Does an Exogenous or an Endogenous Growth Model Fare Better? Evidence from the GDP growth rates of 24 OECD countries

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Abstract

This paper evaluates typical exogenous and endogenous growth models in light of their transitional dynamics implications. Rather than selecting a very special stochastic process of technology shock so as to match a specific output process, we assume only a simple AR transitory shock in both growth models. After deriving the growth rate of output under the two models, this paper tests the cross-equation restrictions for 24 OECD countries' output growth rates. We find all but one of the growth series pass the endogenous growth hypothesis. However, even with the transitional dynamics implications in both models, in 75% of the OECD countries the output dynamics are observationally equivalent between the endogenous and the exogenous growth models.

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1. Introduction

Identifying the driving force behind economic growth is of great importance both in the design of policy and for theoretical

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interest. It is well known today that, given a process for output, we can always choose an exogenous technology process which can match that output. Therefore, from a theoretical point of view, there is no way of telling exogenous and endogenous growth models apart based on the output process adopted. However, is such a complicated shock empirically plausible? Or are the implied structural parameters reasonable? If we assume a simple process for the transitory shock in both the exogenous and endogenous models and apply a standard structural model estimation to the data set, can we determine which of the growth models fares better for economic growth?

A number of recent studies have sought to employ time-series methods to evaluate growth theories because there exist many problems of cross-country regression method in finding the source of growth.[1] Evans (1996b) and Kocherlakota and Yi (1996) apply structural vector Autoregressions (AR) with long-run restrictions to distinguish endogenous from exogenous growth models.[2] Their intuition is that permanent (temporary) shocks have permanent effects on the output growth rate (output level) in an endogenous growth model, but have none in an exogenous growth model. Bernad and Durlauf (1995) and Evans (1996a, 1998) employ panel data to evaluate growth theories. Their basic idea is that an exogenous growth model implies stationary output differentials

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1 See Levine and Renelt (1992), Levine and Zervos (1993), and Evans (1996a) for example.

2 This approach uses sufficient long-run restrictions, a method popularized by Blanchard and Quah (1989), to discriminate between various growth models. However, Cooley and Dwyer (1998) prove that the long-run restriction approach could fail to identify structural dynamics correctly despite the data satisfying the long-run restrictions.

while an endogenous growth model implies nonstationary ones. However, Lau and Sin (1997) argued that it can be observational equivalence for the stochastic cointegration between output and capital stock implied by an endogenous growth model and an exogenous one.

All of the above studies focus on the steady-state implications of growth models. Since there is also transitional growth associated with an economy away from its steady state, the previous approach needs a complement. This paper proposes evaluating the growth theories in their transitional dynamics. A previous study by King and Rebelo (1993) chooses structural parameters and initial conditions for the capital stock and labor productivity in order to investigate quantitative transitional dynamics in neoclassical growth models. Eckstein et al. (1996), on the other hand, demonstrate that a closed-form log-linear representation of the dynamic laws of motion for the stocks of human and physical capital can be obtained in order to distinguish between different sources of growth. It can be shown that even though the endogenous growth model and the exogenous growth model have the same external dynamics, coming directly from our assumptions relating to the exogenous transitory shock, they have different internal dynamics characterized by their system's eigen values which are functions of the structural parameters.

In practice, one of the main difficulties with the transitional-dynamics approach is the unavailability of data series if we want to test a model rather than calibrate it. Economists do not have measures of some of the key state variables in growth models, such as the technology level, the stock of human capital, the stock of physical capital, or the quality of products, etc. To solve this problem, this paper follows Campbell's (1994) procedure towards obtaining a solution, which yields the explicit Autoregressive Moving Average (ARMA) representation of the output growth rate in various growth models that can have the same transitory shock. One striking feature of this procedure is that the dynamic properties of economic growth can be fully explored without relying on the availability assumption concerning the driving force behind growth.

The remainder of this paper is arranged as follows. Section 2 studies two types of growth model commonly used in the growth literature, one a standard exogenous growth model and the other a typical endogenous growth model. Assuming a simple autoregression (AR) process for a transitory productivity shock in both models, this paper then transforms the associated necessary first-order conditions to their stationary representations and derives the approximated time-series representations of the output growth rates for these models. Section 3 presents the time series evidence on the GDP growth rate in twenty-four OECD countries. The evaluation of these models includes examining the plausibility of the estimated parameters and testing the cross-equation restrictions of the two models. Doing this helps us answer the question as to whether, assuming the same transitory shock applies, an exogenous growth model or an endogenous one fares better in terms of output process? Section 4 concludes.

2. Two Growth Models

In this section two distinct growth models are introduced. The first of these is the neoclassical model of exogenous growth with technical progress, which is independent of economic agents' behavior. The second growth model is an endogenous one in which the source of growth is controlled by economic agents.

2.1 Specification of models

Assume that there is a representative consumer whose expected lifetime utility is given by:

$$E\left[\sum_{t=0}^{\infty}\beta^{t}\frac{C_t^{1-\sigma}-1}{1-\sigma}\middle| t\right],$$

in which C_t is consumption at time *t*, $E[x_t|s]$ denotes the conditional expectation of a variable x_t given information available at time *s*, parameter β is the discount factor, and σ is the coefficient of relative risk aversion.[3]

Secondly, consider a Cobb-Douglas production technology, which a representative firm produces with physical capital stock K_t, labor input $1-l_t$ and technology level E_t:

$$Y_t = a_t K_t^{\alpha}\left[E_t(1-l_t)\right]^{1-\alpha}, \tag{1}$$

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

Term E_t is the source of economic growth. In the neoclassical growth model, E_t is an exogenous technical progress that cannot be interpreted by any change related to input:

$$\ln E_t = g^{EX} + \ln E_{t-1} + \varepsilon_t^{E}, \tag{2}$$

[3] We simply assume no endogenous leisure. As shown in Ladron-de-Guevara et al. (1999), when leisure enters the utility function, one may encounter the problem of multiple steady states for an endogenous growth model.

in which g^{EX} is the expected growth rate of E_t and $\{\varepsilon_t^E\}$ is an i.i.d. $N(0, \sigma_E^2)$ sequence.[4]

In the new growth models, there is a shift in the formulation of technical progress. That is, technology is market-driven in an endogenous growth model. Therefore we may assume that the accumulation of E_t is characterized by

$$E_{t+1} = \rho K_t^{\varpi} (E_t l_t)^{1-\varpi} + (1-\delta^E)E_t, \tag{3}$$

in which ρ is a positive technology parameter, ϖ is the capital share in terms of the production of new technology, and δ^E is the rate of depreciation for E_t. Here E_t can be interpreted either as the number of intermediate inputs (Romer 1990), as the quantity of a fixed number of intermediate inputs (Grossman and Helpman 1991), or simply as human capital (Lucas 1988). For simplicity, let us assume further that the accumulation of E_t requires only labor and that there is no depreciation as far as the endogenous technology is concerned $(\varpi = \delta^E = 0)$.

The resource constraint in the endogenous growth model at time *t* is identical to that in the exogenous growth model and is given by

$$Y_t = C_t + K_{t+1} - (1-\delta)K_t,$$

in which δ is the rate of depreciation of the physical capital stock.

We solve both growth models by maximizing the utility of a representative economic agent. In the case of the exogenous growth model, the representative agent chooses $\{C_t,\ l_t,\ K_{t+1}\}$ for all $t \geq 0$ in order to maximize the expected value of his

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4 When $\sigma_E^2 = 0$, $\ln E_t$ exhibits a deterministic linear time trend.

intertemporal utility function. In the case of the endogenous growth model, the representative agent chooses $\{C_t,\ l_t,\ K_{t+1},\ E_{t+1}\}$ instead.

2.2 Steady state implications

The balanced growth condition implies the stationarity of Y_t/E_t, C_t/E_t and K_t/E_t in both the exogenous and endogenous growth models. However, for sustained growth of per capita output, the explanation offered by the neoclassical model is that technical progress is exogenous, and that the cross-country differences in the long-run economic growth rate are merely attributable to different g^{EX}s.

In the endogenous model without externalities, ρ is not only the maximal growth rate of E_t but also the steady-state real rate of interest (r). Assuming that $a_t = a$, $\forall t$, and the two inequality constraints $\beta(1+r) > 1$ and $\sigma > 1 + \ln\beta / \ln(1+r)$ hold in the endogenous growth model,[5] there exists one positive steady-state growth rate of output denoted by g^{EN}, where

$$g^{EN} = [\beta(1+\rho)]^{1/\sigma} - 1.$$

Unlike in the case of the neoclassical growth model, the value of g^{EN} is determined by the structural parameters in the representative household's preferences, σ, β and ρ.

2.3 Time series representation for growth rates of output

To show how the process of output growth rates is derived, this

5 These constraints guarantee the transversality condition of the problem to hold and the discounted value of the objective function to be bounded.

paper cites the endogenous growth model as an example. Without loss of generality, let us assume that $\ln a_t$ has the following AR(1) representation:

$$(1-\gamma_1 L)(\ln a_t - \ln a) = \varepsilon_t^a ,$$

in which $|\gamma_1| < 1$, L is the lag operator ($L^j x_t \equiv x_{t-j}$), and $\{\varepsilon_t^a\}$ is an i.i.d. $N(0, \sigma_a^2)$ sequence. Given that both C_t and K_t contain an upward trend induced by E_t, we transform the first-order conditions of the model into a stationary form. Let $x_t \equiv X_t / E_t$ for any upper-case letter variable X_t, and let us define $\hat{x}_t \equiv \ln(x_t / x)$ for any stationary variable x_t with unconditional mean x. We then have the closed-form solution of $\hat{k}_{t+1}$:

$$\hat{k}_{t+1} = \omega_1 \hat{k}_t + \omega_2 \hat{a}_t , \tag{4}$$

as well as the decision rule for $\hat{l}_t$ expressed as

$$\hat{l}_t = \omega_3 \hat{k}_t + \omega_4 \hat{a}_t , \tag{5}$$

in which ω_1,..., ω_4 are complex functions of structural parameters.[6]

Using the approximation that $\ln l_t = \ln l + l^{-1}(l_t - l)$, log-linear approximating the production function in equation (1) yields the following expression of a demeaned output growth rate, denoted by g_t,

[6] The mathematical derivation of equations (4) and (5) is available upon request.

$$g_t \equiv \ln Y_t - \ln Y_{t-1} - g^{EN}$$
$$= \hat{a}_t - \hat{a}_{t-1} + \alpha\left(\hat{k}_t - \hat{k}_{t-1}\right) - \frac{(1-\alpha)l}{1-l}\left(\hat{l}_t - \hat{l}_{t-1}\right) + \rho l_{t-1} - g^{EN}.$$

From the closed-form solution of $\hat{k}_{t+1}$ and $\hat{l}_t$, the transitional path of g_t can be solved as

$$g_t - \mu_1 g_{t-1} - \mu_2 g_{t-2} = \mu_3 \varepsilon_t^a + \mu_4 \varepsilon_{t-1}^a + \mu_5 \varepsilon_{t-2}^a, \tag{6}$$

in which

$$\begin{aligned}
\mu_1 &= \omega_1 + \gamma_1, \\
\mu_2 &= -\omega_1 \gamma_1, \\
\mu_3 &= 1 - (1-\alpha)l/(1-l)\omega_4, \\
\mu_4 &= \alpha\omega_2 - \omega_1 - 1 + \rho l \omega_4 + (1-\alpha)l/(1-l)[(1+\omega_1)\omega_4 - \omega_2\omega_3], \\
\mu_5 &= \rho l[(1-\omega_1)\omega_4 + \omega_2\omega_3] - (\mu_3 + \mu_4).
\end{aligned} \tag{7}$$

It is clear from (7) that ω_1 and γ_1 represent the characteristic roots of the AR component in the ARMA(2,2) representation of g_t. More specifically, term ω_1 characterizes internal dynamics in the endogenous growth model, while γ_1 represents the external dynamics induced by the AR(1) representation of productivity shock $\ln a_t$ in the model.

It is worth mentioning that the lag length in the time-series representation of g_t depends on the specification of the exogenous shocks. For example, if $\ln a_t$ is a white noise $(\gamma_1 = 0)$, then the time-series representation of g_t becomes an ARMA(1,2) model. If $\ln a_t$ follows a process of AR(2):

$$(1-\gamma_1 L)(1-\gamma_2 L)(\ln a_t - \ln a) = \varepsilon_t^a,$$

with $|\gamma_2| \le |\gamma_1| < 1$, then g_t follows an ARMA(3,3) process. In general, when the exogenous productivity shock $(\ln a_t)$ is an AR(p) representation with $p \ge 1$, the time-series representation of g_t is an ARMA$(p+1, p+1)$ representation.

Under the simplified assumption that $\ln a_t$ is AR(1) and that shock $\{\varepsilon_t^a\}$ is independent of $\{\varepsilon_{t+j}^E\}$ for all j, this paper applies a similar solution procedure to obtain the following time-series representation of $\hat{k}_{t+1}$ in the exogenous growth model:

$$\hat{k}_{t+1} = s_1 \hat{k}_t + s_2 \hat{a}_t - \varepsilon_{t+1}^E .$$

Here s_1 represents the stable characteristic root in the AR component of the exogenous growth model, and s_2 is a non-linear function of structural parameters.

Given that labor is useful merely in the final goods production process in the exogenous growth model and thus $l_t = 0$, taking the natural logarithm of both sides in (1) yields

$$\ln Y_t = \ln a_t + \alpha \ln K_t + (1-\alpha) \ln E_t .$$

Substituting the closed-form solution of $\hat{k}_{t+1}$ into the above equation yields the demeaned growth rate of output for the exogenous growth model:

$$g_t - \theta_1 g_{t-1} - \theta_2 g_{t-2} = \varepsilon_t^a + \theta_3 \varepsilon_{t-1}^a + \theta_4 \varepsilon_{t-2}^a + \theta_5 \varepsilon_t^E + \theta_6 \varepsilon_{t-1}^E + \theta_7 \varepsilon_{t-2}^E , \quad (8)$$

in which

$$\begin{aligned} \theta_1 &= s_1 + \gamma_1 , \\ \theta_2 &= -s_1 \gamma_1 , \\ \theta_3 &= (\alpha s_2 - s_1) - 1 , \\ \theta_4 &= -(\alpha s_2 - s_1) , \end{aligned} \quad (9)$$

and θ_i, $i =$ 5, 6, 7, are complex functions of structural parameters.

Note that both ε_t^a and ε_t^E are serially uncorrelated random variables, and thus equation (8) also implies an ARMA(2,2) representation for g_t in the exogenous growth model.

As in the endogenous growth model, the time-series representation of g_t is also an ARMA$(p+1, p+1)$ model when the exogenous productivity shock $(\ln a_t)$ follows an AR(p) process with $p \geq 1$. However, from the coefficients in the AR components of g_t in (6) and (8), it is clear that even though the endogenous growth model and the exogenous growth model have the same external dynamics characterized by γ_1, they have different internal dynamics characterized by ω_1 and s_1, respectively. These findings suggest that the time-series facts may discriminate between these two growth models due to different sets of restrictions.

3. Time Series Evidence

This section presents evidence relating to both the exogenous and endogenous growth models in the OECD countries. Twenty-three OECD countries' real GDP series were obtained from the *OECD Annual National Accounts Data Base*, while German real GDP as well as the population series for the OECD countries were taken from *International Financial Statistics*. Yugoslavia is excluded from our data set due to lack of data. In this paper real output is divided by population to derive per capita real output. All data are annual and for all countries begin in 1960 and end in 1997.

To evaluate the statistical significance of the various growth models, this paper uses the exact maximum likelihood method to estimate the structural parameters and to test whether or not the set of restrictions implied by the growth models holds.[7] For example, if the output growth rate follows an ARMA(2,2) process, the restrictions are equations (7) in the case of the endogenous growth model while they are equations (9) in the case of the exogenous growth model.

Even though many empirical papers on growth theory assume a productivity shock that is based on an AR(1) process, here the choice of lag length is based on the data. Remember that when $\ln a_t$ is AR(n), where $n \geq 1$, our growth models imply that g_t follows an ARMA($n+1, n+1$) process. This paper uses the likelihood ratio (LR) test to determine the optimal lag length. Our LR test indicates that most productivity shocks in the OECD countries follow an AR(1) process, with the exceptions of Ireland and Norway. These two countries' technology shocks are AR(2).

When $\ln a_t$ follows an AR(1) (or an AR(2)) process, we estimate the 5 (or 7) parameters in the unrestricted ARMA(2,2) (ARMA(3,3)) model to obtain the output growth rate. In order to have enough degrees of freedom for conducting the testing, a restricted model cannot have more parameters to be estimated than an unrestricted model. This paper imposes the values of the following structural parameters a priori: the discount rate (β) is 0.96 annually, the depreciation rate (δ) is 0.1 per year, the capital share (α) is 0.35, and the expected growth rate of E_t in the exogenous growth model (g^{EX}) is 2.7%, which is the average of the OECD countries' output growth rates in the sample period.

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7 This paper uses the computationally burdensome exact likelihood estimation because it is more accurate than the approximation method when either the AR or the MA component of the series has a root near one, or the sample period is short.

Therefore, the sets of structural parameters under consideration are $\{\rho, \sigma, \gamma_1, (\gamma_2,) \sigma_a^2\}$ and $\{\sigma, \gamma_1, (\gamma_2,) \sigma_a^2, \sigma_E^2\}$ in the case of the endogenous growth model and the exogenous growth model, respectively.[8]

Table 1 reports the estimation results for the endogenous growth model. The second to the fifth columns present the estimated structural parameters, while the sixth column is the implied steady-state growth rate in the endogenous growth model. The statistics relating to the LR test, which has a χ^2 distribution, are presented in the last column of Table 1.[9] There are only 2 out of 24 countries for which the endogenous growth model hypothesis is rejected at the 5% significance level, while no country is significant at the 2.5% level. The endogenous growth model fares extremely well even under the most stringent restrictions!

The last row of Table 1 presents the average values of the 24 OECD countries' estimates. Keep in mind that ρ equals the steady-state real rate of interest ($\rho = r$). Thus, the implied average value of *r* is 5%, an estimate roughly consistent with that in the research on real business cycles. The term σ is the inverse of the elasticity of substitution between intertemporal consumption.

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8 According to the theoretical models, there are nonnegative restrictions on the parameters and restrictions, such as $\sigma > 1 + \ln\beta / \ln(1+\rho)$ for the endogenous growth model, and $\sigma > 1 + \ln\beta \; / \ln(1 + g^{EX})$ for the exogenous growth model. In addition, we further constrain reasonable parameter ranges so that $0.010 < \sigma < 10.0$ and $0.042 < \rho < 0.080$ and use a GAUSS application, the Constrained Maximum Likelihood method, to perform the estimation.

9 Since there are 5 (7) and 4 (5) parameters to be estimated in the unrestricted and restricted ARMA(2,2) (ARMA(3,3)) models, respectively, the number of degrees of freedom in relation to the χ^2 test is one (two) for both the endogenous and exogenous models.

An average of 0.22 seems too low, however, searching for a maximum with an initially high σ either makes the function value converge to a lower local maximum or σ itself quickly declines to reach the better maximum. The term g^{EN} is the implied steady-state growth rate of output in the endogenous growth model and it averages 4.05%. Even though this value is higher than the sample mean of 2.7% for the 24 OECD countries, the difference is not so distinct when precluding the periods with price instability in the 1970s and the European financial crisis in the early 1990s.

The estimation results of the exogenous growth model are displayed in Table 2. The second to the fifth columns present the estimated structural parameters, while the sixth column is the implied steady-state real rate of interest in the exogenous growth model. The findings relating to the LR test in the final column show that the exogenous growth model hypothesis is rejected for one-third of the OECD countries at the 5% significance level and is rejected for one-quarter of them at the 2.5% level.

As for the estimated σ, an average equal to 0.17 is even lower than its endogenous counterpart. This low estimate of relative risk aversion appears to be a characteristic of this time-series analysis.[10] In fact, a higher σ causes the growth model to be easily rejected with the exception of Denmark. This finding is consistent with that in King and Rebelo (1993), who assign values for σ of between 1.0 and 10.0 in order to conduct a simulation and

[10] One referee suggests a possible explanation for the low estimate, the approximation errors of the log-linear system. If we include second-order terms in doing Taylor's expansion and consider the degree of prudence in the model, the estimated σ 's may not be so low.

find counterfactual implications for the neoclassical exogenous growth model. On the other hand, the average of γ_1, the (large) eigenroot of the productivity shocks process, is 0.898. It is higher in the exogenous growth model than in the endogenous growth model. King et al. (1988) point out that the principle serial correlation in a detrended output in the case of an exogenous growth model derives mainly from the persistence of technology shocks. Note that γ_1 characterizes the external dynamics of the model, while σ and other parameters govern the stable root characterizing the endogenous dynamics. If the stable root of a growth model captures more of the transitional process of output, then less persistence of the technology shock is needed to induce the transitional dynamics. This may be a reason why the endogenous growth model fares better than the exogenous one in this paper.

Of the two shocks that govern the forecasting errors of the output growth rates in the exogenous growth model, the temporary one (σ_a^2) is in general more volatile than the permanent one (σ_E^2). In most cases the estimated σ_a^2 in the exogenous growth model is close to the estimated σ_a^2 in the endogenous model, and no implausibly large shock is needed to match the output growth rates of the two models. The term *r* is the implied steady-state real rate of interest in the exogenous growth model and has an average value of 0.047, which is very close to the estimate for the endogenous growth model.

This paper is also concerned with the sensitivity of the LR test to the values of the structural parameters fixed a priori. The question is whether the implications of the growth model for some countries were rejected because the assigned values were wrong or whether the rejection is indeed genuine. Taking Costello's (1993) G-6 study as an example, the estimates of the capital share range from 0.31 to 0.48. Since the steady-state growth rates may also depend on the country being considered, this paper thus attempts to use different capital shares (and steady-state growth rates in the exogenous growth model) in the estimation. The capital shares assigned are 0.31, 0.35, 0.4, 0.45, and 0.5, and the steady-state growth rates assigned are 2.7% (an average of the 24 OECD countries in the sample), and 4.05% (an average of the estimates in the endogenous growth model), or the specific country's own sample mean. By assigning various capital shares, steady-state growth rates and their combinations, this paper reports the estimation results with the maximal likelihood function value.

The best results in the cases of Ireland and the U.K. for which the endogenous growth hypothesis is rejected with α equal to 0.35 are shown in Table 3. The second column gives the new capital share assigned. The value assigned to this capital share which yields the best result is 0.31 in the case of the U.K., the same value assigned to the estimate in Costello (1993), while the corresponding value for Ireland is 0.45. The findings in relation to the LR test are currently insignificant at the 5% level for the U.K. and at the 2.5% level in the case of Ireland.

Table 4 shows the best results in countries for which the exogenous growth hypothesis is rejected with α equal to 0.35 and g^{EX} equal to 0.027. The second and third columns in Table 4 present the new capital shares and the steady-state growth rates, as respectively assigned. From the last column it is seen that the exogenous growth model cannot be rejected at the 5% level for Finland and Greece and at the 2.5% level for Ireland, Norway, Spain, Switzerland, and the U.K. However, the set of cross-equation restrictions implied by the exogenous growth model is firmly rejected in the case of Japan.

Several findings presented in Table 4 are worth mentioning. First, in general, the estimated likelihood value increases as we raise the assigned capital share. However, it is not sufficiently important to cause the exogenous growth model not to be rejected except in the cases of Finland and Greece. Second, the assigned steady-state growth rate plays only a minor role in the transitional growth. We do not have any significant evidence against the value of 2.7% as a steady-state growth rate in the exogenous growth model. Third, the estimates of σ are even lower and those of γ_1 even higher than the estimates in Table 2. When the persistence of transitional growth does not leave much for the stable root to capture, the estimate of σ remains at a low value while γ_1 becomes more important in terms of governing the transitional dynamics of growth rates. Fourth, the implied steady-state real rate of interest is 0.045, there being no significant change from that recorded in Table 2.

This paper also summarizes with respect to countries. Ireland is the only country whose growth cannot be explained by both the exogenous and endogenous growth models at the 5% significance level of the χ^2 test. On the contrary, the growth of 18 OECD countries can be explained by the exogenous as well as the endogenous growth models. However, for some countries, the evidence indeed yields more support for the endogenous growth model than for the exogenous growth model. These countries include Japan, Norway, Spain, Switzerland and the U.K. The Japanese experience is also part of the evidence that King and

Rebelo (1993) provide as a counterfactual implication of transitional dynamics in the case of the neoclassical growth model.

4. Conclusions

Assuming that the transitory productivity shock remains the same, this paper derives the closed forms of the output growth rate imposed by both a typical endogenous growth model and a neoclassical growth model. Using the exact maximum likelihood estimation method, the estimated structural parameters are not found to be implausible, but there are certain distinct differences between the two growth models in relation to two estimates, namely, the persistence of the transitory shock and the implied steady-state growth rate of output. In general, the persistence of the transitory shock is lower in the endogenous growth model than in the exogenous model, while the implied steady-state growth rate of output is higher in the endogenous growth model.

By testing the cross-equation restrictions for the GDP growth rates of 24 OECD countries, the endogenous growth hypothesis cannot be rejected with reasonable parameter estimates except in the case of Ireland. We also find that in 75% of the OECD countries the growth rate dynamics are not distinguishable between the endogenous and exogenous growth models even with the same transitory technology shock process assumption. However, in the cases of Japan, Norway, Spain, Switzerland and the U.K., the output evidence does provide more support for the endogenous growth model than it does for the exogenous growth model.

There are at least three further extensions. Firstly, deriving the process of other variables, such as consumption, and estimating the system simultaneously may be helpful for discriminating different growth models. Secondly, since our endogenous growth model is rejected by Ireland's economic growth rates, a more general endogenous growth model might fit better. Lastly, this paper does not discuss the conditional convergence implications of the growth models. The estimated reduced form of economic growth rates can be applied to compute sigma convergence for further research.[11]

[11] Readers can refer Lee et al. (1997) as an example.

Table 1 Estimates in the Endogenous Growth Model (I)

Country	ρ	σ	γ_1	σ_a^2	g^{EN}	LR
Australia	0.053	0.204	0.787	4e-4	5.26%	0.210
Austria	0.055	0.270	0.960	3e-4	4.87%	2.882
Belgium	0.054	0.233	0.961	4e-4	4.98%	2.689
Canada	0.048	0.127	0.881	4e-4	4.79%	0.121
Denmark	0.058	0.650	0.917	5e-4	2.43%	1.235
Finland	0.042	0.010	0.385	6e-4	4.20%	0.750
France	0.049	0.154	0.971	2e-4	4.69%	0.264
Germany	0.042	0.010	0.307	3e-4	3.25%	2.008
Greece	0.051	0.188	0.978	9e-4	4.58%	1.725
Iceland	0.043	0.028	0.525	0.001	4.29%	0.002
Ireland[a]	0.052	0.235	0.882	6e-4	4.43%	6.928*
Italy	0.054	0.230	0.966	4e-4	5.32%	2.094
Japan	0.047	0.105	0.977	6e-4	4.51%	2.284
Luxembourg	0.042	0.010	0.258	0.001	4.03%	0.294
Netherlands	0.050	0.163	0.872	3e-4	4.87%	0.929
New Zealand	0.080	1.236	0.803	9e-4	2.97%	0.351
Norway[b]	0.042	0.010	0.421	2e-4	3.69%	5.727
Portugal	0.045	0.065	0.677	0.001	4.40%	1.696
Spain	0.045	0.065	0.935	4e-4	4.44%	1.148
Sweden	0.042	0.018	0.527	3e-4	1.79%	2.445
Switzerland	0.042	0.010	0.366	5e-4	3.25%	3.080
Turkey	0.080	1.148	0.794	0.001	3.20%	1.180
U.K.	0.042	0.010	0.308	3e-4	3.47%	4.316*
U.S.	0.042	0.010	0.280	3e-4	3.47%	0.900
Average	0.050	0.216	0.697	6e-4	4.05%	

Note.—In the estimation, this paper sets $\beta = 0.96$, $\delta = 0.1$, and $\alpha = 0.35$.

* Significant at the 5% level for the LR test.

[a] $\gamma_2 = 0.257$.

[b] $\gamma_2 = -0.197$.

Table 2 Estimates in the Exogenous Growth Model (I)

Country	σ	γ_1	σ_a^2	σ_E^2	r	LR
Australia	0.071	0.855	4e-4	6e-6	0.044	0.218
Austria	0.323	0.823	0	8e-4	0.051	3.628
Belgium	0.204	0.984	4e-4	3e-5	0.047	3.537
Canada	0.031	0.974	4e-4	4e-6	0.043	0.225
Denmark	1.975	0.886	5e-4	6e-6	0.098	1.155
Finland	0.010	0.967	8e-4	3e-6	0.042	5.589**
France	0.064	0.995	2e-4	1e-4	0.043	3.747
Germany	0.010	0.890	3e-4	1e-6	0.042	2.631
Greece	0.192	0.994	0.001	1e-5	0.047	4.661*
Iceland	0.014	0.909	0.001	3e-6	0.042	0.415
Ireland[a]	0.011	0.942	0	0.002	0.042	7.974**
Italy	0.010	0.965	0	0.001	0.042	1.954
Japan	0.024	0.998	8e-4	4e-5	0.042	11.163**
Luxembourg	0.138	0.853	0.001	3e-5	0.045	1.1463
Netherlands	0.106	0.949	3e-4	4e-6	0.045	1.671
New Zealand	0.443	0.718	9e-4	3e-6	0.054	0.359
Norway[b]	0.014	0.898	2e-4	5e-6	0.042	7.074*
Portugal	0.019	0.906	0.001	3e-5	0.042	1.367
Spain	0.010	0.998	5e-4	4e-6	0.042	10.623**
Sweden	0.010	0.894	1e-5	7e-4	0.042	3.231
Switzerland	0.010	0.866	4e-5	9e-4	0.042	5.737**
Turkey	0.475	0.716	0.001	4e-6	0.055	1.191
U.K.	0.010	0.750	3e-4	2e-6	0.042	5.600**
U.S.	0.010	0.830	3e-4	8e-6	0.042	1.372
Average	0.174	0.898	5e-4	2e-4	0.047	

Note.— In the estimation, this paper sets $\beta = 0.96$, $\delta = 0.1$, $g^{EX} = 0.027$ and $\alpha = 0.35$.

* Significant at the 5% level for the LR test.

** Significant at the 2.5% level for the LR test.

[a] $\gamma_2 = -0.484$.

[b] $\gamma_2 = -0.054$.

Table 3　Estimates in the Endogenous Growth Model (II) with different assignments of α

Country	α	ρ	σ	γ_1	g^{EN}	LR
Ireland[a]	0.45	0.054	0.249	0.861	4.71%	6.873*
U.K.	0.31	0.042	0.010	0.290	3.66%	3.540
Average	0.38	0.048	0.130	0.576	4.19%	

Note.— In the estimation, this paper sets $\beta = 0.96$ and $\delta = 0.1$.

* Significant at the 5% level for the LR test.

[a] $\gamma_2 = 0.272$.

Table 4　Estimates in the Exogenous Growth Model (II) with different assignments of α and g^{EX}

Country	α	g^{EX}	σ	γ_1	r	LR
Finland	0.50	2.70%	0.010	0.939	0.042	3.352
Greece	0.50	2.70%	0.214	0.992	0.048	2.309
Ireland[a]	0.50	4.05%	0.338	0.893	0.056	6.882*
Japan	0.50	2.70%	0.036	0.998	0.043	6.438**
Norway[b]	0.50	2.70%	0.011	0.872	0.042	6.527*
Spain	0.50	2.70%	0.010	0.997	0.042	5.017*
Switzerland	0.45	1.45%	0.010	0.933	0.042	4.348*
U.K.	0.50	2.70%	0.010	0.712	0.042	4.736*
Average	0.49	2.71%	0.080	0.917	0.045	

Note.— In the estimation, this paper sets $\beta = 0.96$ and $\delta = 0.1$.

* Significant at the 5% level for the LR test.

** Significant at the 2.5% level for the LR test.

[a] $\gamma_2 = 0.296$.

[b] $\gamma_2 = -0.139$.

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外生與內生成長模型何者解釋力佳？——OECD 國家產出成長率的實證分析

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摘　要

本文以產出成長率的動態過程來評估外生與內生成長模型的解釋力。不同於假設特殊的外生干擾過程來說明產出的時間序列，本文假設簡單的自我迴歸外生干擾過程，利用模型隱含的動態過程來解釋產出的成長率。透過 24 個 OECD 國家的產出成長率資料分別來檢定模型的跨式限制時，其中只有一個國家的概似檢定結果拒絕了內生成長模型的理論限制。然而本文也發現，外生成長模型與內生成長模型對高達 75% 的 OECD 國家成長率有看起來完全相同的解釋能力。

關鍵字：外生成長、內生成長、動態過程
JEL 分類：C51, C52, O40