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Abstract

Many cases of successful economic development, such as South Korea, exhibit long periods of sustained capital accumulation rates. This empirical feature is at odds with the standard neoclassical growth model which predicts initially high and then declining capital accumulation rates. We show that minor modifications of the neoclassical model go a long way towards accounting for the transition dynamics of the South Korean economy. Our modifications recognize that (1) agriculture essentially does not use reproducible capital, and that during the transition period (2) the relative price of capital declines substantially, and (3) the nonfarm employment share increases substantially.

Keywords: neoclassical growth model, transition dynamics, industrialization, price of capital, South Korea

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

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1. Introduction

The neoclassical growth model is a fundamental building block of modern macroeconomics, yet the transition dynamics predicted by the neoclassical model are strongly at odds with the experience of many Asian growth miracles, for example, 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 most Asian economies that made a successful transition started out with low initial investment rates that gradually increased over time as shown in Figure 1.

[Figure 1. Investment Rates of Asian Growth Miracles]

For the case of the South Korean economy we argue that two minor modifications 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 applied growth economics that emphasize the role of a large agricultural sector and a high relative price of capital during the early stages of development.[1] We choose the Korean economy for two reasons. First, its economic growth has been studied extensively as a successful case of economic development. Second, we have reliable data on the two newly added features—the relative size of the agricultural and industrial sectors and the relative price of capital—since 1960.

Table 1 summarizes these features of the Korean economy. First, in the early stage of economic development, agriculture, a sector that does not rely heavily on physical capital, makes up a significant part of the economy. For example, in 1963 agriculture accounted for more than 30 percent of Korean GDP and 70 percent of employment. Thus, a low aggregate capital-output ratio does not necessarily imply a high rate of return to capital. Second, we note that the relative price of investment goods is high in less developed economies. For Korea, the relative price of capital in 1963 was more than twice its relative price today. This feature also reduces the implied rate of return on capital in the early stages of development. Finally, we note that not only did the aggregate employment rate in Korea increase over

[1] The two contributions of this literature that are most relevant for our work are Caselli and Feyrer (2007) and Gollin, Parente, and Rogerson (2007)

time, but the shift of employment from agriculture to the nonfarm sector increased the nonfarm employment rate even more. Thus the marginal product of capital using aggregate employment also overstates the return to capital.

Our observations for the development path of Korea are consistent with theose of Caselli and Feyrer (2007) for a 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 nonfarm 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 these observations we use the growth model to study the transition dynamics of capital accumulation in the nonfarm sector of the Korean economy. Our approach is based on Gollin, Parente, and Rogerson (2007) who study the equilibrium transition from a land- and 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 sector and the nonfarm sector during this transition, we take this allocation as given and study its implications for the capital accumulation path of the nonfarm economy. We quantitatively assess the role of the declining agricultural sector and the declining price of capital by calibrating the model economy to the development experience of Korea for 1960-2005. Accounting for these two features substantially reduces the rate of returns to capital. For example, the implied rate of returns to capital in 1960 significantly decreases from 90 percent, according to the standard capital-output ratio in a one-sector neoclassical model, to a still high but more reasonable rate of 15 percent, according to our analysis.

We interpret the transition of the Korean economy as the perfect foresight equilibrium of our calibrated growth model. Following Chari, Kehoe, and McGrattan (2007) we introduce 'wedges' into the model such that the observed allocation is feasible and optimal. The wedges are measured total factor productivity, autonomous demand for nonfarm GDP, and 'financial frictions' to satisfy the intertemporal optimality condition. We treat these wedges as exogenous processes, along with other drivers measured from Korean data, such as the relative price of capital, the nonfarm employment rate, capital income tax rate, the population growth rate, etc. We evaluate the impact of each component on the transition by a sequence of counterfactual experiments. These experiments suggest that the three most important contributors to the observed transition of the Korean economy are (1) the increasing nonfarm employment rate, (2) the declining relative price of capital, and to a lesser extent (3) the declining financial frictions.

This paper is organized as follows. Section 2 summarizes the related literature. In Section 3 we present a modified growth model that distinguishes between a labor-intensive agricultural sector and a capital-using nonfarm sector. In Section 4 we describe the data for Korea and how we use them in a way that is consistent with our model. We then calibrate our model to the Korean economy for the period 1960-2005. In Section 5 we illustrate how the model-consistent use of the data affects the measured rate of return to capital and total factor productivity. In Section 6 we compute the counterfactual transition paths to evaluate the contribution of the different exogenous drivers of growth. Section 7 concludes.

2. Related Literature

Before we proceed with our analysis we briefly summarize how this paper is related to the literature on economic development from the perspective of the neoclassical growth model. There is an established literature that studies the properties of transitional capital accumulation paths in the growth model and to what extent parameterized versions of the growth model can account for observed transition paths of aggregate per capita output, especially the Asian 'growth miracles.' There is also recent literature that takes a more disaggregate view of economic development. This literature emphasizes the transition from a predominantly agricultural economy to a modern industrialized economy and the associated reallocation of resources.

The standard growth model embodies balanced growth, that is, in the long run per capita growth is determined by productivity growth. On this balanced growth path (BGP), per capita capital and output grow at the rate of productivity growth, and the capital-output ratio and the rate of return on capital remain constant.[2] If the economy starts out with a capital stock that is below its long-run capital stock, the rate of return to capital is high,

[2]If the relative price of capital is exogenous and changing over time and production is Cobb-Douglas, then these statements apply to the value of capital, for example, Greenwood,. Hercowitz, and Krusell (1997).

and the economy is accumulating capital at a relatively faster rate on the transition to the balanced growth path. Thus capital deepening, that is, an increasing capital-output ratio, contributes to output growth.

Barro and Sala-i-Martin (1995) characterize the transition dynamics of the investment rate in the optimal growth model with Cobb-Douglas production and constant intertemporal elasticity of substitution preferences. They show that for any given capital coefficient in the production function there exists a critical value for the intertemporal elasticity of substitution such that the investment rate declines (increases) on the transition path if the intertemporal elasticity of substitution is above (below) the critical value.[3] The larger the capital coefficient, that is, the less the rate of return on capital responds to deviations of capital from the BGP, the higher is the critical value for the elasticity of substitution. For a reasonable calibration of growth rates and interest rates on the BGP, the critical value of the elasticity is close to the capital income share. Thus, for a standard calibration of the growth model with a capital income share of one-third, the critical value for the elasticity of substitution is about one-third.

The capital income share also determines the speed of transition to the BGP. Empirical evidence suggests that convergence to the BGP is slow, for example, Mankiw, Romer, and Weil (1992). Again, Barro and Sala-i-Martin (1995) show that the standard growth model can account for 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. This broad concept of capital then also implies a very high investment rate on the BGP, and implicitly assumes that measured GDP misses a large fraction of actual output, namely investment in human capital and other kinds of intangible capital.

Our work complements earlier quantitative research on the role of capital accumulation for growth. 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 extremely high real interest rates in the early stages of development, a prediction that appears to hold

[3] Smetters (2003) shows that if the factor elasticity of substitution in the production function is not unity, the savings rate can exhibit a non-monotone transition path.

neither in developed nor developing economies.[4]

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. 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. Chen, İmrohoroğlu, and İmrohoroğlu (2006) show that the observed hump-shaped savings rate in Japan can be accounted for if economic agents perfectly foresee the relatively high TFP growth in the early 1970s, that is, Japanese households delay their savings and investment in the 1960s. 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. For a model with two unspecified types of capital, Rappaport (2006) argues 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.

More recent literature studies how declining capital goods prices and the transition from agriculture to industry affects development. Unlike our contribution, most of this work studies the implications of these features for cross-sections of countries that are on balanced growth paths. Restuccia and Urrutia (2001) point out that in cross-sectional data, real investment rates are negatively correlated with the relative price of capital, and that a high relative price of capital lowers the real capital-output ratio on the balanced growth path. Hsieh and Klenow (2007) argue that the negative correlation between the relative price of capital and real income is due to low income countries being relatively less efficient in the production of capital goods and tradable goods. Caselli and Feyrer (2007) show that in a cross-section of countries the nonfarm output share appears to be positively correlated

[4]King and Rebelo (1993) also show that allowing for capital adjustment costs reduces the implied rates of return to capital but instead implies extraordinarily high values of installed capital during early development.

with the nominal investment share such that defining the return to capital with respect to nonfarm output and accounting for the relative price of capital lowers the cross-sectional variance of the return to capital. Gollin et al (2007) and Duarte and Restuccia (2010) discuss the implications of sectoral transformation, that is, the transition from a predominantly agricultural economy to an industrialized economy for aggregate labor productivity. Duarte and Restuccia (2010) study how changes in sectoral productivity lead to the reallocation of labor across sectors and changes in aggregate labor productivity. Gollin et al (2007) study the determinants of the timing of take off, that is, when a developing economy will start to adopt modern capital-intensive technologies.[5] Unlike Gollin et al (2007) and Duarte and Restuccia (2010), we take the sectoral allocation of labor as given and study its implications for capital accumulation in the nonfarm sector. Finally, according to our growth accounting, the financial friction, emphasized by Buera and Shin (2010), played a significant role in the early stage of economic development in Korea. However, the importance of financial frictions is limited compared to that of the relative price of capital and the transition from agriculture since the mid 1970s.

3. 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) where the agricultural sector uses labor only.

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.

$$\sum_{t=0}^{\infty} \beta^t n_t \left(\frac{c_t^{1-\sigma} - 1}{1-\sigma} + \bar{a} \right), \tag{3.1}$$

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

with $0 < \beta < 1$ and $\sigma > 0$.[6] 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},

$$e_{at} + e_{yt} = e_t. \tag{3.2}$$

The agricultural good is produced using labor as the only input[7]

$$a_t = A_{at} e_{at}, \tag{3.3}$$

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

$$y_t = k_t^{\alpha} \left(A_{yt} e_{yt}\right)^{1-\alpha}, \tag{3.4}$$

and A_{yt} is labor-augmenting technical change in manufacturing. In the following we refer to the agricultural sector as the farm sector and to the manufacturing sector as the nonfarm sector of the economy.

The nonfarm good is used for private consumption; investment in capital goods, x_t; and public consumption, g_t,

$$y_t = c_t + q_t x_t + g_t. \tag{3.5}$$

The price of investment goods in terms of consumption goods, q_t, is exogenous and reflects the marginal rate of transformation between consumption and investment goods. Investment augments the capital stock,

$$k_{t+1} = \frac{n_t}{n_{t+1}} \left[(1-\delta) k_t + x_t \right], \tag{3.6}$$

[6] 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 (3.1) 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 $\bar{a}$.

[7] According to Kim and Park (1985), as quoted in Young (1995), land represents most of the capital input in Korea's agricultural sector from 1960 through 1980. According to Pyo (1996) the nonfarm sector used 85% of all equipment and 98% of all structures in 1960.

and capital depreciates at rate δ. We take a broad view of public consumption and include not only government purchases, but also net exports. In the following we refer to public consumption as autonomous demand for goods and take it as exogenous.

We assume that markets are competitive. Wages, w_t, and the capital rental rate, u_t, are equal to their marginal products. Aggregate output is defined as

$$Y_t = y_t + w_t e_{a,t}. \tag{3.7}$$

We allow for the taxation of income at rate τ_t, and we assume that the government budget is balanced through some additional lump sum tax.

We study the perfect foresight equilibrium path of the growth model. The rate of return on capital is

$$R_t^K = \left\{ (1 - \tau_{t+1}) \frac{u_{t+1}}{q_{t+1}} + \left[1 - (1 - \tau_{t+1})\,\delta\right] \right\} \frac{q_{t+1}}{q_t}. \tag{3.8}$$

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

$$R_t^H = \beta^{-1} \left(\frac{c_{t+1}}{c_t} \right)^{\sigma}. \tag{3.9}$$

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

$$R_t^H = f_t R_t^K. \tag{3.10}$$

We interpret the "wedge," f_t, as representing financial frictions: a fraction $1 - f_t$ of the returns on capital is diverted by the financial intermediation sector.

In the long run, population is assumed to grow at a constant rate, γ_n.[8] We also assume that in the long run productivity in the farm and nonfarm sector and the relative price of capital change at constant rates γ_{A_a}, γ_{A_y}, and γ_q, and that the employment rate, e, the autonomous spending share in output, g/y, the income tax rate, τ, and financial frictions, f, are constant. In particular, following Gollin et al (2007), we assume that productivity in the agricultural sector is increasing over time, $\gamma_a > 1$. Thus there exists a limiting balanced

[8] We use γ_x to denote the growth rate of a variable x.

growth path where nonfarm output, expenditure components, and capital grow at constant rates, and all employment is in the nonfarm sector.

For a given time path of nonfarm productivity, A_{yt}, the relative price of capital, q_t, and the nonfarm 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},

$$\begin{aligned} \tilde{y}_t &\equiv \frac{y_t}{z_{yt}} \text{ and } z_{yt} \equiv A_{yt} e_{yt} q_t^{-\alpha/(1-\alpha)}, \\ \tilde{k}_t &\equiv \frac{k_t}{z_{kt}} \text{ and } z_{kt} \equiv A_{yt} e_{yt} q_t^{-1/(1-\alpha)}. \end{aligned}$$

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

$$\tilde{y}_t = \tilde{c}_t + \tilde{x}_t + \tilde{g}_t = \tilde{k}_t^{\alpha}, \tag{3.11}$$

$$\left(\frac{z_{k,t+1}}{z_{k,t}}\right)\gamma_{n,t+1}\tilde{k}_{t+1} = (1-\delta)\,\tilde{k}_t + \tilde{x}_t, \tag{3.12}$$

$$\beta\left(\frac{z_{k,t+1}}{z_{k,t}}\right)^{\sigma}\left(\frac{\tilde{c}_{t+1}}{\tilde{c}_t}\right)^{\sigma} = f_t\frac{q_{t+1}}{q_t}\left\{(1-\tau_{t+1})\,\alpha\frac{\tilde{y}_{t+1}}{\tilde{k}_{t+1}} + [1-(1-\tau_{t+1})\,\delta]\right\}. \tag{3.13}$$

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

4. Data and Calibration

It is crucial to obtain the data that are consistent with our model. In this section we provide a detailed explanation on data sources and how we use the data to account for the growth of the nonfarm sector of the Korean economy. We also describe the calibration procedure. For the calibration purpose, we assume that by year 2005, the Korean economy was close to its balanced growth path.

Most of our National Income Account (NIA) data for South Korea 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 by the Hodrick-Prescott filter with a smoothing parameter of 100.

The annual data from 1953 to 2005 for GDP and its expenditure components (private and public consumption, investment in equipment and structures), in current prices and in constant 2000 prices are downloaded from the BoK website. Structures includes both residential and nonresidential structures. We construct the relative price of investment goods in terms of consumption goods from the implied BoK price indices. We define total real investment as the sum of real investment in equipment and structures, and we define the relative price of total investment as the ratio of nominal and real total investment.

Aggregate employment from 1960 to 2005 is the number of employees from the Total Economy Data Base, Conference Board (2009). We use sectoral data (agriculture and nonfarm) on persons employed and value-added from 1963 to 2005 from the GGDC 10-Sector Data Base, Timmer and de Vries (2007).[9] 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. The participation rate is the per capita labor supply.

We interpret the actual time paths for observable variables of the Korean economy as the perfect foresight equilibrium paths of the growth model. Thus, aggregate time series variables have to satisfy all resource constraints and optimality conditions, Equations (3.4), (3.5), (3.6), (3.8), (3.9), and (3.10). This has several implications. 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 nonfarm sector.[10] Third, we define autonomous spending as the residual from the NIA expenditure identity for nonfarm GPO after accounting for pri-

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

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

vate consumption and investment, using Equation (3.5). Thus, our measure of autonomous spending combines government spending with the value of net exports. Fourth, we construct the capital stock using the HP-trend values for investment as inputs to the perpetual inventory approach defined by the capital accumulation equation (3.6) and the depreciation rate.

The capital stock is constructed from the time series of aggregate investment using the perpetual inventory method. We assume that capital, both equipment and structures, depreciates at rate $\delta = 0.053$.[11] Following the convention in the literature, we construct the initial value of capital stock based on the investment in 1953 and the average growth rate of real investment during the first 10 years of available data.[12] While this is a crude approximation, it does not have a significant impact on the transition dynamics for 1960 and onward. The size of initial capital stock is very small and an approxiation error almost disappears by year 1960, the beginning year of our analysis.

The list of 'observed' exogenous drivers of the Korean transition from 1960 to 2005 includes the relative price of capital, q_t, the nonfarm employment rate, e_{yt}, the capital income tax rate, τ_t, autonomous spending, g_t, and the population growth rate, $\gamma_{n,t}$. In the introduction we have already pointed to the declining relative price of capital and the increasing nonfarm employment rate, Table 1. From 1960 on, the relative price of capital declined by more than a factor of two, and employment in the nonfarm sector increased significantly. Although the overall employment rate increased by only 10 percent from 48 percent in 1963 to 53 percent in 2005, the nonfarm employment rate more than doubled from 19 percent in 1963 to 45 percent in 2005. The autonomous spending share increased almost monotonically from close to zero in 1960 to about 25 precent in 2005. This monotone increase reflects the combination of a slight increase of the government spending share and a switch from a current account surplus in the 1960s to a current account deficit 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

[11] 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, Timmer and van Aark (2002).

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

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 $\gamma_q = 1$. 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. Given the observations on Korean population growth, we set population growth on the BGP at $\gamma_n = 1.01$.

For what we consider to be the relevant definition of output, towards the end of our sample the total capital stock in the Korean economy is close to three times output. 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 $qk/y = 3.0$.[13] 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 is 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, Barro and Sala-I-Martin (1995). Using the preference parameter together with the BGP values for consumption growth rate and the rate of return on capital, we use the household Euler equation to obtain the time preference parameter $\beta = 0.97$.

Our measure of government spending is a residual and includes not only government spending, but also net exports. We calibrate the BGP value of the government spending share in a roundabout way, using the transition dynamics to the BGP starting with initial

[13] 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 exceeds the observed long-run value for the U.S.

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 $\rho = 0.95$. Conditional on the BGP value for the government spending share we can construct the log-linear approximation of the growth model. We then choose the government spending share such that in 2005 the log-linear approximation generates the consumption observed for the Korean economy in 2005.

5. Korea's Transition

Accounting for the change in the relative price of capital and the size of the nonfarm sector provides a different perspective on Korea's transition dynamics. We now evaluate the implications of these two features for the measurement of capital accumulation, financial frictions, and productivity improvements.

One of the salient failures of the neoclassical model in accounting for the economic transition is the rate of return to capital. The rate of return to capital is often measured by the inverse capital-output ratio. Capital-deepening, that is, an increasing capital-output ratio 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 nonfarm 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 nonfarm 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 nonfarm output only increases by a factor of three. Thus, after taking into account the declining relative price of capital and the small initial share of nonfarm output, the Korean economy's capital stock in 1960 was substantially closer to its long-run equilibrium than the usual real capital-output ratio suggests. Similarly, we observe that the nominal nonfarm investment rate appears to be more stable than the real aggregate investment rate, Figure 2.B. But note that even the nominal nonfarm investment rate still increases from about 20 percent in the 1960s before it stabilizes around 35 percent in the 1970s.

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

We now turn to the implications of industrialization and the declining relative price of capital for the measurement of financial frictions as defined by the growth model. In Figure 3 we plot the time path for various measures of the real rate of return on capital implied by our calibration of the Korean economy. The rates of return on capital are calculated using equation (3.8). All measures use the same time path for the capital stock, but they differ with respect to the definition of the capital-using economy 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 NIA measure of real aggregate GDP (along with $q = 1$ and $\tau = 0$). This is the measure implied by the aggregate capital-output ratio (the marginal product of capital) used in most cross-country growth accounting exercises. Based on this measure we would conclude that the returns to capital in Korea in 1960 should have been almost 90 percent. Since Korea at that time was mostly an agricultural economy that did not rely much on physical capital, the aggregate capital-output ratio grossly overstates the rate of return to capital. The next line depicts the rate of return on capital using real nonfarm GPO from the NIAs and we see that correcting for the appropriate output measure reduces the initial rate of return on capital by a third but it still remains at a high rate of 62 percent. Accounting for changes in the relative price of capital further reduces the return on capital. As of 1960, the implied rate of return is now 18 percent. Finally, accounting for capital income tax rats further reduces the measured rate of return on capital. In sum, when appropriate care is taken of the measure of output, the relative price of capital, and the capital income tax rate, the rate of returns to capital in Korea in 1960 is around 13 percent.

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

The assumption that production is Cobb-Douglas has proven to be a useful abstraction for the analysis of long-run growth. There is some evidence, however, that capital and labor are complementary in production, for example, Antras (2004). One might therefore think that conditional on Korea's low initial nonfarm employment some degree of capital-labor complementarity would lower the implied rate of return on capital. For the way we calibrate production this turns out not to be the case. In fact, assuming Cobb-Douglas production yields lower initial returns to capital than assuming complementarity between capital and labor. In our calibration the capital coefficient in a CES production function

$$y_t = \left[\left(1 - \alpha^{CES}\right)\left(A_{yt}e_{yt}\right)^{\rho} + \alpha^{CES}k_t^{\rho}\right]^{1/\rho}$$

is determined by the capital-income share and the capital-output ratio on the BGP

$$\alpha^{CES} = \alpha\left(\frac{k}{y}\right)^{-\rho}.$$

Substituting this term for the capital coefficient in the expression for the capital rental rate, that is, the marginal product of capital, we get after some algebra that

$$u_t^{CES} = \alpha\left(\frac{k/y}{k_t/y_t}\right)^{-\rho}\frac{y_t}{k_t} = \left(\frac{k/y}{k_t/y_t}\right)^{-\rho}u_t^{CD}.$$

Since we start from a capital-output ratio below the BGP value, the initial capital rental rate increases with the degree of complementarity, $\rho < 0$.

The household rate of return is implied by the consumption Euler equation (3.9), 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 we started out with, and the wedge also quickly diminishes to almost zero by the mid-1980s. We should note that towards 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, 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.

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

Using 'correct' measures of output and employment also affects the measured total factor productivity for the Korean economy, one of the major driving forces of economic development. In Figure 4, we plot measures of total factor productivity implied by different measures of output and employment. All measures use the same capital stock series. For the first measure, we use total real GDP from the NIAs and total employment, the solid line. This standard measure indicates that TFP increased by 90 percent from 1960 to 2005. For the second measure we try to account for the transition to an industrialized economy and get a measure of nonfarm TFP, dashed line. Our output and labor input measures are real nonfarm GPO from the NIAs and nonfarm employment. According to this second measure nonfarm TFP increased by only 10 percent from 1960 to 2005. In fact, for this measure nonfarm TFP declined from 1960 to 1980 before rebounding, which is somewhat unusal. From the perspective of the model, however, the relevant measure of nonfarm output is nonfarm output in terms of consumption goods; that is, nominal nonfarm GPO deflated by the consumption goods price index. This model-consistent measure of TFP, which is used in our quantitative analysis of Korea, has also increased more or less monotonically from 1960 to 2005, but half as much as the conventional measure of TFP based on aggregate output and employment.

6. Counterfactuals

We have recovered three exogenous "wedges"—measures of nonfarm productivity, A_{yt}; financial frictions, f_t; and autonomous spending, g_t—by interpreting the transition dynamics of the Korean economy as a perfect foresight equilibrium path. We now study the contributions of these wedges and other measured exogenous drivers—the relative prices of capital, q_t; nonfarm employment, e_{yt}; capital income taxes, τ_t; and population growth, γ_n—to the transition dynamics of Korea. For this purpose we construct counterfactual equilibrium growth paths where we hold these exogenous drivers fixed at their long-run values on the balanced growth path.

According to these counterfactuals, increasing nonfarm employment had the largest impact on the transition, followed by a declining relative price of capital, and then financial frictions. Figure 5 plots the transition dynamics of per capita capital, per capita nonfarm output, and the nominal investment rate for the actual Korean data and four experiments. For the first experiment (labeled as 'f') we eliminate financial frictions, that is, we set $f_t = 1$ for all periods but keep all other exogenous variables at their observed/constructed values. Given the initial capital stock in 1960, we then solve the growth model for the perfect foresight equilibrium.[14] For the next two experiments, we cumulatively eliminate the effects of changes in the relative price of capital (labeled as 'q') and the nonfarm employment rate (labeled as 'e_y') by sequentially fixing each exogenous variable at its BGP value for the entire transition path. For the final experiment, we fix all remaining exogenous variables at their BGP values (labeled as 'All') and calculate the transition that is driven solely by the deviation of the initial capital stock from its BGP value.

[Figure 5. Counterfactual Transition Paths]

The transition path for the last experiment where all exogenous variables are fixed at their BGP values corresponds to the typical analysis of the transition dynamics in the neoclassical growth model. The rapid convergence of per capita output to its BGP is driven by the rapid

[14] We solve the nonlinear equation system (3.11) through (3.13) for the years 1960 to 2005 for the equilibrium capital stock path using the log-linear approximation of the growth model to obtain consumption in the year 2005 conditional on the state of the economy in 2005.

rate of capital accumulation, the dashed lines in Figure 5.A and B. The high rate of capital accumulation is driven by the extraordinarily high return on capital which induces a high initial investment rate that is declining over time, Figure 5.C. This is the capital accumulation driven transition dynamics studied by King and Rebelo (1993) and this transition dynamics is obviously quite different than the one that was observed for the Korean economy, the solid lines in Figure 5.

Once we allow for the declining relative price of capital and the transition from agriculture, financial frictions have a limited impact on the transition of per capita capital and output after late 1970s. The biggest impact of financial frictions occurs in the late 1960s when, according to the counterfactual, without financial frictions Korea should have raised the capita capital by about 40 percent and per capita nonfarm output by 15 percent relative to their actual values. While these are substantial numbers, the impact of financial frictions pales in comparison to the effects of a declining relative price of capital and increasing employment in the nonfarm economy. If the relative price of capital had always been at its BGP value then in the late 1960s it would have raised capital by an additional 100 percent and nonfarm output by an additional 40 percent relative to their actual growth path values. If in addition the transition to an industrialized economy had been immediate and the nonfarm employment rate had been at its BGP value from the beginning, capital (nonfarm output) would have been another 140 percent (100 percent) higher relative to the actual growth path in the late 1960s.

Figure 5.C suggests that financial frictions are in part responsible for the initial low investment rates in the 1960s. Removing financial frictions increases the average investment rate in the early 1960s to more than 35 percent and introduces a declining trend starting in 1970. On the other hand, setting the relative price of capital and the nonfarm employment rate at their respective BGP values from 1960 on has an even bigger impact on the investment rate. The combined cumulative effect of these three counterfactuals would have been to raise the investment rate to more than 50 percent in 1960. This pattern of investment is even more extreme than in the usual exercise where all exogenous variables are fixed at their BGP values and accounts for the fast transition.

Compared to the effects of nonfarm employment, the relative price of capital, and financial frictions, the impact of the remaining exogenous variables on the Korean transition is minor. The rapid increase of the autonomous spending share until the 1970s has a rather limited impact on the growth path, in that capital and nonfarm output would have been 5 percent to 10 percent lower if that share had always been at its higher BGP value. Labor-augmenting technical change plays some role in the latter part of the sample. Since we assume that TFP growth on the BGP is consistent with long-run TFP growth in the United States, but measured TFP growth in Korea towards the end of the sample declines, the counterfactual delivers a higher growth path. Finally, the impact of the remaining exogenous variables, population growth, autonomous spending, and income taxation is small, since the cumulative impact of fixing the values for financial frictions, the relative price of capital, nonfarm employment, and TFP growth at their respective BGP values yields a transition path that is very close to the path when we fix all exogenous variables at their BGP values. Overall, it is hard to distinguish the differences between these counterfactuals, so we have omitted them from the graphs in Figure 5.

7. 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 apparently fails to account for the dynamics of investment rates and the prolonged path of capital accumulation of the development process in many countries. For the Korean economy we show that this apparent failure 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 lowers the implied rates of return to capital during early stages of development and contributes significantly to the relatively low investment rates. The quantitative analysis based on the calibrated model suggests that the three most important contributors to the observed transition of the Korean economy are (1) the increasing nonfarm employment rate, (2) the declining relative price of capital, and to a lesser extent (3) the declining financial frictions.

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. Like in many other developing economies, the aggregate capital mostly consisted of structure, especially residential, at the onset of the transition. As a result, the capital-output ratio for equipment was much lower than for structures. Thus, the implied rates of return and financial frictions are potentially quite different for the two types of capital. Second, the interaction between human and physical capital (e.g., capital-skill complementarity in Krusell, Ohanian, Rios-Rull and Violante (2000)) might be also important for the sluggish accumulation of capital, as the supply of skilled labor is very limited in the early stage of economic developments.

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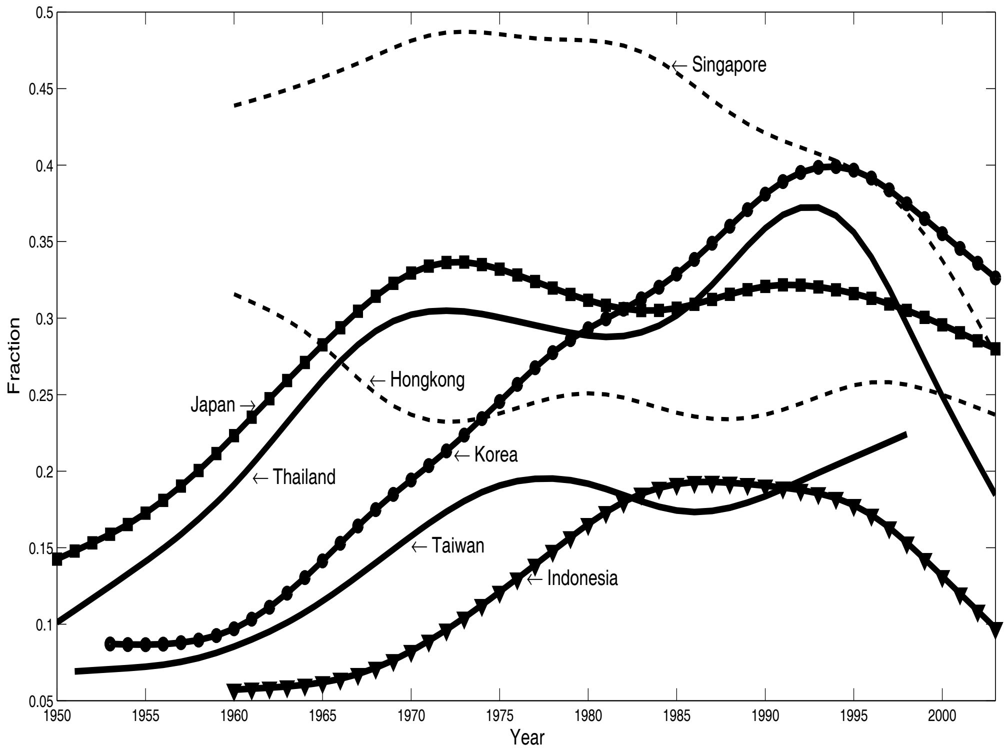
Table 1: Transformation of Korean Economy

	1963	2005
Size of Nonfarm Economy		
Value Added Share	66%	98%
Employment Share	31%	92%
Employment Rate		
Aggregate Economy	48%	53%
Nonfarm Economy	19%	45%
Relative Price of Capital	2.3	1.0

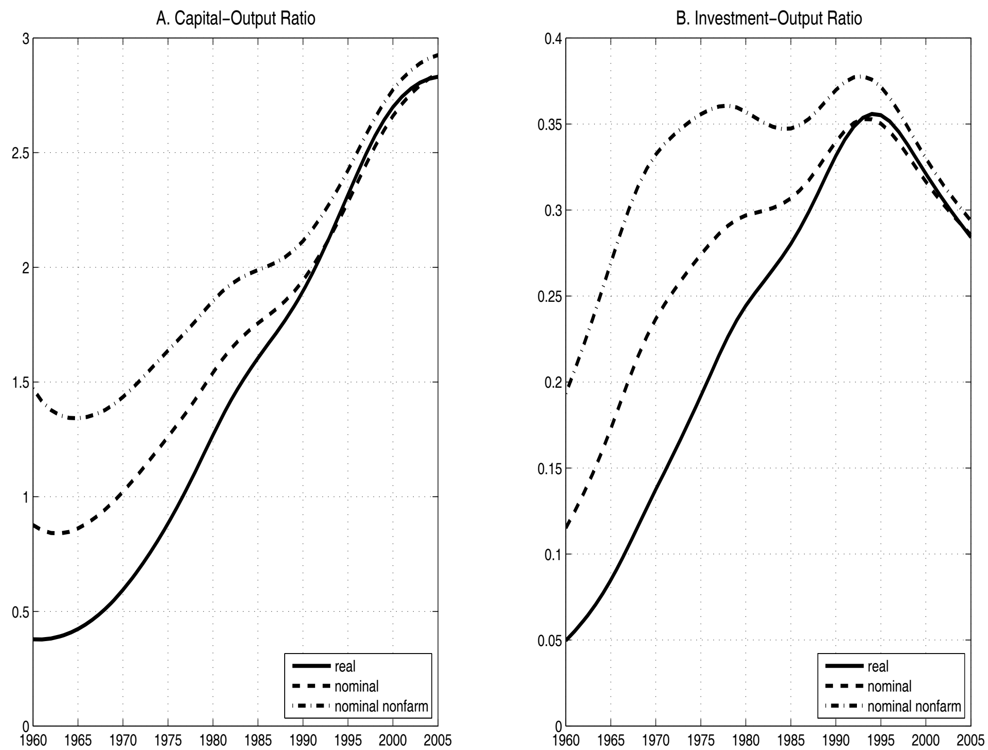
Notes: See Section 4 for the detailed explanation about the data.

Figure 1: Investment Rates For Asian Growth Miracles



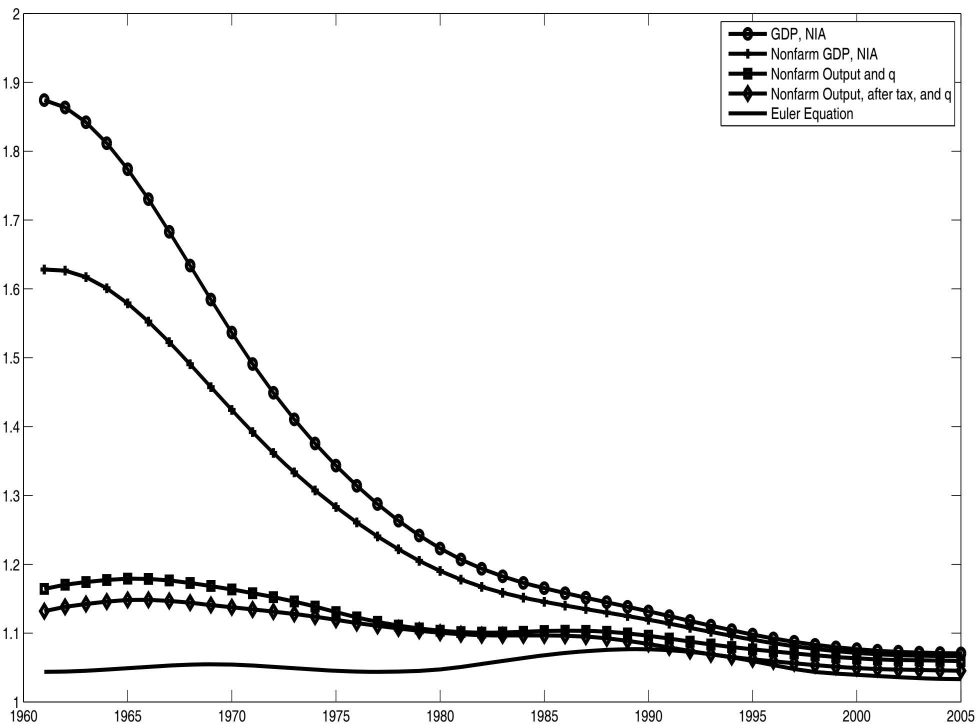
Notes: Data are based on the Penn World Table v6.2.

Figure 2: Capital Accumulation



Notes: For "nominal nonfarm," nominal nonfarm GDP is used for the output measure.

Figure 3: Implied Rates of Return on Capital



Notes: For "Nonfarm GDP and q," nonfarm GDP and the actual time series of relative price of capital (q_t) are used to compute the implied rate of returns to capital. For "Nonfarm GDP, after tax, and q," the time series of capital income tax rates (τ_t) is used along with nonfarm GDP and q. "Euler Equation" line reflects the rate of return implied by the Euler equation for consumption in the model.

Figure 4: Total Factor Productivity

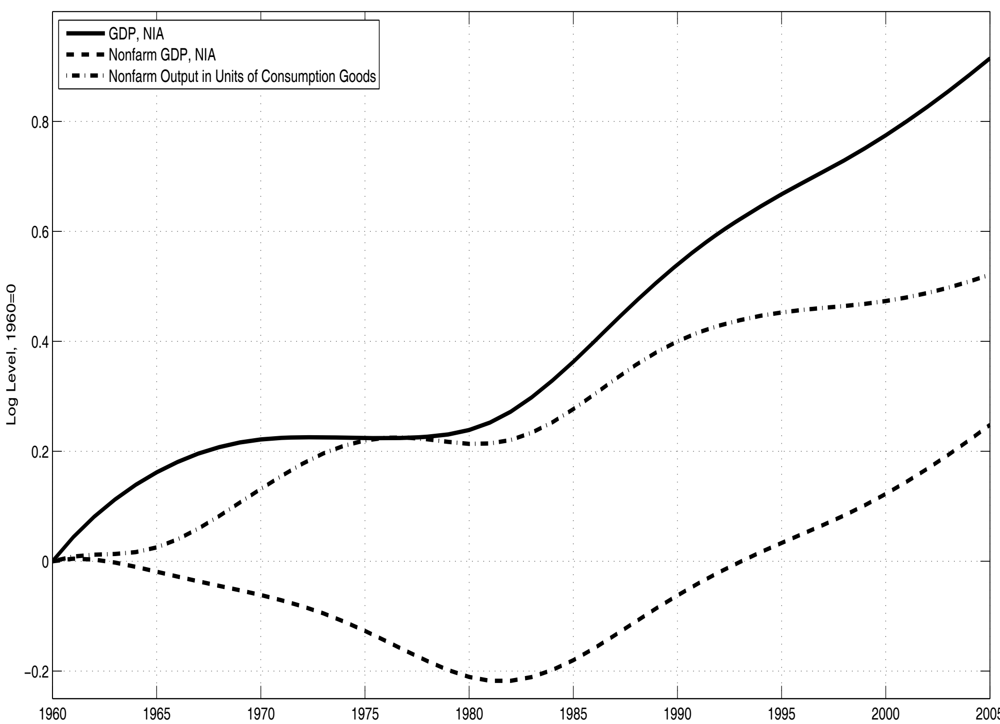
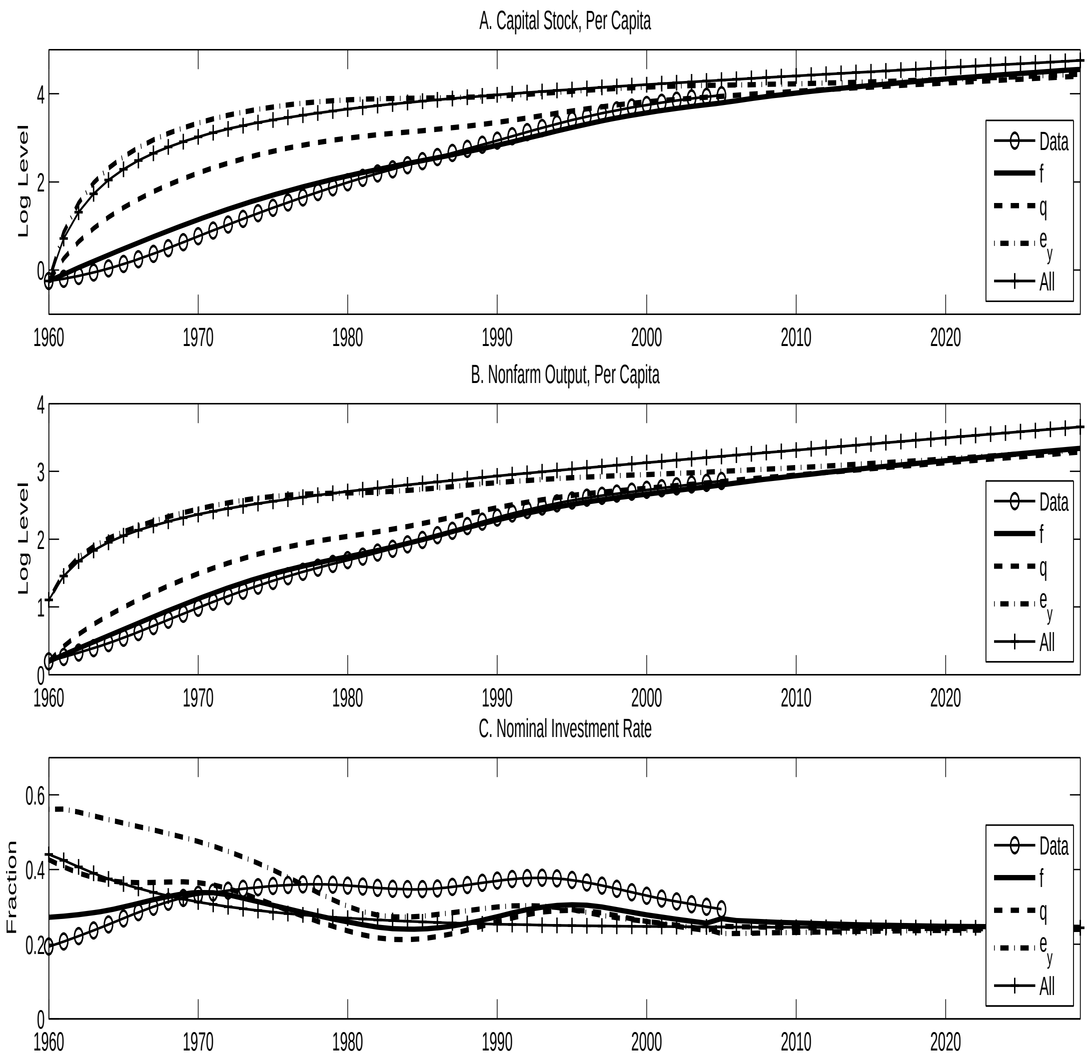


Figure 5: Counterfactual Transition Paths



Notes: The line labeled by "f" denotes the transition path when there are no financial frictions ($f_t = 1$); "q" denotes the path when the relative price of capital is also constant ($q_t = 1$) as well as f; "e_y" denotes the path when nonfarm employment is also constant at its balanced growth path, $e_{yt} = e_y$ as well as f and q. "All" denotes the path when all exogenous variables and wedges are set to their balanced growth path values.