Working Paper Series

Transition Dynamics in the Neoclassical Growth Model: The Case of South Korea

WP 11-04R

Yongsung Chang
University of Rochester and Yonsei University

Andreas Hornstein
Federal Reserve Bank of Richmond

THE FEDERAL RESERVE BANK OF RICHMOND
RICHMOND ▪ BALTIMORE ▪ CHARLOTTE

Transition Dynamics in the Neoclassical Growth Model: The Case of South Korea*

Yongsung Chang† and Andreas Hornstein‡

August 26, 2013

Federal Reserve Bank of Richmond Working Paper No. 11-04R

Abstract

Many successful examples of economic development, such as South Korea, exhibit long periods of sustained capital accumulation. This process is characterized by a gradually rising investment rate along with a moderate rate of return to capital, both of which are strongly at odds with the standard neoclassical growth model that predicts an initially high and then declining investment rate with an extremely high return to capital. We show that minor modifications of the neoclassical model go a long way toward accounting for the capital accumulation path of the South Korean economy. Our modifications recognize that (i) agriculture (which makes up a large share of the aggregate economy in the early stage of development) does not rely much on capital and (ii) the relative price of capital declined substantially during the transition period.

Keywords: Neoclassical Growth Model, Transition Dynamics, Industrialization, Price of Capital, South Korea

JEL: E13, E22, O11, O13, O14, O16, O4, O53

* We would like to thank discussants and participants at various conferences and seminars, in particular, Francesco Caselli, Jang-Ok Cho, Seijik Kim, Yongjin Kim, Kyoungmook Lim, Jong-Wha Lee, Jaewoo Lee, Diego Restuccia, and Kei-Mu Yi. Kangwoo Park has provided excellent research assistance. Any opinions expressed are those of the authors and do not necessarily reflect those of the Federal Reserve Bank of Richmond or the Federal Reserve System. Our e-mail addresses are `yongsung.chang@gmail.com` and `andreas.hornstein@rich.frb.org`.

† University of Rochester and Yonsei University

‡ Federal Reserve Bank of Richmond

1. Introduction

The neoclassical growth model is a fundamental building block of modern macroeconomics, yet the economic development (i.e., transition dynamics) predicted by the neoclassical model is strongly at odds with the experience of many growth miracles such as South Korea or Taiwan. These countries started out with low initial capital stocks, which according to the standard growth model would imply high initial rates of return to capital and correspondingly high initial investment rates. Yet, as Figure 1 shows, most Asian economies that made a successful transition started out with low initial investment rates that gradually increased over time.

[Figure 1. Investment Rates of Asian Growth Miracles]

For the case of the South Korean economy, we argue that with two minor modifications a calibrated version of the neoclassical model can account for most of the capital accumulation pattern observed in the data since 1960. Our approach builds on recent insights in the economic growth literature that emphasize the role of a large agricultural sector (Gollin, Parente, and Rogerson, 2007) and a high relative price of capital during the early stages of development (Caselli and Feyrer, 2007). An analysis of Korea's development process is of interest for two reasons. First, it has been studied extensively as a successful case of economic development. Second, we have reliable data on the two newly added features: the transition from an agricultural to an industrialized economy and the declining price of capital. Table 1 summarizes these features for the Korean economy. First, in 1963 agriculture accounted for two-thirds of aggregate employment and one-third of GDP. Since agriculture does not rely heavily on physical capital, a low aggregate capital-output ratio (or investment-GDP ratio) therefore does not necessarily imply a high rate of return to capital. Second, in 1963 capital goods were more than twice as expensive as they were in 2005. This initial high relative price of capital also lowers the implied rate of return on capital in the early stages of development.

These observations on the development process of Korea are consistent with those of Caselli and Feyrer (2007) based on a broader cross-section of countries. They show that the size of the agricultural sector and the relative price of capital are negatively correlated with the level of development, measured as aggregate per capita output. Caselli and Feyrer (2007) then calculate rates of return on capital in the non-agricultural sector, accounting for differences in the relative price of capital, and find that this correction substantially reduces the variation of estimated returns to capital in the cross-section of countries.

Based on detailed data for the Korean economy, we quantitatively evaluate the transition dynamics of the neoclassical model augmented for the industrialization process. We use the framework of Gollin et al. (2007), who study the equilibrium transition from a labor-intensive agricultural economy to a capital-intensive industrial economy. Whereas Gollin et al. (2007) are interested in the determinants of the allocation of labor between the agricultural and non-agricultural sectors during this transition, we take this allocation as given and study its implications for the economy's capital accumulation path. We assess the role of the expanding industrial sector and the declining relative price of capital by calibrating the model to the Korean development experience from 1960 to 2005. Accounting for these two features substantially reduces the implied rate of return to capital relative to the standard one-sector neoclassical growth model during the early phase of development. In particular, the model-implied real interest rate in 1960 decreases from a high 90 percent to a more reasonable 13 percent.

Next, following Chari, Kehoe, and McGrattan (2007), we introduce three "wedges" into the model so that the model's equilibrium outcome exactly matches the observed transition dynamics of the Korean economy. The wedges we introduce to fill the gap between the model and the data are measured total factor productivity (TFP) to account for the production of non-agricultural goods, "financial frictions" to satisfy the intertemporal optimality condition for consumption, and autonomous demand for non-agricultural output to satisfy the resource constraint for non-agricultural goods. We then evaluate the quantitative importance of all exogenous drivers for the transition dynamics of the Korean economy from 1960 to 2005 and find that four drivers account for 90 percent of capital and output growth over this period, and the standard neoclassical transition dynamics account for the remaining 10 percent of capital accumulation during this time period. First, the two newly introduced features—employment growth in the non-agricultural sector and the declining relative price of capital—account for close to 60 percent of the growth in capital and output, with the capital price decline contributing relatively more to capital growth and the increase in non-agricultural employment contributing relatively more to output growth. Second, the non-agricultural TFP and financial frictions wedges account for close to 30 percent of capital and output growth, with declining financial frictions contributing relatively more to capital growth and increasing TFP contributing more to output growth. Although the quantitative contribution of financial frictions remains modest for the overall transition path of capital and output, the decline of financial frictions plays an important role for the hump-shaped path of the investment rate.

Our work complements earlier quantitative research on the growth contribution of capital accumulation, such as King and Rebelo (1993) and references therein for a comprehensive analysis of the transition dynamics in the standard growth model. As Mankiw, Romer, and Weil (1992) and Barro and Sala-i-Martin (1995) show, for a neoclassical growth model to generate a prolonged process of capital accumulation requires either a capital share that is much larger than measured in the data and/or low values of the intertemporal elasticity of substitution for consumption.[1] A more recent literature studies how declining capital goods prices (e.g., Hsieh and Klenow (2007), Caselli and Feyrer (2007), Restuccia and Urrutia (2001)) and the transition from agriculture to industry (e.g., Gollin et al. (2007), Duarte and Restuccia (2010)) affect development. We follow this literature but take the sectoral allocation of labor as given and study its implications, together with the declining relative price of capital, for capital accumulation in the non-agricultural sector.[2] The closest paper to our approach is Lu (2012), who also adopts a "wedge" approach to identify the relative importance of the different forces that drive growth in four Asian economies: Hong Kong,

[1]There is also a large literature that focuses on the properties of investment during this transition. 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 Japan in 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. Chen, İmrohoroğlu, and İmrohoroğlu (2006) show that if economic agents perfectly foresee the relatively high Japanese TFP growth rates of the early 1970s, then their optimal response will exhibit a hump-shaped savings rate. 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 are consistent with the transition period in Japan and Germany. For a model with two unspecified types of capital, Rappaport (2006) shows that high adjustment costs in one sector can lead to transition dynamics with increasing investment rates even if the sector is small. Papageorgiou and Perez-Sebastian (2006) discuss the possibility of hump-shaped investment rates in an endogenous growth model with embodied technology where the lack of human capital delays an adoption of new technology.

[2]Ngai (2004) includes the relative price of capital in a model like Gollin et al. (2007) and studies its implications for transition dynamics.

Singapore, South Korea, and Taiwan. Unlike Lu's analysis, which is explicitly limited to the standard one-sector growth model, we emphasize the declining relative price of capital and the sectoral transformation away from agriculture. Jones and Sahu (2009) also adopt the wedge approach for a multi-sector analysis (agriculture, manufacturing, and services) of the Indian economy. They focus on the role of relative distortions for the allocation of labor and capital across sectors, and not so much on the role of capital accumulation during the transition. In particular, they do not allow for changes in the relative price of capital. Finally, Buera and Shin (2013) explicitly model the financial frictions wedge and the TFP wedge and argue that financial frictions contribute to the prolonged capital accumulation process. In their model, collateral constraints act as financial frictions, and the TFP wedge reflects the inefficient allocation of resources due to tax distortions. In Buera and Shin (2013), removing the tax distortions generates a delayed transition to the long-run equilibrium, relative to the standard transition dynamics of the neoclassical growth model, only if there are financial frictions.

This paper is organized as follows. Section 2 presents a modified growth model that distinguishes between a labor-intensive agricultural sector and a capital-using non-agricultural sector. In Section 3 we describe the data for Korea and how they are used in a way that is consistent with our model. Then, the model parameters are calibrated to the Korean economy for the period 1960-2005. In Section 4 we show that, once we take into account the transition to an industrialized economy and the declining price of capital, the model can reproduce the development process of the Korean economy. In Section 5 we compute counterfactual transition paths to evaluate the quantitative contribution of various drivers of economic development. Section 6 concludes.

2. Model Economy

Our model of the Korean economy is a modest extension of the standard neoclassical growth model. To capture the transition from a traditional agricultural economy to an industrialized economy, we adopt a simplified version of Gollin et al. (2007).

There is a representative household with constant intertemporal elasticity of substitution preferences for per capita consumption of a manufactured good, c_t, and an agricultural good, a_t, and utility is proportional to population size, n_t. For simplicity we assume that the household consumes a fixed per capita amount $\bar{a}$ of the agricultural good.

$$\sum_{t=0}^{\infty} \beta^t n_t \left(\frac{c_t^{1-\sigma} - 1}{1-\sigma} + \bar{a} \right), \tag{2.1}$$

with $0 < \beta < 1$ and $\sigma > 0$.[3] In the following, all variables are expressed in per capita terms.

Household labor supply, e_t, is exogenous and labor is allocated between the production of agricultural goods, e_{at}, and manufactured goods, e_{yt},

$$e_{at} + e_{yt} = e_t. \tag{2.2}$$

The agricultural good is produced using labor as the only input,

$$a_t = A_{at} e_{at}, \tag{2.3}$$

and A_{at} is labor productivity in the agricultural sector. The manufactured (or non-agricultural) good, y_t, is produced with a Cobb-Douglas production technology using labor and (reproducible) capital, k_t, as inputs:

$$y_t = k_t^{\alpha} \left(A_{yt} e_{yt} \right)^{1-\alpha}, \tag{2.4}$$

and A_{yt} is labor-augmenting technical change in the non-agricultural sector. Abstracting from reproducible capital as an input in the Korean agricultural sector is a justifiable approximation. During the initial phase of development from 1960 to 1980 when the agricultural sector is still large, land represents most of the capital input in Korea's agricultural sector; see Kim and Park (1985). Furthermore, in 1960 almost all of the reproducible capital stock, 85 percent of all equipment and 98 percent of all structures, was used in the non-agricultural sector; see Pyo (1998).

The non-agricultural good is used for private consumption and investment in capital

[3] Gollin et al. (2007) 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 (2.1) when consumption of the agricultural good is $a \geq \bar{a}$. We simply assume that the agricultural sector is productive enough such that in equilibrium the sector provides the fixed per capita consumption amount $\bar{a}$.

goods, x_t,

$$y_t = c_t + q_t x_t + g_t. \tag{2.5}$$

The autonomous demand for goods, g_t, includes public consumption and net exports. The price of investment goods in terms of consumption goods is denoted by q_t.[4] Investment augments the capital stock,

$$k_{t+1} = \frac{n_t}{n_{t+1}} \left[(1-\delta) k_t + x_t \right], \tag{2.6}$$

and capital depreciates at rate δ.

We assume that markets are competitive. Wages, w_t, and the capital rental rate, u_t, are equal to their marginal products. Aggregate GDP is defined as the value of agricultural and non-agricultural production in units of the non-agricultural good,[5]

$$Y_t = y_t + w_t e_{a,t}. \tag{2.7}$$

Income is taxed at rate τ_t, and we assume that the government budget is balanced through some additional lump-sum tax.

Under perfect foresight, the rate of return on capital is

$$R_t^K = \left\{ (1-\tau_{t+1}) \frac{u_{t+1}}{q_{t+1}} + \left[1 - (1-\tau_{t+1})\delta\right] \right\} \frac{q_{t+1}}{q_t}. \tag{2.8}$$

The after-tax rate of return for the household consistent with intertemporal utility maximization is defined by the Euler equation

$$R_t^H = \beta^{-1} \left(\frac{c_{t+1}}{c_t} \right)^{\sigma}. \tag{2.9}$$

We allow for a divergence between the rate of return on capital and the rate of return faced by the household,

$$R_t^H = (1-f_t) R_t^K. \tag{2.10}$$

[4] For a two-sector interpretation of this technology, see Greenwood, Hercowitz, and Krusell (1997).

[5] In the following we take the allocation of labor to the two sectors, agriculture and manufacturing, as given. With free mobility of labor between the two sectors this is equivalent to productivity in the agricultural sector satisfying $\bar{a} = A_a e_a$ and the price of the agricultural goods satisfying $p_a = w/A_a$.

We interpret the "wedge," f_t, as representing financial frictions: a fraction f_t of the returns on capital is diverted by the financial intermediation sector. Thus, we have introduced three wedges (TFP in the non-agricultural sector, A_{y_t}, the financial frictions, f_t, and autonomous spending, g_t) to fill the gap between the model and the actual data. In Section 4, the wedges are constructed as residuals so that the observed time series of the (calibrated) Korean economy represents a perfect foresight competitive equilibrium.

Our analysis of the Korean capital accumulation process below will proceed in two steps. First, in Section 4 we will show that accounting for the structural transformation toward a non-agricultural economy and the declining relative price of capital helps us to interpret the economic development process of Korea from a neoclassical perspective. Second, in Section 5 we conduct the counterfactual experiments to evaluate the contributions of all exogenous drivers to the transitional paths of output and capital.

To compute the transition dynamics of the model, we first need to specify the steady state. We assume that the Korean economy converges to an asymptotic balanced growth path (BGP) where the following variables grows at constant rates. Population grows at rate γ_n, productivity in the agricultural and non-agricultural sector grow at γ_a and γ_y, respectively, and the relative price of capital declines at rate γ_q. The income tax rate is constant at rate τ, financial frictions are constant at f, and the aggregate employment rate remains constant at e. Together with positive productivity growth in agriculture, the latter implies that the employment share of agriculture asymptotically goes to zero in our long-run equilibrium.

There exists a limiting BGP where non-agricultural output, expenditure components, and capital grow at constant rates, and all employment is in the non-agricultural sector. For a given time path of non-agricultural productivity, A_{yt}, the relative price of capital, q_t, and the non-agricultural employment rate, e_{yt}, we have a stationary transformation for the model. For this transformation, output and consumption are scaled by z_{yt} and investment and the capital stock are scaled by z_{kt},

$$\tilde{k}_t \equiv \frac{k_t}{z_{kt}} \text{ and } z_{kt} \equiv A_{yt} e_{yt} q_t^{-1/(1-\alpha)}. \tag{2.11}$$

$$\tilde{y}_t \equiv \frac{y_t}{z_{yt}} \text{ and } z_{yt} \equiv A_{yt} e_{yt} q_t^{-\alpha/(1-\alpha)}, \tag{2.12}$$

For the stationary economy, the expressions for the resource constraint, production, capital accumulation, and intertemporal optimality are rewritten as

$$\begin{aligned} \tilde{y}_t &= \tilde{c}_t + \tilde{x}_t + \tilde{g}_t = \tilde{k}_t^{\alpha}, & (2.13) \\ \left(\frac{z_{k,t+1}}{z_{k,t}}\right) \gamma_{n,t+1} \tilde{k}_{t+1} &= (1-\delta)\, \tilde{k}_t + \tilde{x}_t, & (2.14) \\ \beta \left(\frac{z_{y,t+1}}{z_{y,t}}\right)^{\sigma} \left(\frac{\tilde{c}_{t+1}}{\tilde{c}_t}\right)^{\sigma} &= (1-f_t)\, \frac{q_{t+1}}{q_t} \left\{ (1-\tau_{t+1})\, \alpha \frac{\tilde{y}_{t+1}}{\tilde{k}_{t+1}} + [1-(1-\tau_{t+1})\, \delta] \right\}. & (2.15) \end{aligned}$$

These equations, together with a transversality condition, characterize the transition dynamics of the perfect foresight equilibrium in the growth model.

3. Data and Calibration

As we evaluate the quantitative implications of the declining capital price and sectoral transformation, it is crucial to carefully calibrate the model to the observed data for the Korean economy. In this section we provide a detailed explanation of our data sources and calibration procedure. For the model calibration, we assume that by 2005 the Korean economy has essentially completed its transformation from an agriculture-dominant economy to an industrialized one—i.e., it is close to its balanced growth path.

Most of our National Income Account (NIA) data are from the Bank of Korea (BoK). In addition, we use the data on aggregate employment, sectoral employment, and gross product originating (GPO) from the Groningen Growth and Development Center (GGDC). Since we are mainly interested in the long-run transition dynamics of the Korean economy, we remove short-run fluctuations using the Hodrick-Prescott filter with a smoothing parameter of 100, a conventional value for annual data.

Annual data from 1953 to 2005 for GDP and its expenditure components (private and public consumption, investment in equipment and structures) are available in both current and constant (base year 2000) prices from the BoK. Structures include both residential and non-residential structures. Real total investment is defined as the sum of real investment in equipment and structures. The price index of total investment is the ratio between nominal and real total investment. Finally, we construct the relative price of investment goods in terms of consumption goods as the ratio of the price index of total investment and the price index of private consumption.

Aggregate employment from 1960 to 2005 is the number of employees based on the Total Economy Data Base (Conference Board (2009)). We use sectoral data (agricultural and non-agricultural) on persons employed and value-added from 1963 to 2005 from the GGDC 10-Sector Data Base (Timmer and de Vries (2007)).[6] Per capita values are expressed relative to the working age population. Data on the working age population (15 years and older) from 1953-2005 are from the Penn World Table 6.2v1.

We interpret the actual path of the Korean economy as the perfect foresight equilibrium of the model. Thus, aggregate time series variables have to satisfy all resource constraints and optimality conditions; see Equations (2.4), (2.5), (2.6), (2.8), (2.9), and (2.10). This has several implications in terms of measurement. First, the measure of real output consistent with our theory is GDP in terms of consumption goods, not the standard measure of real GDP from the NIAs. Second, since we have separated the agricultural sector from the rest of the economy and we assume that this sector produces a separate consumption good, the natural interpretation of the agricultural sector's output is that of food production. We therefore exclude the consumption of food and alcohol from our definition of consumption produced by the non-agricultural sector.[7] Third, we define autonomous spending as the residual from the NIA expenditure identity for non-agricultural GPO after accounting for private consumption and investment, using Equation (2.5). Thus, our measure of autonomous spending combines government spending and net exports. Fourth, we construct the capital stock using the perpetual inventory approach with the Hodrick-Prescott trend values of investment as an input to the capital accumulation equation (2.6).

We assume that capital, both equipment and structures, depreciates at the rate $\delta = 0.053$.[8] Following the convention in the literature, we construct the initial value of the capital stock as the steady-state capital stock associated with investment in 1953 and the

[6] We extrapolate sectoral employment and value-added data to the three years prior to 1963 assuming constant 1963 employment and value-added shares.

[7] In most industrialized economies, distribution accounts for the largest share of food consumption. Thus our correction understates the contribution of the non-agricultural sector to consumption, at least towards the end of the sample. None of our results depend crucially on this correction.

[8] This represents a weighted average of standard depreciation rates assumed for equipment, $\delta_e = 0.10$, and structures, $\delta_s = 0.03$ per year; for example, see Timmer and van Ark (2002).

average growth rate of real investment during the first 10 years of available data.[9] While this is a crude approximation, it does not have a significant impact on the transition dynamics from 1960 onward. The size of the initial capital stock is very small and any approximation error almost disappears by 1960, the beginning year of our analysis.

In addition to the initial capital stock that is far below its steady-state value, we have a number of time-varying drivers of the Korean economic transition from 1960 to 2005. We have direct observations on four of these drivers: the relative price of capital (q_t), the non-agricultural employment rate (e_{yt}), the capital income tax rate (τ_t), and the population growth rate ($\gamma_{n,t}$). The three remaining drivers are constructed as wedges from the model: financial frictions (f_t), measured TFP of the non-agricultural sector (A_{yt}), and autonomous spending (g_t).

We have already mentioned the declining relative price of capital and the increasing non-agricultural employment rate (Table 1). The autonomous spending share increased almost monotonically from close to zero in 1960 to about 25 percent in 2005. This monotone increase reflects the combination of a slight increase in the government spending share and a switch from a current account deficit in the 1960s to a current account surplus in the mid-1980s. Our measure of the capital income tax rate, the effective marginal income tax rate from Hyun, Won, and Yoo (2000) for the period 1960 to 1998, does not show a clear trend. It declines from about 20 percent in 1960 to less than 5 percent in 1980 and then rebounds to about 20 percent in 1998. Finally, the population growth rate declines steadily from a high of 3 percent in the early 1970s to close to 1 percent in 2005.

Per capita output growth on the BGP is determined by the growth rate of labor-augmenting technical change and the growth rate of the relative price of capital. Since the gross rate at which the relative price of capital declines seems to be converging to one, we set $\gamma_q = 1$ for the steady state. We take the United States as a reference point for long-run growth, and since average U.S. per capita output growth has been about 2 percent, we set $\gamma_{A_y} = 1.02$. Based on the evidence for the effective marginal income tax rate, we fix the capital income tax rate at $\tau = 0.2$ after 2000. The population growth rate declines steadily from a high of 3 percent in the early 1970s to close to 1 percent in 2005. Given

[9] $K_{1953} = \frac{I_{1953}}{\delta+\gamma_{I,0}-1}$ where $\gamma_{I,0}$ is the gross growth rate of investment for the first 10 years.

the observations on Korean population growth, we set population growth on the BGP at $\gamma_n = 1.01$.

Toward the end of our sample the capital-output ratio of the Korean economy (based on our corrected GDP measure) is close to 3. Given that the relative price of capital is close to one at that time, we set the nominal capital-output ratio on the BGP at $qk/y = 3.0$.[10] According to Bernanke and Gürkaynak (2001), the Korean capital income share is relatively stable over time, and the average capital income share for Korea is $\alpha = 0.35$. Given the assumptions on depreciation, the capital income share, the nominal capital-output ratio, and the capital income tax rate, we get the implied rate of return on capital on the BGP, $R^K = 1.05$.

We assume logarithmic preferences, $\sigma = 1$, which are consistent with standard parameterizations of preferences in business cycle applications of the growth model. Everything else equal, a lower intertemporal elasticity of substitution, higher σ, would make it easier to obtain an increasing investment rate on a transition path, according to Barro and Sala-i-Martin (1995). Using the preference parameter together with the BGP values for the consumption growth rate, the rate of return on capital, and assuming that there are no financial frictions on the BGP, $f = 0$, the household Euler equation determines the time preference parameter, $\beta = 0.97$.

We calibrate the BGP value of the autonomous spending share in a roundabout way, using the transition dynamics to the BGP starting with initial conditions for the endogenous and exogenous state variables in 2005. The endogenous state is simply the observed capital stock in 2005. For the exogenous state variables, we assume that starting in 2005 all exogenous variables converge to their BGP values according to an AR(1) process with persistence parameter $\rho = 0.9$. Conditional on the BGP value for the autonomous spending share, we can construct the log-linear approximation of the growth model. We then choose the autonomous spending share such that in 2005 the log-linear approximation generates the consumption observed for the Korean economy in 2005.

[10] For comparison, based on the net capital-stock data from the BEA, the nominal capital-output ratio for the U.S. has been fluctuating between 2 and 2.5 since the 1950s. Thus, our assumption on the BGP value of the Korean capital-output ratio slightly exceeds the observed long-run value for the U.S.

4. Equilibrium Transition

Accounting for the measured decline in the relative price of capital and the transformation toward an industrialized economy from agriculture provides a different perspective on Korea's transition dynamics. As we emphasized in the introduction, between 1963 and 2005, the relative price of capital declined by a factor of 2.3, and employment in the non-agricultural sector increased from 31 percent to 92 percent.[11] We now discuss how these two newly added features affect the transition dynamics.

One of the salient features of the neoclassical model in accounting for the economic transition is the rate of return to capital. This rate of return is often measured by the inverse capital-output ratio. Capital-deepening is then associated with a declining rate of return to capital. In an economy with a changing price of capital, the relevant measure of capital deepening is not the real capital-output ratio but the nominal capital-output ratio, that is, the ratio of nominal capital to nominal output. The same holds for the investment-output ratio. Furthermore, if capital is mainly used in the non-agricultural sector, then the denominator of the capital-output ratio has to be adjusted accordingly. In Figure 2.A we plot both the real and nominal capital-output ratio when output is aggregate GDP (solid and dashed lines), and the nominal capital-output ratio when output is non-agricultural GDP (dash-dot line). For the period from 1960 to 2005 the ratio of real capital to real aggregate output increases by a factor of eight, whereas the ratio of nominal capital to nominal non-agricultural output increases only by a factor of three. Thus, after taking into account the declining relative price of capital and the small initial share of non-agricultural output, the relevant capital-output ratio for the Korean economy in 1960 was substantially higher than the usual measure. Similarly, Figure 2.B shows that the nominal non-agricultural investment rate appears to be more stable than the real aggregate investment rate. However, it clearly still shows that the non-agricultural investment rate increased over time from about 20 percent in the 1960s to 35 percent in late 1970s.

[Figure 2. Capital Accumulation in Korea, 1960-2005]

[11] The overall employment rate increased by only 10 percent from 48 percent during the same period.

Turning to the rate of return on capital, Figure 3 shows the time path for various measures of the rate of return implied by our calibrated model, Equation (2.8). All measures use the same time series for the capital stock, but they differ with respect to the definition of output and the treatment of the relative price of capital and capital income taxes. The top line represents the rate of return on capital when we use the standard measure of real aggregate GDP (along with a constant relative price of capital, $q = 1$, and no adjustment for taxes, $\tau = 0$). Based on this measure, used in most cross-country growth accounting exercises, we would conclude that the return to capital in Korea in 1960 was almost 90 percent. The next line depicts the rate of return using real non-agricultural output. Correcting for the appropriate output measure reduces the initial rate of return by a third, but it still remains at a high rate of 62 percent. Accounting for changes in the relative price of capital (q_t) further reduces the initial return to capital to 18 percent. Finally, accounting for capital income tax rates (τ_t) further reduces the initial return to capital to 13 percent. To summarize, after one accounts for the relevant measures of capital's marginal product, relative price, and taxes, the model-implied rate of return to capital in Korea in 1960 is high, but not extraordinarily high.

[Figure 3. Implied Rates of Return on Capital in Korea, 1960-2005]

The household rate of return is implied by the consumption Euler equation (2.9), the bottom line in Figure 3. At the beginning of the sample, that rate of return is about 8 percent. Comparing the model-consistent rate of return on capital with the household interest rate suggests that in the early 1960s financial frictions might have implied a loss of 5 percent for households. While this is a significant wedge, it is substantially smaller than the 80 percent wedge if one does not consider the decline in the relative price of capital and the transformation toward an industrialized economy. Furthermore, the model no longer requires a financial wedge by the mid-1980s in order to match the interest rates in the data.[12]

[12] Note that toward the end of the sample, the household rate of return actually exceeds the rate of return on capital. This negative financial friction results from our calibration of the household's time preference parameter. We assume that there are no financial frictions on the BGP, so that the interest rate is equal to the return on capital, and the latter is implied by our assumption on the capital-output ratio on the BGP. Given the assumption on household consumption growth and intertemporal elasticity of substitution,

Using "correct" measures of output and employment also affects the measured TFP for the Korean economy. In Figure 4, we plot measured TFP implied by different measures of output and employment. All measures use the same capital stock series. The first measure is standard TFP based on aggregate GDP and employment, the solid line. This standard measure indicates that TFP increased by 90 percent from 1960 to 2005. The second measure is non-agricultural TFP (dashed line). The non-agricultural TFP increased by only 10 percent from 1960 to 2005. In fact, according to this measure, non-agricultural TFP declined from 1960 to 1980 before rebounding, which is somewhat unusual. From the perspective of the model, however, the relevant measure of non-agricultural output is non-agricultural output in terms of consumption goods, that is, nominal non-agricultural output deflated by the consumption goods price index. This model-consistent measure of TFP shows a reasonable monotonic increase from 1960 to 2005, but half as much as the conventional measure of TFP based on aggregate output and employment.

[Figure 4. Total Factor Productivity in Korea, 1960-2005]

5. Counterfactuals

We now evaluate the quantitative contributions of the different drivers—newly introduced features that are directly measured (non-agricultural employment and the relative price of capital) and model-implied wedges—to the transition dynamics of Korea. For this purpose we calculate the "marginal" contribution of each driver by constructing a counterfactual equilibrium growth path where we keep the driver constant at its initial value. From this exercise we conclude that over the long run, the most important drivers of Korean growth have been increased non-agricultural employment and a reduced relative price of capital, followed by higher TFP and reduced financial frictions. These four drivers account for close

---

we then obtain the time preference parameter. There are two alternative calibrations that avoid negative financial frictions on the sample path. First, we can choose the time preference parameter such that the financial frictions wedge never exceeds one. This procedure implies a capital-output ratio of 4.3 on the balanced growth path, which is substantially higher than the already high capital-output ratio in the current calibration. Second, we can increase the intertemporal elasticity of substitution. Both procedures will increase the impact of financial frictions in the early sample period, but not in any dramatic way. We therefore decided to stay with our more conventional calibration.

to 90 percent of capital and output growth from 1960 to 2005. Even though the endogenous transition from a low initial capital stock to a higher BGP capital stock makes a substantial contribution to capital accumulation during the first 20 years of development, the long-run contribution of the transitional dynamics is limited to 10 percent.

Our growth accounting scheme uses counterfactuals to decompose the cumulative change in capital and output into components that are attributable to changes in the different exogenous drivers and the divergence of the initial capital stock from its BGP value. To be precise, let $\Delta \ln k_t = \ln k_t - \ln k_{1960}$ denote the cumulative log difference between the capital stock in year t and the initial year 1960. We decompose the change in the capital stock as follows

$$\Delta \ln k_t = \sum_i \left(\Delta \ln k_t - \Delta \ln k_t^{CF,i}\right) + \left\{\Delta \ln k_t - \Delta \ln k_t^{CF,0} - \sum_i \left(\Delta \ln k_t - \Delta \ln k_t^{CF,i}\right)\right\} + \Delta \ln k^{CF,0}, \tag{5.1}$$

where $k^{CF,i}$ denotes the counterfactual capital stock obtained when we fix the i-th exogenous variable at its initial value and set all other exogenous variables at their actual values, and $k^{CF,0}$ denotes the counterfactual capital stock obtained when we fix all exogenous variables at their initial base period values. The first term in this expression can be interpreted as the sum of the marginal contributions coming from the changes in the different exogenous variables, and the second term captures potential non-linear interactions between the different exogenous variables. The third term captures the standard transition effect due to an initial capital stock being different from its BGP value (implied by the initial values of exogenous variables). Table 2 displays the decomposition of the marginal contributions of various drivers based on equation (5.1).

[Table 2. Sources of Korean Growth]

For the discussion of marginal contributions, it is useful to distinguish between non-agricultural employment, the relative price of capital, and TFP on the one hand, and the remaining exogenous drivers on the other hand. We single out these three factors because they determine the scale of the economy in the long run, as can be seen from the stationary transformation of capital and output in the growth model, equations (2.11) and (2.12). Over the long run—that is, the time period from 1960 to 2005—the three scale factors account for more than 60 percent of growth in the capital stock and 80 percent of growth in non-agricultural output, with most of it coming from an increase in non-agricultural employment and a decline in the relative price of capital. This feature is consistent with the three variables determining the scale of the economy. Over the medium term, however, the overall contributions of these variables to growth are smaller than their direct scale effect would suggest. For example, for the period 1960 to 1970 the contribution of non-agricultural employment growth to capital accumulation was only 16 percent, even though this was the period when employment was growing the fastest.

The smaller medium-term contribution to growth of the scale factors can be attributed to the countervailing transition effects that the changes in the scale factors induce. The endogenous transition dynamics are characterized by the system of normalized variables, (2.13), (2.14), and (2.15). From the normalized Euler equation (2.15) it is apparent that most of the exogenous variables will affect the transition dynamics through their impact on the effective discount rate or the return to capital. In the case of non-agricultural employment, rapid growth means a high growth rate of the output scale factor, which in turn implies a smaller effective discount factor. The representative household being effectively less patient requires a higher rate of return to capital and cuts back on capital accumulation. This endogenous response to fast employment growth counteracts the direct scale effect, and the net contribution of employment growth to capital accumulation over the medium term is below its long-run contribution. Over the long run, these transitional effects are, however, quite small, and the contributions of the scale factors are remarkably close to the direct contributions associated with their impact on the scale factors for capital and output.

The second group of exogenous variables—financial frictions, autonomous spending shares, income tax rates, and population growth rates—affect only the transition dynamics of per capita capital and output; they have no direct scale effects. Among this group, reduced financial frictions have the biggest impact in the long run, accounting for 20 percent of capital accumulation and 10 percent of output growth from 1960 to 2005. Note that even though most of the decline in financial frictions took place by 1970, the growth contributions of financial frictions are actually increasing over time and are biggest after 1980. The other non-scale variables make no appreciable long-run contributions to capital or output growth. For the period 1960 to 2005 the combined contributions of these variables is less than 1 percent. Significant contributions to growth from reductions in the income tax rate and autonomous spending are limited to the period from 1960 to 1970, and even in this period, the combined contribution to output growth stays around 10 percent.

So far we have studied the marginal effect one exogenous variable at a time. If we add up all these marginal effects and compare them with the effect of fixing all exogenous variables at their initial 1960 values, we can obtain a measure of how much the changes in the exogenous variables interact with each other. As we can see from Table 2, Column (10), the interaction effects from the simultaneous change in all exogenous variables are quantitatively quite limited, at most about 6 percent.

Finally, fixing all exogenous variables at their initial 1960 values also yields the typical transition dynamics for capital in the neoclassical growth model (King and Rebelo (1993)). Starting out with a capital stock that is below its BGP value, the capital stock converges rapidly within 10 years toward its BGP value. During the early phase of development in the 1960s and 1970s, this transition makes a significant contribution to capital and output growth: close to 40 percent of capital growth and 20 percent of output growth. The magnitude of the contribution coming from the capital transition declines over time, but it remains over 10 percent even for the full period from 1960 to 2005.

The rapid convergence of the capital stock for the counterfactual capital-only transition is accompanied by the typical neoclassical transition dynamics for the investment rate path, which starts out high and then declines toward its BGP value. In Figure 5, we plot the time path of the actual nominal investment rate in the Korean economy, as well as the investment rate paths for each of the counterfactuals we just described. As is typical for most of the East Asian growth miracles, the actual Korean investment rate, the solid black line, is hump-shaped, increasing first and then declining, unlike the counterfactual capital-only transition path of the investment rate, the dashed black line. According to the counterfactuals, fixing any one of the exogenous variables at its 1960 value does not change the basic hump-shaped path of the investment rate. This suggests that the dynamics of the Korean investment rate are the joint product of the dynamics of all exogenous variables. It is, however, true that financial frictions have the biggest impact on the investment rate path. Keeping financial frictions at their initial value (solid pink line) persistently lowers the investment rate. Not only does the investment rate not increase as much as observed from the 1960s to the early 1970s, the investment rate then also declines much earlier and faster in the late 1970s. But recall that even though financial frictions have, according to our counterfactuals, the biggest impact on the investment rate, their impact on overall capital accumulation remains limited. Thus, capital and output accumulation are not necessarily closely tied to the investment rate.[13]

[Figure 5. Sources of Variation in the Investment Rate]

We have shown that a sustained increase in employment in the non-agricultural sector and a sustained decline in the relative price of capital are important for understanding the prolonged process of capital accumulation of Korea. We have not provided a reason why employment in the non-agricultural sector increased only gradually and why capital was so expensive in Korea in the 1960s. A study of these two topics is beyond the scope of this paper, but we want to comment briefly on them.

First, why was labor not reallocated from the agricultural sector to the non-agricultural sector at a faster rate? In our model we assume that prices and wages in the agricultural sector adjust such that the returns to labor are the same in both sectors. Thus, we do not assume any barriers that prevent a faster reallocation of labor toward the non-agricultural sector. For the Korean economy, it is reasonable to assume that the net return of moving out of agriculture for older workers in rural areas would have been quite limited. First, investment in nonfarm human capital would have generated a relatively low rate of return for older workers. Second, the Korean government regulated the ownership of farm land, which likely generated some rents for older rural farmers. These factors should have limited the flow of older workers out of the agricultural sector. In fact, according to Kim and

[13] As our discussion indicates, allowing for the shift of employment toward the non-agricultural sector and a declining relative price of capital affects the interpretation of the transition dynamics. In Lu's (2012) one-sector interpretation of the South Korean growth path, a substantial part of output growth in the period prior to 1985 is attributed to financial frictions, and in the period after 1985 to TFP growth. In our setup increasing non-agricultural employment and a declining relative price of capital make bigger contributions than either TFP growth or declining financial frictions (Table 2).

Topel (1995), there is little evidence that labor migration out of agriculture was a major source of increasing employment in Korean manufacturing. Virtually all of manufacturing's employment growth was achieved by hiring ever-larger numbers of new entrants to the labor force, and there was no net hiring of workers older than age 25. Thus, it appears that employment in the Korean non-agricultural sector was growing about as rapidly as one could have expected.

Second, why was capital so expensive in Korea at the early stage of development? On this aspect Korea has not been an exception. Rather it is well known that the relative price of capital and income levels are negatively correlated across countries; see, for example, Restuccia and Urrutia (2001) or Caselli and Feyrer (2007). Hsieh and Klenow (2007), as well as Barro (1991), argue that in many low-income countries a high relative price of capital is largely driven by cheap consumption goods. Eaton and Kortum (2001), in turn, argue that poor countries tend to specialize in the production of consumption goods and import capital goods. Trade barriers that are highly correlated with income then contribute to higher prices of capital goods in poor countries.

6. Conclusion

Capital deepening played an important role during the transition of the Korean economy from an agricultural economy to a modern industrialized economy. While capital accumulation is a core element of the neoclassical growth model, the model-implied dynamics are strongly at odds with the actual pattern of investment rates in many countries. Using various detailed data from the Korean economy, we show that this apparent failure of the model is mainly due to using the "wrong" data to evaluate the model. First, the neoclassical growth model with its emphasis on capital accumulation applies to the capital-intensive modern industrialized sector of the economy and not to the more labor-intensive agricultural sector of the economy. Second, in the early stage of economic development, the relative price of capital is high. Accounting for both features dramatically lowers the model-implied rates of return to capital during early stages of development and contributes significantly to the relatively low investment rate. The quantitative analysis based on the calibrated model suggests that the two most important sources of long-run capital accumulation in the Korean economy have been increasing employment in the non-agricultural sector and a declining relative price of capital, accounting for about 55 percent of capital growth from 1960 to 2005. Increased TFP and reduced financial frictions contributed an additional 30 percent to capital growth, whereas the contribution coming from the endogenous transition of the capital stock toward its long-run BGP value accounts for only 10 percent of capital accumulation over the long run. These standard transition dynamics were, however, more important during the first 20 years of development from 1960 to 1980, accounting for 20 to 40 percent of capital accumulation.

While our model successfully accounts for a prolonged path of capital accumulation, it abstracts from some important features of the transition of the Korean economy. Similar to many other developing economies, at the onset of the transition path, structures, in particular, residential structures, made up most of the aggregate capital stock. As a result, the capital-output ratio for equipment was much lower than that for structures. Thus, the implied rates of return and financial frictions for the two types of capital are potentially quite different. In the context of a disaggregated model of the capital stock, the interaction between human and physical capital (e.g., capital-skill complementarity as in Krusell, Ohanian, Rios-Rull and Violante (2000)) might have been important for the sluggish accumulation of capital, as the supply of skilled labor is limited in the early stage of economic development. Finally, our model does not consider international trade, which has been recognized as an important factor for economic growth among East Asian countries. For example, Connolly and Yi (2009) argue that a large set of institutional and trade policy reforms have contributed to the economic growth of Korea.

References

[1] Barro, Robert J. (1991). Economic Growth in a Cross Section of Countries. *Quarterly Journal of Economics*, 106 (2) 407-43.

[2] Barro, Robert J., and Xavier Sala-i-Martin (1995). *Economic Growth.* McGraw-Hill: New York.

[3] Bernanke, Ben S., and Refet S. Gürkaynak (2001). Is Growth Exogenous? Taking Mankiw, Romer, and Weil Seriously. In Ben S. Bernanke and Kenneth Rogoff (eds.), *NBER Macroeconomics Annual 2001.* MIT Press: Cambridge MA.

[4] Buera, Francisco J., and Yongseok Shin (2013). Financial Frictions and the Persistence of History: A Quantitative Exploration. *Journal of Political Economy* 121 (2), 221-272.

[5] Caselli, Francesco, and James Feyrer (2007). The Marginal Product of Capital. *Quarterly Journal of Economics* 122 (2), 535-568.

[6] Chari, V.V., Patrick J. Kehoe, and Ellen R. McGrattan (2007). Business Cycle Accounting. *Econometrica* 75 (3), 781-836.

[7] Chen, Kaji, Ayşe İmrohoroğlu, and Selahattin İmrohoroğlu (2006). The Japanese Saving Rate. *American Economic Review* 96 (5), 1850-58.

[8] Christiano, Lawrence J. (1989) Understanding Japan's Saving Rate: The Reconstruction Hypothesis. *Federal Reserve Bank of Minneapolis Quarterly Review* 13 (Spring), 10-25.

[9] Conference Board (2009). Total Economy Database, June 2009, http://www.conference-board.org/economics/database.cfm

[10] Connolly, Michelle and Kei-Mu Yi (2009). How Much of South Korea's Growth Miracle Can Be Explained by Trade Policy? Working Papers 09-19, Federal Reserve Bank of Philadelphia.

[11] Duarte, Margarida, and Diego Restuccia (2010). The Role of the Structural Transformation in Aggregate Productivity. *Quarterly Journal of Economics* 125 (1), 129-73.

[12] Eaton, Jonathan, and Samuel Kortum (2001). Trade in Capital Goods. *European Economic Review* 45 (7), 1195-1235.

[13] Gilchrist, Simon, and John C. Williams (2004). Transition Dynamics in Vintage Capital Models: Explaining the Postwar Catch-Up of Germany and Japan. Federal Reserve Bank of San Francisco Working Paper 2004-14.

[14] Gollin, Douglas, Stephen L. Parente, and Richard Rogerson (2007). The Food Problem and the Evolution of International Income Levels. *Journal of Monetary Economics* 54 (4), 1230-55.

[15] Greenwood, Jeremy, Zvi Hercowitz, and Per Krusell (1997). Long-Run Implications of Investment-Specific Technological Change. *American Economic Review* 87 (3), 342-362.

[16] Hayashi, Fumio (1986). Why is Japan's Savings Rate so Apparently High? In Stanley Fischer (ed.) *NBER Macroeconomics Annual* 1986, 147-210.

[17] Hsieh, Chang-Tai, and Peter J. Klenow (2007). Relative Prices and Relative Prosperity. *American Economic Review* 97 (3), 562-85.

[18] Hyun, Jin K., Yunhi Won, and Ilho Yoo (2000). The Economic Impact of Tax Incentive Policy in Korea. mimeo.

[19] Jones, John Bailey, and Sohini Sahu (2009). Transition Accounting for India in a Multi-Sector Dynamic General Equilibrium Model. Working Paper, Department of Economics, SUNY-Albany.

[20] Kim, Kwang-suk, and Joon-kyung Park (1985). Sources of Economic Growth in Korea: 1963-1982. Korea Development Institute: Seoul.

[21] Kim, Dae-Il, and Robert H. Topel (1995). Labor Markets and Economic Growth: Lessons from Korea's Industrialization, 1970-1990. In R. B. Freeman and L. F. Katz, *Differences and Changes in Wage Structures* Chicago and London: University of Chicago Press, 227-64.

[22] King, Robert G., and Sergio T. Rebelo (1993). Transitional Dynamics and Economic Growth in the Neoclassical Model. *American Economic Review* 83 (4), 908-931.

[23] Krusell, Per, Lee Ohanian, Victor Rios-Rull, and Giovanni Violante (2000). Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis. *Econometrica* 68 (5), 1029-53.

[24] Lu, Shu-Shiuan (2012). East Asian Growth Experience Revisited from the Perspective of a Neoclassical Model. *Review of Economic Dynamics* 15, 359-376.

[25] Mankiw, N. Gregory, David Romer, and David N. Weil (1992). A Contribution to the Empires of Economic Growth. *Quarterly Journal of Economics* 107 (2), 407-438.

[26] Ngai, Rachel N. (2004). Barriers and the Transition to Modern Growth. *Journal of Monetary Economics* 51 (7), 1353-1383.

[27] Papageorgiou, Chris, and Fidel Perez-Sebastian (2006). Dynamics in a Non-scale R&D Growth Model with Human Capital: Explaining the Japanese and South Korean Development Experiences. *Journal of Economic Dynamics & Control* 30 (6), 901-930.

[28] Pyo, Hak K. (1998). Estimates of Fixed Reproducible Tangible Assets in the Republic of Korea, 1953-1996. Korea Development Institute.

[29] Rappaport, Jordan (2006). A Bottleneck Capital Model of Development. *Journal of Monetary Economics* 53 (8), 2113-2129.

[30] Restuccia, Diego, and Carlos Urrutia (2001). Relative Prices and Investment Rates. *Journal of Monetary Economics* 47 (1), 93-121.

[31] Timmer, Marcel P., and Gaaitzen J. de Vries (2007). A Cross-Country Database for Sectoral Employment and Productivity in Asia and Latin America, 1950-2005. Groningen Growth and Development Centre Research Memorandum GD-98, Groningen: University of Groningen, August 2007. http://www.ggdc.net/databases/10_sector.htm

[32] Timmer, Marcel P., and Bart van Ark (2002). Capital Formation and Productivity Growth in South Korea and Taiwan: Beating Diminishing Returns through Realising the Catch-Up Potential. Groningen Growth and Development Centre, March 2002.

[33] Young, Alwyn (1994). Lessons from the East Asian NICs: A Contrarian View. *European Economic Review* 38 (3-4), 964-973.

[34] Young, Alwyn (1995). The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience. *Quarterly Journal of Economics* 110 (3), 641-80.

Table 1. Transformation of the Korean Economy

	1963	2005
Size of Agricultural Sector (in percent)		
Employment Share	69	8
Value-Added Share	34	2
Relative Price of Capital	2.3	1.0

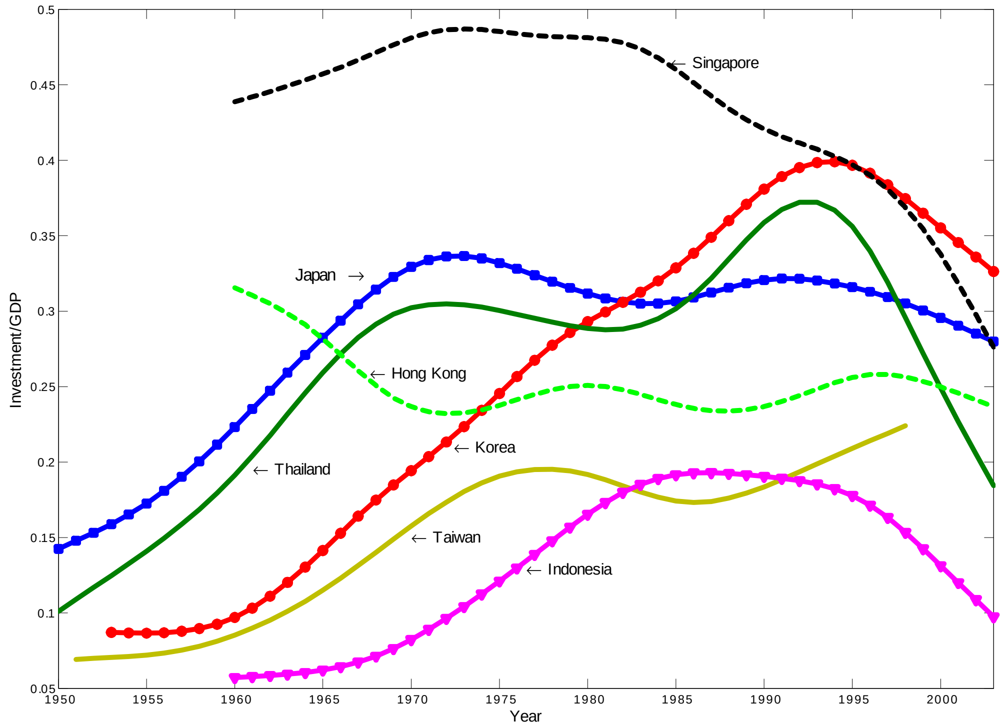
Notes: See Section 3 for a detailed explanation of the data.

Table 2. Sources of Growth in the Korean Economy

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
		A. Sources of Capital Accumulation								
Year t	$\ln k_t - \ln k_{1960}$	Marginal Contributions (in percent)								
		e_y	q	A_y	f	g	τ	n	res.	$k_0 - k^*$
1970	1.01	16.2	7.2	-0.4	8.1	14.3	8.5	3.8	4.3	38.1
1980	2.24	24.9	18.0	6.3	14.4	4.7	6.1	0.2	4.6	21.0
1990	3.19	27.1	23.8	6.6	19.9	-0.6	2.2	-0.7	6.4	15.3
2005	**4.22**	**27.9**	**26.8**	**8.5**	**19.3**	**0.8**	**-0.3**	**-0.3**	**5.5**	**11.7**
		B. Sources of Output Growth								
Year t	$\ln y_t - \ln y_{1960}$	Marginal Contributions (in percent)								
		e_y	q	A_y	f	g	τ	n	res.	$k_0 - k^*$
1970	0.79	51.8	3.2	10.6	3.6	6.4	3.8	1.7	1.9	17.0
1980	1.49	51.4	9.4	12.6	7.5	2.4	3.2	0.1	2.4	11.0
1990	2.12	49.5	12.5	15.7	10.5	-0.3	1.1	-0.4	3.4	8.1
2005	**2.66**	**47.3**	**14.9**	**17.4**	**10.7**	**0.5**	**-0.2**	**-0.2**	**3.1**	**6.5**

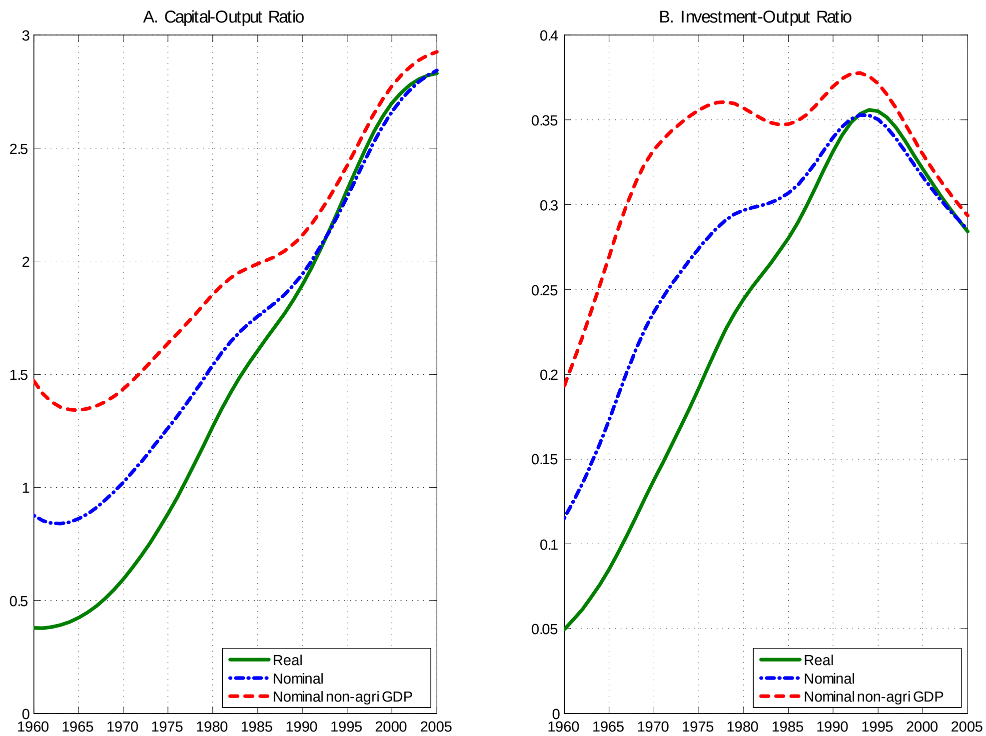
Notes: Column (2) denotes the log difference between year t and the initial year 1960. The decomposition of marginal contribution is based on equation (5.1) in Section 5. Numbers in Columns (3) through (9) denote the contribution of non-farm employment (e_y), the relative price of capital (q), TFP (A_y), financial frictions (f), autonomous spending (g), income tax rates (τ), and population growth (n). Column (10), "res." captures the residual term from possible non-linear interactions among variables, respectively. Column (11), $k_0 - k^*$, captures the transition from the initial capital stock being below its BGP value.

Figure 1. Investment Rates for Asian Growth Miracles



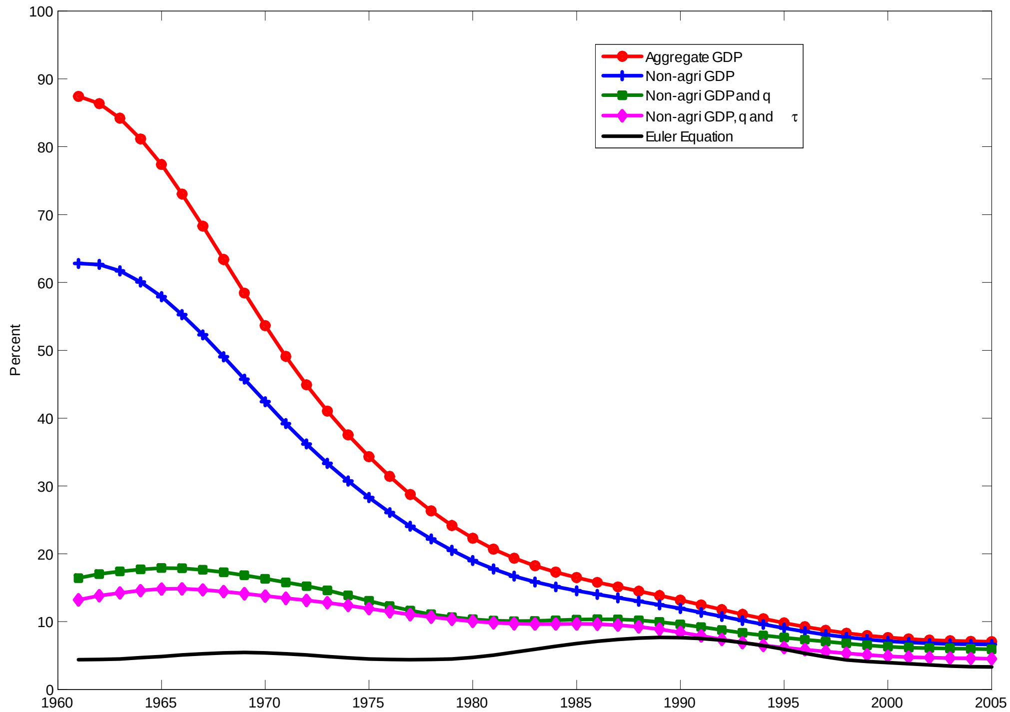
Notes: Data are based on the Penn World Table v6.2.

Figure 2. Capital Accumulation in Korea, 1960-2005



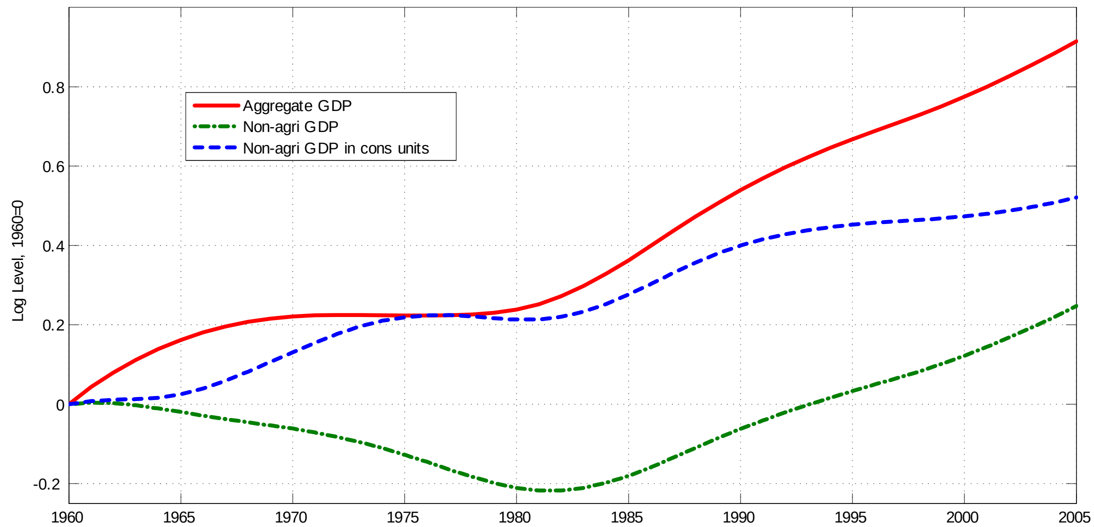
Notes: The capital-output and investment-output ratios are calculated as described in Section 4 for "Real" and "Nominal" values of capital, investment, and aggregate GDP. For the ratio "Nominal non-agri GDP" we use nominal non-agricultural GDP as a measure of output.

Figure 3. Rates of Return on Capital in Korea, 1960-2005



Notes: The implied rate of return to capital is calculated as described in Section 4 using data on aggregate GDP; non-agricultural GDP, "Non-agri GDP"; non-agricultural GDP and the relative price of capital, "Non-agri GDP and q"; and non-agricultural GDP, the relative price of capital, and the tax rate on capital income, "Non-agri GDP, q, and τ." The implied rate of return for the household is labeled "Euler Equation."

Figure 4. Total Factor Productivity in Korea, 1960-2005



Notes: TFP is calculated as described in Section 4 using data on aggregate GDP; non-agricultural GDP, "Non-agri GDP"; and non-agricultural GDP in units of consumption goods, "Non-agri GDP in cons units."

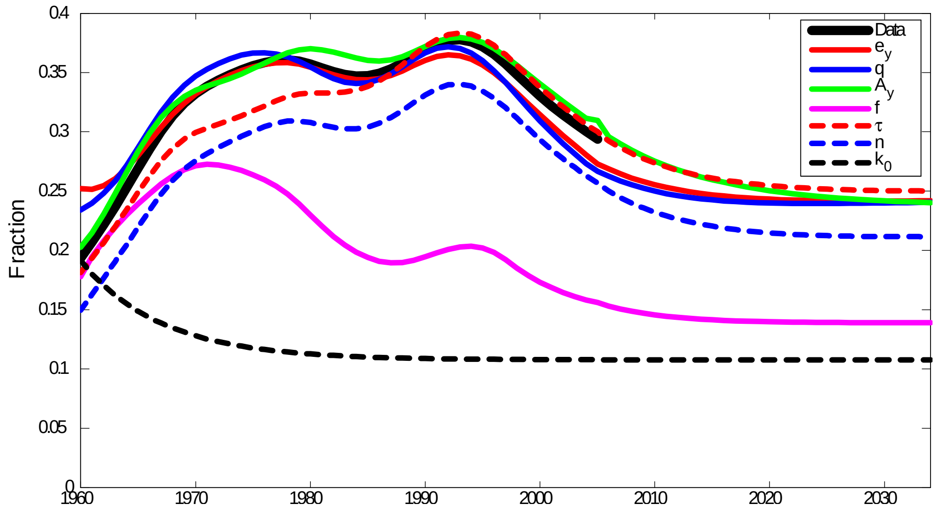


Figure 5. Investment Rate under Each Counterfactual Scenario

Notes: 'Data' denotes the actual normalized capital stock. The other lines represent the investment rate under each counterfactual scenario where each variable is fixed at its initial 1960 value (and all other variables are set to actual values). For example, 'e_y' denotes the investment rate when non-agricultural employment remains at its 1960 level; all other exogenous drivers are as in the data. 'k_0' denotes the traditional neoclassical transition dynamics —i.e., all exogenous drivers remain at their 1960 values.