Can Capital Fundamentalism be Revived? A General Equilibrium Approach to Growth Accounting

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1. Introduction

In the view of capital fundamentalism, the best way to promote economic growth is simply increasing investment. Differences in national stocks of capital were the major determinants of differences in the levels of national income. A straightforward piece of advice on development problem is that public policies must be designed to speed up a nation's physical capital accumulation. However, the neoclassical growth model and growth accounting research in the 1950s and 60s indicated that differences in the patterns of investment were not the factors behind cross-country differences in living standard in the long run.

Recent explosions of researches in growth accounting have reinstated capital fundamentalism at the forefront of economic analysis and policy discussions. For example, Jorgenson et al. (1987) found that capital accumulation is the most important source of economic growth, while productivity growth is the least important source in the U.S. economy. King and Levine (1994) found that capital-output ratio is systematically related to the level of development. Kim and Lau (1994, 1995) concluded that capital accumulation remains the most important source of economic growth, followed by labor in the East Asian newly industrialized countries (NICs). In DeLong and Summers (1992), international comparisons suggested a very special role for equipment investment as a trigger for productivity growth, which led them to make a policy prescription that equipment investment should receive special incentives.

The purpose of this paper is to econometrically evaluate the role of physical capital accumulation in economic growth and development. Such an exploration is essential to understanding whether capital fundamentalism should guide public policy recommendations and research strategies. Unlike previous studies, we provided the growth accounting exercises in a general equilibrium framework. We first characterize

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different sets of restrictions on transitional path implied by old and new growth theories, which allow us to explore how transitional dynamics depend on parameters of preference, production technology and exogenous shocks. To achieve this, we propose a solution procedure which yields the explicit ARMA representation of output growth rate in various growth models. A growth model is to be used as a description of actual growth experience, its ARMA representation must be consistent with the ARMA counterpart in actual growth path. We employ this research strategy by presenting the time series "facts" about GDP growth rates, and then check whether there is a model that likewise delivers the ARMA representation of the data.

To achieve the identification of the model, the value of capital share in production function must be given a priori. We estimate structural parameters for various growth models under the pre-specified values of capital share. In addition to statistical evaluation of the model performance, we vary the value of capital share to trace its dynamic effects on output growth as growth accounting exercises, focusing on the fraction of long-run growth that can be plausibly attributed to physical capital accumulation. The estimation and hypothesis testing also help us answer the question if there are enough time-series characteristics in the data to discriminate various growth models.

New growth theory enhances the importance of capital accumulation either through the introduction of additional reproducible input factor like human capital or through externalities. For example, Mankiw, Romer and Weil (1992) included human capital in a neoclassical growth model and found the cross-country evidence in favor of the neoclassical models: While maintaining the assumption of decreasing returns to capital, physical capital accumulation generates larger effects on growth. The explanatory power in their cross-country regression comes from steady state. Recently, King and Rebelo (1993) conducted dynamic simulations to learn about the quantitative transitional dynamics in various neoclassical growth models with intertemporally optimizing households. They found that lengthy transitions occur only with very low intertemporal substitution, but then the model has predictions inconsistent with observed variation in interest rates, asset prices and factor shares over time and across countries. They all adopted the neoclassical classical models with decreasing returns to capital. Romer (1986) emphasized the external effects of capital accumulation through the following channel. When firms accumulate capital, they inadvertently contribute to the productivity of capital held by others.

Another strand of development is endogenous growth models which focussed on the formulation of technical progress. It has been motivated by the two empirical regularities: First, many countries have experienced the sustained growth in per capita output. Second, there has been a significant cross-country disparity of growth paths for a long period of time. The accumulation of additional reproducible factors like human capital or knowledge requires intermediate input factors. For example, Romer (1990) used the number of intermediate inputs to model the accumulation of another reproducible input factor. Grossman and Helpman (1991) emphasized the importance of the quantity of the fixed number of intermediate inputs.

As argued in Romer (1990), the production function in the above type of model has the feature of increasing returns to scale. The increasing returns provide a role for government policy in enhancing social welfare. Permanent changes in variables that are potentially affected by government policy induce permanent changes in growth rates. Also, the advice offered by endogenous growth models on development policies is very different from that offered by capital fundamentalism. For example, Kocherlakota and Yi (1996) found that government policy variables such as marginal tax rates and money supply (M2) growth rate have permanent effects on GNP growth rates. This result stands in marked contrast to the neoclassical growth model in which the long run growth rate is determined by the exogenous technical progress. In general, endogenous growth model has shifted its focus from the specification of production function to the formulation of technical progress. If this type of model provides a better characterization of economic growth dynamics, then the possibility of resuscitating capital fundamentalism will decrease.

The organization of the paper is as follows. Section 2 reviews three types of growth models commonly used in the growth literature. In Section 3, we drive the time-series representation of transitional dynamics in those models presented in Section 2. We emphasized different specifications of exogenous shocks in the model implied different ARMA representations of transitional paths. In Section 4, we first present the time series evidence on per capita real output growth in Japan, South Korea, Taiwan and U.S. Then we take these models to the time-series data in the above four countries and test the time-series implications of the models. Results from the growth accounting exercises suggested a much smaller role for physical capital accumulation in economic development and growth than that advocated by capital fundamentalism. Section 5 concludes.

2. The Models

In this section, we present exogenous and endogenous growth models. The first of these is the neoclassical model of exogenous growth in which the engine of growth is the exogenous technical progress. The second class of growth models include the stochastic versions of *Ak* model and the intermediate-goods-based models without externality. In specifying preferences and technology, we set the specification criterion that makes it possible to uniquely solve in closed form for output growth dynamics.

A representative consumer ranks a sequence of current and future consumption according to the expected present value of current and future utilities:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma} - 1}{1-\sigma},$$

in which c_t is consumption at time *t*, $E_0 x \equiv E[x|\Omega_0]$ denotes the conditional expectation of *x* given information available at time 0, Ω_0, parameter β is the constant discount factor between 0 and 1, and σ is the relative risk averse measure which is positive. The value of σ determines the elasticity of intertemporal substitution. It is a crucial factor in consumption growth.

Consider a constant returns to scale production technology which at least uses the reproducible factor k_t and labor $1-l_t$ as inputs:

$$y_t = a_t k_t^{\alpha}\left[h_t(1-l_t)\right]^{1-\alpha}, \tag{1}$$

in which y_t is output at time *t*, α is the capital share, and a_t is the stationary exogenous productivity shock.

2.1 Neoclassical models of exogenous growth

In the neoclassical growth model, h_t is an exogenous technical progress:

$$\log h_t = g_h + \log h_{t-1} + \varepsilon_{ht}, \tag{2}$$

in which ε_{ht} is a white noise with mean zero and variance σ_h^2. Hence g_h is the expected growth rate of h_t. Here h_t can be interpreted in many ways: as improvements in knowledge such as organization routines, better management of inventory, or other changes that do not require knowledge to be embodied in new equipment. When $\sigma_h^2 = 0$, equation (2) can be solved as $\log h_t = \log h_0 + g_h t$, which states that $\log h_t$ exhibits a deterministic linear time trend.

Under the specfication in equation (2), equation (1) is a standard production function with Harrod-neutral technical progress. Since $1-l_t$ is not a decision variable in this neoclassical growth model, let $l_t = 0$ for simplicity. The resource constraint at time *t* is given by

$$y_t = c_t + k_{t+1} - (1-\delta)k_t,$$

in which δ is the constant rate of depreciation for all reproducible factors.

According to the production technology in equation (1), trends in y_t and k_t are completely determined by the Harrod-neutral labor augmenting technical progress, h_t. The resource constraint imposes the equality between the consumption growth rate and the output and capital stock growth rates in steady states. The balanced growth conditions simply state the stationarity of following variables: $y_t / h_t, c_t / h_t$, and k_t / h_t. Hence, for the phenomenal sustained growth in per capita output, the explanation offered by this model is exogenous technical progress. It is silent on the cross-country difference in economic growth rate in the long run.

2.2 Ak models of endogenous growth

The first wave of endogenous growth models focussed on constant returns to a sufficiently broad definition of capital as the device for generating endogenous growth. Its essence is reflected in the equation *y = Ak.*

In order for equation (1) to match the *Ak* specification, h_t becomes another reproducible factor. The laws of motion for these two reproducible factors are:

$$k_{t+1} = i_{kt} y_t - (1-\delta) k_t ,$$

$$h_{t+1} = i_{ht} y_t - (1-\delta) h_t ,$$

here the fixed factor such as labor does not enter the production of reproducible factors. This capital accumulation technology was used in the Mankiw, Romer and Weil's (1992) augmented Solow model. The resource constraint is given by $c_t = (1 - i_{kt} - i_{ht}) y_t$. Although this model allows the second input factor h_t to accumulate endogenously, the two types of capital must accumulate in lockup. We can rewrite equation (1) in terms of a new form of production function:

$$y_t = \tilde{a}_t k_t , \tag{3}$$

in which $\tilde{a}_t \equiv a_t i^{1-\alpha}$ with $i = (1-\alpha)/\alpha$. Here i is the steady state value of h_t / k_t. Equation (3) looks exactly like the standard *Ak* production function in which the parameter multiplying k_t is a stationary productivity shock.

As argued in Jones (1995), the formulation of the two reproducible factors production technology is more appealing intuitively than the common *Ak* structure because it explicitly recognizes the role of human capital (or knowledge) in production. Even though the two types of accumulable factors move together, the specification of production technology is likely to be robust to a number of changes and interpretations of the two-factors models. The non-stochastic steady state growth rate of output denoted g_y is determined by

$$g_y = -\delta + \tilde{a} i_k ,$$

in which $\tilde{a} = a \cdot i$ and i_k is the steady state value of investment rate for k_t. Like the neoclassical growth model, the steady state ratio of output to capital (y_t / k_t) is constant in the *Ak* model. However, the investment rate (i_k) is the determinant of output growth rate in the *Ak* model. It also implies that the investment rate and growth rate must have similar statistical properties in the steady states.[1]

Recently, Jones and Manuelli (1990) studied a convex model of equilibrium growth. To generate sustained growth in per capita income, they simply impose a lower bound on marginal product of capital so that the marginal product must stay above the discount rate for investment to remain profitable. One example under their consideration is

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[1] One major weakness is that this model lacks transitional dynamics. One way to generate the transitional path requires that a_t be a stationary stochastic process. Then the transitional path is solely driven by stationary exogenous productivity shock. Or one can incorporate the adjustment costs in the models. As noted in Turnovsky (1996), the model with adjustment costs may have multiple steady states. However, he showed that the stable steady states may violate the transversality conditions, while the unstable ones do not have meaningful transitional dynamics.

$Ak_t + g(k_t)$ with $\beta(A+1-\delta)>1$ and $g(k_t)>0$, and clearly the *Ak* model is the simplest example. They also show that the presence of increasing returns to scale is neither necessary nor sufficient to generate sustained growth. Since the convex structure of their model and the lack of externalities, competitive equilibrium is Pareto optimal. Unlike models with increasing returns/externalities, the distortionary policies are not optimal in the convex model of growth. For example, in the presence of externalities generated by capital stock, it is likely that optimal policy requires subsidizing investment. Even though the *Ak* model also emphasizes the importance of government policy in determining g_y through its permanent effect on i_k, this policy will increase the output growth rate to a suboptimal (too high) level. In other words, the capital fundamentalism should be revived in the *Ak* model, but its policy prescription on promoting investment cannot be optimal.

As documented in Jones (1995), U.S. and other OECD countries' growth rates do not exhibit large persistent changes. Since the investment rate exhibits large persistent changes, he concluded that the Ak growth model is not consistent with time series evidence.

2.3 The intermediate-goods-based model of endogenous growth

Another strand of development of endogenous growth models shifted from the specification of production function to the formulation of technical progress. More specific, the determinants of g_h are left unexplained within the neoclassical growth model. This new growth model seeks to remedy this omission.

Unlike the Ak model, the accumulation of reproducible factor h_t requires labor engagement (l_t):

$$h_{t+1} = (1+\rho_h l_t)h_t, \tag{4}$$

in which ρ_h is the technology parameter. ρ_h can be interpreted as the maximal growth rate of h_t, and the actual growth rate of h_t is determined by the labor engaged in R&D or in human capital accumulation, l_t: $\rho_h l_t$. The balanced growth condition implies the stationarity of y_t / h_t, c_t / h_t, and i_t / h_t. One policy implication is that subsidies to the R&D activities or human capital accumulation can increase l_t and therefore increases the balanced growth rates.

Here h_t can be interpreted either as the number of intermediate inputs (Romer 1990) or as the quantity of the fixed number of intermediate inputs (Grossman and Helpman 1991) or as human capital (Lucas 1988). Here we cast h_t as the engine of economic growth. Labor can be used either in the production of final output or in search for innovation or in human capital accumulation. Since leisure is not a decision variable for the representative household, labor is an intermediate goods in production. The resource constraint at time *t* is identical to that in the neoclassical model of exogenous growth. As argued in Romer (1990), the production function now has the feature of increasing returns to scale: given h_t, doubling k_t and $1-l_t$ to production is sufficient to double final output; doubling h_t as well would lead to more than a doubling of final output.

Given the specification of h_t in (4), the accumulation of h_t does not require any use of final goods. It is not a required specification of the accumulation technology for h_t. Suppose that k_t is another input factor in the accumulation of h_t. As long as the accumulation technology of h_t is constant returns to scale with respect to all reproducible factors, we can still cast h_t as the engine of growth. One such specification is:

$$h_{t+1} = \rho_h k_t^{\phi} \left[l_t h_t \right]^{1-\phi} + (1-\delta) h_t .$$

When $\phi = 0$ and $\delta = 0$, this specification simply reduces to the original one. Evidently, alternative specifications can affect the steady state output growth rate.

Another specification emphasizes the role of learning-by-doing in human capital accumulation: work effort accelerates human capital accumulation.[2] Total time endowment is allocated either to leisure activities or to work efforts. Hence, labor is not an intermediate good. For example, the effect of providing a PC to a secretary accustomed to working with a typewriter. Marginal product of labor and final output all increase right away. Once the secretary rapidly accumulates skill while working with PC, her future expected earning should also increase as the result of human capital accumulation. This consideration could offset the wealth effect on leisure. However, as shown in Ladron-de-Guevara et al. (1997), when leisure enters utility function and $\rho_h > 0$, one may encounter the multiple steady states problem. We believe that labor employment decisions are important in the study of aggregate fluctuations, and will not consider this specification simply for this reason.

Recently, Jones (1995) used the prediction of long-run growth effects to design time-series tests for endogenous growth models. More specific, when the R&D-based model holds in steady states, the implied growth rate must have a positive trend as the total number of labor devoted to the R&D activities increases over time. He found evidence against the R&D-based model.

3. Time-series representation of transitional path

We derive the time-series representations of transitional paths for both the neoclassical growth model and the intermediate-goods-based growth model. First, we solve for dynamic competitive equilibrium, and transform the associated necessary first-order conditions to alternative stationary representations. Since the stationary representations are highly non-linear functions of relevant variables, the log-linear approximation of these representations is implemented around the non-stochastic steady states. Once the log-linear approximations are expressed as linear expectations difference equations, it is straightforward to obtain the closed-form solution of output growth rate

[2] One example is Christiano and Eichenbaum (1988).

using the conventional solution procedure in rational expectations literature.

In absence of increasing returns/externality, dynamic competitive equilibrium can be characterized by exploiting the equivalence between competitive equilibrium and Pareto optimal allocation. The intertemporal allocation problem faced by the social planner is to choose contingency plan, c_t, k_{t+1}, and l_t, to maximize the expected present value of current and future utilities subject to resource constraint and the laws of motion for accumulable factors.

For example, for the intermediate-goods-based growth model, a social planner chooses $\{c_t, l_t, h_{t+1}, k_{t+1}, t \geq 0\}$ to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma} - 1}{1-\sigma},$$

subject to

$$a_t k_t^{\alpha} \left[(1-l_t)h_t\right]^{1-\alpha} = c_t + k_{t+1} - (1-\delta)k_t,$$
$$h_{t+1} = (1+\rho_h l_t)h_t.$$

Here we assume that $\log a_t$ has an AR(1) representation:

$$\log a_t = (1-\gamma_a)\log a + \gamma_a \log a_{t-1} + \varepsilon_{at},$$

in which $|\gamma_a| < 1$, and ε_{at} is a white noise with mean zero and variance σ_a^2. The Pareto optimal allocation of k_{t+1}, h_{t+1}, c_t and l_t must satisfy the necessary first-order conditions for any realization of a_t:

$$c_t^{-\sigma} a_t k_t^{\alpha}\left[(1-l_t)h_t\right]^{-\alpha} = \beta(1+\rho_h)E_t\left\{c_{t+1}^{-\sigma} a_{t+1} k_{t+1}^{\alpha}[(1-l_{t+1})h_{t+1}]^{-\alpha}\right\},$$
$$c_t^{-\sigma} = \beta E_t\left(c_{t+1}^{-\sigma}\left\{\alpha a_{t+1} k_{t+1}^{\alpha-1}[(1-l_{t+1})h_{t+1}]^{1-\alpha} + 1 - \delta\right\}\right),$$
$$a_t k_t^{\alpha}\left[(1-l_t)h_t\right]^{1-\alpha} = c_t + k_{t+1} - (1-\delta)k_t.$$

Since both c_t and k_t contain an upward trend induced by h_t, we transform the above conditions in an alternative stationary form. Let $\tilde{x}_t \equiv x_t / h_t$, for any random variable x_t. Then we have the following stationary representations:

$$\tilde{c}_t^{-\sigma} = \beta E_t\left\{[\tilde{c}_{t+1}(1+\rho_h l_t)]^{-\sigma}[\alpha a_{t+1}\tilde{k}_{t+1}^{\alpha-1}(1-l_{t+1})^{1-\alpha} + 1 - \delta]\right\}, \tag{5}$$

$$\tilde{c}_t^{-\sigma} a_t \tilde{k}_t^{\alpha}(1-l_t)^{-\alpha} = \beta(1+\rho_h)E_t\left\{[\tilde{c}_{t+1}(1+\rho_h l_t)]^{-\sigma} a_{t+1}\tilde{k}_{t+1}^{\alpha}(1-l_{t+1})^{-\alpha}\right\}, \tag{6}$$

$$(1+\rho_h l_t)\tilde{k}_{t+1} = a_t \tilde{k}_t^{\alpha}(1-l_t)^{1-\alpha} - \tilde{c}_t + (1-\delta)\tilde{k}_t. \tag{7}$$

Imposing $\sigma_a^2 = 0$, then $a_t = a$ and equations (5)-(7) imply a set of restrictions on the non-stochastic steady state values of l_t, $\tilde{c}_t$ and $\tilde{k}_t$ denoted l, $\tilde{c}$ and $\tilde{k}$, respectively:

$$\beta(1+\rho_h l)^{-\sigma}\left[a\alpha\tilde{k}^{\alpha-1}(1-l)^{1-\alpha}+1-\delta\right]=1, \tag{8}$$

$$\beta(1+\rho_h)(1+\rho_h l)^{-\sigma}=1, \tag{9}$$

$$(1+\rho_h l)\tilde{k}-a\tilde{k}^{\alpha}(1-l)^{1-\alpha}+\tilde{c}-(1-\delta)\tilde{k}=0. \tag{10}$$

From equations (8)-(10), we can determine unique values of l, $\tilde{k}$, and $\tilde{c}$ in terms of structural parameters in preferences and technology. First, from equation (9), we have l in terms of β, ρ_h and σ:

$$l=\frac{\left[\beta(1+\rho_h)\right]^{1/\sigma}-1}{\rho_h}.$$

Once we have the value of l, the non-stochastic steady state growth rate of output can be obtained from the specification of h_t in equation (4):

$$g_h=\left[\beta(1+\rho_h)\right]^{1/\sigma}-1.$$

Unlike the neoclassical growth model, the value of g_h is determined by the structural parameters in the representative household's preferences, σ, β and ρ_h. It remains to determine the value of $\tilde{k}$ and $\tilde{c}$. Note that the non-stochastic steady-state real interest rate denoted r is given by

$$r=\left[a\alpha\tilde{k}^{\alpha-1}(1-l)^{1-\alpha}+1-\delta\right]-1.$$

It is clear from equations (8) and (9) that r must satisfy $r=\rho_h$. Then the above expression of r yields $\tilde{k}$ in terms of structural parameters in preferences and technology. Finally, we substitute the resulting expressions of l and $\tilde{k}$ into equation (10) and have the value of $\tilde{c}$.

According to Jones and Manuelli (1990), one sufficient condition for the sustained long-run growth in per capita output is

$$\beta\left[a\alpha\tilde{k}^{\alpha-1}(1-l)^{1-\alpha}+1-\delta\right]>1.$$

It is clear from equations (8) and (9) that the sufficient condition is satisfied as long as $\beta(1+\rho_h)>1$.

Define $c_t^*\equiv\log\tilde{c}_t-\log\tilde{c}$, $k_t^*\equiv\log\tilde{k}_t-\log\tilde{k}$, $l_t^*\equiv\log l_t-\log l$, and $a_t^*\equiv\log a_t-\log a$. Then we apply the certainty equivalence principle to obtain the log-linear approximation of equations (5)-(7) around c_t^*, k_t^*, l_t^* and a_t^*:

$$\sigma\left(E_t c_{t+1}^*-c_t^*\right)+(1-\alpha)\phi_0 k_{t+1}^*+\frac{(1-\alpha)l}{1-l}\phi_0 E_t l_{t+1}^*+\frac{\sigma\rho_h l}{1+\rho_h l}l_t^*-\phi_0 E_t a_{t+1}^*=0, \tag{11}$$

$$\sigma\left(E_t c_{t+1}^* - c_t^*\right) - \alpha\left(k_{t+1}^* - k_t^*\right) - \frac{bl}{1-l}\left(E_t l_{t+1}^* - l_t^*\right) + \frac{\sigma\rho_h l}{1+\rho_h l} l_t^* - E_t a_{t+1}^* + a_t^* = 0, \qquad (12)$$

$$\phi_1 c_t^* + \phi_2 k_{t+1}^* - (\alpha+\phi_3) k_t^* + \left[\phi_4 + \frac{(1-\alpha)l}{1-l}\right] l_t^* - a_t^* = 0, \qquad (13)$$

in which coefficients, $\phi_0, \ldots, \phi_4$, are non-linear functions of structural parameters in preferences and technology:

$$\phi_0 = \frac{\rho_h + \delta}{1+\rho_h},$$
$$\phi_1 = 1 - \frac{\alpha(\delta + \rho_h l)}{\rho_h + \delta},$$
$$\phi_2 = \frac{\alpha(1+\rho_h l)}{\rho_h + \delta},$$
$$\phi_3 = \frac{\alpha(1-\delta)}{\rho_h + \delta},$$
$$\phi_4 = \frac{\alpha \rho_h l}{\rho_h + \delta}.$$

Equations (11)-(13) are the system of expectational linear difference equations of $c_t^*, k_t^*,$ and l_t^*. We substitute out c_t^* and l_t^* in equations (11)-(13) to yield the following third-order linear expectational difference equation of k_t^*:

$$E_t\left[(1-m_1 L)(L^{-1} - m_2)(L^{-1} - m_3) k_{t+1}^*\right] = m_4 a_t^*,$$

in which $m_1, \ldots, m_4$ are non-linear functions of structural parameters and L is the lag operator with $L^j k_t^* \equiv k_{t-j}^*$. In particular, we have $m_1 = \alpha(1+\rho_h)/\left[\alpha + \rho_h + \delta(1-\alpha)\right]$, $m_2 = 1 + \tilde{c}/\left[(1+\rho_h l)\tilde{k}\right]$, and $m_3 = (1+\rho_h)/(1+\rho_h l)$. It is straightforward to show that $0 < m_1 < 1, m_2 > 1$ and $m_3 > 1$. The stationarity requirement of k_t^* forces us to solve the two unstable roots, m_2 and m_3, forwards, and the stable root, m_1, backwards. After some algebra, we have the closed-form solution of k_{t+1}^*:

$$k_{t+1}^* = m_1 k_t^* + E_t\left[\frac{m_4 a_t^*}{m_2 m_3 (1 - m_2^{-1} L^{-1})(1 - m_3^{-1} L^{-1})}\right].$$
$$= m_1 k_t^* + \frac{m_4}{(m_2 - \gamma_a)(m_3 - \gamma_a)} a_t^*.$$

Using the fact that $\log l_t = \log l + l^{-1}(l_t - l)$, the log-linear approximation of production function in equation (1) gives the following expression of demeaned output growth rate denoted z_t:

$$z_t \equiv \log y_t - \log y_{t-1} - g_h$$
$$= a_t^* - a_{t-1}^* + \alpha\left(k_t^* - k_{t-1}^*\right) - \frac{(1-\alpha)l}{1-l}\left(l_t^* - l_{t-1}^*\right) + \rho_h l_{t-1} - g_h.$$

Finally, from equations (11)-(13) and the closed-form solution of k_{t+1}^{*}, the transitional path of z_t can be solved as

$$z_t - \mu_1 z_{t-1} - \mu_2 z_{t-2} = \mu_3 \varepsilon_{at} + \mu_4 \varepsilon_{a,t-1} + \mu_5 \varepsilon_{a,t-2}, \tag{14}$$

in which

$$\mu_1 = m_1 + \gamma_a,$$
$$\mu_2 = -m_1 \gamma_a,$$

μ_3, μ_4 and μ_5 are non-linear functions of structural parameters.[3] It is clear from (14) that m_1 and γ_a represent the characteristic roots of the AR component in the ARMA(2,2) representation. m_1 characterizes endogenous dynamics in the endogenous growth model, while γ_a represents the exogenous dynamics induced by the AR(1) representation of a_t. Since m_1 depends on the value of capital share (α), we can evaluate the transitional dynamic effects of physical capital accumulation by varying the value of α.

One salient feature of this solution procedure is that dynamic properties of output growth rate can be fully explored without relying on the observability assumption of h_t. That is, the time-series representation of transitional path encompasses various interpretations of h_t as long as h_t satisfies the specification in (4). Finally, the time-series representation of transitional path depend on the specification of exogenous stochstic shocks. For example, if a_t is white noise $(\gamma_a = 0)$, then time-series representation of z_t becomes an ARMA(1,2) representation. In general, when the exogenous productivity shock (a_t) is an AR(*p*) representation with $p \geq 1$, the time-series representation of z_t is an ARMA$(p+1, p+1)$ representation.

For the neoclassical growth model, we apply the similar solution procedure to obtain the following time-series representation of k_{t+1}^{*}:

$$k_{t+1}^{*} = s_1 k_t^{*} + s_0 a_t^{*} - e^{-g_h} \varepsilon_{h,t+1}.$$

Here s_1 represents the stable characteristic root in the AR component in the noeclassical growth model, and s_0 is a non-linear functions of structural parameters. Taking the natural logrithm of both sides in (1) gives

$$\log y_t - \log h_t = \log a_t + \alpha(\log k_t - \log h_t),$$

and then substituting the closed-form solution of k_{t+1}^{*} into the above equation yields the growth rate of demeaned output:

[3] For the complete description of the solution procedure can be obtained upon the request from the authors.

$$z_t - \theta_1 z_{t-1} - \theta_2 z_{t-2}$$
$$= \varepsilon_{at} + w_1 \varepsilon_{a,t-1} + w_2 \varepsilon_{a,t-2} + w_0' \varepsilon_{ht} + w_1' \varepsilon_{h,t-1} + w_2' \varepsilon_{h,t-2}, \tag{15}$$

in which

$$\theta_1 = s_1 + \gamma_a,$$
$$\theta_2 = -s_1 \gamma_a,$$
$$w_1 = (\alpha s_0 - s_1) - 1,$$
$$w_2 = -(\alpha s_0 - s_1),$$

and w_i', for $i = 0,1,2$, are non-linear functions of structural parameters. Both ε_{at} and ε_{ht} enter (15) as innovations in the time-series representation of transitinal dynamics. Since they are serially uncorrelated random variables, the time-series representation in (15) also implies an ARMA(2,2) representation for z_t.

As in the intermediate-goods-based models of endogenous growth, the time-series representation of z_t is also ARMA$(p+1, p+1)$ model when the exogenous productivity shock (a_t) is an AR(*p*) process with $p \geq 1$. However, from the coefficients in the AR components of z_t in (14) and (15), it is clear that even though the neoclassical growth model and the intermediate-goods-based growth model have the same exogenous dynamics characterized by γ_a, they have different endogenous dynamics characterized by m_1 and s_1, respectively. If a growth model is used to characterize actual growth experience, the theoretical ARMA representation of transitional path must be consistent with the ARMA counterpart implied by the actual growth path. The above results suggest that the time series facts may discriminate between these two growth models due to different sets of restrictions.

Finally, suppose that the exogenous technical progress follows a linear deterministic trend, that is, $\varepsilon_{ht} = 0$, for all *t*. Equation (15) becomes

$$z_t - \theta_1 z_{t-1} - \theta_2 z_{t-2} = \varepsilon_{at} + w_1 \varepsilon_{a,t-1} + w_2 \varepsilon_{a,t-2}.$$

As displayed in the expressions of w_1 and w_2, there is a unit root in the MA component: $1 + w_1 + w_2 = 0$. Then equation (15) is further collapsed to an ARMA(2,1) representation:

$$y_t^* - \theta_1 y_{t-1}^* - \theta_2 y_{t-2}^* = \varepsilon_{at} + w_2 \varepsilon_{a,t-1},$$

in which $y_t^* = \log y_t - \log h_t - \log \tilde{y}$ and $\tilde{y}$ is the steady state value of $\tilde{y}_t$. This model has been studied by King and Rebelo (1993). Since $\log h_t$ exhibits a linear deterministic trend, the appropriate stationarity inducing procedure is to remove the trend component: $\log h_0 + g_h t$ from $\log y_t$. Note that the characteristic roots in the AR component are identical across different trend specifications of technical progress. That is, physical capital accumulation in the neoclassical model generates the same endogenous dynamics both for z_t with the random-walk specification of h_t and for y_t^* with the linear deterministic trend specification of h_t. However, the two trend specifications of h_t

imply different stationarity inducing procedure and have different ARMA representations.

It is clear from the solution procedure that the time-series representation of output growth rate depends on the specification of either technical progress or the reproducible factor in equation (1). Growth in the two types of growth model can arise for the following two reasons. First, there is the nonstochastic steady-state growth associated with the technical progress in the neoclassical growth model or the reproducible factor in the endogenous growth model. Second, there is transitional growth associated with movement from an initial capital stock toward the steady-state growth path. Here the transitional path is determined by the exogenous productivity shock (a_t) and physical capital accumulation. Hence, the discussion of properties of transitional growth can be misleading when we ignore information contained in the nonstochastic steady state growth in the derivation of the time-series representation of transitional growth.

4. The role of capital accumulation in economic growth

In this section, we present evidence on the empirical significance of exogenous and endogenous growth models in Japan, South Korea, Taiwan and the U.S. and provide growth-accounting exercises in the general equilibrium framework. More precisely, we evaluate the role of physical capital accumulation in economic growth and development by varying the value of capital share in estimation. Such an exploration can help us understand whether capital fundamentalism should guide public policy recommendations and research strategies.

A growth model is to be used as a description of actual growth and development experiences, the theoretical ARMA representation of transitional path must be consistent with its estimated counterpart. Here we use the statistical selection criterion to choose the optimal lag length in the ARMA representation of output growth rate, and verify if the theoretical lag lengths in various exogenous and endogenous growth models can be consistent with the selected ones.

In Section 3, we derived that different growth models imply different sets of restrictions on structural parameters. To evaluate the statistical significance of various models, we use the exact maximum likelihood method to estimate structural parameters in various growth models and test whether or not the set of restrictions implied by growth models holds. This also allows us to answer the question if there are rich enough time-series characteristics to discriminate between new and old growth models.

To achieve identification, the value of capital share must be given a priori. It in turns justifies our growth-accounting exercises in the general equilibrium framework. Suppose that growth models hold. If the impact on the statistical performance of models is not significant by varying the value of capital share, then the physical capital accumulation cannot play an important role in accounting for transitional paths under current specifications. Therefore, capital fundamentalism should not be revived as the guideline of research and policy prescription.

4.1 Time series evidence on output growth rates

The countries involved are Japan, South Korea, Taiwan and the U.S. South Korea and the U.S. real GDP and Japan real GNP series were taken from *International Financial Statistics*, while Taiwan real GDP series were taken from *National Income Accounts, Taiwan*. We divide real total output by total population to construct the per capita real output. All data are annual series. The sample period is 1952-1995 for Taiwan, 1953-1994 for Japan, 1949-1995 for U.S., and 1954-1994 for South Korea.

Figures 1-2 display the graphic description of the logarithm of per capita real output series for the four countries. We also plot the growth rate of per capita real output and the per capita real output with linear time trend removed. When technical progress exhibits a linear deterministic trend, removing linear deterministic trend from the log of per capita real output before estimation is the required stationarity-inducing procedure. As discussed in Section 3, the physical capital accumulation in the neoclassical growth model implies similar endogenous dynamics for both the per capita real output growth rate (z_t) and the logarithm of per capita real output series with linear trend removed (y_t^*). Another dynamics is induced by the AR(1) representation of a_t in the productivity shock. When z_t and y_t^* have similar dynamics, then we say that the neoclassical growth model is consistent with actual output growth experience. Visual inspections of Figure 2 reveal that the neoclassical growth model only receive some supports from the U.S. data series. For the other three countries, we need very different exogenous dynamics induced by a_t to account for very different dynamics between z_t and y_t^*.

For Japan and South Korea output series, both linear time trend residuals and annual growth rates display different time series characteristics. There was a structural break in the mean of annual growth rate around 1962 as clearly revealed in panels A and C of Figure 2. The mean shift also occured around 1970 in Taiwan. On the other hand, the U.S. growth rates appear to fluctuate around a constant mean for the entire sample period. Formal testing results for a single endogenously chosen mean shift in growth rates are reported in Table 1. Testing result supports the null hypothesis that U.S. growth rates are well described by a stochastic process with a constant mean and little persistence. However, there was significant evidence against the null hypothesis in Japan, South Korea and Taiwan. Output growth rates fluctuate around two different means in the entire sample period for these three countries. It will be difficult to test the steady state properties of growth models using the per capita real output series in these three countries.

According to steady state properties in endogeous growth models, one testable implication is that the economic variables highlighted by endogenous models as the determinant of the steady state growth rate must have the similar time series properties of per capita output growth rates. For example, Jones (1995) found that the persistence of economic variables is not consistent with that of real output growth rates, and concluded that many *Ak* and R&D-based growth models are rejected. When the sample period is extended from 1987 back to 1870, the U.S. growth rates still fluctuate around a constant mean for extended period. However, Japanese output growth rates apparently fluctuate around a constant mean until World War II but after the war they jump upward and then decline slowly over subsequent years. The above evidence indicates that the time series properties of output growth rates sensitively depend on the sample period chosen. Hence, the statistical rejection in Jones (1995) only suggested that it is not appropriate to directly test the steady state implications of growth models. The ARMA representation of the per capita real output growth obtained in Section 3 characterizes the transitional paths. Hence, it is more appropriate to be used in the evaluation of various model along the transitional paths.

To select the optimal lag length for the AR and MA components in the ARMA representation of transitional path, we apply the Akaike's information criterion (AIC) to the per capita real output series in the four countries. For the annual growth rate of per capita real output (z_t), we concluded from Table 2 that 1) Both Japan and Taiwan data series admit a parsimonious ARMA(1,1) model. 2) South Korea data series is well represented by an ARMA(1,2) model. 3) U.S. data series can be represented by an ARMA(2,1) model. Results in Section 3 show that different specifications of exogenous stochastic shocks (a_t) give different time-series representations of transitional paths. If the theoretical ARMA representation of growth rates describes the time series facts, then a useful growth model is the one that likewise delivers an ARMA representation of the data. Given the above results on lag length, we cannot find any specifications of a_t so that the theoretical ARMA representation of transitional path are consistent with the growth and development experiences in Japan, Taiwan and the U.S. However, for the South Korea both neoclassical and endogenous growth models can deliver a consistent implication for the ARMA representation when a_t is assumed to follow a white noise process.

For the per capita output series with linear time trend removed, the AIC results can be summarized as follows. 1) The ARMA(1,1) model is a good description of Taiwan series. 2) South Korea series are well represented by an ARMA(2,1) model. 3) The ARMA(2,2) model well describe the Japan data series. 4) The ARMA(1,2) model well describe the U.S. data series. Apparently, when the technical progress is assumed to be a linear deterministic time trend, the neoclassical growth model receives supports in Taiwan and South Korea.

Straightforward comparisons of the theoretical lag length and its empirical counterpart indicated that growth models specifications cannot obtain the lag length observed in the actual growth experience. These comparisons only offer informal evaluation of the model performance. Since different growth models also impose different sets of restrictions, we need to explore these restrictions and formally evaluate the model performance. To do this, notice that most of dynamic characteristics of output growth rates seem to be satisfactorily represented by relatively low order ARMA models, and that different stationarity inducing procedures imply different ARMA representations. We take these findings to be the facts of transitional paths in formal evaluations.

4.2 Estimating structural parameters in growth models

Here we use the exact likelihood function in estimation. Even though the timedomain and frequency-domain approximations of the likelihood function have been widely used in the estimation of ARMA models, we shall use the computationally burdensome exact likelihood function in estimation for the following reasons. First, Newbold (1974) argued that when either the AR component or the MA component has a root near one, or the sample period is not long enough, the estimation results cannot be accurate. Second, Phadke and Kedem (1978) also argued that when the MA component has a root near one, parameter estimates using the exact likelihood function have smaller mean square errors than those obtained using the approximation methods.

Given a set of structural parameters denoted Θ, we first obtain the theoretical covariance matrix for z_t denoted $\Sigma(\Theta)$. Here $\Sigma(\Theta)$ is a $T \times T$ symmetric matrix in which T is the number of observations in z_t series. Let $Z_T = (z_1, z_2 \cdots, z_T)$ be the $T \times 1$ column vector of T observations of z_t. Then the exact likelihood function can be expressed as

$$-\frac{T}{2}\log 2\pi - \frac{1}{2}\log\det\left[\Sigma(\Theta)\right] - \frac{1}{2} Z_T' \Sigma(\Theta)^{-1} Z_T.$$

Here the dimension of $\Sigma(\Theta)$ increases with the sample size. We find an maximum liklihood estimate of Θ to maximize the exact likelihood function. Given the AR(1) specification of a_t and the random-walk with drifts specification of h_t, both exogenous and endogenous growth models imply the ARMA (2,2) representation of z_t. For the identification, we impose the values of the following structural parameters a priori: the constant discount rate (β), the constant depreciation rate (δ), the capital share (α), and the maximal growth rate of h_t in the endogenous growth model (ρ_h) and the expected growth rate of h_t in the neoclassical growth model (g_h). Hence the set of structural parameters under consideration is $\Theta_1 = \{\sigma, \gamma_a, \sigma_a^2\}$, and $\Theta_2 = \{\sigma, \gamma_a, \sigma_a^2, \sigma_h^2\}$, for the endogenous growth model and the neoclassical growth model, respectively.

Let L_u be the value of the log likelihood function as its maximum for the unrestricted ARMA (2,2) model of per capita output growth rate and L_r the maximum value of the log likelihood function for the ARMA (2,2) under alternative sets of restrictions incorporated in (14) for the endogenous growth model or in (15) for the neoclassical growth model. Then $-2(L_r - L_u)$ is asymptotically distributed as $\chi^2(n)$, where *n* is the number of restrictions imposed by the model. High values of the likelihood ratio lead to rejecting the restrictions.

Before estimating structural parameters and conducting growth accounting exercises, we estimate the unrestricted ARMA(2,2) model for the per capita real output growth rate. For the annual output growth rate in each of the four countries, we present in panel 3 of Table 2 coefficient estimates of the unrestricted ARMA(2,2) model. The similarities and differences of the four series are apparent here. The ARMA(2,2) representation of Japanese and U.S. per capita growth rate has an insignificant moving average coefficient at the lag two. On the other hand, the ARMA(2,2) representation of South Korean and Taiwanese per capita growth rate has significant MA coefficients.

Now we conduct the likelihood ratio test for the restricted ARMA (2,2) model against the unrestricted counterpart in the four countries. Two general findings from Table 3 are worth mentioning. First, the implied value of the stable (characteristic) root in the AR component (m_1 in the endogenous growth model and s_1 in the neoclassical growth model) increases with the assigned value of α. As shown in Section 3, the empirical importance of physical capital accumulation in transitional growth can be characterized by the stable root. Second, the value of the χ^2 statistic declines slightly as the assigned value of capital share increases in the two types of growth models for Japan, South Korea and Taiwan. These results suggest a much smaller role for physical capital accumulation in growth than that advocated by capital fundamentalism. On the other hand, with regard to the U.S. data, the χ^2 statistic decreases with an increase in α in the neoclassical growth model, but it increases with an increase in α in the endogenous growth model. This suggests that the role of physical capital accumulation even diminishes when we allow for the additional reproducible factor in the production function. Hence, if the our discussion is restricted on the empirical significance of physical capital accumulation along transitional growth in the framework of the neoclassical growth model, then the resulting implications could be misleading.

According to the χ^2 statistic reported in Table 3, several country-specific findings are apparent. First, the set of cross-equation restrictions implied by the neoclassical growth model is rejected at the 5% significance level in Japan. Second, we did not have any significant evidence against the set of cross-equation restrictions imposed either by the endogenous growth model or by the neoclassical growth model in the three other countries. Third, for Japan and South Korea, the empirical evidence yields more support for the intermediate-goods-based endogenous growth model than for neoclassical growth model. Fourth, in the U.S. data series, the neoclassical growth model receives more support than the endogenous growth model does. Fifth and finally, for Taiwan, there is an almost identical statistical performance between the two models.

4.3 Growth accounting in the general equilibrium framework

In this subsection, we conduct the growth accounting exercises in a general equilibrium framework. The ARMA representation of output growth rate allows us to explore how transitional dynamics depend on parameters of preference, production technology and exogenous shocks. As noted above, the value of capital share in production function must be given a priori as an identifying assumption. Hence, we can vary the value to trace its dynamic effects on output growth as growth accounting exercises.

We propose to use *L/L'* as a measure of the empirical significance of physical capital accumulation in accounting for the transitional path of output growth rate. Here *L* (*L*') denotes the maximum value of likelihood function with either $\rho_h \neq (=) 0$ in the engoneous growth model or $g_h \neq (=) 0$ in the neoclassical growth model. The value of *L*' measures the model performance without either the technical progress or the additional reproducible factor. Therefore, it measures the empirical significance of physical capital accumulation along transitional dynamics. We expect that *L/L'* is greater than or equals one. When $L/L'=1$, the exogenous technical progress in the neoclassical growth model or the accumulation of reproducible factor did not play any significant role in transitional dynamics.

According to Table 3 as the value of capital share increases, the value of *L/L*' only decreases slightly in the four countries. That is, physical capital accumulation takes a slightly more important role in the transitional growth when neither technical progress nor the additional reproducible factor are allowed in the model. Generally, it is a much smaller role than that is required by capital fundamentalism.

We found that the physical capital accumulation plays a significant role in the U.S. transitional path of output growth. The model performance did not greatly improve even with the exogenous technical progress or the additional reproducible factor added to the model. This finding is consistent with that in Jorgenson et al. (1987). Comparisons of estimates of γ_a between the two types of growth model indicate that the additional reproducible factor enhances the role of physical capital accumulation. More precisely, the role of exogenous productivity shock (a_t) reduces significantly once we incorporate the additional reproducible factor into the growth model. On the other hand, the technical progress or the additional reproducible factor play an more important role in accounting for transitional growth in Japan as the value of *L/L*' varying between 1.346 and 1.229. Generally, the additional reproducible factor enhances the empirical significance of physical capital accumulation in transitional growth in Japan. For example, the estimated stable root increased from 0.242 to 0.798 when the value of α is pre-specified at 0.35 in Japan. This finding is consistent with Mankiw et al. (1992) who show that the introduction of human capital in production can enhance the role of physical capital accumulation.

As revealed by the value of *L/L*' in Table 3, both the technical progress and the reproducible factor played a significant role in the development process of Taiwan and South Korea. Our findings are contrary to results in recent research. Young (1995) emphasized the fundamental role of factor accumulation in explaining the extraordinary postwar growth of four East Asian NICs. The region's growth was largely achieved through heavy investment and a big shift of labor from farms into factories rather than through technical progress or organizational changes. Kim and Lau (1994, 1995) also found that capital accumulation is the most important source of economic growth in the East Asian NICs.

The intertemporal substitution elasticity $(1/\sigma)$ is another crucial determinant in transitional dynamics. Estimates of σ became significantly larger in the endogenous growth model than in the neoclassical growth model in both Japan and South Korea. With less intertemporal substitution in preference, agents choose smoother consumption profiles and hence smaller investment. As a result, output grows much more slowly. Since the technical progress did not enhance the role of physical capital accumulation in transitional dynamics, the persistence of transitional growth did not leave much room for the stable root (s_1) to capture, and therefore the estimate of σ must stay at a low value.

On the other hand, the endogenous and exogenous dynamics characterized by m_1 (or s_1) and γ_a switched their relative importance between the two types of growth model in both Taiwan and the U.S. Hence, we found that the estimate of σ stays relatively constant between the two types of model. Nevertheless, we did not find lengthly transitional paths in the four countries.

Recently, King and Rebelo (1993) conducted dynamic simulations to learn about the quantitative transitional dynamics in various neoclassical growth models with intertemporally optimizing households. They parameterize the model parameters and generate the "time-series data" from the closed-form solution, and compare a selective set of second-moment properties of the generated data with those of actual series with the trend removed in evaluating the performance of the model. They found that very low intertemporal substitution in preference in order to generate the "time-series facts", which is not consistent with our findings.

5. Concluding Remarks

Recent researches in growth accounting have reinstated capital fundamentalism at the forefront of economic analysis and policy discussions. The development of new growth theory suggests that the importance of capital accumulation can be enhanced either by the introduction of additional reproducible input factor like human capital or by externalities. However, based upon the growth accounting conducted in this paper, we found a much smaller role for physical capital accumulation in growth than that advocated by capital fundamentalism. There is little support for the view that capital fundamentalism should guide research agenda and policy advice at least in the four countries. Moreover, there is little reason to believe that our empirical findings could provide any positive evidence that increasing investment will cause faster growth.

Since the additional reproducible factor can enhance the role of physical capital accumulation in transitional growth, we hope that future research into the economic, institutional determinants underlying this factor will improve our ability to design policies that promote sustained economic growth.

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Table 1: The statistical properties of growth rates

	Japan	South Korea	Taiwan	USA
	I. Endogenous mean shift			
1. Mean shift date	1962	1962	1970	1973
2. Coefficient	2.454	5.699	-4.963	-0.976
3. F test statistic	6.611*	22.702*	52.481*	1.885
	(0.014)	(0.000)	(0.000)	(0.177)
	II. Unit root tests			
ADF test statistic	-1.217**	-2.252**	-3.475	-3.831

Note:
The Mean shift is taken from Bai, Lumsdaine and Stock (1991). The following equation is estimated: $z_t = \alpha + \beta I_{[t>T^*]} + \varepsilon_t$, in which I is an indicator that takes the value one for $t > T^*$.
* Significant at the 5% level for the F-ratios.
** Reject the null hypothesis that there is no unit root.

Table 2: The Empirical Results for Reduced-form ARMA Models

ARMA (*p*, *q*)	Japan	South Korea	Taiwan	USA
I. The selection of lag length (*p, q)* in ARMA models (using AIC)				
1. Annual growth rate of per capita output (z_t)				
ARMA (1, 1)	-188.75*	-145.90	-190.96*	-211.60
ARMA (1, 2)	-187.42	-148.40*	-189.55	-214.13
ARMA (2, 1)	-187.03	-148.36	-189.69	-214.75*
ARMA (2, 2)	-186.90	-147.98	-187.70	-212.76
2. Residuals with linear time trend removed (y_t^*)				
ARMA (1, 1)	-184.92	-150.71	-199.34*	-224.43
ARMA (1, 2)	-185.50	-151.02	-197.69	-224.49*
ARMA (2, 1)	-193.33	-157.96*	-199.26	-223.45
ARMA (2, 2)	-196.24*	-156.03	-198.46	-222.50
II. Estimates of ARMA (2, 2) model: $z_t - \alpha_1 z_{t-1} - \alpha_2 z_{t-2} = e_t + \beta_1 e_{t-1} + \beta_2 e_{t-2}$				
α_1	0.006	1.877	0.419	1.020
	(0.238)	(0.049)	(0.139)	(0.383)
α_2	0.715	-0.972	0.484	-0.288
	(0.124)	(0.042)	(0.139)	(0.333)
β_1	0.640	-1.863	0.000	-0.960
	(0.289)	(0.135)	(0.100)	(0.408)
β_2	-0.360	1.000	-1.000	-0.040
	(0.279)	(0.141)	(0.099)	(0.399)

Note:
The Akaike Information Criterion (AIC) selects the model for which AIC= $-2\log L + 2(p+q+1)$ is a minimum. Here L is the value of likelihood function. We estimate ARMA model using the maximum exact likelihood estimation.
*means the minimal AIC.
Number in parenthesis is the standard deviation of coefficient estimates.
Data Source: See Section 4 for description.

Table 3: Estimates in various growth models

α	σ	γ_a	σ_a^2	σ_h^2	stable root	χ^2	L / L'
					I. Japan		
					1. neoclassical growth model		
0.35	0.010	0.998	0.001	3e-5	0.242	10.490*	1.293
0.40	0.010	0.997	0.001	0.000	0.285	8.604*	1.259
0.45	0.014	0.996	0.001	0.000	0.384	7.034*	1.229
					2. endogenous growth model		
0.35	0.091	0.948	5e-4		0.798	2.062	1.346
0.40	0.092	0.938	5e-4		0.830	1.906	1.303
0.45	0.091	0.926	5e-4		0.857	1.818	1.262
					II. South Korea		
					1. neoclassical growth model		
0.35	0.123	0.982	0.001	3e-5	0.645	2.568	1.241
0.40	0.142	0.979	0.001	7e-6	0.700	2.162	1.212
0.45	0.172	0.976	0.001	4e-5	0.754	1.848	1.184
					2. endogenous growth model		
0.35	0.200	0.938	0.001		0.798	1.532	1.249
0.40	0.208	0.930	0.001		0.830	1.384	1.218
0.45	0.212	0.922	0.001		0.857	1.288	1.188
					III. Taiwan		
					1. neoclassical growth model		
0.35	0.010	0.907	0.001	3e-6	0.246	3.800	1.396
0.40	0.010	0.881	0.001	0.000	0.285	3.680	1.353
0.45	0.010	0.869	0.001	4e-6	0.330	3.680	1.312
					2. endogenous growth model		
0.35	0.019	0.427	7e-4		0.798	4.106	1.394
0.40	0.010	0.321	7e-4		0.830	3.854	1.352
0.45	0.010	0.342	7e-4		0.857	3.742	1.312
					IV. USA		
					1. neoclassical growth model		
0.35	0.012	0.722	4e-4	3e-6	0.267	0.760	1.078
0.40	0.011	0.704	4e-4	6e-6	0.307	0.652	1.076
0.45	0.010	0.681	4e-4	1e-5	0.332	0.568	1.075
					2. endogenous growth model		
0.35	0.010	0.239	5e-4		0.798	1.188	1.076
0.40	0.010	0.260	5e-4		0.830	1.742	1.070
0.45	0.010	0.281	5e-4		0.857	2.310	1.066

Note:

In estimation, we set the values of following parameters as follows: $\beta = 0.96$, $\delta = 0.1$, $\rho_h = 0.042$ and $g_h = 0.025$, and assign α to 0.35, 0.40 and 0.45.

* Significant at the 5% level for χ^2 test.

L denotes the value of likelihood function with $\rho_h \neq 0$ or $g_h \neq 0$ and L' denotes the value of likelihood function with $\rho_h = 0$ or $g_h = 0$.