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Empirics for Economic Growth and Convergence in Asian Economies: A Panel Data Approach

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This paper tests the null hypothesis of endogenous growth theories which predict cross country differences in trend growth rates against the alternative hypothesis of exogenous growth theories which predict the same trend growth rates. We use the modified test procedure with heterogeneous intercepts allowing different growth rates across economies. We apply the test to 17 Asian countries and NIEs with panel data. Our results are consistent with neoclassical growth theories which predict the convergence of the 17 Asian countries and NIEs, but which imply that trend growth rates are different across economies. These results support the conditional convergence of the exogenous growth model against the endogenous growth model.

I. Introduction

The endogenous growth models introduced by Paul Romer (1986), Robert Lucas (1988) and Sergio Rebelo (1991) relax the neoclassical assumption of diminishing returns to reproducible factors. Under neoclassical assumption, per capita income converges across economies. However, this hypothesis cannot explain the cross-country difference in income per capita or rates of growth. Endogenous growth models assume constant returns to broadly defined capital including human capital and the stock of knowledge. Therefore constant returns to the accumulation of reproducible factors accompany cross-country differences in trend growth rates. Among the theories explaining the differences are countries that have different market structures, government polices, technologies, and so forth.

Kormendi and Meguire (1985), Barro and Xavier Sala-i-Martin (1991, 1992), Mankiw, Romer and Weil (1992) present evidence that economies are neoclassical and that per capita income converges across economies. All of these studies examine the cross-sectional relationship between the growth rate of per capital income and the level of per capita income at some initial point.[1] When the relationship is found to be negative, they conclude that per capita income converges. However, tests based on cross-sectional regressions of growth rates on initial levels have been shown to be invalid. Evans and Karras (1996) show that this

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1. Durlauf and Quah (1999) survey regressors that, in the literature, have been used in cross-country regressions. The suggested table includes 36 different categories of variables and 87 specific examples. Also, Temple (1996) provide an literature overview of these studies.

approach is valid only under incredible assumptions. Specifically, the economies must have identical first-order autoregressive dynamic structures and all permanent cross-economy differences must be completely controlled.

The panel framework can provide dramatic improvements in statistical power compared to performing a separate unit root test for each individual time series. The panel unit-root test advanced by Quah (1992, 1994) and Levin and Lin (1992, 1993) was widely used in several applications on tests of the PPP hypothesis and convergence hypothesis. Im-Pesaran-Shin(IPS) (1997) consider the more general cases where errors are serially correlated and heterogeneous across countries and where the errors in different regressions contain a common time-specific component. Evans and Karras (1996) develop a different framework for testing that allow differences in trend growth rates across economies with heterogeneous intercepts valid under much less restrictive conditions. Using Monte Carlo methods, Goddard and Wilson (2001) suggested that a panel estimator outperforms both the unconditional and conditional cross-sectional and pooled OLS estimators in the presence of heterogeneous individual effects.

The results in previous studies are generally favorable for the neoclassical stochastic growth model in the developed country group and for the endogenous growth models in a large sample of countries including both industrialized and developing countries. Evans and Karras (1996) find strong evidence for conditional convergence of 48 contiguous U.S. states and a group of 54 countries. Fleissig and Straus (1999) find overwhelming evidence that the OECD real per capita GDP are trend stationary using bootstrap methods. However, Bernard and Durlauf (1995) employ standard univariate methods and fail to reject the null hypothesis of no convergence even for pairs of OECD countries. Bohl (1999) shows that empirical findings are generally not favorable for the neoclassical stochastic growth model using eleven West German Lander.

We follow the methodology of Im-Pesaran-Shin(IPS) (1997) and Evans and Karras (1996) for empirical tests and apply the growth performance of 17 Asian countries with panel data. The data set is a good example testing the exogenous and endogenous growth models. The diversity of countries making up Asia is greater than in any other region in the world. That diversity is in part a reflection of geography, climate, and natural resource endowments.[2] In addition, the Asian country group has shown remarkable economic performance and shares a cultural background more similar than any other regional country group. This paper tests the null hypothesis of endogenous growth theories which predict cross-country differences in trend growth rates against the alternative hypothesis of exogenous growth theories which predict the same trend growth rates using the panel unit-root test procedures. We employ Monte Carlo simulations to provide the critical values for the empirical distributions.

We find strong evidence that the per capita incomes of 17 Asian countries and Newly Industrialized Economies converge around a cross-country group mean. However, growth

2. ADB (2001), "Over the past five decades, development and modernization in Asia have surpassed other developing regions as more Asian countries have recorded faster growth and social change," *Key Indicators of Developing Asian and Pacific Countries*, p. 1.

rates do not parallel balanced growth paths that appear to be absolute. These results support the conditional convergence of exogenous growth model against the endogenous growth model.

This paper is organized as follows. Section II discusses methodology of the tests and the model. Section III presents empirical results. Section IV concludes.

II. Discussion for Tested Model

Levin and Lin (1992, 1993) and Im-Pesaran-Shin(IPS) (1997) consider general models that include individual specific intercepts and time specific common effects, and allow for possibility of correlated errors across economies and time series for panel data. The individual specific intercepts can be used to predict different trend growth rates for a sample of countries.

$$\Delta y_{nt} = \boldsymbol{m}_n + \boldsymbol{r}_n y_{nt-1} + e_{nt}, \quad \Delta y_{nt} = y_{nt} - y_{nt-1}, \tag{1}$$

$$n = 1,2,\ldots, N \; ; \quad t = 1,2,\ldots,T$$

where y_{nt} is the logarithm of output per capita for country n and at time t and $\boldsymbol{m}_n$'s are different intercepts over the individuals. e_{nt} is composed of two effects. $e_{nt} = \boldsymbol{l}_t + \boldsymbol{e}_{nt}$ where $\boldsymbol{l}_t$ is a time-specific common effect that allows for a degree of dependency across economies and $\boldsymbol{e}_{nt}$ is an idiosyncratic random effect that is independently distributed across economies. To remove the effects of the common component $\boldsymbol{l}_t$ and to apply unit root test, we subtract the cross-sectional mean from the individual y_{nt} at time t.

$$\Delta z_{nt} = \boldsymbol{d}_n + \boldsymbol{b}_n z_{nt-1} + \sum_{i=1}^{p} \boldsymbol{f}_n \Delta z_{nt-i} + \boldsymbol{z}_{nt},$$

$$z_{nt} = y_{nt} - \overline{y} \; ; \; \overline{y} \equiv N^{-1} \sum_{n=1}^{N} y_{nt}, \qquad n = 1,2,\ldots,N \; ; \; t = 1,2,\ldots,T \; . \tag{2}$$

This model allows for heteroscedasticity and serial correlation across time series. The Augmented Dicky-Fuller test(p) statistic for unit root tests is used to get rid of the serial correlation problem including some lagged-difference terms of the dependent variable in the regression equation. Levin and Lin (1993) and Im-Pesaran-Shin(IPS) (1997) propose unit root tests for dynamic heterogeneous panels based on the mean of individual unit root statistics. IPS (1997) test null hypothesis $H_0 : \boldsymbol{b}_n = 0$ and $\boldsymbol{d}_n = 0$ for all n against the alternative hypothesis that $H_1 : \boldsymbol{b}_n < 0$ for some n and $\boldsymbol{b}_n = 0$ for the others $(N - n)$, and $\boldsymbol{d}_n \neq 0$ for some n .

However, endogenous growth models require the conditions not only that $\boldsymbol{b}_n = 0$ for all n but also $\boldsymbol{d}_n \neq 0$ for all n . The recent endogenous growth models show that differences in technology, preferences, government policy, and market structure generate different trend growth rates. We formulate the modified test procedure with heterogeneous intercepts, where this allows different growth rates across economies. We use a kind of weighted least squares method, an approach used by Evans and Karras (1996), which can exploit the structure of panel data set.[3]

Using ordinary least squares, we obtain the standard error of estimates, $\hat{s}_n$ from Equation (2) and calculate new series, $\tilde{z}_{nt} = z_{nt} / \hat{s}_n$, $\tilde{d}_{nt} = d_{nt} / \hat{s}_n$, $\tilde{z}_{nt} = z_{nt} / \hat{s}_n$ for each n. The tested model is expressed as:

$$\Delta \tilde{z}_{nt} = \tilde{d}_n + b\,\tilde{z}_{nt-1} + \sum_{i=1}^{p} f_n \Delta \tilde{z}_{nt-i} + \tilde{z}_{nt}, \tag{3}$$

$$n = 1,2,\ldots,N\,;\; t = 1,2,\ldots,T\,.$$

The null hypothesis $H_0 : b_n = b = 0$ for all n is rejected in favor of the alternative $H_1 : b_n < 0$ for all n if t-ratio exceeds an appropriately chosen critical value.[4] Otherwise, H_0 may hold. Under the null, the test statistics have nonstandard distribution and we need a simulated distribution of the statistics for finite samples. We perform Monte Carlo simulation with 10,000 iterations to generate the critical values for inference under the null model. We calculate F-ratio if null hypothesis can be rejected. F-ratio is obtained by square of the t-ratio of the estimator of d_n from Equation (2).[5] The null hypothesis $H_0 : d_n = 0$ for all n is rejected in favor of the alternative hypothesis $H_1 : d_n \neq 0$ for all n if F-ratio exceeds an appropriately chosen critical value.[6] We employ Monte Carlo simulations to provide the critical values for empirical distributions under the null model.

The interpretation of the results entails the following steps. If t-ratio exceeds an appropriately chosen critical value, the observations are stationary around mean and so the group countries converge. This model supports the Neoclassical growth theory. If F-ratio exceeds an appropriately chosen critical value, convergence is conditional. The case means that growth rates of per capita income are different. If not, convergence may be absolute. If t-ratio does not exceed an appropriately chosen critical value, the observations are nonstationary and this model supports the Endogenous growth model. If F-ratio exceeds an appropriately chosen critical value, economies grow at different rates. If F-ratio does not

3. Evans and Karras have shown that under the null hypothesis $t(\hat{b})$ converges in distribution to standard normal as T and $N \to \infty$ while $N/T \to 0$. F-ratio converges in distribution to $F[N-1, (N-1)(T-p-1)]$ as $T \to \infty$ while N and p remain fixed. However, we employ Monte Carlo simulation with 10,000 iterations to provide approximate distributions for inference since the asymptotic distribution of $t(\hat{b})$ and f do not approximate the distribution of the samples.

4. When the null hypothesis is accepted, per capita GDP series are nonstationary and diverge among group countries.

5. $f = \sum [t(\hat{d}_n)]^2 / (N-1)$.

6. The null hypothesis means that group countries have the same trend growth rate.

exceed an appropriately chosen critical value, the economies have the same trends growth rates and they still diverge because the observations are nonstationary.

III. Empirical Results

The data for relevant variable were obtained from the Penn World Tables (PWT) 5.6 of Summers and Heston (1991, 1995). The panel data consists of real GDP per capita for the following 17 Asian countries from 1960 to 1992: Bangladesh(BAN), China(CHI), Hong Kong(HON), Indonesia(INDO), India(INDI), Iran(IRA), Israel(ISR), Japan(JAN), Korea (KOR), Malaysia(MAL), Pakistan(PAK), Philippines(PHI), Singapore(SIN), Sri Lanka(SRI), Syria(SRY), Taiwan(TAIW), and Thailand(THAI).[7] Each series is measured in terms of a common international basket of goods.

Table 1 shows the GDP per capita of Asian countries in 1960 and 1992 respectively, and the average growth rate during each period. Countries such as Bangladesh, Thailand, and Korea had similar levels of per capita GDP of less than $1,000 in 1960. However, Korea grew in excess of 6 percent annually and had per capita GDP five or two times larger than Bangladesh and Thailand in 1992. The newly industrialized economies(NIEs)-namely Hong Kong, Korea, Singapore, and Taiwan-recorded the strongest growth performances of the group in the region from 1960 to 1992, with GDP growth rising to 6.63 percent. In terms of GDP growth, Bangladesh and Philippines grew at less than 1.5 percent per year.

Table 1 GDP per capita and Average Growth Rate

Countries[a]	GDP per capita ($)[b]		Average Growth Rate (%)[c]
	1960	1992	
BAN	952	1510	1.44
CHI	567	1493	3.03
HON	2247	16471	6.23
INDO	766	1282	1.61
INDI	638	2102	3.73
IRA	2946	3685	0.70
ISR	3477	9843	3.25
KOR	904	7484	6.60
MAL	1420	5746	4.37
PAK	638	1432	2.53
PHI	1133	1689	1.25
SIN	1658	12653	6.35
SRI	1259	2215	1.77
SRY	1575	3890	2.83
TAIW	1256	10470	6.63

7. The selected countries are 8 high-performing Asian economies (The East Asian Miracle (1993)), and some of ASEAN member countries and oil countries. We omitted the Asian countries which did not supply the data during the extended sample period.

Table 1 (Continued)

Countries[a]	GDP per capita ($)[b]		Average Growth Rate (%)[c]
	1960	1992	
THAI	943	3942	4.47
JAP	2954	15105	5.10

Notes: [a] Bangladesh(BAN), China(CHI), Hong Kong(HON), Indonesia(INDO), India(INDI), Iran(IRA), Israel(ISR), Japan(JAN), Korea(KOR), Malaysia(MAL), Pakistan(PAK), Philippines(PHI), Singapore(SIN), Sri Lanka (SRI), Syria(SRY), Taiwan(TAIW), and Thailand(THAI).

[b] GDP per capita are from Penn World Tables(PWT) 5.6. for the 17 Asian countries from 1960 to 1992. Data are measured in terms of a common international basket of goods.

[c] Growth rate = $\left\{\sum_{t=1}^{n}(\log y_t - \log y_{t-1})\right\}/n$

Table 2 shows that GDP per capita levels exhibit considerable cross-sectional correlations. The strong correlation occurs among The East Asian Miracle countries, especially between Korea and Taiwan (0.997), Taiwan and Hong Kong (0.995), and Thailand and Korea (0.994). However, correlations between Iran and the other countries have negative values. The reason for this is not difficult to grasp from looking at Table 1: Iran has the lowest growth rate (0.70) during the sample period.

We test the Equation (3) for the null hypothesis $H_0 : \boldsymbol{b}_n = \boldsymbol{b} = 0$ for all n meaning that the observations are nonstationary around mean and so the group countries diverge. Table 3 reports our estimates of b together with t-ratio, and 1 per cent and 5 percent critical values of t-ratio according to lag length p_i, $i = 1, \cdots 4$. The critical values for 1 percent and 5 percent significance level are obtained from the Monte Carlo simulations under the null model. The estimates of b are negative and the t-ratios for estimates b are less than the 5 percent critical value of empirical distribution. The null hypothesis is rejected at the 5% significance level regardless of the number of the lagged terms. Therefore, the data are consistent with converging income per capita among the 17 Asian countries.[8]

8. Our experiments beside the earlier driven test models consider the presence of positive heterogeneous AR(1) serial correlations in $\boldsymbol{z}_{nt}$ at Equation (2),

$$\boldsymbol{z}_{nt} = \boldsymbol{g}_n \boldsymbol{z}_{nt-1} + e_{nt}\ , \quad n = 1, 2, \ldots, N\ ;\ t = 1, 2, \ldots, T\ .$$

We estimate the following model adjusted with the serial correlation coefficient estimator obtained by the estimating a model (2),

$$\Delta(z_{nt} - \hat{g}_n z_{nt-1}) = \boldsymbol{d}_n(1 - \hat{g}_n) + \boldsymbol{b}_n(z_{nt-1} - \hat{g}_n z_{nt-2}) + (\boldsymbol{z}_{nt} - \hat{g}_n \boldsymbol{z}_{nt-1})\ ,$$

where $\hat{g}_n$ is the serial correlation coefficient estimator. Under the null hypothesis, the estimate of $\boldsymbol{b}$ is –0.1160 with standard error 0.0219 and marginal significance level 0.0000. This result also supports the convergence hypothesis.

Table 3 Estimates, t-ratios and Critical Values for 17 Asian Countries

Number of lags (p_i)	$\hat{b}$ [a]	t-ratio[a]	Critical Values[b]	
			1%	5%
1	–0.024	–2.446	–3.037	–2.376
2	–0.033	–3.190	–3.191	–2.442
3	–0.034	–3.168	–3.196	–2.518
4	–0.038	–3.399	–3.309	–2.531

Notes: [a] Estimates and t-ratios are obtained from Equation (3)

$$\Delta \tilde{z}_{nt} = \tilde{d}_n + b\tilde{z}_{nt-1} + \sum_{i=1}^{p} f_n \Delta \tilde{z}_{nt-i} + \tilde{z}_{nt}$$

[b] Critical values are gained from the Monte Carlo simulation under null model (2)

$\Delta z_{nt} = d_n + \sum_{i=1}^{p} f_n \Delta z_{nt-i} + z_{nt}$. $H_0 : b_n = b = 0$ means that per capita GDP series are nonstainary and diverge among group countries.

The next step is to test whether convergence is absolute or conditional. In Table 4, we present the F-ratio and critical values according to lag length p_i, $i = 1, \cdots 4$.

Table 4 F-ratio and Critical Value for 17 Asian Countries

Number of lags (p_i)	$f(\hat{d}_n)$ [a]	Critical Values[b]	
		1%	5%
1	3.233	1.532	1.809
2	3.254	1.584	1.836
3	2.947	1.581	1.831
4	3.284	1.581	1.829

Notes: [a] $f(\hat{d}_n)$ are obtained from Equation (2)

$$\Delta z_{nt} = d_n + b_n z_{nt-1} + \sum_{i=1}^{p} f_n \Delta z_{nt-i} + z_{nt}$$

[b] Critical values are gained from the Monte Carlo simulation under null model (2)

$\Delta z_{nt} = b_n z_{nt-1} + \sum_{i=1}^{p} f_n \Delta z_{nt-i} + z_{nt}$. $H_0 : d_n = 0$ means that group countries have the same trend growth rate.

The F-ratio is obtained by square of the t-ratio of the estimator of d_n from Equation (2). The critical values for 1 percent and 5 percent significance level are obtained from the Monte Carlo simulations under the null model. We compute $f(\hat{d}_n)$ as 3.233, 3.254, 2.947 and 3.284 under the different lagged terms. The null hypothesis $H_0 : d_n = 0$ for all n can be rejected at 1% and 5% significance level for all lag terms. The results provide fairly strong evidence for conditional convergence and we can accept the prediction that the 17 Asian countries have different trend growth rates. Conclusively, the empirical evidence for the samples of the 17 Asian countries are consistent with neoclassical growth theories.

Now, let us apply this procedure to 4 East Asian fast growers, NIEs, during the same period. We test the Equation (3) for the null hypothesis $H_0 : b_n = b = 0$ for all n. At Table

5, the estimates of b are negative and the t-ratios for estimates b are less than the 1 percent critical value of empirical distribution.

Table 5 Estimates, t-ratios and Critical Values for NIEs

Number of lags (p_i)	$\hat{b}$ [a]	t-ratio[a]	Critical Values[b]	
			1%	5%
1	–0.131	–3.098	–2.650	–1.977
2	–0.133	–2.932	–2.711	–2.026
3	–0.144	–3.007	–2.829	–2.037
4	–0.192	–4.321	–2.768	–2.082

Notes: [a] Estimates and t-ratios are obtained from Equation (3)

$$\Delta \tilde{z}_{nt} = \tilde{d}_n + b\tilde{z}_{nt-1} + \sum_{i=1}^{p} f_n \Delta \tilde{z}_{nt-i} + \tilde{z}_{nt}$$

[b] Critical values are gained from the Monte Carlo simulation under null model (2)

$\Delta z_{nt} = d_n + \sum_{i=1}^{p} f_n \Delta z_{nt-i} + z_{nt}$. $H_0 : b_n = b = 0$ means that per capita GDP series are nonstainary and diverge among group countries.

The null hypothesis is strongly rejected at the 1% significance level regardless of the number of the lagged terms.[9] Therefore, the observations for the Newly Industrialized Economies are stationary around mean and so the group countries converge. We also test whether convergence is absolute or conditional. Table 6 presents the F-ratio and critical values according to lag length p_i, $i = 1, \cdots 4$.

Table 6 F-ratio and Critical Values for NIEs

Number of lags (p_i)	$f(\hat{d}_n)$ [a]	Critical Values[b]	
		1%	5%
1	2.254	0.587	1.082
2	1.953	0.647	1.134
3	1.884	0.712	1.150
4	3.836	0.707	1.136

Notes: [a] $f(\hat{d}_n)$ are obtained from Equation (2)

$$\Delta z_{nt} = d_n + b_n z_{nt-1} + \sum_{i=1}^{p} f_n \Delta z_{nt-i} + z_{nt}$$

[b] Critical values are gained from the Monte Carlo simulation under null model (2)

$\Delta z_{nt} = b_n z_{nt-1} + \sum_{i=1}^{p} f_n \Delta z_{nt-i} + z_{nt}$. $H_0 : d_n = 0$ means that group countries have the same trend growth rate.

9. In case of 17 Asian countries, the null hypothesis is rejected at the 5% significance level regardless of the number of the lagged terms.

We compute $f(\hat{d}_n)$ as 2.254 1.953, 1.884 and 3.836 under the different lagged terms. The null hypothesis $H_0 : d_n = 0$ for all n can be rejected at 1% and 5% significance level for all lag terms. The results can accept the prediction that the Newly Industrialized Economies have the different trend growth rates and provide fairly strong evidence for conditional convergence.

IV. Conclusions

This paper investigated whether the 17 Asian countries and NIEs converge and whether the economies grow at different rates. To provide the answer for these questions, we employ a model allowing for country-specific characteristics which might influence per-capita growth rates. We find strong evidence that the per capita incomes of 17 Asian countries and Newly Industrialized Economies converge around a cross-country group mean. However, growth rates do not parallel balanced growth paths that appear to be absolute. These results support the conditional convergence of the exogenous growth model against the endogenous growth model. A final caveat should be entered upon these results: The empirical study for growth theory might be subject to great variation depending on different sample countries and sample periods.

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