Are Asian Countries Converging?
Using Dynamic Random Variable Models

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<Abstract>

This paper analyzes the convergence in per capita GDP among the 17 Asian countries over the period 1960-1992. We use a dynamic random variables model which allows for both country differences and similarities to enter into the analysis of growth and convergence and also correct for heteroskedastic and correlated error terms over time and country panel data. We find evidence in favor of regional convergence in 17 Asian countries with a rate of convergence of around 2% a year.

Key words: convergence, Solow growth model, a dynamic random variables model
JEL classification: O41, O47

I. Introduction

Are Asian countries experiencing convergence in levels of GDP? Growth researchers have examined this question through time-series and panel-data techniques. Under neoclassical assumption of diminishing returns to reproducible factors, per capita income converges across economies. Recent applied analysis provides several definitions of convergence. beta-convergence means a negative cross-section correlation between the initial level and subsequence growth rate of the per capita income levels. sigma-convergence means that the variance of the level of income with a group of economies is decreasing over time. beta-convergence can be unconditional or conditional, depending on whether additional control variables are absent or present in the cross-section regression.[1] The results in previous studies are generally favorable for the convergence in the developed country group and for the divergence in the large sample of countries including both industrialized and developing countries.

In the last few years, there have been several important advances in the empirical literature on growth and convergence. 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 convergence hypothesis. Im-Pesaran-Shin (IPS, 1997) considers 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. 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.

Bond, Hoeffler, and Temple(BHT, 2001) discuss a potentially serious problem with first-differenced generalized method of moments(GMM) in the context of empirical growth models, and then recommend system GMM estimator for consideration in subsequent empirical growth research suggested by Blundell and Bond(1998). The system GMM estimator combines the standard set of equations in first-differences with suitably lagged levels as instruments, with an additional set of equations in levels with suitably lagged first-differences as instruments.

In this paper, we consider a random coefficients approach which allows for both country differences and similarities to enter into the analysis of growth and convergence, and use a dynamic random variables model correcting for heteroskedastic and correlated error terms over time and country panel data. The model developed by Swamy(1974) with a modification suggested by Maddala et al.(1997). Koop and Tole(1999) recommend flexible random coefficients specification which allows for a greater degree of cross-country heterogeneity to examine the relationship between deforestation and gross domestic product per capita. Garcia-Cerrutti(2000) estimates elasticities of demand for residential electricity and natural gas using dynamic random variables models. This model deals with similarity and allows responses to changes in growth factors to vary across countries, and assumes that t

[1] Cellini and Scorcu(2000)

he responses all come from a joint distribution with a common mean and uses a random variables model.

We find evidence in favor of regional convergence in 17 Asian countries. These results support the conditional convergence of exogenous 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. Model and Estimation Methods

It is usual in the analyses of panel data, either fixed-effects models or random-effects models, to assume cross-sectional homogeneity of slope coefficients, which is an unreasonable assumption from time to time. In order to relax the homogeneity of slope coefficients, a commonly used model is the random-coefficient model, where the parameters are supposed to come from a common distribution. In this paper, the random-coefficient model will be used to predict different trend growth rates for a sample of countries in Asia.

The model assumed through this article is as follows: for each country i of the N countries,

$$Y_i = X_i \beta_i + \varepsilon_i \qquad (1)$$

where the Y_i is the vector of dependent variable with T yearly observations and ε_i is the error vector having the same dimension with Y_i ; the X_i is $T \times K$ matrix that may include a 1-year lagged dependent variable; and the β_i is a $K \times 1$ parameter vector to estimate.

In the random coefficient models,

$$\beta_i = \beta + \mu_i \qquad (2)$$

where $E\mu_i = 0$, $E\mu_i \mu_j' = \Delta$ for $i = j$, $E\mu_i \mu_j' = 0$ otherwise. Swamy(1974) also assumes that $E\varepsilon_i = 0$ and $E\varepsilon_i \varepsilon_j' = \sigma_{ij}\Omega_{ij}$, which allows for heteroskedastic, first-order autoregressive, and mutually correlated errors. It is also assumed that the random coefficient β_i and ε_i are independent of each other for all i and j and they are not correlated with X_i for all i

We first estimate the model introduced above with the generalized least squares(GLS) estimation method and then compare the results with a shrinkage-type approach described in Swamy(1974), which is similar to the empirical Bayes estimators studied in Maddala et al.(1997). Maddala et al. suggested that an iterative method can improve the efficiency over GLS which is asymptotically consistent but inefficient in this case. The details of the Swamy's shringkage-type estimation method can be found in Appendix A at the end of this paper.

III. Data and empirical results

1. Data

We consider the real GDP per capita expressed in 1985 US dollars, population growth, real investment share of GDP, real government share of GDP, and openness rate for the following 17 Asian countries over the period from 1960-1992: Bangladesh(BAN), China(CHI), Hong Kong(HON), India(INDI), Indonesia(INDO), 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). The data for relevant variable are obtained from the Penn World Tables(PWT) 5.6 of Summers and Heston(1991, 1995).

2. Estimating the Solow growth model

We apply a dynamic random variables model(Cshctwa) correcting for heteroskedastic and correlated error terms over time and country and a shrinkage-type approach(Swamy) described by Swamy(1974) to estimation of the Solow growth model. Based on the ordinary squares method, F-tests at 5% level reject the null hypothesis of homogeneity across countries. Lagrange multiplier also reject at the 5% significance level the null hypothesis of homoskedasticity across countries.

Table 1-3 report the empirical results of this study. Table 1 presents the estimates and t-statistics for Cshctwa models. For the average of the Cshctwa estimates, per capita lagged GDP is significant and has negative sign. Our estimate(t-statistics) of coefficient on initial income is -0.097(-4.42). This result, together with results from Kim(2001), suggests here there is stronger evidence in favor of convergence for Asian countries.[2] This Cshctwa model results indicate a rate of convergence of 0.0192 a year, which is surprisingly similar to standard cross-section finding.[3] For the average of the Cshctwa estimates, the investment rate and population growth are insignificant.

An examination of Table 2 contains the estimates and t-statistics for Swamy models. For the average of the Swamy estimates, per capita lagged GDP remains significant at 10% significance level and has also negative sign. Our estimate(t-statistics) of the coefficient on initial income is -0.145(-1.61). This result indicates a rate of convergence

[2] Kim(2001) uses the modified test procedure with heterogeneous intercepts allowing different growth rates across economies.

[3] Barro and Sala-i-Martin(1995) shows that the joint estimate(standard error) of convergence rate is 0.0197(0.0026), compared with an OLS estimate of 0.0206(0.0024) for 48 U.S. states and 0.0279(0.0033) for Japanese prefectures. BHT(2000) report that the system GMM results indicate a rate of convergence of around 2% a year.

of 0.0234 a year. The results for the average of the Swamy estimates indicate that the investment rate has a significant positive effect on the steady state level of per capita GDP and population growth rate remain insignificant.

We review the direct growth effects of initial conditions, policy variables, and other explanatory variables in growth of Asian countries. Table 3 reports our results for Swamy model, where the logarithm of real investment share of GDP, real government share of GDP, and openness are included as additional explanatory variables. The model results indicate a rate of convergence of 0.0246 a year. Throughout the paper, our results indicate a low convergence rate, in the range from 1.9% to 2.46% a year. Importantly, the results indicate that the openness rate and investment rate have a significant positive effect on the steady state level of per capita GDP.

IV. Concluding Remarks

This paper examined the convergence in per capita GDP among the 17 Asian countries over the period 1960-1992. We apply a dynamic random variables model correcting for heteroskedastic and correlated error terms over time and country to estimation of the Solow growth model. We find evidence in favor of regional convergence in 17 Asian countries with a lower rate of convergence of around 2% a year. The results indicate that the openness rate and investment rate have a significant positive effect on the steady state level of per capita GDP.

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<Table 1> Estimation of the Solow growth model using the Cshctwa model

Country	$\log(y_{it-1})$	(t-stat.)	$\log(s_{it})$	(t-stat.)	$\log(n+g+\boldsymbol{d})$	(t-stat.)
BAN	-0.188	-1.65	-0.015	-0.14	-10.942	-2.32
CHI	-0.027	-0.31	0.146	1.21	4.052	2.93
HON	-0.016	-0.21	0.142	1.28	-0.998	-1.07
INDI	-0.020	-0.17	-0.061	-0.47	-7.078	-0.56
INDO	-0.139	-1.69	0.130	1.19	-1.081	-0.60
IRAN	-0.143	-1.39	-0.098	-0.84	-12.589	-1.53
ISR	-0.045	-0.55	0.068	0.60	-1.033	-1.00
JAN	-0.081	-1.06	0.143	1.27	-3.725	-3.26
KOR	-0.088	-1.10	0.085	0.78	-5.062	-2.09
MAL	-0.233	-2.82	0.372	3.20	-7.483	-2.25
PAK	-0.032	-0.39	-0.130	-1.13	-16.326	-4.06
PHI	-0.354	-3.52	0.148	1.32	-7.746	-2.39
SIN	-0.027	-0.36	0.054	0.49	-0.976	-1.06
SRI	-0.075	-0.88	0.060	0.55	-1.230	-0.74
SRY	-0.066	-0.80	-0.005	-0.04	3.012	0.73
TAIW	0.014	0.19	-0.016	-0.15	-0.609	-0.50
THAI	-0.131	-1.59	0.113	1.04	-7.604	-3.60
Implied l	0.0191					
Average	-0.097	(-4.42)	0.067	(0.59)	-4.554	(-1.28)

Note: Cshctwa: Cross-sectionally heteroskedastic, and correlated timewise first-order autoregressive model

Country: Bangladesh(BAN), China(CHI), Hong Kong(HON), India(INDI), Indonesia(INDO), 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).

Dependent Variable: $\Delta \log y_{it}$

Data source: PWT5.6 for 17 Asian countries from 1960-1992

<Table 2> Estimation of the Solow growth model using the Swamy model

Country	$\log(y_{it-1})$	(t-stat.)	$\log(s_{it})$	(t-stat.)	$\log(n+g+d)$	(t-stat.)
BAN	-0.079	-0.22	0.135	1.22	27.622	5.86
CHI	-0.064	-0.40	-0.057	-0.48	-0.157	-0.11
HON	-0.165	-0.28	0.410	3.67	-1.999	-2.15
INDI	-0.229	-0.24	0.513	3.90	6.625	0.53
INDO	0.196	0.17	-0.110	-1.00	6.252	3.48
IRAN	0.011	0.02	-0.218	-1.88	-50.442	-6.11
ISR	-0.079	-0.38	0.067	0.60	0.725	0.70
JAN	-0.144	-0.59	-0.107	-0.94	-7.885	-6.90
KOR	-0.217	-0.48	0.001	0.01	-16.868	-6.97
MAL	0.662	0.19	-0.278	-2.40	348.825	104.65
PAK	-0.399	-0.31	0.549	4.77	46.480	11.55
PHI	-0.177	-0.47	0.016	0.15	24.858	7.68
SIN	-0.061	-0.36	-0.151	-1.36	-0.518	-0.56
SRI	-0.437	-0.32	0.179	1.64	-13.393	-8.07
SRY	-0.044	-0.10	0.055	0.49	-20.445	-4.95
TAIW	-0.032	-0.14	-0.054	-0.49	0.626	0.52
THAI	-1.203	-0.28	-0.038	-0.35	-72.216	-34.16
Implied l	0.0234					
Average	-0.145	(-1.61)	0.054	(5.17)	16.358	(0.00)

Note: Swamy: a shrinkage-type approach described by Swamy.
Country: Bangladesh(BAN), China(CHI), Hong Kong(HON), India(INDI), Indonesia(INDO), 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).
Dependent Variable: $\Delta \log y_{it}$
Data source: PWT5.6 for 17 Asian countries from 1960-1992

<Table 3> Estimation of the growth model using the Swamy model

Country	$\log(y_{it-1})$	(t-stat.)	Log(I/Y)	(t-stat.)	Log(gov)	(t-stat.)	Log(open)	(t-stat.)
BAN	-0.566	-3.60	0.026	0.19	0.374	1.33	0.127	2.04
CHI	-0.362	-2.22	0.332	2.39	0.657	2.43	0.045	0.72
HON	-0.020	-0.12	0.119	0.87	0.013	0.05	0.042	0.69
INDI	-0.169	-1.06	0.043	0.33	0.142	0.52	0.098	1.54
INDO	-0.117	-0.71	0.084	0.59	0.027	0.10	0.039	0.63
IRAN	-0.130	-0.81	-0.057	-0.41	-0.021	-0.07	0.074	1.19
ISR	-0.059	-0.36	0.038	0.28	-0.065	-0.23	0.065	1.05
JAN	-0.143	-0.88	-0.136	-1.07	-0.398	-1.51	-0.047	-0.76
KOR	-0.141	-0.86	0.072	0.52	-0.390	-1.43	0.001	0.01
MAL	-0.277	-1.68	0.355	2.53	0.032	0.12	0.154	2.51
PAK	-0.147	-0.91	-0.077	-0.57	0.088	0.32	0.080	1.29
PHI	-0.346	-2.15	0.144	1.01	0.114	0.41	0.085	1.35
SIN	-0.035	-0.21	0.121	0.86	-0.094	-0.34	-0.051	-0.84
SRI	-0.033	-0.20	-0.023	-0.17	-0.175	-0.64	-0.005	-0.09
SRY	-0.121	-0.74	0.010	0.07	0.074	0.26	0.109	1.78
TAIW	-0.007	-0.04	-0.055	-0.41	-0.051	-0.19	0.035	0.58
THAI	-0.065	-0.40	0.073	0.52	0.017	0.06	0.083	1.34
Implied l	0.0246							
Average	-0.161	(-4.09)	0.063	(1.88)	0.020	(0.30)	0.055	(3.66)

Note: Swamy: a shrinkage-type approach described by Swamy
Country: Bangladesh(BAN), China(CHI), Hong Kong(HON), India(INDI), Indonesia(INDO), 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).
Dependent Variable: $\Delta \log y_{it}$
Openness rate: (exports + imports)/GDP
Data source: PWT5.6 for 17 Asian countries from 1960-1992

Appendix A

The shrinkage-type estimator derived in Swamy(1974) for the model (1) and (2) in section II can be written as follows:

$$\hat{b} = \left\{X'\hat{\Omega}^{-1}X + \left(I_N \otimes \hat{\Delta}^{-1}\right)\right\}^{-1}\left\{X'\hat{\Omega}^{-1}Y + \left(\Gamma_N \otimes \hat{\Delta}^{-1}\hat{b}^*\right)\right\}$$

where $X = diag\{X_1, X_2, \Lambda, X_N\}$, $\hat{\Omega} = \left\{\hat{s}_{ij}\hat{\Omega}_{ij}\right\}$ for $i, j = 1,2,\Lambda, N$, I_N denotes an identity matrix of order N, Γ_N is a column vector of ones, $\hat{b}^*$ is the average of GLS estimates based on the OLS estimates of the first-order of autoregressive coefficient $\hat{r}_i$ and the OLS residual $\hat{u}_i$, and finally, $\hat{s}_{ij}$, $\hat{\Omega}_{ij}$, and $\hat{\Delta}$ are consistently estimated as follows:

$$\hat{s}_{ij} = \frac{\tilde{u}_i'\tilde{u}_j}{T} \quad \text{such that } \tilde{u}_{ti} = \begin{cases} (1-\hat{r}_i^2)^{1/2}\hat{u}_{ti} \text{ for } t = 1 \\ \hat{u}_{it} - \hat{r}_i\hat{u}_{t-1,i} \text{ for } t > 1 \end{cases},$$

$$\hat{\Omega}_{ij} = \frac{1}{1-\hat{r}_i\hat{r}_j}\begin{bmatrix} 1 & \hat{r}_i & \Lambda & \hat{r}_i^{T-1} \\ \hat{r}_j & 1 & \Lambda & \hat{r}_i^{T-2} \\ \Lambda & \Lambda & \Lambda & \Lambda \\ \hat{r}_j^{T-1} & \hat{r}_j^{T-2} & \Lambda & 1 \end{bmatrix}, \text{ and}$$

$$\hat{\Delta} = \frac{1}{N(N-1)}\sum_{i=1}^{N}\hat{s}_{ij}\left(X_i'\hat{\Omega}_{ii}^{-1}X_i\right)^{-1}X_i'\hat{\Omega}_{ii}^{-1}\hat{\Omega}_{ij}\hat{\Omega}_{jj}^{-1}X_j\left(X_j'\hat{\Omega}_{jj}^{-1}X_j\right)^{-1} + \frac{1}{N-1}\sum_{i=1}^{N}\left(\hat{b}_i^* - \hat{b}^*\right)\left(\hat{b}_i^* - \hat{b}^*\right)' - \frac{1}{N}\sum_{i=1}^{N}\hat{s}_{ii}\left(X_i'\hat{\Omega}_{ii}^{-1}X_i\right)^{-1}.$$