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OPENNESS, UNEMPLOYMENT, AND ECONOMIC GROWTH IN EAST ASIA

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Abstract

Barro and Sala-i-Martin (2004) analyzed the empirical determinants of growth. The data set used in this paper consists of panel data of several macroeconomic variables observed for 55 years (1950~2004) in six East Asian areas. Following the implications of semi-endogenous growth theory, we regressed output growth on the determinants of steady-state income. The estimation and test results suggest the existence of significant relationship between steady-state income and (trend weighted) R&D input both in Japan and South Korea. In addition, following Cellini (1995), we also consider co-integration and error-correction methods for the growth regression of East Asian areas. We extend previous analysis using structural VAR to other Asian areas, Japan and Taiwan for estimating impulse responses of the growth of production to unemployment. In addition, we find that openness and terms of trade affect growth in Asian countries.

Keywords: Growth Regression, East Asian Areas, R&D Input, Unemployment, Openness, Cointegration.

INTRODUCTION

Typical examples of large changes in relative incomes are growth miracles. This depicts the story where growth in a country far exceeds the average. Prominent growth miracles are the newly industrializing countries (NICs) of East Asia-South Korea, Taiwan, Singapore, and Hong Kong- starting around 1960.

We can see plots of R&D intensities showing increasing trends in two relatively developed countries, Japan (JAP) and South Korea (KOR), in East Asia from the 1960s to 2005 (Fig. 1). For R&D intensity, we consider only Japan, and Korea, due to limited data availability from OECD. So, with regard to research efforts, extension of inference to other countries is very unproductive.

In the past, many economists presented some explanation for the growth of per capita income of these areas. However, they all ignore the R&D (intensity or expenditures). In Romer's (1986) endogenous growth model, knowledge is created via a R&D process. In addition, most of the previous research has focused mainly on Western developed countries, neglecting the convergence problem in the East Asian areas.

Figure 1: The Trend of R&D Intensity of Korea and Japan(s_R)

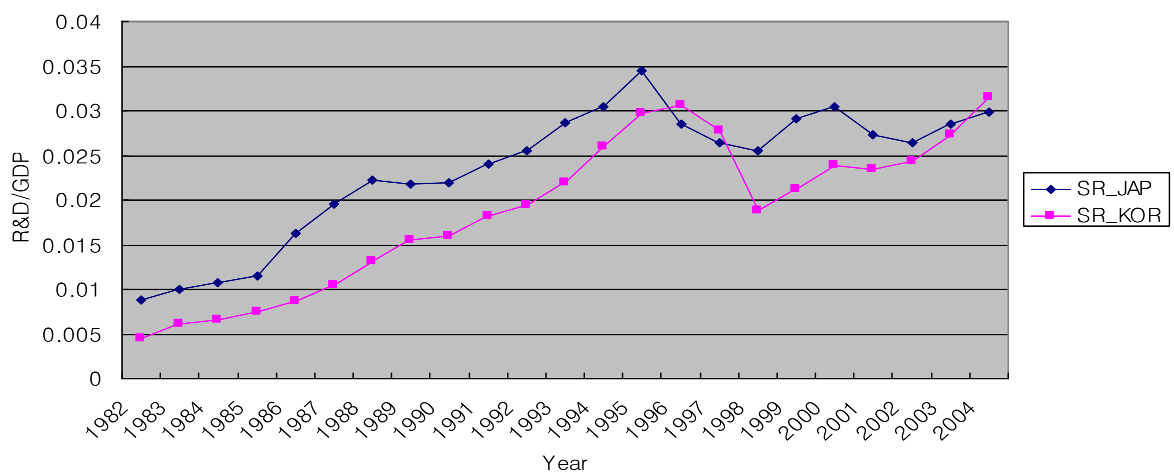
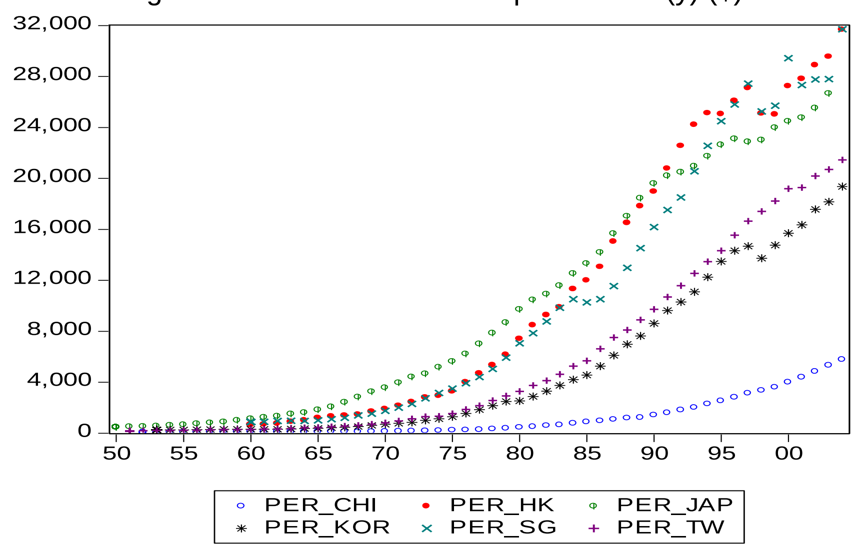


Figure 2: The Trend of Per Capita Income(y) ($)



Note: China (CHI), Hong Kong (HK), Japan (JAP), Korea (KOR), Singapore (SG), and Taiwan (TW)

In cross-country study, Mankiw, Romer and Weil (1992) have argued that the augmented Solow model is opt in forecasting the common rate of (efficiency) growth among countries. Baumol (1986), Hamilton et al. (1998), and Barro and Sala-i-Martin (2004) considered a cross-country growth regression model to examine convergence. In addition, Cellini (1997) further analyzes the error correction model for the Solow growth model. He considers the non-stationarity of income per worker and uses a co-integration method. This paper carries their analyses one step further to ask whether changes in the growth rate of the East Asian six areas between the 1950s and the 2000s can be explained by this framework.

In analyzing these problems, we use semi-endogenous growth model of Jones (1995b) as main theoretical backgrounds, not endogenous model of Romer (1990) nor Schumpeterian model of Aghion and Howitt (1998). Jones (1995b) showed that U.S. growth rates do not exhibit large persistent changes, although the determinants of long-run growth highlighted by the endogenous growth model do exhibit these changes. However, per capita output is proportional to the share of R&D in the population of an economy along a balanced growth path. The scale effect exhibited by the model is measured in levels, not in growth. A larger economy provides more potential creators for knowledge.

We developed a model to examine Jones' argument using tests of regression coefficients in a panel setting for the East Asian economies. If research effort is positively correlated with steady-state income per capita, then the regression coefficient associated with long-run income level (i.e., structural variable) in the growth regression equation would be significant and positive (a significant negative coefficient on the initial income level coincides with the implications of neoclassical growth theory, as countries close to a steady-state experience a slowdown in growth).

Hobijin and Jovanovic (2001) support the argument that if the productivity slowdown in the 1970s resulted from the IT revolution, then improved productivity growth in the 1990s reflects the revolution. Jones (2002) also presents the hypothesis that the flip side of the slowdown after 1973 is the rise in growth in the 1995-98 period, that is the "New Economy". These changes might affect the world frontier, and the pattern and speed at which East Asian countries converge at target income. Aghion and Howitt (2009) find that in China and the Asian tigers, per capita GDP manages to converge toward levels in industrialized countries.

This paper seeks to test several growth models by focusing on the economic forces underlying scale effects (in income levels) of technological progress (*Generally, scale effects mean that an increase in the number of workers employed in R&D increases the long-run growth rate, as shown in Romer's model (1990)*). Using the model put forth by Jones (1995), we performed panel regressions to determine whether semi-endogenous model provides relative good characterization of long-run economic growth in East Asian areas. We mainly focus on the growth rate of output in the process of transition dynamics, and not on the long-term growth rate of output per capita. This makes some difference from the view of Schumpeterian growth theory.

In addition, in this paper, we also discuss the most recent data on the output growth, and unemployment. In particular, we explore the hypothesis that production growth (or technological change induced by R & D investment) increased the unemployment rate. That is, we test the hypothesis that technological change would plausibly lead to an increase in the unemployment rate in the East Asian areas. Davis and Haltiwanger (1992) show that since industrial innovations raise the job destruction rate through skill obsolescence, there will be a positive relationship between growth and unemployment.

We incorporate related variables such as R&D intensity and R&D expenditures into previous growth models.

Section 2 examines basic growth model regarding technical progress. Section 3 presents the results of growth regression for Asian areas with regard to openness. Section 4 considers long-run relationship between growth and unemployment in Asian areas. Section 5 examines the case of Chinese economic growth and relationship between terms of trade and economic growth. Finally, section 6 concludes.

PREVIOUS LITERATURE AND BASIC MODEL

Empirical Analysis: Growth Regression

Many economists have recently presented sophisticated empirical analysis for cross-country growth regression (Islam (1995), Caselli, Esquivel, and Lefort (1996), Cellini (1997), Bond, Hoeffler, and Teple (2001) and Barro and Sala-i-Martin (2004)). These studies raise basic methodological issues.

The objection to standard growth regressions is that they assume a country's steady-state income determinants are fixed over time. Cellini (1997) solves this problem by using co-integration and error-correction methods. We apply the same tools to test endogenous growth theory. Sarno (2001) also takes ECM approach. He shows that long-run equilibriums of G7 countries follow nonlinear error corrections. In addition, he asserts that there exist significant spillovers within the G7. However, he used R&D data for only measuring productivity(or technology), not for growth regression

Conditional convergence should not be confused with absolute convergence, which applies when poor economies grow faster than rich ones (the poor tend to catch up). In β convergence view (Barro and Sala-i-Martin, 1992), convergence applies if a poor economy tends to grow faster than a rich one.

In contrast to this, in this paper, we explicitly consider the variability of long-run equilibrium level of income in exogenous growth theory. The previous studies also neglect the implication of Romer's (1990) endogenous growth theory that research effort is main determinant of income and its growth. The growth of per capita income (or labor productivity) is associated with knowledge creation activity. In this context, Ha and Howitt (2006), Madson(2008) test the implication of Schumpeterian growth theory by co-integration and simulation. However, they do not use the standard growth equation setting.

Economic Growth Models: Exogenous v/s. Semi-Endogenous

Because the number of researchers is growing rapidly, the original Romer (1990) formulation of Schumpeterian endogenous growth predicts that the growth rate of the advanced economy should also have risen rapidly over the last 40 years (World research effort has steadily increased over the last 40 years). However, Jones (1995a) pointed out that this is not the case. For example, the average growth rate of the U.S. economy has been very close to 2% per year for the last hundred years.

We first consider a neoclassical growth model with exogenous technological progress. The production technology for the final-goods sector (*Y*) is expressed by an aggregate Cobb-Douglas production function:

The steady-state growth rates of A (technology) and output are constant and given by:

$g_A = g_y = g_k$, y: output per capita, k: capital per capita.

This "Solow model with technological progress" predicts that growth rate is determined by the rate of exogenous technological change.

$Y = (K)^{\alpha} (AL_Y)^{(1-\alpha)}$ (1)

K: physical capital, L_Y: labor input in final good sector

Along a balanced growth path, we get: y*(t) = (s K / n + g A + d) ^(α/1-α) A(t) (2), where y* is the steady state income per capita, s K is the physical investment rate, g A is the average annual growth rate of productivity, and d is the depreciation rate of physical capital. Note that income per capita at any time (*t*) may be written as a function of the parameters and of the exogenous variable (for the technology) A(*t*) (Jones, 2002).

Final output is produced using labor, L_Y, and intermediate goods, *x*. Research in turn generates designs for new intermediate inputs (*Romer, 1990 assumed that, in the intermediate sector, firms must pay a sunk cost of product innovation whose outlay is compensated with monopoly rents*):

$Y = (\Sigma x_j^{\alpha})(AL_Y)^{(1-\alpha)} = (K)^{\alpha}(AL_Y)^{(1-\alpha)}$ (1)'[1]

The speed at which new designs are generated depends on both the number of people available to discover new knowledge, L_A, and the existing number of designs, A, according to:[2]

$\Delta A = \delta L_A^{\lambda} A^{\varphi}$ ($\Delta A = \delta L_A$, when $\lambda=1$, $\varphi=0$)

In estimation, we denote the equation describing technological progress so that R&D cost is fixed in terms of goods rather than labor. The speed at which new designs are generated depends on both the aggregate amount of research, *N*, and the existing number of designs, *A*, according to: s A ≡ N/Y.

"Semi-endogenous" growth model predicts that the growth rate is determined by parameters of the knowledge production function(g_A) and the population growth rate(n).[3] Along a balanced growth path,[4] the R&D equation can be solved for the level of *A* in terms of the labor force, and combining this equation with (1)', we get: [5]

$y^*(t) = (s_K / n + g_A + d)^{(\alpha/1-\alpha)}(1 - s_R)\, A(t) = (s_K / n + g_A + d)^{(\alpha/1-\alpha)}(1 - s_R)\, \alpha\, e^{\delta LA\, t}$ (2)'

where s_R is the share of the population engaged in R&D so that $s_R L = L_A$.[6]

One difference from Solow model is the terms, $(1 - s_R) A(t) = (1 - s_R)\, \alpha\, e^{\delta LA\, t}$, which adjusts for the difference between output per worker L_Y and per capita L. Another difference from Romer's model is the term, $A(t) = \alpha\, e^{\delta LA\, t}$, which implies that, for sustaining growth, more researchers are needed for more technologies.

Any equation can be used to see the effects of research effort. First, we consider the term $(1-s_R) = \sigma$ as constant.[(i)] We regress output growth on a constant, one-year lagged output (initial income), the determinants of steady-state income, $y^*(s_K, n)$, and the linear function of R&D intensity $[(s_R)L(t)]$. We consider this regression as a restricted regression model because it puts several limits on coefficients. Second, we consider the fact that, for sustaining growth, more researchers are needed for more technologies. [(ii)] Third, we consider the fact that productivity is expressed as the (linear) function of labor input used to R&D. [(iii)] Fourth, we consider the fact that productivity is expressed as the (quadratic) function of labor input used to R&D. [(iv)] In section 3.2, we use these models for estimation of growth regression models.

1 Therefore *A* now refers indifferently to the current number of designs or the current number of intermediate inputs.

2 In estimation, we denote the equation describing technological progress so that R&D cost is fixed in terms of goods rather than labor. The speed at which new designs are generated depends on both the aggregate amount of research, *N*, and the existing number of designs, *A*, according to: s A ≡ N/Y.

3 To slightly simplify things, assume that λ=1 and φ=0. Then, gA =n. (Jones, 2002)

4 The only difference with the Solow model is the presence of the term (1- sR), which adjusts for the difference between output per worker, *LA*, and output per capita, *L*.

5 dA/dt=δL A, A=e δLAtC

6 In this model, per capita output is proportional to the steady-state population. The model exhibits a scale effect in levels.

Economic Growth: Fundamentals and Openness

Convergence Regressions- Data and Some Facts

The data set consists of panel data of several macroeconomic variables (GDP per capita growth, investment ratio, TFP growth rate, and R&D expenditures/intensity) observed for 55 years (1950~2007) in 11 East Asian areas (Korea, Japan, Taiwan, Hong Kong, China, Singapore, Malaysia, Thailand, Indonesia, Philippines, Nepal). In this section, we consider only Japan, and Korea in using R&D effort, due to no availability of R&D data of non-OECD Asian countries. They were obtained from the Bank of Korea, World Bank, IFS, PENN World Tables and OECD. Missing data is very common in panel data sets. For this reason, panels in which group sizes differ are not unusual (Greene, 2008).

Barro and Sala-i-Martin (2004) provides winners (countries) from 1960 to 2000. Those are 20 countries with the highest per capita growth rates. The winners include 9 economies in East Asia (Taiwan, Singapore, Korea, Hong Kong, Thailand, Chia, Japan, Malaysia and Indonesia). They use an empirical framework that relates growth rate to variables. First, initial levels of the stock of physical capital and human capital in the forms of educational attainment and health. Second, control variables such as government consumption, the extent of international openness, the terms of trade, the fertility rate, macroeconomic stability, rule of law and democracy, and so on.

We examined a simple panel model of the effect of various factors like research effort on the growth of output. Another data set consists of monthly macro-economic variables, such as rate of unemployment, Industrial Production Index, observed for 9 years (2000-2008) in the four East Asian areas. We use a proxy variable for the growth index of industrial production. In this study, we omit the problem of measurement error.

Table 1: Fundamental parameter values

	y97	**G**	s_K	**n**	**y60**
US	1	0.0139	0.204	0.01	1
SIN	0.895	0.0537	0.348	0.0181	0.205
HK	0.708	0.0523	0.202	0.015	0.171
TW	0.656	0.056	0.24	0.0121	0.138
JPN	0.619	0.0438	0.344	0.0045	0.205
KOR	0.596	0.0594	0.326	0.011	0.111
CHI	0.097	0.0351	0.235	0.0132	0.044
IND	0.17	0.0391	0.264	0.0177	0.067
MAL	0.461	0.0411	0.317	0.0267	0.168
NEP	0.072	0.0226		0.0254	0.052
PHI	0.124	0.0145	0.166	0.0247	0.122
THAI	0.233	0.0437	0.151	0.0153	0.077

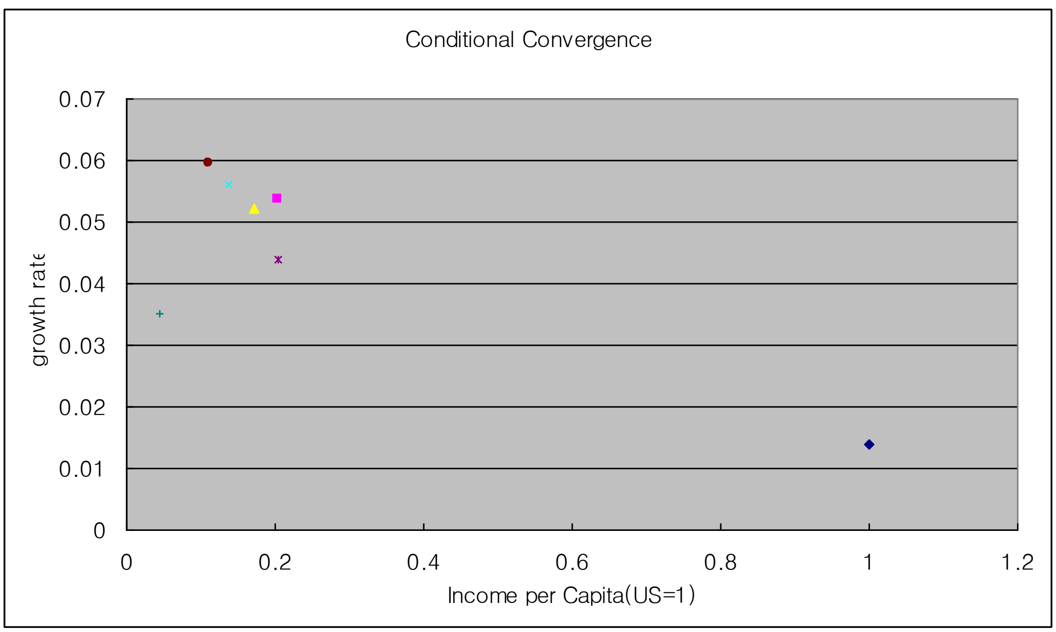
(Jones 2002, Appendix)

where *y97* is per capita GDP in 1997 (relative to the U.S.), *g* is the average annual growth rate, s_K is the physical investment rate, *n* is the population growth rate, and y'* is the steady state income per capita (relative to the U.S.)(Jones, 2002)

Figure 3: Growth Rate Versus Initial Per Capita GDP(1960-1997)

CHI	China
COM	Combidia
HK	Hong Kong
IND	Indonesia
JAP	Japan
KOR	Korea
MAL	Malaysia
NEP	Nepal
PHI	Philippines
SG	Singapore
THAI	Thailand
TW	Taiwan

- More Rich 6 Countries



- Including Less Rich 5 Countries

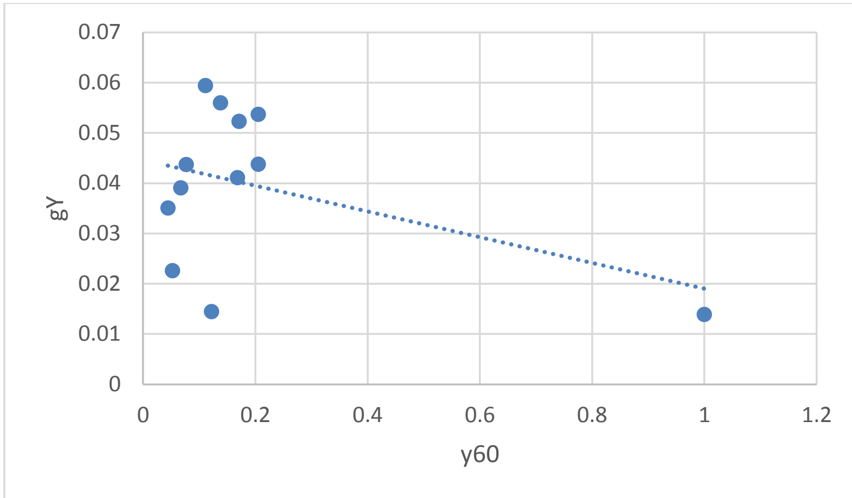
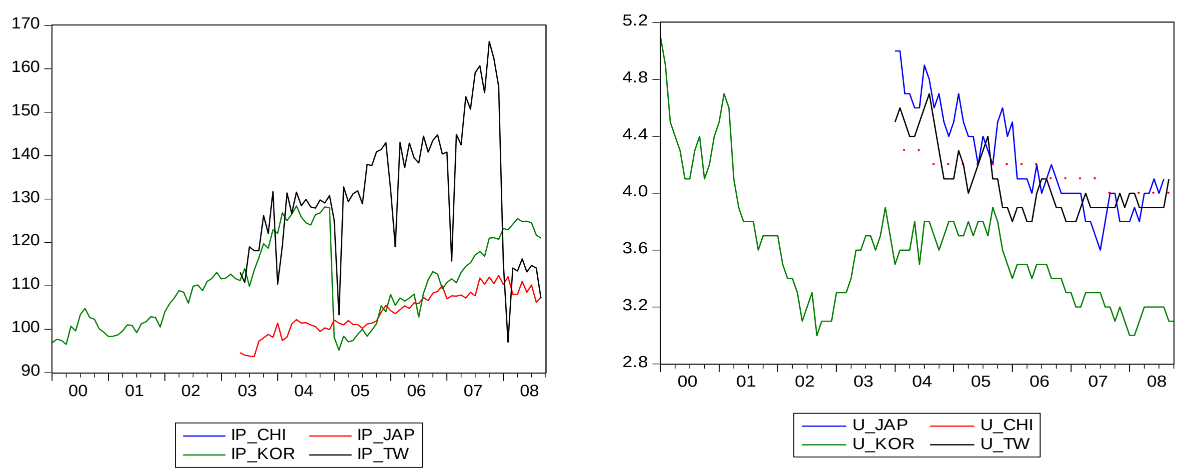


Figure 4 reveals the ability of the convergence proposition to explain why some countries grew fast and others slowly over the course of the 20C. The graph plots a country's initial income (in 1960) against the growth rate from 1960 to 1997. The figure reveals weak negative relationship. Countries such as Singapore, Hong Kong, Taiwan, Korea that were relatively poor grew most rapidly. We used the data for industrial production (IP) index and unemployment rate (U) for 4 Asian Countries to investigate the relationship between output growth and labor market.

Figure 4: The Industrial Production (IP) Index and Unemployment Rate(U) for 4 Asian Countries (index, %)(OECD, BOK)



Note: China(CHI), Japan(JAP), Korea(KOR), Taiwan(TW)

Overall, an increase in the Industrial Production (IP) Index is associated with a decrease in the unemployment rate (U) in 4 East Asian areas.

Growth Regression: Semi-Endogenous Model and Convergence

In this paper, we use the fixed effects method not because of the data structure, but because of the data generating process.[7] Consider a growth regression of the form:[8]

$y(t) - y(t-1) = \alpha + \beta\, y(t-1) + \gamma y^*(t) + \varepsilon$ (4)

Rearranging this equation produces: $y(t) = \alpha' + \beta'\, y(t-1) + \gamma' X(t) + u$ (5)

To investigate whether dividing the growth period into one-year increments has any significance, we can regress output growth on a constant, one year lagged output (initial income) and the row-vector of determinants of steady-state income, $X[=y^*(s_K, n)]$. Islam (1995) divides the total period into five-year time increments. The main reasons for this are that errors are less influenced by cycle and less likely to be serially correlated. If the coefficients for the determinant of steady-state income, *X*, is significant and has the expected sign, then this regression result implies the phenomenon of "conditional convergence."

First, we estimated the (neoclassical) growth regression model by fixed-effects panel estimation with the strong restriction that each coefficient is the same across areas and over time except for individual country effects. This estimation is a LSDV(least squares dummy variable) procedure. The result shows that most coefficients are significant. In this regression we include the ratio variable of physical investment and the measure of external openness (OPEN) (Source: Penn World Tables). The coefficients are positive and significant.

Table 2: Growth Regression: Solow Model[9]

Dependent Variable: LOG(PER CAPIA INCOME=y), Fixed Effects				
Sample (adjusted): 1951 2004				
Total pool (unbalanced) observations: 297, Cross-sections included: 6				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.106	0.032	-3.315	0.001**
$LOG(y_{-1})$	0.987	0.002	460.304	0.000**
$LOG(s_K)$	0.088	0.011	8.264	0.000**

Dependent Variable: LOG(y)		Fixed Effects		
Sample (adjusted): 1951 2004				
Total pool (unbalanced) observations: 297				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.137692	0.041159	-3.345391	0.0009**
$LOG(y_{-1})$	0.984884	0.003105	317.242	0.0000**
$LOG(s_K)$	0.094919	0.011264	8.426686	0.0000**
N	0.00404	0.004027	1.003285	0.3166
OPEN	0.0002	0.000111	1.794905	0.0737*

7 In general, for "wide and short" panel data, a fixed effects estimation model is used.(Kennedy, 2003)

8 Here, $y^*(t) = a+bX$, and *X* is the (row-vector of) determinant of steady-state income, (investment rate, population growth, etc.).

9 If the estimated coefficient or test result is statistically significant, we use ** or *, to denote a 5% or 10% significance level, respectively.

In the semi-endogenous growth model, per capita output is proportional to the population of world economies, L(*t*), along a balanced growth path. To understand this principle, consider an economy that starts out below its steady state. If the share of R&D is permanently increased, the economy is now farther below its balanced growth path and we can expect it to grow rapidly to catch up to this state (Jones, 2002).

Changes in research intensity only affect the long-term level of income, not the growth rate. This leads to an increase in the rate of short-term income growth by the principle of transition dynamics. The estimate of β' in a model with linear R&D intensity is 0.742 (speed of convergence, λ =0.298 from $\beta' = e^{-\lambda t}$).[equation (i)] The regression suggests somewhat significant convergence. The value of the implied speed of convergence is λ of 29.8%! The coefficients for the determinants of steady-state income, (s_R) $Y^*(t)$ are significant and positive. In this equation, we used long-term final output instead of total population.

Table 3: Fixed Effects Estimation Result (Semi-Endogenous) (i)

Dependent Variable: LOG(y)				
Sample (adjusted): 1982 2004	Fixed Effects			
Cross-sections included: 2				
Total pool (unbalanced) observations: 45				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.46884	0.324306	4.529179	0.0001
LOG(y_{-1})	0.742577	0.049776	14.91842	0.000**
LOG(s_K)	0.122726	0.053036	2.314001	0.026**
N	-0.158959	0.040345	-3.94003	0.0003**
LOG(RD= $s_R Y^*$)	0.069741	0.030049	2.320912	0.0256**

Table 4: Fixed Effects Estimation Result (Semi-Endogenous) (ii)

Dependent Variable: LOG(y) Fixed Effects				
Sample (adjusted): 1982 2004				
Total pool (unbalanced) observations: 45				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.079335	0.46246	2.333899	0.025
LOG(y_{-1})	0.792449	0.029134	27.20004	0.000**
LOG(s_K)	0.263533	0.061306	4.298675	0.0001**
N	-0.170577	0.038057	-4.482185	0.0001**
LOG(RD)* TREND	0.000315	0.000146	2.155871	0.0375**
LOG(s_R)	0.002743	0.028888	0.094946	0.9249

Table 5: Fixed Effects Estimation Result (Semi-Endogenous) (iii)

Dependent Variable: LOG(y) Fixed Effects				
Sample (adjusted): 1982 2004				
Total pool (unbalanced) observations: 45				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.003713	0.503278	1.99435	0.0533
LOG(y_{-1})	0.657365	0.086376	7.61055	0**
LOG(s_K)	0.076839	0.06507	1.180866	0.245
n	-0.127306	0.047965	-2.654114	0.0115**
LOG(RD)	0.177062	0.094031	1.883016	0.0674*
LOG(s_R)	-0.08642	0.071794	-1.203717	0.2361

The estimate of β' in model with product term of trend and R&D is 0.792 (λ =0.233). [equation (ii)] The coefficients for the determinants of steady-state income, RD *(*trend*), are significant and have the expected sign. These results also show that in an augmented Solow model, there may be biased estimation from the omission of R&D related variables. From these results, we can examine the fit of the semi-endogenous growth model and infer that the model explains well why one area in East Asia grows much faster than other areas. Also, we can conclude that when individuals(firms or government) decide s_R or RD in the pursuit of profit, growth is endogenous. It would be natural to see that growth rates differ across countries with different R&D intensities.

Growth Regression: Openness and Convergence

Barro and Sala-i-Martin (2004) use a measure of the extent of international openness, the ratio of exports and imports to GDP. Larger countries are known to be less open because trade offers a large market that can substitute effectively. Their explanatory variable filters out the nominal relationship of openness to the logs of population and area. This variable reflects the influences of government policies, such as tariffs, and trade restrictions.

The country intercepts vary considerably, suggesting that the assumption of differing intercepts is appropriate. To confirm this fact, we test the hypothesis that all country specific constants are equal.

We tested the joint significance of the fixed effects estimates in LS specifications. We first estimate unrestricted equation and then the appropriate restricted ones. And, we display the test output. The measure of openness by World Bank (2000) raises the balanced growth path income and (observed) per capita income Table 6.

Table 6: Fixed Effects Estimation Result (Openness)

Dependent Variable: y
Sample (adjusted): 1950 2004
Cross-sections included: 6
Total pool (unbalanced) observations: 322

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-3697.105	994.8367	-3.716293	0.0002**
sK	176.3934	44.53584	3.960706	0.0001**
OPEN	85.57945	12.71320	6.731544	0.0000**
Fixed Effects (Cross)				

Table 7: Test for Cross-Section Fixed Effects

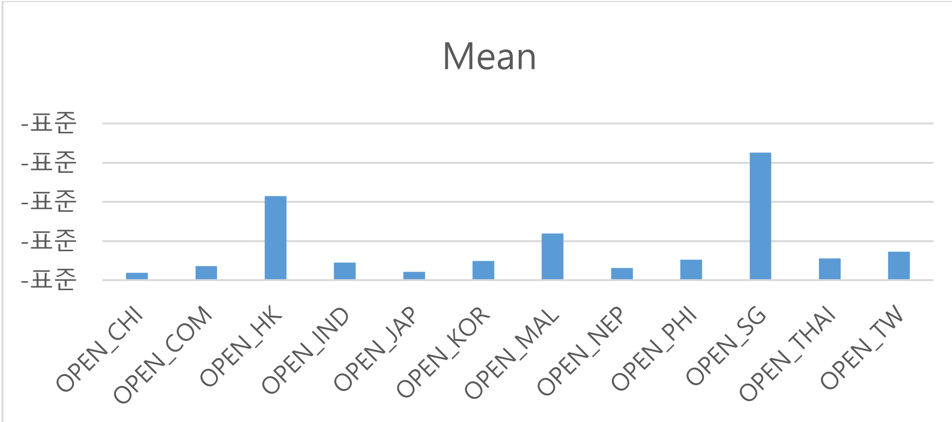
Redundant Fixed Effects Tests			
Test cross-section fixed effects			
Effects Test	Statistic	d.f.	Prob.
Joint Significance of the cross-section effects			
Cross-section F (using sums-of-squares)	6.988514	(11,578)	0.0000**
Cross-section Chi-square (using the likelihood function)	73.922120	11	0.0000**

Barro and Sala-i-Martin (2004)'s measure of openness is highly sensitive to country size. So, they filtered the ratio for its relation in a regression context to the logs of population and area. The specification is appropriate if the trade ratio is exogenous to growth. Estimation results show that there is only weak statistical evidence that openness stimulates economic growth.

Acemoglu, Aghion and Zilibotti (2006) regress the average growth rate on a country's deviation to the U.S. per capita income at the beginning of the period. They show that growth rate decreases more rapidly as a country approaches the frontier when openness is low. This implies that a low degree of openness does not appear to be detrimental to growth in countries far below the frontier.

We split the sample of countries into two groups according to countries that are more open (HK, MAL, SG) and less open (CHI, COM, KOR, NEP, PHI, THAI, TW). To measure openness, one can use exports and imports divided by GDP. This measure may suffer endogeneity problem. We solved this problem by spitting the sample into two groups, and then estimated growth regression separately.

Figure 5: Measure of Openness



Note: World Bank(2000), the World Bank's Global Development Network Growth Database

While we use the measure of World Bank (2000), Frankel and Romer (1999) construct a more exogenous measure of openness that relies on characteristics such as land area, common borders, geographical distance and population.

Now, consider a growth regression of the form:

$y(t) - y(t - 1) = \alpha + \beta\, y(t - 1) + \gamma y^*(t) + \varepsilon$ (4)

Rearranging this equation produces: $y(t) = \alpha' + \beta'\, y(t - 1) + \gamma' X(t) + u$ (5)

$\beta' = (1+ \beta) = e^{-\gamma t}$

where γ=speed of convergence.

To investigate whether dividing the sample into two groups has any significance, we can regress output growth on a constant, one year lagged output (initial income) and the row-vector of determinants of steady-state income, $X[=y^*(s_K, L)]$. If the coefficients for the determinant of steady-state income, *X*, is significant and has the expected sign, then this regression result implies the phenomenon of "conditional convergence."

We estimated the (neoclassical) growth regression model by fixed-effects panel estimation with the strong restriction that each coefficient is the same across countries except for individual country effects. The result shows that most coefficients are significant. In this regression we include the ratio of physical investment and the measure of external openness (OPEN). Their coefficients are positive and significant.

Contrary to Acemoglu, Aghion and Zilibotti(2006), it becomes increasingly helpful to growth as the Asian country approaches the frontier. The higher estimate of coefficient β' is the lower speed of convergence γ, for less open countries.

Table 8: Estimation for Speed of Convergence (More Open Countries)

Dependent Variable: LOG(yt)				
Sample (adjusted): 1956 1990				
Total pool (unbalanced) observations: 95				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.033131	1.746830	-2.308828	0.0233**
LOG(y(t-1))	0.911842	0.041058	22.20840	0.0000**
LOG(sK)	0.018276	0.032913	0.555291	0.5801
LOG(L)	0.325021	0.145568	2.232780	0.0281**
Fixed Effects (Cross)				
_HK--C	0.002551			
_MAL--C	-0.282342			
_SG--C	0.326848			

Estimation for Speed of Convergence (Less Open Countries)

Dependent Variable: LOG(PER?)				
Cross-sections included: 9				
Total pool (unbalanced) observations: 323				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.587297	0.476028	-5.435181	0.0000**
LOG(PER?(-1))	0.960744	0.007756	123.8764	0.0000**
LOG(SK?)	0.069883	0.010965	6.373311	0.0000**
LOG(L?)	0.160400	0.031259	5.131286	0.0000**

Instrumental Variables Estimation and Panel GMM Estimation

However, in the results of the fixed effects estimation presented above, there is an important econometric problem. First of all, this problem involves correlated individual effects. The log value of lagged income per capita may be correlated with a compound error term. In this case, OLS and GLS estimators are biased and inconsistent. Therefore, we perform a first difference transformation to eliminate heterogeneity.

$y(t) - y(t - 1) = \beta' [y(t - 1) - y(t - 2)] + \gamma'[X(t) - X(t - 1)] + [u(t) - u(t - 1)]$

However, this equation still has endogeneity problems and the (difference of) lagged income per capita may be correlated with the composed error term. Additionally, one component of the steady-state income and the function of R&D can be determined endogenously. In this case, we can use simple instrumental variables (IV) estimation. We use the lagged levels, $y(t - 2)$, $y(t - 3)$, and the lagged differences $[y(t - 2) - y(t - 3)]$ as instrumental variables for $[y(t - 1) - y(t - 2)]$.

The (pooled) instrumental variables (IV) estimation results show the estimates for the determinants of steady-state income. The coefficient for the multiplicative term of R&D expenditure and TREND is significant and has the expected sign. We omit the second term in the right hand side of the regression equation because of a problem with insufficient degrees of freedom.

Table 9: Pooled IV/Two-stage EGLS Estimation Result (Semi-Endogenous)

Dependent Variable: ΔLOG(y) Fixed Effects				
Method: Pooled IV/Two-stage Least Squares				
Sample (adjusted): 1983 2004				
Cross-sections included: 2				
Total pool (unbalanced) observations: 43				
Instrument list: C LOG(n) LOG(s_K) LOG(n) LOG($s_{K\ -1}$)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.007890	0.010419	0.757297	0.4534
ΔLOG(y_{-1})	0.489861	0.172774	2.835278	0.0072**
ΔLOG(RD)* TREND	0.004881	0.000804	6.070336	0.0000**

Finally, since the fixed effects problem is serious, we can consider Arellano and Bond's (1991)[10] GMM estimation.[11] But, Bond et al.(2001) assert that if the time series are "short", the first-differenced GMM estimator is not good due to the weak instruments problem.[12] We postpone this analysis for future research.

Table 10: Summary: Effects of R&D Efforts

Log(y)	**RD**	**RD*Trend**	**s_R**
Fixed Effects(i)	++		
Fixed Effects(ii)		++	+
Fixed Effects(iii)	++		-
Pooled IV		++	

(++: positively significant, --: negatively significant, +: positively insignificant, -: negatively insignificant)

Table 5 shows many coefficients for research efforts seem to have significant positive values. These partially coincide with the implication of semi-endogenous growth theory. The increase in research input causes the steady-state income to increase and then, the growth rate of income. The contribution of this paper is that it explicitly consider R&D-related variable in growth regression for Asian areas.[13] We show that the steady-state income level depends not only on the investment rate and population growth, as in Solow model, but also on the R&D input(effort),

[10] Arellano, et al.(1991) suggest that a dynamic panel data model with lagged dependent variables on the right-hand side can be consistently estimated using lagged dependent variables as instrumental variables.
[11] The main implication of their argument is that there is a large amount of information to be used from the implied relationships between levels and first differences.
[12] In spite of these risks, we can apply first-differenced GMM in the hope that our data are relatively long, so it can prevents the bias problem of weak instruments.
[13] In convergence regression, income growth is regressed on initial income and steady-state income levels.

as in Jones' semi-endogenous growth model, across Asian areas. In this paper, we show that data from some developed (or developing) countries sampled in Asia support semi-endogenous growth implications. The addition of the R&D share variable that determines the steady-state income increases the estimated speed of convergence.

Economic Growth and Unemployment

Endogenous Growth and Unemployment

Many literatures have tried to characterize how equilibrium unemployment rate reacts to the rate of technological change.[14] Two approaches are divided on that view (Hornstein et al., 2005). The first approach (Aghion and Howitt, 1998) argues that new equipment enters the economy through the creation of new matches ("creative destruction effect").[15] The second approach (Mortensen and Pissarides, 1998)[16] proposes the alternative view that the new technologies enter into firms through the process of upgrading plant units. Hornstein, Krusell and Violante (2003) find that (in the vintage-matching model) the link between capital-embodied growth and unemployment does not strongly depend on the form through which new technology enters into capital goods.

In general growth process, unemployment is caused by workers moving to new plants utilizing new technology. This is called the "creative destruction effect" (Aghion and Howitt, 1998). There also is the opposite effect, namely a capitalization effect, whereby an increase in growth raises the rate of returns of a plant, thereby encouraging more job creation (*If we introduce the possibility that plants can upgrade their technology, the capitalization effects appear. Before becoming obsolete, production units can adapt to the newest technology*). This capitalization effect increases the equilibrium level of vacancies and hence decreases unemployment. The increase in growth acts positively on the equilibrium rate of vacancy creation. It reduces the net discount rate at which production units capitalize the expected income from future upgrades.

The Schumpeterian second generation endogenous theory of growth [Young (1998), Aghion-Howitt (1998)] provides a way of deleting the scale effect. "Scale effect" means that the same R & D effort can lead to sustained growth of productivity. However, in this paper, we retain the characteristic of "scale effect"(in levels)[17] in this Schumpeterian model.

14 The question of whether faster technological progress(and economic growth) speeds up the destruction of jobs in East Asian economies will be the additional focus of the present paper.

15 Generally, "creative destruction" is used to point the following fact. That is, the successful monopoly innovator destroys the profits(rents) of the previous generation by reducing it obsolete.

16 For small values of the upgrading cost, unemployment falls with growth ("capitalization effect").

17 Young (1998) argues that as population increases, the range of goods over which R & D is spread also grows.

A single final-good (or aggregate consumption) sector produces a homogeneous output good C, according to the CES technology: $C= [\int_0^B Y(i)^{\alpha\upsilon} di]^{(1/\upsilon)}$

where B is the variety of goods and Y(i) is the consumption. α is related to the income share and υ<1 is related to the elasticity of substitution.

Let each variety Y(i) be produced according to the following equations:

$Y_i= (A_i L_{Y i})^{(1-\alpha)} K_i^{\alpha}$,

$\Delta A_i/A_i = \delta L_{A i}$

In the second generation growth models, the variety of consumption goods is proportional to the population. These implications of growth model mainly come from Jones(1999).

We consider the relationships between growth-related variables and labor market variables. We introduce hiring costs ($=cA_t$) and assume that the wage being sought is proportional to the technology ($w_t=aA_t$). There is also the quit rate, b, of workers.[18]

The demand for labor by monopolistic firms is:

$L_D = l^* [\rho+(\varepsilon+1)g_A, w+(\rho+\varepsilon g_A+b)c]$

The above equation means that the ratio of job creation to growth is expressed as a function of ρ, ε, gA, w, b, c and is decreasing in each argument (Aghion and Howitt, 1998). In this Schumpeterian model, there are various exogenous variables: quit rate, the cost of hiring and parameter of real wage level, etc.[19] From these analyses, we can choose some hypotheses for empirical testing research: the unemployment rate is a increasing function of the growth rate of technology g_A, (the hiring cost c, and the quit rate of workers b). In this paper, we test this prediction for growth and unemployment set forth by Aghion and Howitt (1998), for four(or three) Asian areas.

Long-term Relationship

In this section, we first consider whether the IP index (IP) and unemployment rate (U) are stationary. After performing Dickey-Fuller unit root test, we see that the two series are non-stationary.[20] For (panel) unit root tests, first consider an AR (1) process for panel data. This tests the unit root as the null hypothesis H_0: $|\rho_i| = 1$. (ρ_i = 1st order autoregressive coefficients in $y_{it} = \rho_i y_{it-1} + \gamma X^*_{it} \gamma_i + \varepsilon_{it}$) First, the persistence parameters are common across cross-

18 We have the following arbitrage equation: $1= \lambda v(\rho+(\varepsilon+1)gA, w+(\rho+\varepsilon gA+b)c, gA)$

ρ: rate of discount, ε: elasticity of marginal utility

The steady-state growth rate is: $gA=\lambda g(N/A)$

19 Also, there are endogenous variables: job separation, job creation and (natural) rate of unemployment.

20 Recent literature suggests that panel-based unit root tests (and the co-integration test) have higher power than unit root tests on individual time series.

sections so that $\rho_i = \rho$ for all *i*. Alternatively, one can allow ρ_i to vary freely across cross-sections. (EViews 6 User's Guide, 2007)

In total, test results provide several test statistics which evaluate the null hypothesis (unit root). In the case of *IP* and *U*, almost all statistics do reject the null hypothesis at the 5% or 10% significance level, so, we see that these variables are stationary.

Table 8: Pool Unit Root Test Statistics (4 Asian areas)

Series: IP_CHI, IP_JAP, IP_KOR, IP_TW			Series: U_CHI, U_JAP, U_KOR, U_TW		
Sample: 2000M01 2008M10			Sample: 2000M01 2008M10		
Method	Statistic	Prob.**	Method	Statistic	Prob.**
Null: Unit root (assumes common unit root process)					
Levin, Lin & Chu t*	-1.95727	0.0252**	Levin, Lin & Chu t*	-3.22014	0.0006**
Null: Unit root (assumes individual unit root process)					
Im, Pesaran and Shin W-stat	-1.69365	0.0452**	Im, Pesaran and Shin W-stat	-2.31906	0.0102**
ADF - Fisher Chi-square	11.8096	0.0664*	ADF - Fisher Chi-square	15.9177	0.0142**
PP - Fisher Chi-square	11.3475	0.0782*	PP - Fisher Chi-square	15.0665	0.0197**

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Through fixed effects (LSDV) estimation, we can conclude that the economic growth denoted by log difference of IP index has no significant effect on unemployment. It is better to consider the role of R&D again, in the spirit of semi-endogenous model, in analyzing unemployment. But, we only focused only on growth and unemployment.

Table 9: The Effects of (Production) Growth on Unemployment (4 Asian Areas)

Dependent Variable: U - Fixed Effects				
Sample (adjusted): 2000M02 2008M09				
Total pool (unbalanced) observations: 217				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.888054	0.02414	161.0628	0
ΔLOG(IP)	-0.080797	0.458408	-0.176255	0.8603

Finally, we analyze impulse response functions to see the effects of an (IP) production on the rate of unemployment. For this, we construct structural VAR (vector autoregressive) model that explore the causal relationship between time-series variables.[21] Most criteria show that optimal lag length is one. An (reduced-form) VAR (1) is expressed as:

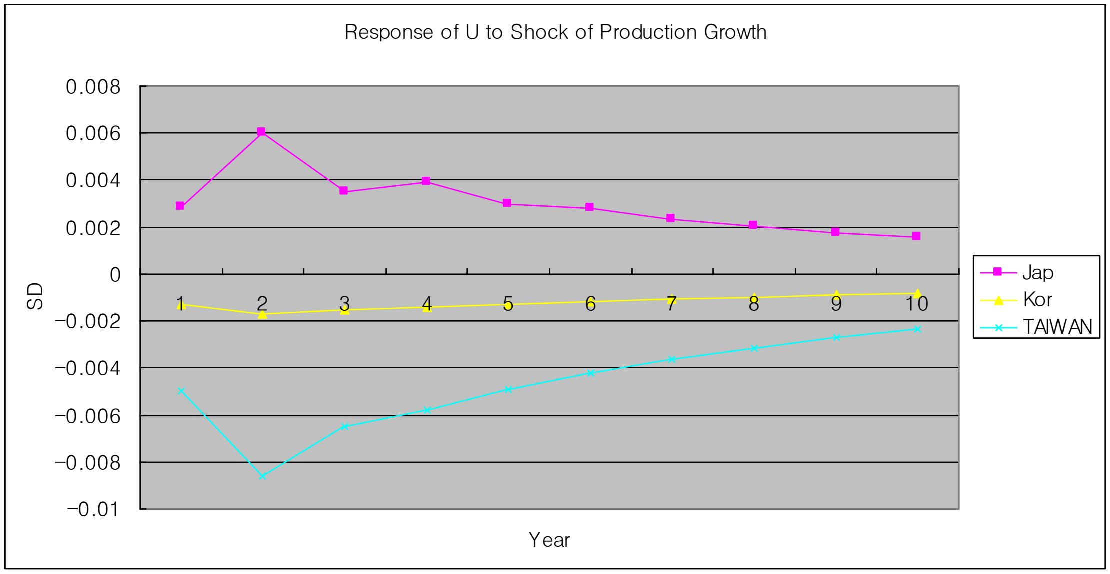
$x_t = \alpha(1) + ß(1) x_{t-1} + \theta(1) y_{t-1} + e_t$, $y_t = \alpha(2) + ß(2) x_{t-1} + \theta(2) y_{t-1} + e_t$

x: growth rate of IP Index, y: unemployment rate.

This can be expressed more easily in matrix form as: $Y_t = CY_{t-1} + V_t$. The real dynamics of impulse responses is complicated by the fact: we should identify the correct shock from unobservable data.(Hill et al., 2008) This complication leads to the identification problem.

More precisely, a structural form is expressed as:[22] $BY_t = AY_{t-1} + E_t$[23] The impulse response(Response of U to IP growth) in this structural VAR shows that the response of U to production growth shock is positive or negative across areas. Chang et al(2004) shows that the decrease of sectoral shift cause job-separation rate and unemployment rate to decrease over the past three decades in Korea. But, we see the change in labor market(unemployment) may come from productivity growth due to R&D efforts. In addition, we do not agree with their argument that growth rate is not primary reason for the decrease of unemployment rate. They present the evidence that similar East Asian countries did not show noticeable trend in unemployment rate. But, we should watch the relationship between unemployment and the following variables of those countries: per capita income growth and productivity growth. In future research, we will consider this problem.

Figure 6: Estimation Results for Impulse Response Functions (3 Asian areas)[24]



21 Lag lengths in a VAR is determined by log-likelihood, likelihood ratio or information criteria.

22 If B is not an identity matrix, the elements(errors)in V are weighted functions(averages) of the elements in E.

23 We impose long-run restriction so that the shocks in unemployment have no effect on production growth in the long-run.

24 We omitted the data for Mainland China due to unavailability of IP data.

From estimated 2-variable (production growth, unemployment rate U) structural VAR model for seeing what the impulse response functions look like using monthly time series data (2000~2008), we can see that the graph shows mixed effects across areas.

Open Economy with Convergence

Economic Growth of China

In this section, we consider soaring growth rates of China. According to its size (population of 1.3 billion), China could become the next great power. China started from such a low level of GDP per capita (*y60*=0.04 is per capita GDP in 1960, relative to the U.S.). Maddison (2001) shows that real GDP per capita was actually lower in 1950 than it had been 80 years earlier in 1870.

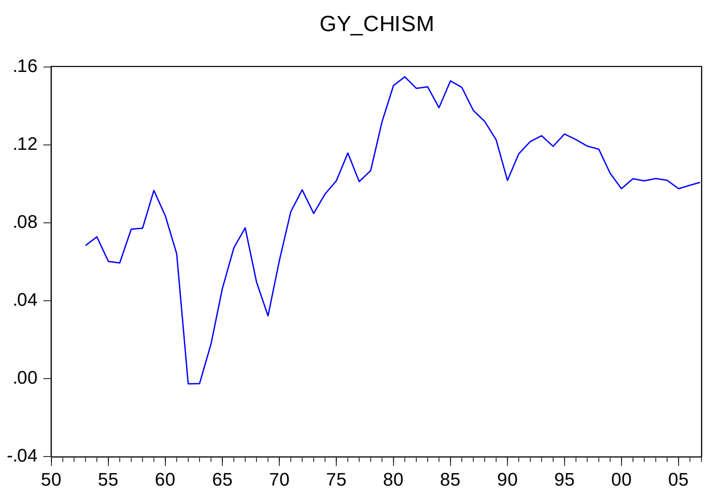
In recent years, real GDP growth in China has been rapid. <Figure > shows the growth rate. In the early 2000s, China's GDP growth has averaged 8.8% per year. Abel, Bernanke, and Croushore (2008) prospected that China should eventually experience high wages & increased standard of living. But, according to them, the main problems in the near future include a weak banking system, income inequality, and unemployment among rural workers

Table 10: Fundamental parameter values

	y97	g	s_K	n	y60
US	1	0.0139	0.204	0.01	1
CHI	0.097	0.0351	0.235	0.0132	0.044

(Jones 2002, Appendix)

Figure 7: Growth Rate of GDP per Capita in China



Term of Trade in an Open Economy

In this section, we consider an attempting at defending the AK model from criticism that it cannot explain convergence. Acemoglu and Ventura (2002) incorporate international trade and terms of trade. The reason that AK model can exhibit convergence is because in an open economy the parameter A can be affected by the country's terms of trade. Barro and Sala-i-Martin (2004) include the growth rate over each decade of the terms of trade, measured by the ratio of export prices to import prices, as a control variable in a growth regression. Their ratio appears as a product with the openness. This variable measures the effect of changes in international prices on the GNI. This real income position rises because of higher export prices. If an increase in the relative price of the goods tends to generate more output, then the effect on growth would be positive. Their estimated coefficient was positive and significant: 0.130(0.053). We can open the economy with (fixed) terms of trade (Aghion and Howitt, 2009). Suppose that producing the Y final good requires not just X but also a foreign produced intermediate product Xf.

Y= $K^{\alpha} X^{(1-\alpha)/2} Xf^{(1-\alpha)/2}$

X and Xf are tradeable goods, but capital is not tradable. Then domestic producers of Y will choose two intermediate products to maximize profits. We have an AK model, with Y=AK, where the constant marginal product of capital A depends negatively on the relative price of foreign goods, pf.

A=$(1-\alpha)/2^{1-\alpha/\alpha}\ pf^{-(1-\alpha)/2\alpha}$

Slower growth in the domestic economy decreases the price of imported intermediate good, thus resulting in a improvement of the country's terms of trade, which in turn increases the rate of capital accumulation. This AK model delivers convergence through capital accumulation.

We estimate the growth equation with a vector of variables (such as s_K) that control for the determinations of steady-state output per capita including terms of trade by World Bank(2001). The estimated coefficients are statistically significant and have positive value. This supports the proposition that considering terms of trade promotes convergence.

Table 11: Income versus Terms of Trade

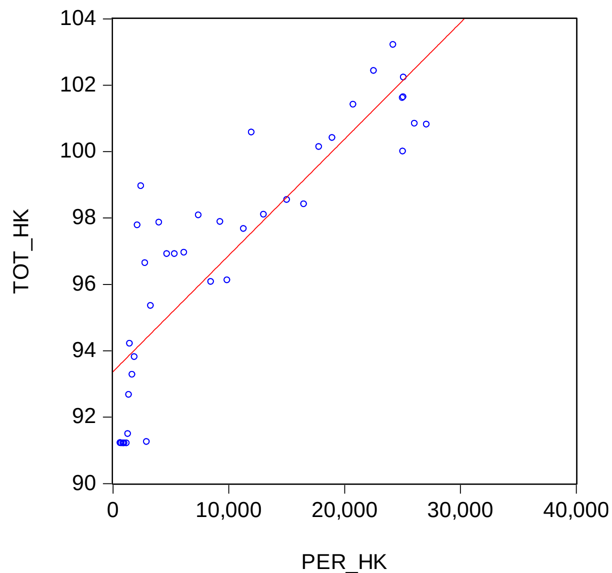
Dependent Variable: LOG(yt)				
Sample (adjusted): 1960 1999				
Cross-sections included: 12				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.114430	0.080535	1.420866	0.1562
LOG(sK)	0.038572	0.011511	3.350822	0.0009**
LOG(y(t-1))	0.964883	0.009747	98.99064	0.0000**

Table 11…

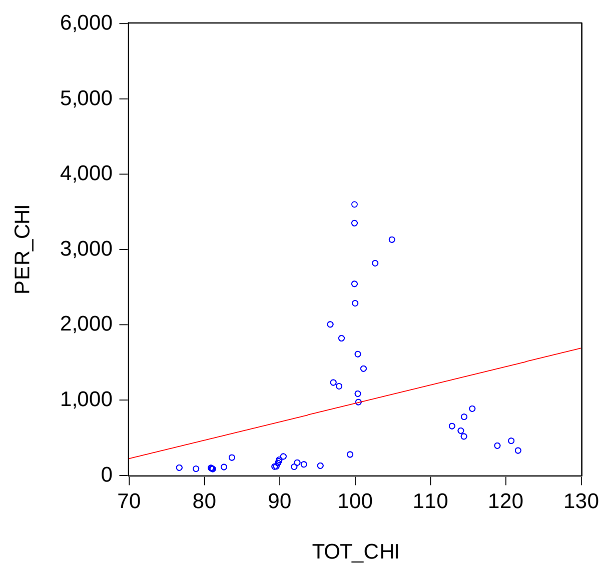
LOG(TOT)	0.024358	0.010178	2.393177	0.0172**
Fixed Effects (Cross)				
Fixed Effects (Period)				

Unfortunately, the model is not consistent with empirical evidence. The prediction that growth reduces terms of trade is counterfactual. In this respect, AK model too cannot explain cross-country convergence. Several examples including cointegration test results show that these confusing counterfactual cases.

Figure 8: Income versus Terms of Trade (HK, CHI)

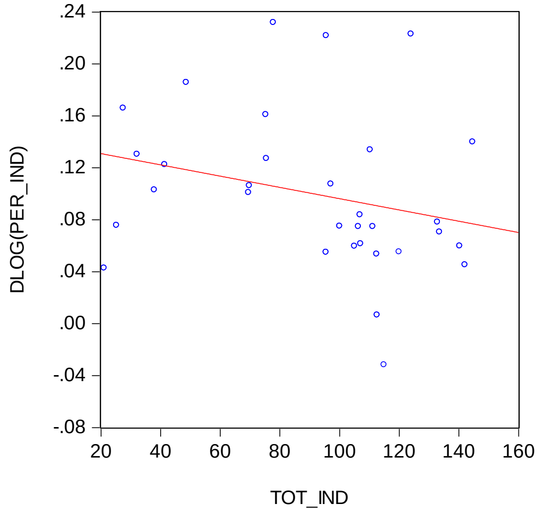


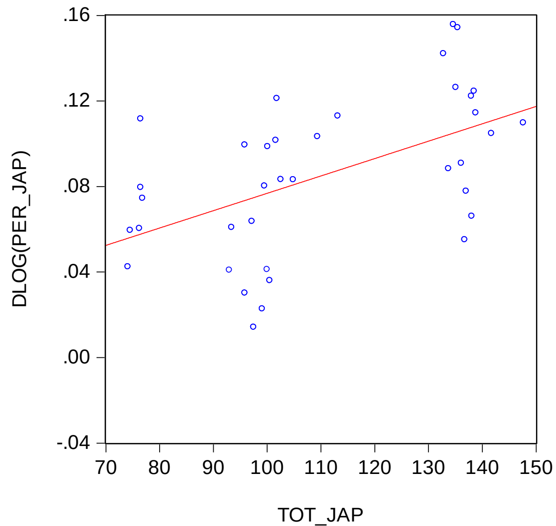
Corr.=0.86



Corr.=0.62

Figure 9: Income Growth versus Terms of Trade (IND, JAP, KOR)





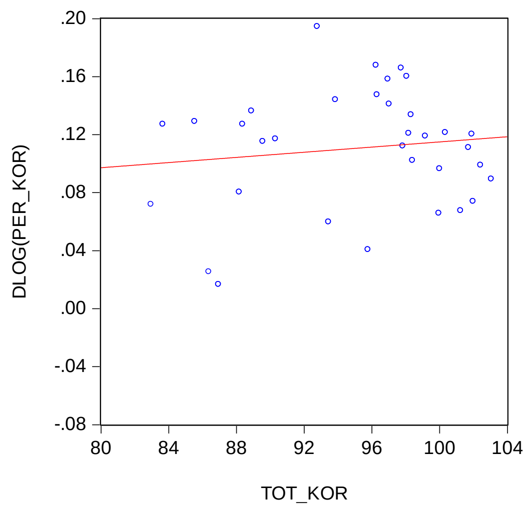


Table 12: Income versus Terms of Trade: Cointegration (IND, JAP, KOR)

Pedroni Residual Cointegration Test				
Series: TOT_HK PER_HK				
Sample: 1950 2007				
Null Hypothesis: No cointegration				
Alternative hypothesis: common AR coefs. (within-dimension)				
			Weighted	
	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	-0.268673	0.6059	-0.268673	0.6059
Panel rho-Statistic	-1.658931	0.0486**	-1.658931	0.0486**
Panel PP-Statistic	-1.554726	0.0600*	-1.554726	0.0600*
Panel ADF-Statistic	-1.777912	0.0377**	-1.777912	0.0377**
Series: TOT_MAL PER_MAL				
Sample: 1950 2007				
Alternative hypothesis: common AR coefs. (within-dimension)				
			Weighted	
	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	1.400289	0.0807*	1.400289	0.0807*
Panel rho-Statistic	-2.804448	0.0025**	-2.804448	0.0025**
Panel PP-Statistic	-3.433852	0.0003**	-3.433852	0.0003**
Panel ADF-Statistic	-2.052664	0.0201**	-2.052664	0.0201**
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic	Prob.		
Group rho-Statistic	-2.109312	0.0175**		
Group PP-Statistic	-3.706884	0.0001**		
Group ADF-Statistic	-2.067343	0.0194**		

SUMMARY AND CONCLUSION

Barro and Sala-i-Martin (2004) argue that for 9 East Asian “miracle” economies, the average growth was 4.9%, and the investment ratio was 25%. Although investment propensities are not the whole story, we tried to relate the growth to its willingness to invest in physical (and knowledge) capital. We also examined the foreign sector, which are characterized by the measure of openness and terms of trade. In special, we considered the case of China. In addition, we briefly studied the relationship between output growth and labor markets.

Aghion and Howitt (1998) analyzed the relationship between economic growth and unemployment with endogenous growth model. New technology is embodied in plants, which are costly to build. Unemployment is caused by workers having to move from a plant utilizing old technology to one utilizing new technology. In analyzing the relationship between growth and unemployment, we explicitly considered the role of R&D. That is, we used semi-endogenous growth model as basic theoretical model for examining the economic growth and convergence of Asian areas.

In this paper, we also showed that “direct creative destruction” (increasing unemployment) is not the only effect of faster productivity growth. Suppose that some technological advances are of a form that can be utilized by existing plants. Then investors will be encouraged to create new plants and vacancies by the possibility of benefiting from future technological advances. (Aghion and Howitt, 1998) Capitalization effect could more than offset the creative destruction effect, resulting in an overall decrease in unemployment when growth rises in South Korea and Taiwan. (Aghion and Howitt, 1998) We showed that the empirical evidence is in favor of both effect from production growth, across three Asian areas. We can infer that due to high industrialization and developed economic structure, Japan has “creative destruction” effect of economic growth on unemployment.

SCOPE FOR FUTURE RESEARCH

Acemoglu and Aghion and Zilibotti (2006) discuss the mechanism for institutional persistence in Asia. They discuss the example of South Korea. In Korea, government subsidized loans to large family-run conglomerates.

In Japan, MITI regulated competition by controlling foreign currency and import licenses and by directing industrial policy. It also subsidized investment by large firm-bank consortia, keiretsu. These institutional factors remained untouched by our study due to relevant data unavailability. This issue will be postponed to future research.

Finally Acemoglu and Ventura (2002) linked to trade and terms of trade in transition dynamics. In this case, even AK models can exhibit convergence in growth rates. This may give implications for adopting appropriate theoretical framework for future empirical research.

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APPENDICES

Growth Regression: Co-integration and Error Correction

The second objection to standard growth regression is that these regressions assume a country’s steady-state determinants are fixed over time. Cellini (1997) solves this problem using co-integration and error-correction methods. He contends that saving rate and population growth rate follow non-stationary processes, so the per capita income series is a stochastically non-stationary process.

We apply the same tools to test endogenous growth theory.[25] According to Cellini (1997), y, n, and s_K are all non-stationary series with unit roots.[26] Thus, we applied augmented Dickey-Fuller unit root tests. These results show that almost all the variables have unit roots.[27]

<Table 1> Unit Root Test Result

	y		s_K		s_R	
ADF	t-Statistic	p-value*	t-Statistic	p-value*	t-Statistic	p-value*
JPN	-1.92	0.32	1.7	0.71	1.7	0.71
KOR	-0.44	0.98	-2.35	0.39	-2.41	0.36

[25] We insert the trend variable into the ADF test equation.
[26] The non-stationarity means that the variables have mean which change over time.
[27] To effectively use DF test, we need to have a lot of observations, and this is not very common in panel data sets.

The Johansen (1988, 1992) approach starts with setting a reduced VAR model.[28] Test and estimation for co-integrating vectors show that there is a long-run relationship between per capita income and the functions of R&D investment.

<Table 2> Johansen Co-integration Test and Estimation Result(Normalized Cointegrating Vector)

Johansen Cointegartion Method(1) **Neoclassical**	**y**	**s_K**	**n**	**Trend**	
JAP	**1**	**-0.35**	**0.32**		
KOR	**No Cointegration**				
Johansen Cointegartion Method(2) **Semi-endogenous**	**y**	**s_K**	**n**	**Trend**	**RD**
JAP	**1**	**-4.46**	**3.04**		**2.33**
KOR	**No Cointegration**				
Johansen Cointegartion Method(3) **Semi-endogenous**	**y**	**s_K**	**n**	**Trend**	**RD^2**
JAP	**1**	**-3.53**	**2.55**		**0.08**
KOR	**No Cointegration**				

Johansen Cointegartion Method(4) **Semi-endogenous**	**y**	**s_K**	**n**	**Trend*RD**
JAP	**1**	**-0.38**	**-0.09**	**-0.002**
KOR	**1**	**0.215**	**-0.053**	**-0.005**

We can set up the ECM (equilibrium correction model).[29] Estimation results show that only the Japanese economy shows significant error correction mechanisms.[30]

<Table 3> ECM Estimation Result for Japan

Dependent Variable: ΔLOG(y_JAP)	

[28] The null hypothesis that there are less than *r* co-integrating vectors is tested using the trace test statistic.
[29] This error correction model shows how much Δy responds (converges) to the co-integrating error.
[30] $\Delta y_t = c + \pi(s_K)\, s_{K\,t-1} + \pi(n) n_{t-1} + \pi(RD) RD_{t-1} + \Sigma_{i=1}^{p-1} \psi'_i (\Delta y_{t-i}, \Delta s_{K\,t-i}, \Delta n_{t-i}, \Delta RD_{t-i})' + \delta' (\Delta y_t, \Delta sK_t, \Delta RD_t) + u_t$

Method: Least Squares				
Sample (adjusted): 1986 – 2004				
Included observations: 19 after adjustments				
	Coefficient	Std. Error	t-Statistic	p-value
C	0.024646	0.007684	3.207355	0.0063**
Cointegrating Error$_{-1}$	-0.420329	0.179662	-2.339554	0.0346**
ΔLOG(s_K_JAP$_{-1}$)	0.174129	0.083092	2.095615	0.0548*
ΔLOG(n_JAP$_{-1}$)	0.07503	0.087559	0.856912	0.4059
ΔLOG(RD_JAP$_{-1}$)	0.028765	0.035836	0.802696	0.4356

<Table 4> Summary: Effects of R&D Efforts

Log(y) Semi-endogenous	**RD**	**RD*t**	**RD^2**
Johansen Cointegration(JAP 2)	**--**		
Johansen Cointegration(JAP 3)			**--**
Johansen Cointegration(JAP 4)		**++**	
Johansen Cointegration(KOR)		**++**	

(++: positively significant, --: negatively significant, +: positively insignificant, -: negatively insignificant)