sector becomes unimportant, that is, the employment and value-added shares of the agricultural sector converge to zero. Thus the economy converges to the balanced growth path of the standard one-sector growth model.

The presence of the agricultural sector does not essentially affect the transitional dynamics of the non-farm sector of the model. In particular, if we assume that production in the non-farm sector is Cobb-Douglas, (1.1), then for standard capital income shares the

¹⁷Gollin et al (2002) consider a slightly more general version where the household's utility function is linear in the consumption of the agricultural good if consumption is less than \bar{a} , and of the form (4.1) when consumption of the agricultural good is $a \geq \bar{a}$.

model predicts that, during the transition to a BGP, the investment rate relative to non-farm output, x/y , declines, if the economy starts out with a capital-output ratio below the BGP value. Using sectoral value-added data we show below that investment rates increase in the Korean economy, whether they are defined relative to aggregate GDP or relative to non-farm GDP.

The fact that agriculture does not use capital does, however, introduce a wedge between the aggregate investment rate and the investment rate with respect to non-farm output. Using the fact that real wages are equal to the marginal product of labor in manufacturing we see that with Cobb-Douglas production in the nonfarm sector, aggregate GDP is proportional to non-farm value-added,

$$q = y \cdot \frac{A_a - \alpha \bar{a}}{A_a - \bar{a}}. \quad (4.7)$$

This in turn implies that the investment rate relative to aggregate GDP is proportional to the investment rate relative to non-farm GDP,

$$\frac{x}{q} = \frac{x}{y} \cdot \underbrace{\frac{A_a - \bar{a}}{A_a - \alpha \bar{a}}}_{\phi}. \quad (4.8)$$

As agricultural productivity increases, the factor ϕ , that relates the aggregate investment rate to the non-farm investment rate, increases. Thus it is possible that, during the transitional period when the share of the agricultural sector declines, the aggregate investment rate increases, even though the non-farm investment rate continues to decline.

We now introduce an agricultural sector into our model economy with CES production, and we calibrate the model with agriculture along the same lines as the one-sector model. On the BGP we match a 6% annual interest rate, a 6% depreciation rate, and a 35% capital income share. We use the labor force participation rate as our measure of total effort e . We normalize 1960 productivity of the agricultural sector at one, and set the fixed consumption of agricultural goods based on the employment share of agriculture in 1960, $\bar{a} = e_{a,1960}$. From the official statistics for South Korea we have the employment share of agriculture in 1963 at 63 percent and in 2000 at 7.9 percent. We assume that in the years 1960 to 1963 the employment share of agriculture declines by two percentage points every year, the average rate during the 1960s. Based on the declining employment share of agriculture we calculate the average annual growth rate of productivity in agriculture as 4.8 percent. We assume that productivity in agriculture continues to increase at this rate, which implies that employment in agriculture falls at this rate. We calculate labor augmenting technical change in the non-farm sector as in Section 3.2 with the appropriate modifications for output and employment of skilled labor. We construct Korean non-farm GDP as the aggregate GDP

from the PWT multiplied by the real non-farm GDP share of the Korean economy. Except for the first five years this does not much affect our estimate of labor augmenting technical change, Figure 5. The impact of the declining productivity up to 1965 on the simulations is muted since we use HP-filtered time series for the forcing variables. We assume that in 1960 the normalized capital stock was 15 percent of its BGP value.

[Figure 15. Productivity in the Nonfarm Sector]

In Figure 16 the solid lines are the time paths for the log of output, the investment rate, and the capital-output ratio for two definitions of output, aggregate GDP (red) and non-farm GDP (blue) for the model simulations. The dashed lines represent the corresponding detrended time paths for the log of output, investment rate, and capital-output ratio for the Korean economy. In the model we match the employment share path of the farm sector in the Korean economy, yet the implied path for non-farm GDP share in the model is quite close to that of the Korean economy. Comparable to the Korean economy the model also predicts that the increase of the investment rate relative to aggregate GDP is more spread out over time than is the increase of the investment rate relative to non-farm GDP.

[Figure 16. Transition and Agriculture]

5. Conclusion

A central idea of virtually all postwar development policies is to stimulate transfers of capital goods from rich to poor countries. Our theory predicts that such policies are often likely to fail. Unless there is enough skilled labor, the transferred capital goods will not be productive. Capital-skill complementarity then suggests that capital transfers need to be complemented by a policy that promotes investment in human capital. Since human capital accumulation takes time, a successful policy may need to be sustained for an extended period of time, possibly generations.

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Table 1. Sources of Per Capita GDP Growth

	Country	g_y	$g_{k/y}$	g_A	g_e
1.	Taiwan :	6.0	2.9	4.4	0.1
	1951-1998	(100.0)	(24.0)	(73.6)	(2.4)
2.	Botswana :	5.8	2.0	3.4	-0.1
	1970-2003		(42.3)	(58.9)	(-1.2)
3.	Korea :	5.0	2.8	2.7	0.8
	1953-2003		(29.8)	(55.0)	(15.2)
4.	Hong Kong :	5.0	0.2	4.1	0.8
	1960-2003		(2.6)	(81.6)	(15.9)
5.	Japan :	4.4	3.1	2.5	0.4
	1950-2003		(33.4)	(58.5)	(8.1)
6.	Singapore :	4.3	0.2	3.2	0.9
	1960-2003		(4.3)	(73.8)	(21.9)
7.	Malaysia :	4.1	3.2	2.1	0.4
	1955-2003		(39.9)	(51.4)	(8.7)
8.	Portugal :	3.7	1.7	2.7	0.4
	1950-2000		(17.4)	(72.1)	(10.5)
9.	Spain :	3.7	1.4	2.7	0.2
	1950-2003		(18.9)	(74.4)	(6.7)
10.	Swaziland	3.6	-1.3	4.2	-0.0
	1970-2003		(-18.0)	(119.3)	(-1.3)
Average across all countries weighted by					
	Population :	2.6	1.7	1.7	0.3
		(100.0)	(36.3)	(59.6)	(4.1)
	GDP:	2.8	0.9	2.1	0.3
		(100.0)	(16.8)	(69.4)	(13.8)

Note: Average growth rates of per capita output, g_y , capital-output ratio, $g_{k/y}$, labor augmenting technology, g_A , and employment rate, g_e . The contributions of the different components to per capita output growth are in parenthesis. A complete description of the data is in the Appendix, and the construction of capital stock data is described in the text. The Appendix contains the corresponding table for the complete sample, Table A.1. Average growth rates and contributions are calculated for the complete sample. The countries are weighted either according to their population size or their real per-capita GDP in 2000.

Table 2. Descriptive Statistics

Variable	Mean	S.D.	Min	Max	Corr(., y)	Corr(., k/y)
Full Sample						
$(x/y)_{i,\tau}$	0.19	0.08	0.03	0.50	0.42	0.72
$(k/y)_{i,\tau}$	1.78	0.80	0.33	3.93	0.66	1.00
$h_{i,\tau}$	5.62	2.73	0.17	12.18	0.85	0.61
$s_{i,\tau}$	0.19	0.16	0.001	0.77	0.79	0.53
Asia						
$(x/y)_{i,\tau}$	0.22	0.11	0.06	0.50	0.56	0.85
$(k/y)_{i,\tau}$	1.54	0.80	0.38	3.93	0.66	1.00
$h_{i,\tau}$	4.70	2.21	0.63	10.09	0.73	0.48
$s_{i,\tau}$	0.15	0.12	0.005	0.57	0.48	0.36
Latin America						
$(x/y)_{i,\tau}$	0.14	0.07	0.03	0.30	-0.19	0.65
$(k/y)_{i,\tau}$	1.53	0.76	0.44	3.36	-0.14	1.00
$h_{i,\tau}$	4.40	1.75	1.43	9.09	0.77	0.11
$s_{i,\tau}$	0.12	0.08	0.02	0.34	0.38	0.17
Africa and Middle East						
$(x/y)_{i,\tau}$	0.13	0.06	0.05	0.30	0.45	0.73
$(k/y)_{i,\tau}$	1.17	0.55	0.33	2.56	0.58	1.00
$h_{i,\tau}$	3.39	2.24	0.17	9.11	0.89	0.49
$s_{i,\tau}$	0.10	0.11	0.001	0.43	0.87	0.53
Developed Economies						
$(x/y)_{i,\tau}$	0.23	0.04	0.15	0.36	-0.19	0.32
$(k/y)_{i,\tau}$	2.37	0.48	1.18	3.61	0.49	1.00
$h_{i,\tau}$	7.80	2.12	1.94	12.18	0.71	0.38
$s_{i,\tau}$	0.30	0.17	0.03	0.77	0.72	0.37

Table 3. Changes in Educational Attainment

Variable	Mean	S.D.	Min	Max
Full Sample				
\widehat{h}_i	2.11	0.93	1.11	5.26
\widehat{s}_i	5.59	4.96	1.33	27.40
Asia				
\widehat{h}_i	2.51	0.80	1.33	3.78
\widehat{s}_i	7.26	7.11	2.01	27.4
Latin America				
\widehat{h}_i	1.95	0.31	1.58	2.64
\widehat{s}_i	5.32	2.35	2.33	10.86
Africa and Middle East				
\widehat{h}_i	3.05	1.31	1.35	5.26
\widehat{s}_i	7.69	6.85	1.87	25.00
Developed Economies				
\widehat{h}_i	1.50	0.31	1.11	2.34
\widehat{s}_i	3.69	2.30	1.32	9.17

Note: Ratio of maximum to minimum level of educational attainment in a country, $\widehat{h}_i = \frac{\max h_{i,t}}{\min h_{i,t}}$, and $\widehat{s}_i = \frac{\max s_{i,t}}{\min s_{i,t}}$.

Table 4. Investment Rates, Capital-Deepening, and Schooling

	(1)	(2)	(3)	(4)	(5)
	All	Asia	Latin America	Africa and Middle East	Developed Countries
$(\frac{k}{y})_{i,\bar{s}}$	0.079 (7.9)	0.114 (5.5)	0.084 (3.28)	0.087 (3.2)	0.026 (1.4)
$h_{i,\bar{s}}$	0.024 (5.9)	0.049 (5.8)	0.018 (1.7)	0.015 (1.5)	0.005 (0.7)
$h_{i,\bar{s}}(\frac{k}{y})_{i,\bar{s}}$	-0.010 (-7.4)	-0.010 (-3.7)	-0.017 (-3.7)	-0.016 (-2.3)	-0.007 (-3.1)
R ²	0.86	0.93	0.77	0.83	0.78
Obs.	437	95	96	80	166
$\frac{\partial(x/y)}{\partial(k/y)} > 0$ at $\bar{s} <$	7.85	11.06	4.70	5.09	3.73

Note: The numbers in parentheses below the parameter estimates are t-ratios based on Huber-White robust estimates. The marginal effect of capital-output ratios on investment rates is positive, $\partial(\overline{x/y})/\partial(k/y) > 0$, if average schooling, \bar{s} , is less than the indicated critical value. The number in parentheses below the critical value indicates the percentage of all observations for which the marginal effect is positive. Similarly for the marginal effect of schooling.

Appendix

The National Income Accounts data are from the Penn World Table Version 6.2 (2006), PWT mnemonic are in parenthesis. The PWT provides two types of price and quantity indices: (1) ‘current price’ estimates based on Geary aggregation of international current prices for each year, and (2) ‘constant price’ estimates based on Geary aggregation of international current prices for benchmark years and interpolation of country-specific constant price NIA data for in between years. For most of our work we use the ‘constant price’ data. Output, y , is real per capita GDP at constant prices constructed as a Laspeyre index (RGDPL), real investment per capita is the private and public investment share of output (KI) times output, $x = y \cdot \text{KI}/100$. The participation rate, e , is the number of workers per capita and is constructed as the ratio of real per worker GDP and real per capita GDP, $e = \text{RGDPL}/\text{RGDPWOK}$. Population, N , is POP.

For Figure 4 we calculate the relative price of investment and real and nominal investment shares based on the ‘current price’ estimates. The relative price of investment goods is the ratio of investment (PI) and private consumption (PC) price index, $q = \text{PI}/\text{PC}$. The real investment rate is the share of private and public investment in real GDP (CI), and the nominal investment rate is $\text{CI} \cdot \text{PI}/\text{P}$, where P is the price index of GDP.

The list of countries we consider are as follows (numbers in parenthesis indicates the sample periods for which NIA data are available). For the panel data analysis in Section 2.4, we restrict the sample period to 1960-2000 because of the limited data on education attainment in Barro and Lee (2000).

- Asia: Hong Kong (1960-2003), India (1950-2003), Indonesia (1960-2003), Japan (1950-2003), Korea (1953-2003), Malaysia (1955-2003), Pakistan (1960-2003), Philippines (1950-2003), Singapore (1960-2003), Sri Lanka (1950-2003), Taiwan (1951-1998), Thailand (1950-2003)
- Africa and Middle East: Botswana (1950-2003), Egypt (1950-2003), Israel (1950-2003), Mali (1960-2003), Malawi (1954-2003), Mauritius (1970-2003), South Africa (1950-2003), Swaziland (1950-2003), Syria (1960-2003), Tunisia (1950-2003), Turkey (1950-2003).
- Latin America: Chile (1951-2003), Colombia (1950-2003), Costa Rica (1950-2003), Ecuador (1951-2003), El Salvador (1950-2003), Jamaica (1953-2003), Mexico (1950-2003), Panama (1950-2003), Paraguay (1951-2003), Trinidad & Tobago (1950-2003), Peru (1950-2003), Barbados (1960-2003), Dominican Republic (1951-2003), Guatemala (1950-2003).

- Developed countries: Austria (1950-2003), Belgium (1950-2003), Denmark (1950-2003), Finland (1950-2003), France (1950-2003), Germany, West (1950-1992), Greece (1951-2003), Iceland (1950-2003), Ireland (1950-2003), Italy (1950-2003), Ireland (1950-2003), Netherlands (1950-2003), Norway (1950-2003), Portugal (1950-2003), Spain (1950-2003), Sweden (1951-2003), Switzerland (1950-2003), United Kingdom (1950-2003); Canada (1950-2003), U.S.A. (1950-2003), Australia (1950-2003), New Zealand (1950-2003)

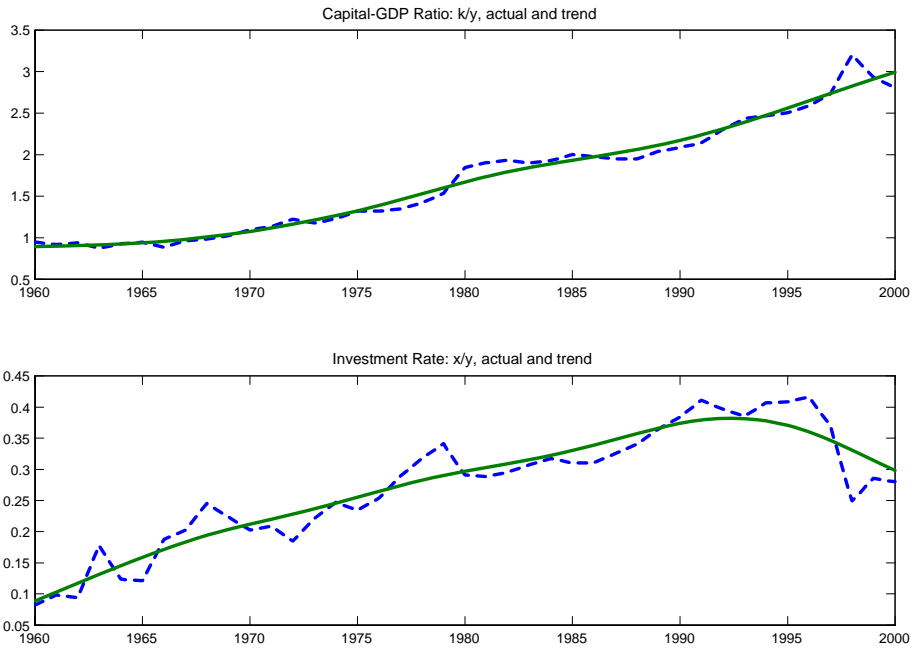


Figure 1. Korea's Capital Accumulation Dynamics

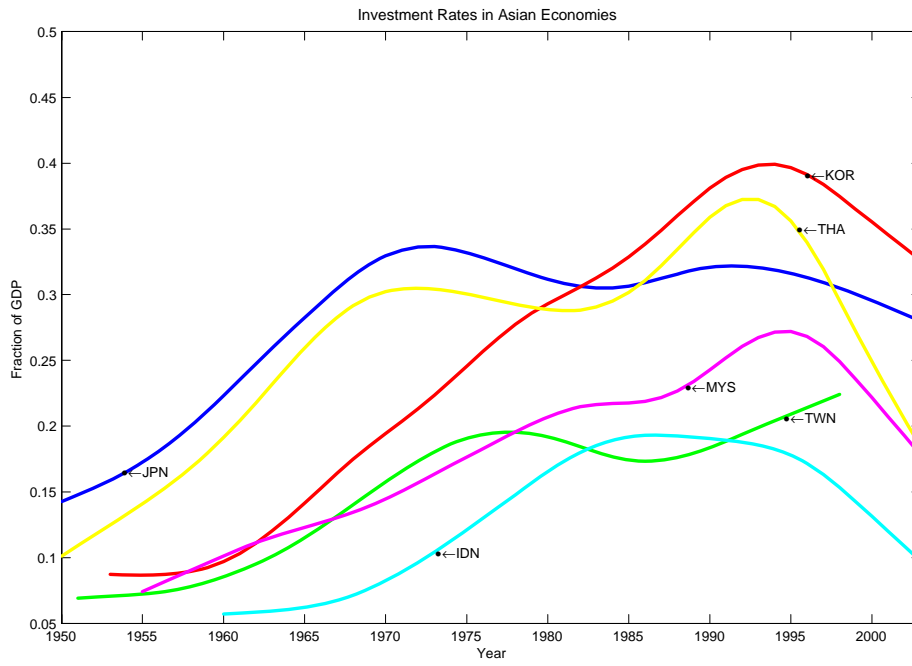


Figure 2. Asian Economies with Increasing Investment Rates

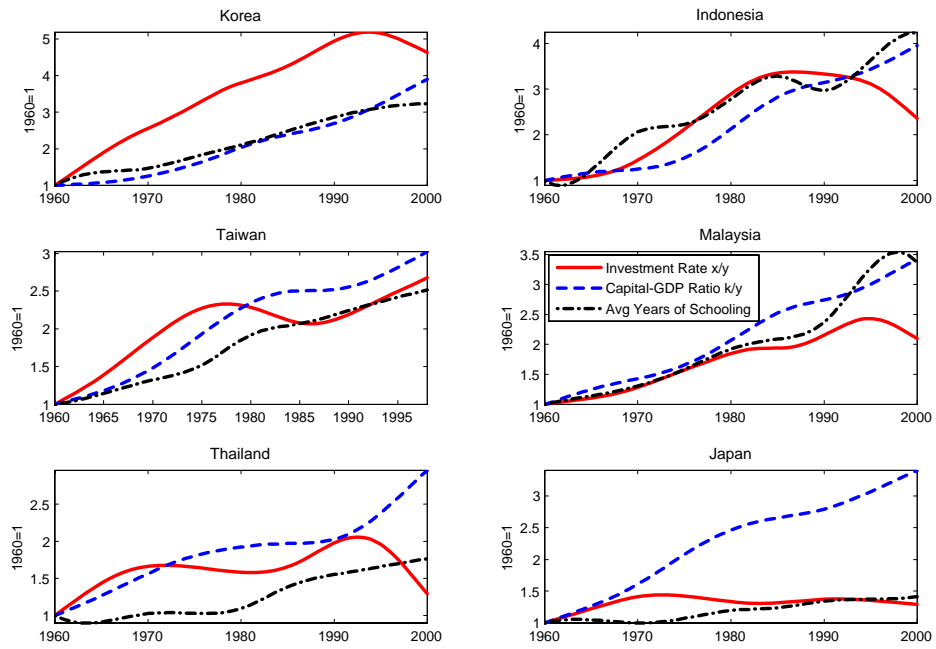


Figure 3. Capital Accumulation in Asian Economies

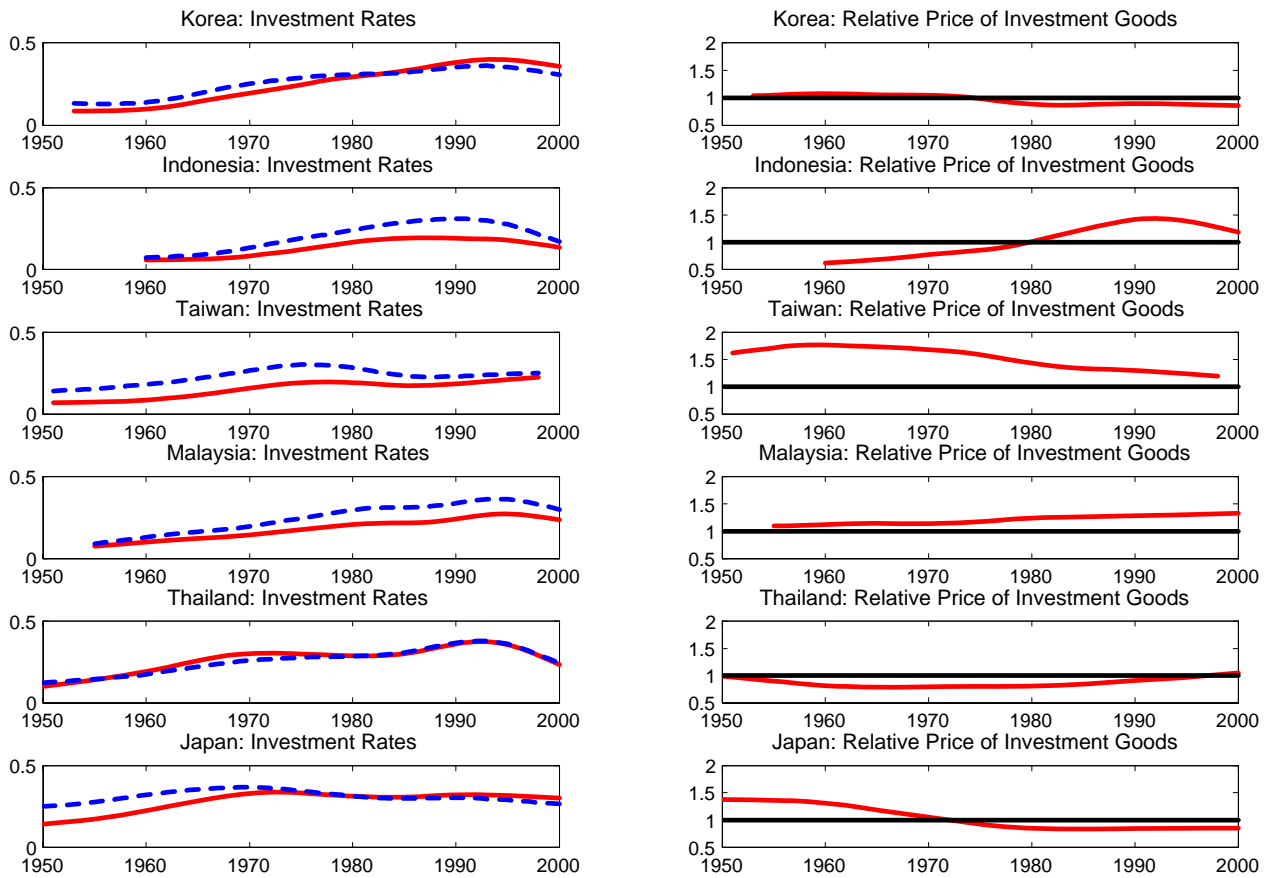


Figure 4. Investment Rates and the Relative Price of Capital

Note: In the six left hand side graphs the solid line denotes the real investment rate and the dashed line denotes the nominal investment rate.

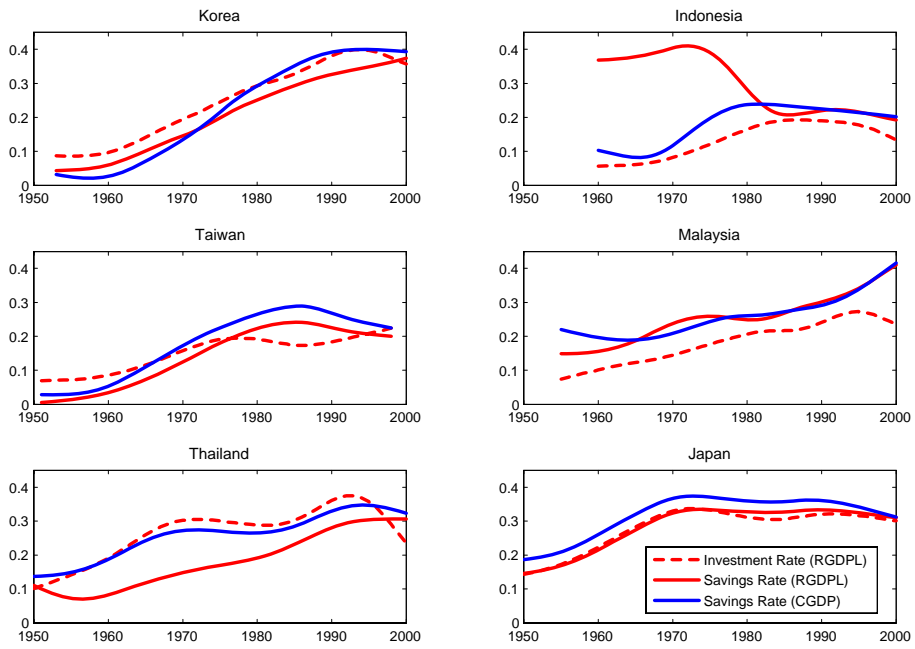


Figure 5. Investment Rates and Savings Rates

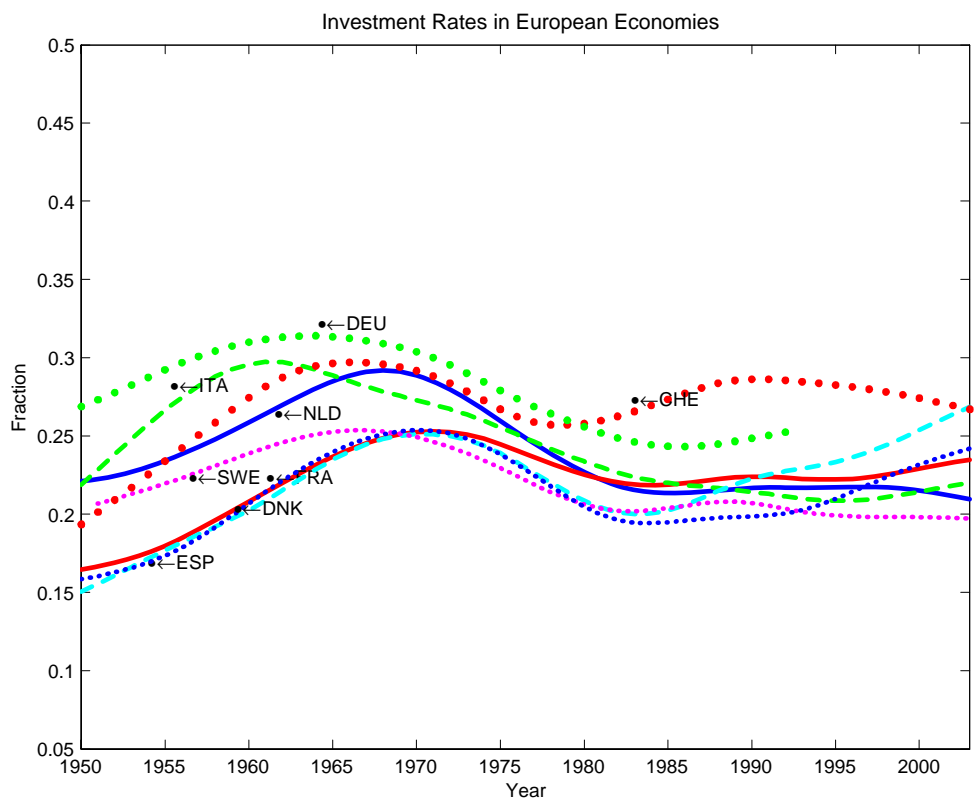


Figure 6. Investment Rates of Mature European Economies

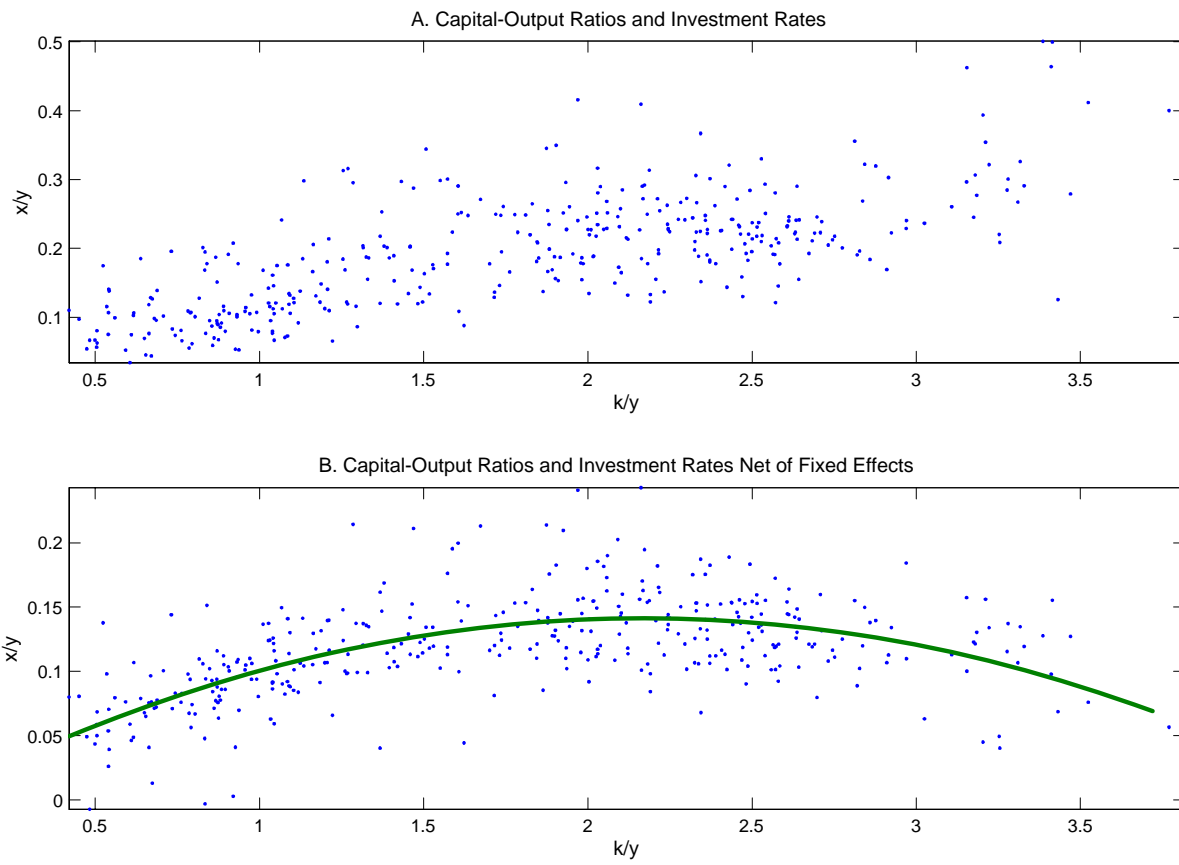


Figure 7. Investment Rates and Development

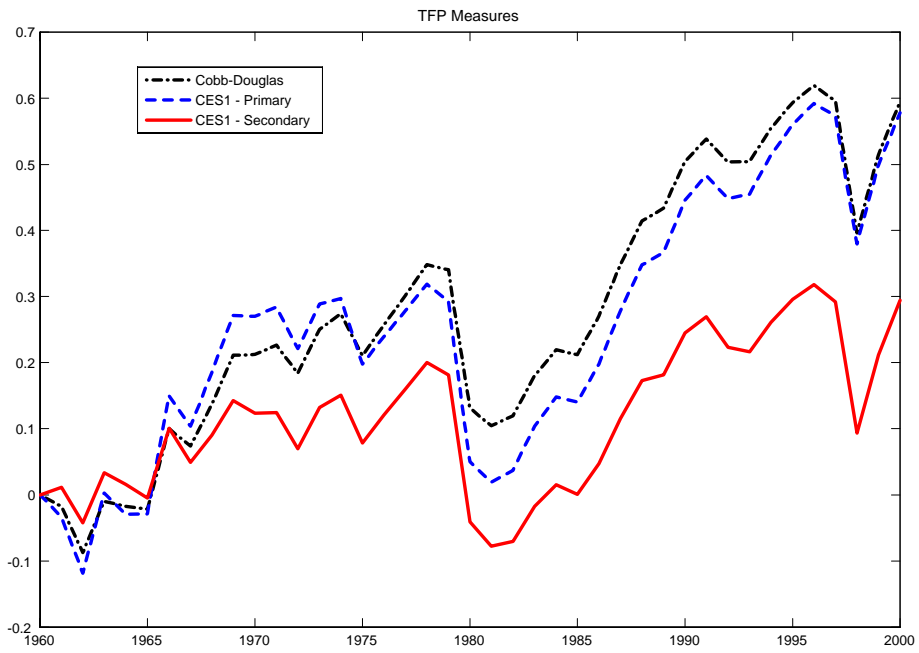


Figure 8. Productivity in Korea, 1960-2000

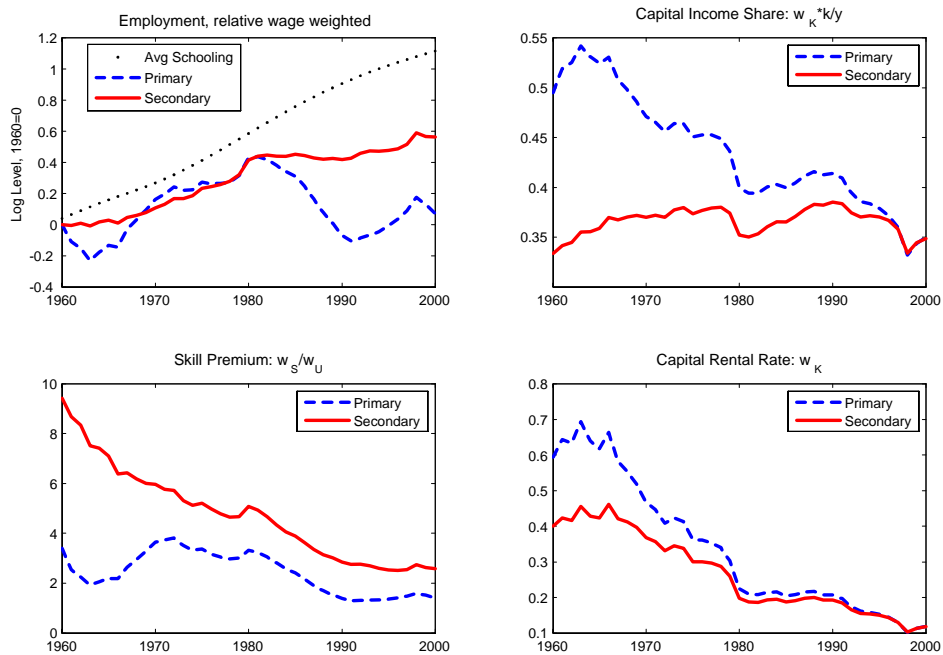


Figure 9. Implicit Factor Prices in Korea, 1960-2000

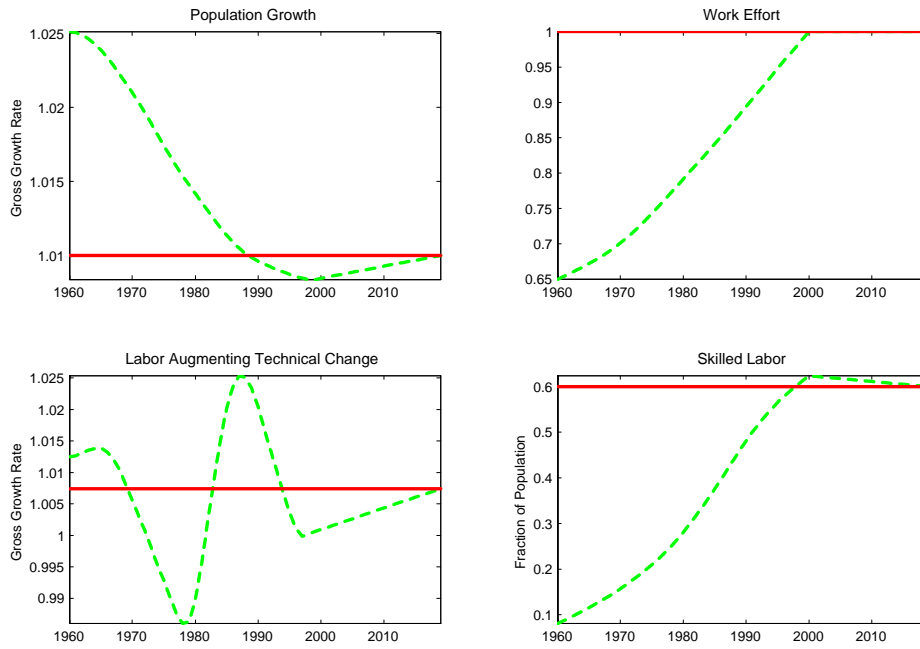


Figure 10. Time Path for Exogenous Variables

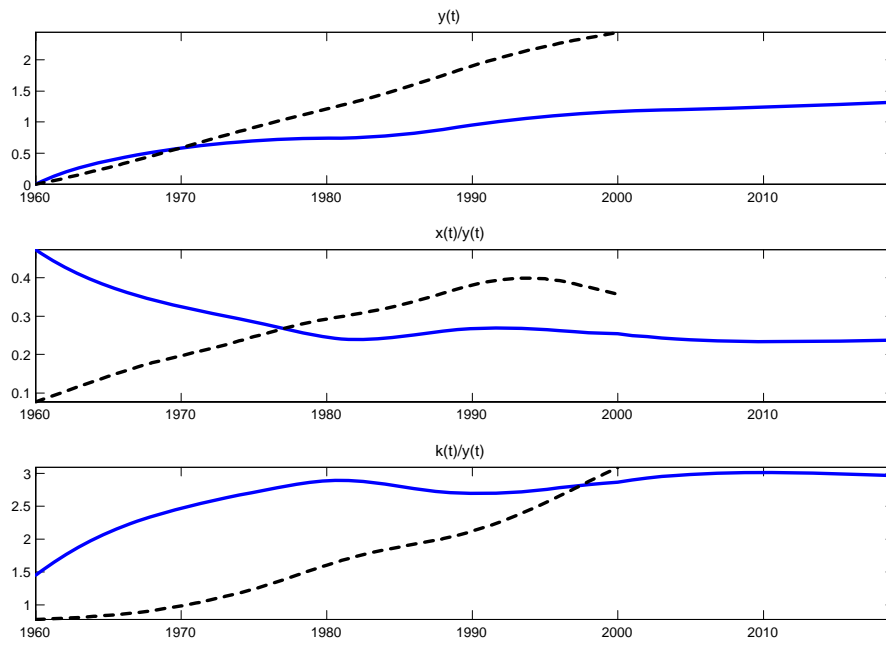


Figure 11. Transition Dynamics With a Constant Skilled Labor Share

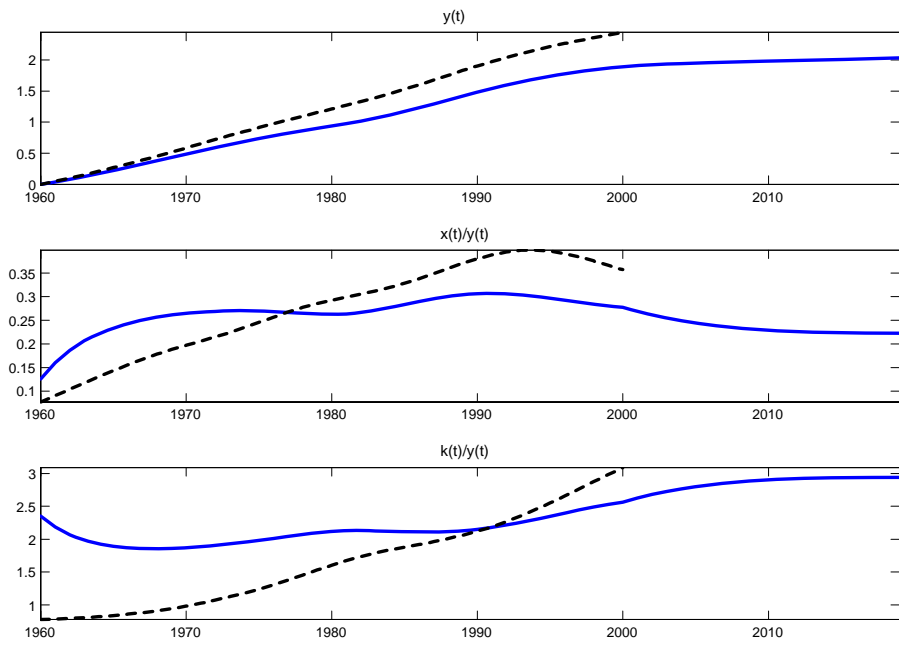


Figure 12. Transition Dynamics with an Increasing Skilled Labor Share

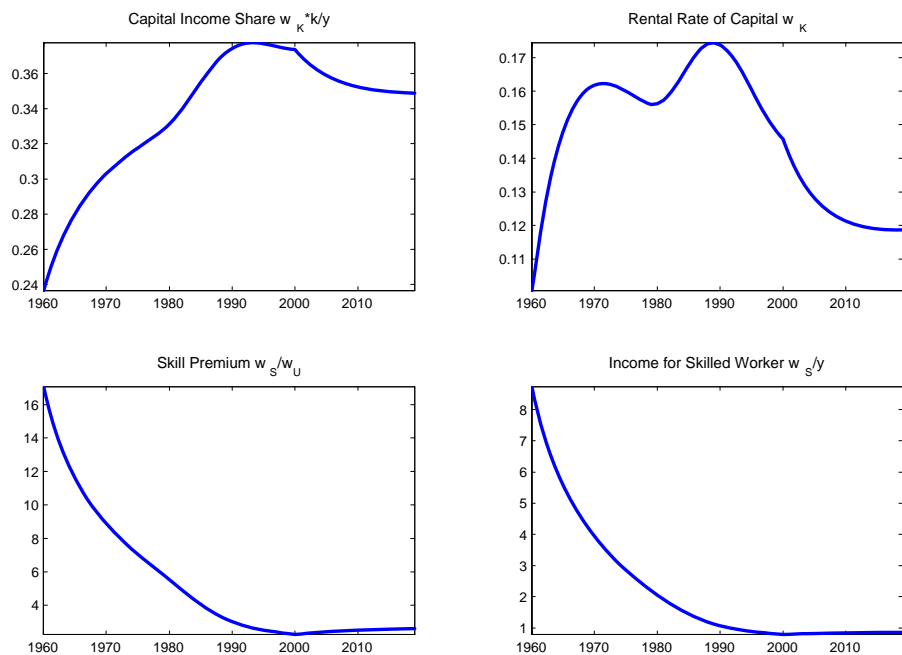


Figure 13. Factor Rentals and Changes in the Skilled Labor Share

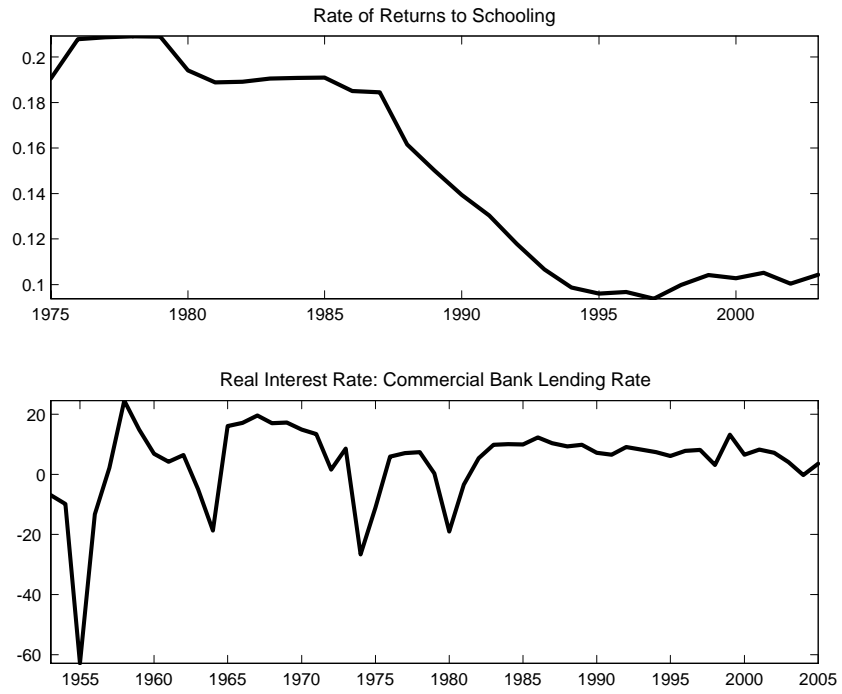


Figure 14. Factor Rentals, Korea

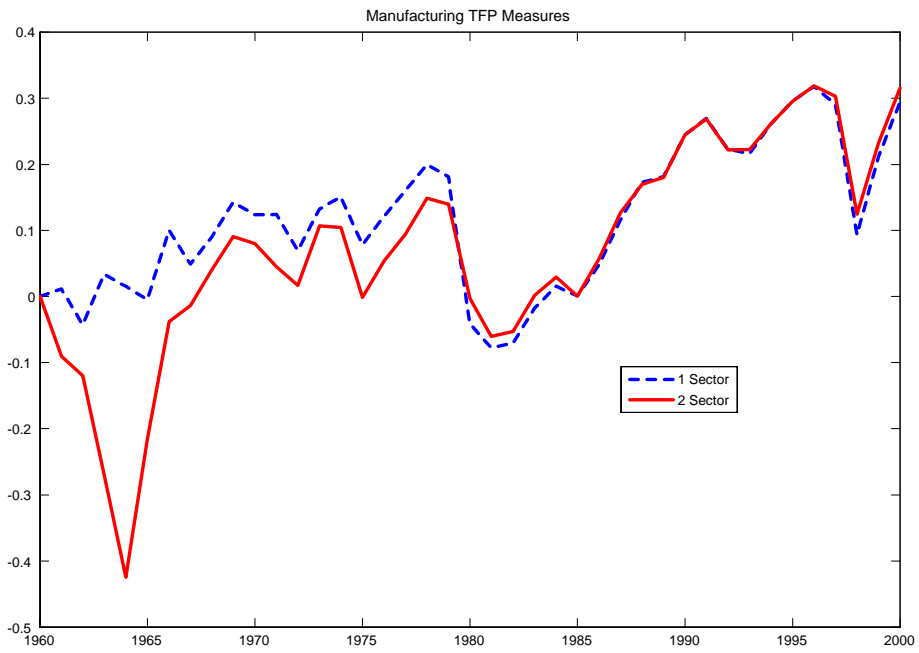


Figure 15. Nonfarm TFP

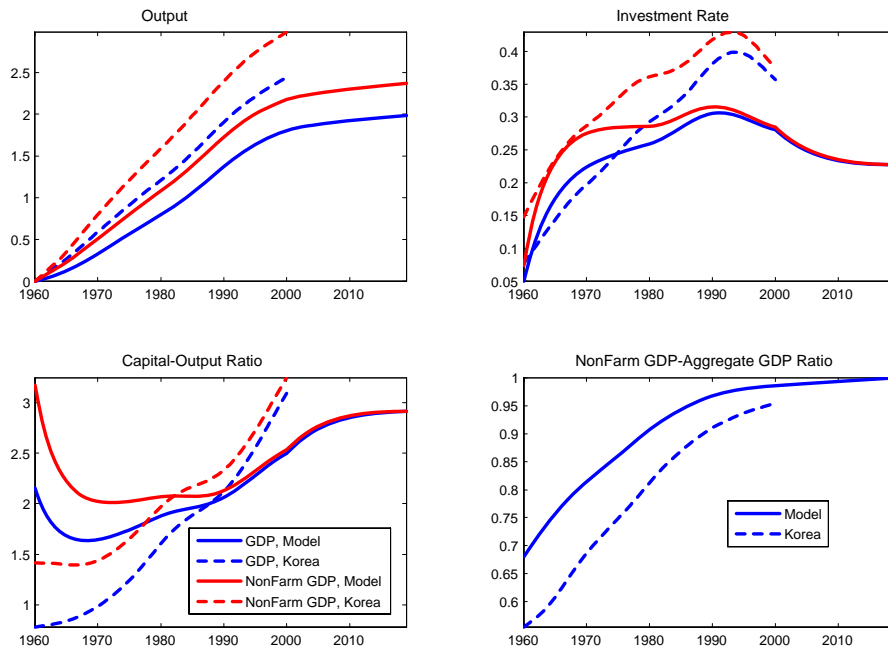


Figure 16. Transition with Agriculture