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An empirical test of exogenous versus endogenous growth models for the G-7 countries

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ABSTRACT

One of the key differences between exogenous and endogenous growth models is that a transitory shock to investment share exhibits different long-run effects on per-capita output. Exploring this difference, the present paper evaluates the empirical relevance of the two growth models for the G-7 countries. The underlying shocks are identified by an application of a dynamic factor model. Results show that a transitory shock to investment share permanently increases per-capita output in four countries, offering support to the endogenous growth model. This shock also contributes considerably to accounting for the long-run variability of per-capita output. Overall, the endogenous model is found to be empirically more plausible than previous time series studies suggest.

1. Introduction

In response to various failures of the standard exogenous growth model, Romer (1986), Lucas (1988), Rebelo (1991), and others developed endogenous growth models in which steady growth can be generated endogenously without any exogenous technical progress. Subsequently, testing the relevance of exogeno us versus endogenous growth models has been a priority for exploring the determinants of long-run growth. Most empirical studies have focused on cross-country variations, especially with respect to convergence issues. Levine and Renelt (1992) surveyed these cross-section studies and concluded that the robust results reject exogenous growth models. Pack (1994), Solow (1994) and Durlauf et al. (2005) suggest that time series studies can make equally important contributions. However, there are only scant time series studies, and the evidence also tends to favor exogenous growth models. Jones (1995), Kocherlakota and Yi (1996), Lau and Sin (1997), and Lau (2008) found that endogenous growth models are not consistent with data in a number of developed countries.

Intrigued by their empirical rejection of endogenous growth models, this paper revisits the exogenous and endogenous growth debate in a time series context.[2] A structural evaluation of the competing growth models is important for policy design, as well as helping to guide future theoretical developments. While there are several variables that characterize long-run growth, investment and output are at the root of both exogenous and endogenous growth models. Hence, we explore how different implications of the long-run behavior of investment and output can be more precisely taken to data in a structural time series framework. Particular motivation is due to Lau (1997, 2008), who shows the time series implications of a Solow–Swan exogenous growth model and a typical AK endogenous growth model. The time series implications provide the analytical basis for the empirical tests explored in this paper.[3] To be specific, Lau assumes that log per-capita output and log per-capita investment are I(1) processes, and they are cointegrated with a coefficient vector of [1, −1]. The investment share, defined as the ratio of per-capita investment to per-capita output, becomes a stationary process. Lau proceeds to prove that a transitory shock to investment

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[2] A group of studies focus on different policy or predictive implications of endogenous growth models. For instance, Bleaney et al. (2001) tested the role of government expenditure/taxation, while Pyo (1995) focused on human capital as a main source of increasing returns. At the time of writing, an empirical study by Cheung et al. (2012) revisits the association between investment and growth using both cross-sectional and time-series regressions. However, all of these studies are based on standard regressions, and hence are not attempts to structurally evaluate exogenous versus endogenous growth models, bearing little direct relevance to the current paper.

[3] In Appendix A, we provide a detailed derivation of the time series implications shown, without derivation, by Lau (1997, 2008). We thank an anonymous referee for making this suggestion.

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share produces permanent effects on log per-capita output in the endogenous growth model, whereas it only has transitory effects in the exogenous growth model. This distinction was similarly used in King et al. (1988) and Kocherlakota and Yi (1996).[4]

In this paper, we follow the distinction put forth by King et al., Kocherlakota and Yi, and Lau, and propose how to empirically test the implied differences between the Solow–Swan exogenous and AK endogenous models of growth. The procedure is based on the dynamic factor models of Stock and Watson (1988), Johansen (1991), Kasa (1992), and Escribano and Peña (1994). These models were developed for the decomposition of permanent and transitory components in a cointegrated system. We make a modification to use in the identification of structural shocks. By construction, the long-run response of log per-capita output to a transitory shock in investment share is allowed to be determined by data. It is not restricted to being zero, which is distinct from other competing methods. Because the long-run response is identified without recourse to restrictions, checking whether it is zero can constitute a legitimate empirical test for differentiating between the two growth models. In the paper, we also conduct a structural analysis using the Beveridge and Nelson (1981) decomposition of a type used for vector error correction models by Mellander et al. (1992), Englund et al. (1994), and Fisher et al. (2000). This alternative specification is consistent with the exogenous growth model, given that a transitory shock in investment share is restricted to produce no permanent effects. The results are utilized to check the robustness of those from the dynamic factor model.

The remainder of this paper is organized as follows. Section 2 discusses the long-run time-series properties of Solow–Swan exogenous and AK endogenous growth models. Section 3 presents the dynamic factor model for examining the empirical consistency of the two growth models with actual data. Section 4 provides the test results for the G-7 countries and discusses policy implications. Section 5 conducts a Monte Carlo experiment to perform a diagnostic check on how well the dynamic factor model performs in recovering the long-run responses of the variables. Section 6 summarizes the major findings of the paper with concluding remarks.

2. Theoretical models

Drawing on Lau (1997, 2008), this section illustrates a stochastic Solow–Swan model with exogenous technological processes and, as its endogenous counterpart, a stochastic AK model of the type suggested by Rebelo (1991). Consider a closed economy which is populated by a constant number of identical agents N. The supply side of the economy is represented by a Cobb–Douglas production function:

$$Y_t = AK_t^{\lambda} N^{1-\lambda} \eta_t^P, \tag{1}$$

where Y_t is output at time t, K_t is capital input at time t, $0<\lambda<1$, and η_t^P is an impulse process to the otherwise constant level of total factor productivity A. The demand side of the economy is represented by:

$$I_t/Y_t = s\eta_t^I, \tag{2}$$

where I_t is investment at time t, s $(0<s<1)$ is the average investment share in output, and η_t^I is an impulse to investment share.

The two impulse processes are assumed to have the form:

$$(1-L)^{\pi_P} Q_p(L) \ln\eta_t^P = \varepsilon_t^P \text{ and } (1-L)^{\pi_I} Q_I(L) \ln\eta_t^I = \varepsilon_t^I, \tag{3}$$

where L is the lag operator, π_j is either 0 or 1, $Q_j(L)$ is a polynomial function in L with all roots outside the unit circle, and ε_t^P and ε_t^I are structural disturbances and are assumed to have a mean of zero and an identity covariance matrix. The impulse process $\ln\eta_t^j$ is I(0) when $\pi_j=0$ and I(1) when $\pi_j=1$. The level of capital stock evolves over time according to

$$K_{t+1} = (1-\delta)K_t + I_t, \tag{4}$$

where $\delta(0<\delta<1)$ is a constant rate of depreciation.

In the Solow–Swan exogenous growth model, log per-capita output and log per-capita investment are I(1) inherited from an I(1) process of productivity. This requires that the productivity and investment share impulses are I(1) and I(0), respectively, and hence, $\pi_P=1$ and $\pi_I=0$ in Eq. (3). The log-linearized equations of motion near the steady-state growth path result in the following vector moving average (VMA) system:

$$\begin{bmatrix} (1-L)\ln y_t \\ (1-L)\ln i_t \end{bmatrix} = (\delta(1-\lambda)L)^{-1} \begin{bmatrix} \delta L Q_P^{-1}(L) & \lambda\delta(1-L)LQ_I^{-1}(L) \\ \delta L Q_P^{-1}(L) & \delta(1-L)LQ_I^{-1}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_t^P \\ \varepsilon_t^I \end{bmatrix}, \tag{5}$$

where y_t and i_t are per-capita output and per-capita investment, respectively.[5]

The AK endogenous growth model of Rebelo (1991) can be summarized using Eqs. (2), (3), (4), and

$$Y_t = AK_t\eta_t^P. \tag{6}$$

If log per-capita output and log per-capita investment are I(1), this model implies that both productivity and investment share impulses are I(0); thus, $\pi_P=0$ and $\pi_I=0$ in Eq. (3). The log-linearization near the steady-state growth path gives the following VMA formation:

$$\begin{bmatrix} (1-L)\ln y_t \\ (1-L)\ln i_t \end{bmatrix} = \begin{bmatrix} \ln(1-\delta+sA) \\ \ln(1-\delta+sA) \end{bmatrix} + \begin{bmatrix} \left(1-\frac{1-\delta}{1-\delta+sA}L\right)Q_P^{-1}(L) & L\left(\frac{sA}{1-\delta+sA}\right)Q_I^{-1}(L) \\ \left(1-\frac{1-\delta}{1-\delta+sA}L\right)Q_P^{-1}(L) & \left(1-\frac{1-\delta}{1-\delta+sA}L\right)Q_I^{-1}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_t^P \\ \varepsilon_t^I \end{bmatrix}. \tag{7}$$

[6]

This shows that as long as $sA>\delta$, the economy grows even without exogenous technological progress.

Both Solow–Swan and AK models of growth in Eqs. (5) and (7) may be rewritten compactly as:

$$\begin{bmatrix} \Delta\ln y \\ \Delta\ln i_t \end{bmatrix} = \text{constant} + \Gamma(L)\varepsilon_t = \text{constant} + \begin{bmatrix} \Gamma_{11}(L) & \Gamma_{12}(L) \\ \Gamma_{21}(L) & \Gamma_{22}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_t^P \\ \varepsilon_t^I \end{bmatrix}, \tag{8}$$

where $\Delta=(1-L)$ is the first difference operator, $\varepsilon_t = \left[\varepsilon_t^P, \varepsilon_t^I\right]'$ is a (2×1) vector of structural disturbances, and $\Gamma(L) = \Gamma_0 + \Gamma_1 L + \Gamma_2 L^2 + \cdots$. The long-run multiplier matrix of the Solow–Swan model can easily be obtained from Eq. (5):

$$\Gamma(1) = \sum_{i=0}^{\infty}\Gamma_i = \begin{bmatrix} \delta Q_P^{-1}(1) & 0 \\ \delta Q_P^{-1}(1) & 0 \end{bmatrix}. \tag{9}$$

[4] A more oft-cited distinction between the two growth models was their predictions about whether a permanent shock to investment share can permanently affect the growth rate of per-capita output. In endogenous growth models, a permanent investment share shock can, while in exogenous growth models it cannot. The empirical application of this distinction may encounter some difficulties, however. See Lau (2008) for details.

[5] Appendix A provides a detailed derivation of (5).

[6] See also Appendix A.