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ECONOMIC GROWTH AND RETURNS TO SCALE

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This paper develops a regression equation nesting a variant of Rebelo's(1991) AK model with Solow's(1956) neoclassical model and tests whether three samples of countries support endogenous or exogenous growth models. The test exploits both time-series and cross-sectional features of the data analyzed. In the 88 Non-oil and the 72 Intermediate country group, their empirical results provide no evidence that individual countries face diminishing returns to the accumulation of reproducible capital. The empirical results of two group countries are more consistent with endogenous growth model than with Solow's neoclassical growth model. However, the result in the OECD countries is more consistent with exogenous growth than with endogenous growth model since we found evidence that individual countries face diminishing returns to the stock of reproducible factors.

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I. INTRODUCTION

The main idea of the neoclassical growth model is diminishing return to reproducible factors in the production function. The lower is the capital-labor ratio in poor country, the larger the rate of return to capital is ceteris paribus. Thus, poor countries should grow faster than the rich country ceteris paribus and should tend to converge to a steady-state growth path along which income per capita grows at the exogenous rate of technological improvement. If countries have access to all useful technical knowledge, per capita output produced with

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diminishing returns in production of reproducible factors should revert in all countries toward balanced growth paths that are parallel.

Some of the empirical growth literature has attempted to support exogenous growth models. Mankiw, Romer and Weil(1992) estimated a share for physical and human capital of 0.67 in an augmented Solow model. This share exceeds 0.33 the share for physical capital alone, but is significantly below unity. Barro and Sala-i-Martin(1992) estimate a share of 0.8 for a broad concept of capital including human capital which is also significantly below unity. These implied models are less influenced by the diminishing returns of the simplest version of the neoclassical growth model. However, the neoclassical model does not by itself explain sustained economic growth and rule out differences in trend growth rates across countries.

Paul Romer(1986), Robert Lucas(1988) and Sergio Rebelo(1991) have introduced a new class of growth theories characterized by endogenous growth. The endogenous growth models assume constant returns to scale in reproducible factors of production.[1] Therefore, they imply that the rate of return should not vary with the level of per capita income keeping the composition of reproducible factors constant. If reproducible factors of production can be produced with constant returns in each country and the incentives to invest in these factors vary across countries, they have different trend growth paths. The same factors that explain level differences in exogenous growth models explain differences in trend growth rates in endogenous growth models.

The theoretical limitation of endogenous growth models is the requirement that to generate an equilibrium of ongoing growth, all production functions must exhibit constant returns to scale in the accumulated factors of production.[2] A aspect of endogenous growth theory stresses the point that human capital in the form of knowledge diffusion and learning by doing contributes to increasing returns in long-run growth(Fingleton and McCombi(1998)). Sengupta(1998) has provided estimates of parameters of log-linear production frontier implied by the optimal input demands for Japan over the period 1965-90. He shows the results that the returns to scale is increasing for all the cases except the GDP model in its forward-looking version. Fingleton and McCombi(1998) provide evidence of large increasing returns to scale for 178 European Union regions over 1979-89.

However, more recent studies seems to be little empirical support for constant returns to physical capital, such as King and Levine(1994) in the favor of decreasing return. Romer(1987) estimated the true elasticity of final goods output with respect to physical capital lying in the range between 0.7 and 1.0. Bayoumi, Coe and Helpman(1996) suggest that R&D, R&D spillovers, and trade play important roles in boosting growth in industrial and developing countries.

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[1] Romer(1986) and Lucas(1988) stress the point that human capital with externality contributes to increasing social returns in long-run growth.

[2] Eicher, T. and Turnovsky, S.(1998), p.4

But their model incorporates diminishing returns to reproducible factors of production(physical and R&D capital). The Barro and Sala-i-Martin(1992, 1995) suggests unconditional convergence using data for regional total output for the USA, the European Union, and Japanese Prefectures.

In this paper, we develop a regression equation that nests an AK model and Solow's exogenous growth model. Using panel data for three samples of countries, we then test endogenous growth models against exogenous growth models.[3] These empirical results provide no evidence that individual countries face diminishing returns to the accumulation of reproducible factors and therefore supports constant returns to scale when we examine a large sample of countries (including both industrialized and developing countries).

The organization of this paper is as follows. Section II describes the model, and derives the implications of the model. Section III presents the estimation strategy and empirical results. Section IV concludes.

II. DISCUSSION OF THE MODEL

The simplest endogenous growth model is the AK model used by Sergio Rebelo (1991). The production function in this model exhibits social constant returns to reproducible factors. The neoclassical growth model of Solow has diminishing returns to scale in reproducible capital. The following model nests both models:

$$Y_{nt}=AK^{\alpha}_{nt-1}H^{\beta}_{nt-1}e^{(1-\alpha-\beta)\gamma t},\quad \alpha>0,\ \beta>0,\ \alpha+\beta\leq 1 \tag{1}$$

$$\Delta(K_{nt}+H_{nt})=s_{nt}Y_{nt}-\delta_{nt}(K_{nt-1}+H_{nt-1}) \tag{2}$$

$$\alpha AK^{\alpha-1}_{nt-1}H^{\beta}_{nt-1}e^{(1-\alpha-\beta)\gamma t}-\delta_{nt}=\beta AK^{\alpha}_{nt-1}H^{\beta-1}_{nt-1}e^{(1-\alpha-\beta)\gamma t}-\delta_{nt} \tag{3}$$

$$n=1,\ \cdots,\ N.\ t=1,\ \cdots,\ T.$$

where Y_{nt} is per capita output in country n during period t; K_{nt} and H_{nt} are the per capita physical and human capital in country n during period t; A and γ are the level of technology and the exogenous rate of technological progress which are assumed to be constant across countries and over time; α and β are physical and human capital's shares in production; δ_{nt} is the common replacement rate for physical and human capital in country n during period t; and s_{nt} is the accumulation rate for country n in period t.

Equation (1) implies a common production technology for all countries, diminishing returns to scale in reproducible factors if $\alpha+\beta<1$ and constant social if $\alpha+\beta=1$. According to equation (2), physical and human capital are immediately fungible into each other, and physical and human capital depreciate at the same rate δ_{nt}. Equation (3) equates their net marginal products.

[3] Islam(1995) and Caselli, Esquivel, and Lefort(1996) used panel data methods to eliminate the unobserved fixed effects.

We point out that if $\alpha+\beta<1$, the model is variant of Solow's(1956) model and if $\alpha+\beta=1$ it is a variant of Rebelo's AK model. From equation (3), we get

$$\frac{\beta}{\alpha}K_{nt-1}=H_{nt-1} \tag{4}$$

We can show equations (5) holds all the times. From equation (4),

$$K_{nt}=\frac{\alpha}{\alpha+\beta}(K_{nt}+H_{nt}),\quad H_{nt}=\frac{\beta}{\alpha+\beta}(K_{nt}+H_{nt}) \tag{5}$$

Next, we use equations (5) plus equation (2) to derive equation (6);

$$\Delta K_{nt}=i_{nt}Y_{nt}-\delta_{nt}K_{nt-1} \tag{6}$$

where $i_{nt}=\frac{\alpha}{\alpha+\beta}s_{nt}$ is the gross investment rate in physical capital for country n in period t. Divide equation (6) by K_{nt-1}

$$\frac{\Delta K_{nt}}{K_{nt-1}}=\frac{i_{nt}Y_{nt}}{K_{nt-1}}-\delta_{nt} \tag{6'}$$

Differentiation of equation (1) gives us the equation for proportional growth rate of output:

$$\frac{\Delta Y_{nt+1}}{Y_{nt}}\cong\frac{\alpha\Delta K_{nt}}{K_{nt-1}}+\frac{\beta\Delta H_{nt}}{H_{nt-1}}+(1-\alpha-\beta)\gamma \tag{7}$$

From (5) and (6'), we can rewrite equation (7) as

$$\begin{aligned}\Delta\ln Y_{nt+1}&=(\alpha+\beta)(i_{nt}\frac{Y_{nt}}{K_{nt-1}}-\delta_{nt})+(1-\alpha-\beta)\gamma\\&=(1-\alpha-\beta)\gamma-(\alpha+\beta)\delta_{nt}+(\alpha+\beta)i_{nt}\frac{Y_{nt}}{K_{nt-1}}\end{aligned} \tag{8}$$

since $\frac{\Delta H_{nt}}{H_{nt-1}}=\frac{\Delta K_{nt}}{K_{nt-1}}$ at all times.
Substituting equation (4) into equation (1) gives us

$$Y_{nt}=BK_{nt-1}^{\alpha+\beta}e^{(1-\alpha-\beta)\gamma t} \tag{9}$$

where $B=A\left[\frac{\beta}{\alpha}\right]^{\beta}$. Solving equation (9) for K_{nt-1}, we obtain

$$K_{nt-1}=Y_{nt}^{\frac{1}{\alpha+\beta}}B^{\frac{-1}{\alpha+\beta}}e^{-(1-\alpha-\beta)\frac{\gamma t}{\alpha+\beta}} \tag{10}$$

From equations (9) and (10), we get

$$\frac{Y_{nt}}{K_{nt-1}}=(e^{-\gamma t}Y_{nt})^{1-\frac{1}{\alpha+\beta}}B^{\frac{1}{\alpha+\beta}} \tag{11}$$

Substituting equation (11) into equation (8) gives us

$$\Delta\ln Y_{nt+1}=(1-\alpha-\beta)\gamma-(\alpha+\beta)\delta_{nt}+(\alpha+\beta)B\ i_{nt}\left(e^{-\gamma t}\frac{Y_{nt}}{B}\right)^{1-\frac{1}{\alpha+\beta}} \tag{12}$$

The tested model is given by

$$\Delta\ln Y_{nt+1}=a+\psi\ i_{nt}(e^{-\gamma t}Y_{nt})^{\zeta}+v_{nt} \tag{13}$$

where $\psi=(\alpha+\beta)B^{\frac{1}{\alpha+\beta}}$, $\zeta=1-\frac{1}{\alpha+\beta}$, v_{nt} is the deviation of $-(\alpha+\beta)\delta_{nt}$ from its mean, and a is $(1-\alpha-\beta)\gamma$ less the mean of $(\alpha+\beta)\delta_{nt}$. Constant returns to scale for K and H implies that $\xi=0$, and diminishing returns imply $\xi<0$. For that reason, the AK model can be tested against the neoclassical Solow model by testing

$$H_0:\zeta=0,\qquad \text{vs}\qquad H_1:\zeta<0 \tag{14}$$

Ⅲ. EMPIRICAL ANALYSIS

1. Data

We obtain data on per capita income and the ratio of real gross domestic investment in physical capital to GDP from the Penn World Tables(PWT) 5.6 of Summers and Heston(1991, 1995). The panel data consists of data for the years 1960-1992 for three samples of countries; the 88 Non-oil, the 72 Intermediate, and the 22 OECD countries among the country data considered by Mankiw, Romer and Weil(1992).[4] MRW's paper has been extremely influential in the growth literature.[5]

[4] Mankiw, Romer, and Weil(1992) considered three samples of countries: the 98 Non-oil, the 75 Intermediate, and the 22 OECD countries for 1960-1985. We omitted the small countries which did not suggest some data during the extended sample period. But the three sample countries used here were based on the sample size considered by MRW.

[5] Temple(1998), p.2. However, MRW's framework has not been without its critics. One of main objection is that MRW assume that a country's initial level of technological efficiency is uncorrelated with the regressors(Aghion and Howitt(1998), p.34).

2. Empirical Results

In the empirical part of Mankiw, Romer, and Weil(1992) used cross-sectional data for various groups of countries, their reduced form equation for steady-state income per capita is

$$\ln Y(T) = (\ln A + gT) - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+d) + \frac{\alpha}{1-\alpha-\beta}\ln i_K + \frac{\beta}{1-\alpha-\beta}\ln i_H \tag{15}$$

where $Y(T)$ is output per worker in 1985, A is the level of productivity, g is the constant exogenous rate of labor augmenting productivity growth, n is the average growth rate of the labor force between 1960 and 1985, d is the constant depreciation rate of physical capital, i_K is average gross investment rate in physical capital between 1960 and 1985, and i_H is a proxy for the average gross investment rate in human capital between 1960 and 1985. They estimated α and β are about 1/3.

Our approach makes use of all of the time variation in the data and allows for the possibility that the error term v_{nt} has country-specific and individual-specific effects. In terms of the theory, we are assuming that physical and human capital depreciates at a rate δ_{nt} that differs across and over time. Specifically, we fit the model

$$\Delta \ln Y_{nt+1} = \psi i_{nt}(Y_{nt}e^{-\gamma t})^{\zeta} + \eta_n + \mu_t + \varepsilon_{nt} \tag{16}$$

where η_n are μ_t treated as country-specific and time-specific fixed effects and ε_{nt} is assumed to be orthogonal to the $i_{nt}(Y_{nt}e^{-\gamma t})^{\zeta}$ and to be independently and identically distributed with a zero mean and finite variance.

In practice, because we do not have exact estimates of the exogenous rate of technological progress(γ), we do not estimate this parameter. The regression model (16) is estimated by imposing the values.[6]

$$\tilde{\gamma} = \frac{\sum_{n=1}^{N}\sum_{t=1}^{T}\Delta \ln Y_{nt}}{NT}, \text{ for } N=88,\ 72, \text{ and } 22, \text{ and } T=33. \tag{17}$$

Table 1 reports our estimates of ψ and ζ for equation (16) with $\gamma=\tilde{\gamma}$. In the 88 Non-oil country group, the estimated coefficients on ζ are not statistically significant since the null hypothesis H_0 can be rejected only the 0.5143 marginal

[6] We do not estimate γ because γ is not identified under the null hypothesis and We want to avoid the problems that result during estimation and testing when there is unidentified parameter under the null. So long as the capital-output ratio does not trend over the samples, our estimate is consistent for γ under the alternative hypothesis.

significance level. Consequently, the null hypothesis $\zeta=0(\alpha+\beta=1)$ cannot be rejected in favor of $\zeta<0(\alpha+\beta<1)$. Individual countries face constant returns to the accumulation of reproducible capital. These empirical results are more consistent with endogenous growth model than with Solow's neoclassical growth model. We can not rule out the possibility that per capital income of these countries diverge. The 72 Intermediate country group yields result similar to the 88 Non-oil country group.

However, we see that ζ is estimated to be significantly negative in the 22 OECD countries from Table 1. Consequently, the null hypothesis $\zeta=0$ $(\alpha+\beta=1)$ can be rejected in favor of the alternative at the 0.0013 marginal significance level.[7] This empirical result is more consistent with Solow's neoclassical growth model than with endogenous growth model.

Our results are not different with existing empirical results of growth regressions. There is no convergence when the Barro and Sala-i-Martin(1992) regression is run for the 1st two samples in Heston and Summers data set. This is the well-known results that we include countries from less developed countries and developing countries. But there is convergence for third sample(OECD).

[Table 1] Results from Fitting Equation(16)

Test regression equation: $\Delta \ln Y_{nt+1}=\psi\ i_{nt}(Y_{nt}e^{-\tilde{\gamma}t})^{\zeta}+\eta_n+\mu_t+\varepsilon_{nt}$

Samples and Parameter Estimates		ψ	ξ
Non-oil (88)	Estimates (Standard error)	0.0016 (0.0006)	-0.0333 (0.0511)
	Significance level	0.0153	0.5143
Intermediate(72)	Estimates (Standard error)	0.0024 (0.001)	-0.0793 (0.0511)
	Significance level	0.0149	0.1207
OECD(22)	Estimates (Standard error)	0.01521 (0.0155)	-0.32391 (0.1007)
	Significance level	0.1889	0.0013

Note: 1. $\tilde{\gamma}$ of the 88 Non-oil, the 72 Intermediate, and the 22 OECD countries are 0.02039, 0.02331, and 0.02736, respectively.

2. Panel data of all samples for the year 1960-1992.

3. $\psi=(\alpha+\beta)B^{\frac{1}{\alpha+\beta}}$, $\zeta=1-\frac{1}{\alpha+\beta}$

[7] There are some of the empirical evidence that rich countries seem to be more neoclassical than other countries. The best paper is Baumol(1986).

More direct evidence of Evans(1996) shows that per capita income levels among OECD countries don't diverge as predicted by earlier endogenous growth models.

Next, on the assumption that $\zeta=0(\alpha+\beta=1)$ from the results from two group countries above, equation (16) reduces to

$$\Delta \ln Y_{nt+1}=\Theta i_{nt}+\eta_n+\mu_t+\varepsilon_{nt} \tag{18}$$

Estilmating equation (18) yielded that Θ are 0.1226(0.000) and 0.1239(0.000) percentage points for the 88 Non-oil countries and the 72 intermediate countries, respectively. The figures in parentheses are standard errors. Because $\Theta=A(\frac{1-\alpha}{\alpha})^{1-\alpha}$, these values for Θ imply that A is 0.0775 and 0.0784 for these two groups of countries if physical capital is paid its marginal product and is paid a third of output. These estimates are reasonable values for the rate of return on accumulated physical and human capital and suggest that rich countries have higher productivity and higher trend growth rates than poor countries.

Ⅳ. CONCLUDING REMARKS

We have developed a regression equation that nests an AK model and Solow's neoclassical model. Using panel data for the three samples, the 88 Non-oil, the 72 Intermediate, and the 22 OECD countries for the years 1960-1992 we tested these two models against each other.

In the 88 Non-oil and the 72 Intermediate country group, since their empirical results provide no evidence that individual countries face diminishing returns to the accumulation of reproducible capital these results are more consistent with endogenous growth model than with Solow's neoclassical growth model. We can not rule out the possibility that per capital income of these countries diverge. However, in the 22 OECD countries, this empirical result is more consistent with Solow's neoclassical growth model than with endogenous growth model. Conclusively, although the results are not entirely consistent with endogenous growth, they are more consistent with endogenous growth than exogenous growth when we examine a large sample of countries including OECD countries.

However, the conflicting findings of these results do not enable to reach any definitive conclusion about whether exogenous or endogenous growth theories better characterize the growth experiences of our sample of countries. Further tests of these two competing theories are necessary before we can offer such any conclusions. We hope to perform these in future research.

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