Economic growth and unemployment in East Asia

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Abstract: Barro and Sala-i-Martin (2004) analyzed the empirical determinants of growth. The data used in this paper consists of panel data of several macroeconomic variables observed for 55 years (1950-2004) in six East Asian countries and regions. Following the implications of semi-endogenous growth theory, the author 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), the author also considers cointegration and error-correction methods as the growth regression of East Asian countries. Meanwhile, Chang, et al (2004) derived the conclusion that the decreases in reallocation shocks are main factor in a downward trend in natural rate of unemployment for South Korea. The author extends this analysis using structural VAR to other Asian countries and regions, Japan and Taiwan region. Impulse responses show that the growth of production in Korea and Taiwan reduce unemployment, but, in Japan, this raises unemployment.

Key words: growth regression; East Asian countries and regions; R & D input; unemployment

1. Introduction

We can see plots of R&D intensities show increasing trends in two relatively developed countries, Japan and South Korea, in East Asia from the 1960s to 2005[1] (see Fig. 1). We can also see the trend of GDP per capita across Asian countries (see Fig. 2).

In the past, many economists presented some explanation for the growth of per capita income of these countries. 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 had focused mainly on western developed countries, neglecting the convergence problem in the East Asian countries and regions.

In cross-country study, Mankiw, Romer and Weil (1992) argued that the augmented Solow model is opt in forecasting the common rate of (efficiency) growth among countries.[2] This paper carries their analyses one step further to ask whether changes in the growth rate of the East Asian six countries and regions between the 1950s and the 2000s can be explained by this framework (see Fig. 2).

In analyzing these problems, we use semi-endogenous growth model of Jones (1995b) as the 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

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[1] For R & D intensity, we consider only Japan, and Korea, due to limited data availability from OECD.

[2] 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.

julong-run growth highlighted by the endogenous growth model do exhibit these changes.[3] 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.[4]

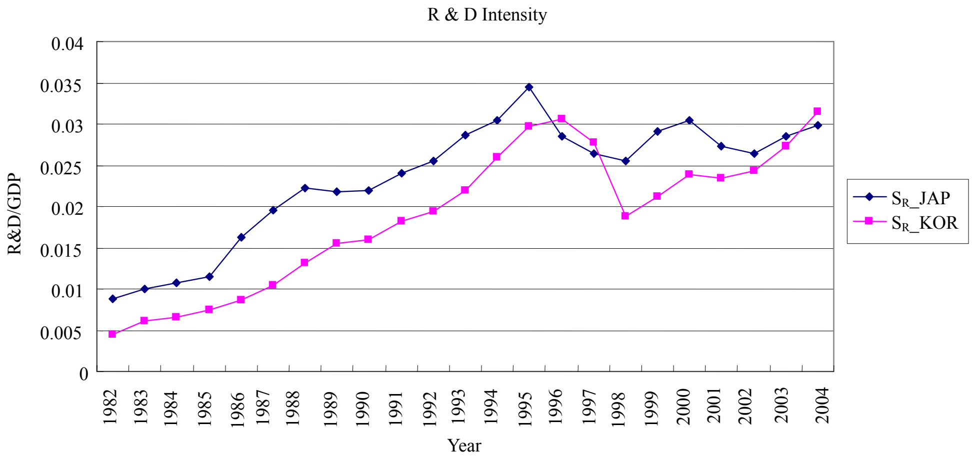


Fig. 1 The trend of R & D intensity (s_R)

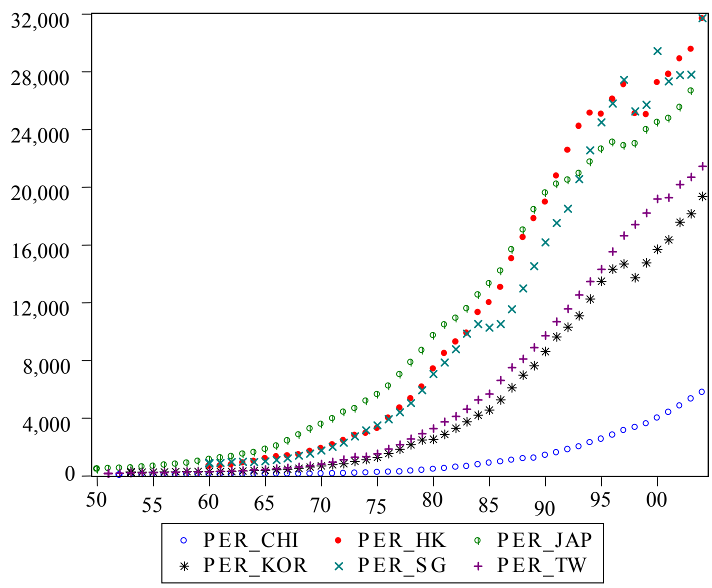


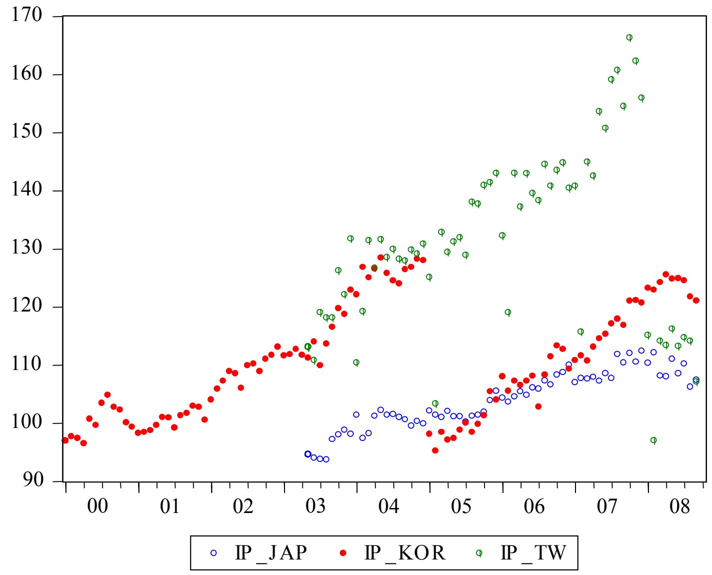
Fig. 2 The trend of per capita income (y) ($): China (CHI), Hong Kong region (HK), Japan (JAP), Korea (KOR), Singapore (SG), Taiwan region (TW)

This paper seeks to test several growth models by focusing on the economic forces underlying scale effects

[3] 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.

[4] 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.

(in income levels) of technological progress.[5] Using the model put forth by Jones (1995),[6] we performed panel regressions to determine whether semi-endogenous model provides relative good characterization of long-run economic growth in East Asian countries and regions.[7]



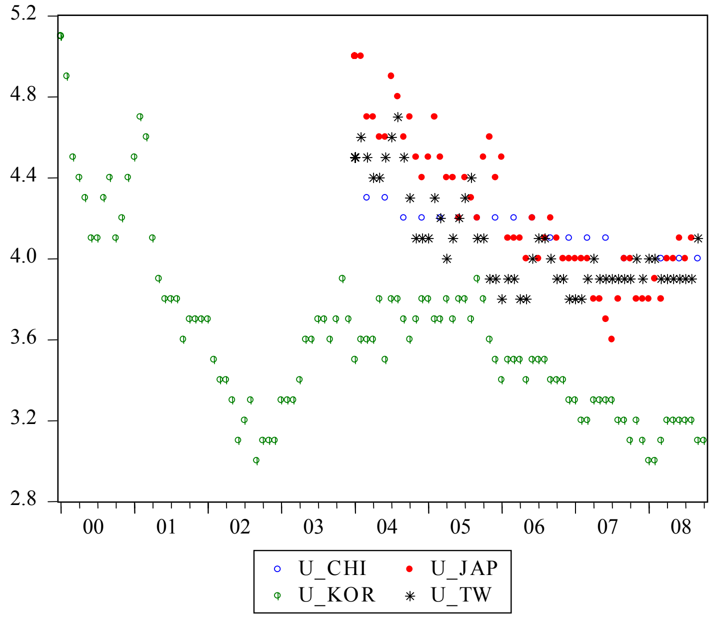


Fig. 3 The industrial production (IP) index and unemployment rate (U) for four Asian countries and regions (index, %) (OECD, BOK): China (CHI), Hong Kong region (HK), Japan (JAP), Korea (KOR), Singapore (SG), Taiwan region (TW)

In addition, in this paper, we also discussed the most recent data on the output growth, and unemployment. In

[5] 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).

[6] In Jones' model, without population growth, per capita income growth eventually stops. For this reason, it is sometimes referred to as a semi-endogenous growth model.

[7] 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.

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 countries and regions (see Fig. 3).[8] We use industrial production index as proxy for production (or income) growth.

Much literature have tried to characterize how equilibrium unemployment rate react to the rate of technological change.[9] Two approaches are divided on that view (Hornstein, et al., 2005). The first approach (Aghion & Howitt, 1998) argues that new equipment enters the economy through the creation of new matches, “creative destruction effect”.[10] The second approach (Mortensen & Pissarides, 1998)[11] proposes a alternative view that new technologies enter into firms through the process of upgrading plant units.[12]

Overall, an increase in the Industrial Production (IP) Index is associated with a decrease in the unemployment rate (U) in the four East Asian countries and regions.

Section 2 examines basic growth model regarding technical progress and labor market. Section 3 presents the results of growth regression for Asian countries. Section 4 considers long-run relationship between growth and unemployment in Asian countries and regions. Finally, section 5 concludes.

2. Previous literature

2.1 Empirical analysis: Growth regression

Many economists have recently presented sophisticated empirical analysis for cross-country growth regression.[13] These studies raise basic methodological issues.

The objection to standard growth regressions is that they assume a country’s or a region’s steady-state income determinants are fixed over time.[14] In contrast to this, in this paper, we explicitly consider the variability of long-run equilibrium level of income in exogeneous growth theory. The previous studies also neglect the implication of Romer’s (1990) endogenous growth theory that research effort is a main determinant of income and its growth.[15] In this paper, we incorporate related variables such as R & D intensity and R & D expenditures into previous growth models.

2.2 Economic growth models: Exogenous vs. Semi-endogenous[16]

Because the number of researcher is growing rapidly, the original Romer (1990) formulation of

8 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.

9 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.

10 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.

11 For small values of the upgrading cost, unemployment falls with growth, “capitalization effect”.

12 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.

13 Islam (1995), Caselli, Esquivel, and Lefort (1996), Cellini (1997), Bond, Hoeffler, and Teple (2001) and Barro and Sala-i-Martin (2004).

14 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 (see appendix).

15 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.

16 Jones (1995, 2002).

Schumpeterian endogenous growth predicts that the growth rate of the advanced economy should also have risen rapidly over the last 40 years.[17] However, Jones (1995a) pointed out that this is not the case.[18]

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:[19]

$$Y = (K)^{\alpha} \ (AL_Y)^{(1-\alpha)} \quad (1)$$ [20]

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

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) $A(t)$.[21]

2.1.1 Semi-endogenous model: The R & D sector and steady-state properties

Final output is produced using labor, L_Y, and intermediate goods, x. Research in turn generates designs for new intermediate inputs:[22]

$$Y = (\Sigma x \ j^{\alpha})(AL_Y)^{(1-\alpha)} = (K)^{\alpha} \ (AL_Y)^{(1-\alpha)} \quad (2)$$ [23]

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:[24] $\Delta A = \delta \, L_A{}^{\lambda} \, A^{\varphi}$ ($\Delta A = \delta \, L_A$, when λ=1, φ=0).

"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).[25] Along a balanced growth path,[26] the R&D equation can be solved for the level of A in terms of the labor force, and combining this equation (2), we get: [27]

$$y^*(t) = (s_K / n + g_A + d)^{(\alpha/1-\alpha)}(1 - s_R) \ A(t) = (s_K / n + g_A + d)^{(\alpha/1-\alpha)}(1 - s_R) \ \alpha e^{\delta L_A t} \quad (3)$$

where s_R is the share of the population engaged in R&D so that s_R L= L_A[28].

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

Following this conclusion, we classify the determinants for long-run income level as follows to set up several econometric models.

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[17] World research effort has steadily increased over the last 40 years.

[18] For example, the average growth rate of the U.S. economy has been very close to 2% per year for the last hundred years.

[19] 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.

[20] 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 .

[21] Jones (2002).

[22] Romer (1990) assumed that, in the intermediate sector, firms must pay a sunk cost of product innovation whose outlay is compensated with monopoly rents.

[23] Therefore A now refers indifferently to the current number of designs or the current number of intermediate inputs.

[24] 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: $s_A \equiv N/Y$.

[25] To slightly simplify things, assume that λ=1 and φ=0. Then, g_A =n (Jones, 2002).

[26] The only difference with the Solow model is the presence of the term (1- S_R), which adjusts for the difference between output per worker, L_A, and output per capita, L.

[27] $d_A/dt=\delta L_A$, $A= e^{\delta L_A tC}$.

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

Four forms of equations for Steady-state income level

$$y^*(t) = (s_K / n + g_A + d)^{(\alpha/1-\alpha)}\sigma(\delta s_R L / g_A) = y^*(t; s_K , n, s_R L) \quad (4)$$

$$y^*(t) = (s_K / n + g_A + d)^{(\alpha/1-\alpha)}(1 - s_R)\ \alpha\ e^{\delta LA\ t} = y^*(t; s_K , n, s_R, L_A\ t) \quad (5)$$

$$y^*(t) = (s_K / n + g_A + d)^{(\alpha/1-\alpha)}(1 - s_R)\ L_A = y^*(t; s_K , n, s_R, L_A) \quad (6)$$

$$y^*(t) = (s_K / n + g_A + d)^{(\alpha/1-\alpha)}(1 - s_R)\ (L_A)^2 = y^*(t; s_K, n, s_R, L_A^2) \quad (7)$$

Any equation can be used to see the effects of research effort. First, we consider the term $(1-s_R) = \sigma$ as constant. From equation 4, 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. Secondly, we consider the fact that, for sustaining growth, more researchers are needed for more technologies. Thirdly, we consider the fact that productivity is expressed as the (linear) function of labor input used to R & D from equation 5. Fourthly, using equation 6 we consider the fact that productivity is expressed as the (quadratic) function of labor input used to R & D. In section 3.2, we use these models for estimation of growth regression models from equation 7.

2.3 Economic growth and labor markets

2.3.1 Endogeneous growth and unemployment

In general growth process, unemployment is caused by workers moving to new plants utilizing new technology. This is called the "creative destruction effect" (Aghion & 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.[29] This capitalization effect increases the equilibrium level of vacancies and hence decreases unemployment.[30]

2.3.2 The second generation endogenous growth models[31]

The Schumpeterian second generation endogenous theory of growth (Young, 1998; Aghion & Howitt, 1998) provides a way of deleting the scale effect.[32] However, in this paper, the author retains the characteristic of "scale effect" (in levels)[33] in this Schumpeterian model.[34] In the second generation growth models, the variety of consumption goods is proportional to the population.[35]

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.[36]

The demand for labor by monopolistic firms is:

[29] 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.

[30] 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.

[31] This classification and summary of growth models mainly come from Jones(1999).

[32] "Scale effect" means that the same R & D effort can lead to sustained growth of productivity.

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

[34] 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 $\upsilon<1$ is related to the elasticity of substitution.

Let each variety *Y(i)* be produced according to the following equations: $Y_i= (A_i\ L_{Yi})^{(1-\alpha)}\ K_i^{\alpha}$, $\Delta A_i/A_i = \delta\ L_{Ai}$

To complete the model, we need to explain how *B* changes over time. We assume that: $B=L^{\beta}$ (β=1).

[35] These implications of growth model mainly come from Jones(1999).

[36] We have the following arbitrage equation: $1= \lambda\ v(\rho+(\varepsilon+1)g_A,\ w+(\rho+\varepsilon g_A+b)c,\ g_A)$; ρ: rate of discount, ε: elasticity of marginal utility; The steady-state growth rate is: $g_A=\lambda g(N/A)$.

$$L_D = l^* [\rho+(\varepsilon+1)g_A,\ w+(\rho+\varepsilon g_A+b)c]^{37} \tag{8}$$

In this Schumpeterian model, there are various exogenous variables: quit rate, the cost of hiring and parameter of real wage level, etc.[38] 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 countries and regions.

Table 1 Fundamental parameter values[39] (Jones, 2002, Appendix)

	y97	g	s_K	n	y60
US	1.000	0.0139	0.204	0.0100	1.000
SIN	0.895	0.0537	0.348	0.0181	0.205
HK	0.708	0.0523	0.202	0.0150	0.171
TW	0.656	0.0560	0.240	0.0121	0.138
JPN	0.619	0.0438	0.344	0.0045	0.205
KOR	0.596	0.0594	0.326	0.0110	0.111
CHI	0.097	0.0351	0.235	0.0132	0.044

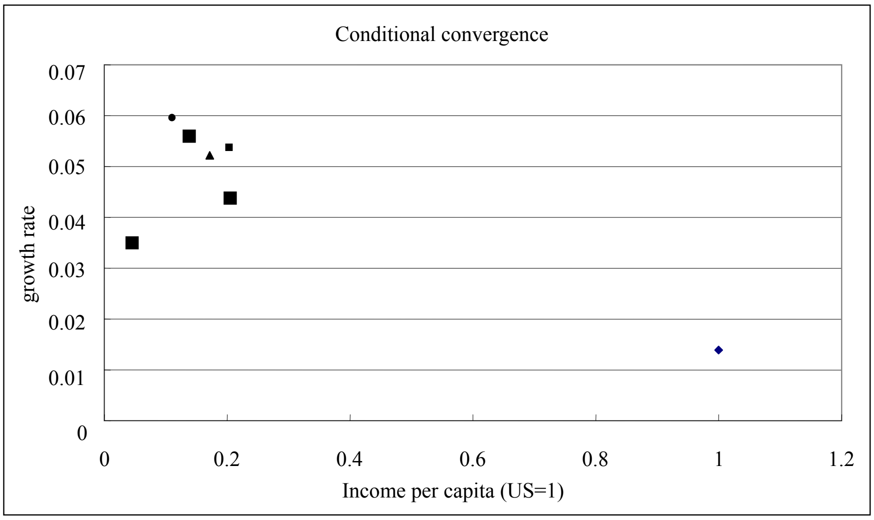

Fig. 4 Relative initial income (y60; to the US) & growth rate (g)

3. Convergence regressions

3.1 Data

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 (1950-2004) in six East Asian countries and regions (Korea, Japan, Taiwan region, Hong Kong region, Mainland China and Singapore).[40] They

[37] This equation means that the ratio of job creation to growth is expressed as a function of ρ, ε, g_A, w, b, c and is decreasing in each argument (Aghion & Howitt, 1998).
[38] Also, there are endogeneous variables: job separation, job creation and (natural) rate of unemployment.
[39] 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).
[40] In this section, we consider only Japan, and Korea in using R&D effort, due to non-availability of R&D data of non-OECD Asian countries.

were obtained from the IFS, PENN World Tables and OECD. The mean values of each variable are showed (see Table 1). We can interpret them as main indices for economic structure of each economy in growth process. Fig. 4 shows each point relating relative initial income (y_{60}) and average growth rate (g) of Asian countries and regions. If we can fit linear regression line well to this scatter diagram, we can say that there is conditional convergence between the US and Asian countries and regions. Because of missing data for some of the variables, we obtained only 297 observations.[41] We examined a simple panel model of the effect of various factors like research effort on the growth of output in these six countries and regions.[42]

The monthly data set consists of macro-economic variables, such as rate of unemployment, industrial production index, observed for 9 years (2000-2008) in the four East Asian countries.[43]

3.2 Growth regression: Semi-endogenous model and convergence

In this paper, we used the fixed effects method not because of the data structure, but because of the data generating process.[44] Consider a growth regression of the form:[45]

$$y(t) - y(t-1) = \alpha + \beta\ y(t-1) + \gamma y^*(t) + \varepsilon \tag{9}$$

Rearranging this equation produces:

$$y(t) = \alpha' + \beta'\ y(t-1) + \gamma' X(t) + u \tag{10}$$

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, $X[=y^*(s_K, n)]$.[46] If the co-efficient 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."

Table 2a Growth regression: Solow model[47]

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**

Firstly, we estimated the (neoclassical) growth regression model by fixed-effects panel estimation with the strong restriction that each coefficient is the same across countries and over time except for individual country or region effects.[48] (see Table 2b). The result shows that most co-efficients are significant. In this regression we include the ratio variable of physical investment and the measure of external openness (OPEN).[49] Their

[41] Missing data is very common in panel data sets. For this reason, panels in which group sizes differ are not unusual (Greene, 2008).

[42] The fixed effects approach takes αi to be a group (industry) specific constant term in the regression model. This approach is suitable for our analysis rather than random effects model.

[43] We use a proxy variable for the growth index of industrial production. In this study, we omit the problem of measurement error.

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

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

[46] 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.

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

[48] This estimation is a LSDV (least squares dummy variable) procedure.

[49] Source: Penn World Tables.

co-efficients are positive and significant. We can compare its result with that of standard Solow model (see Table 2a).

Table 2b Growth regression: Solow model augmented with openness

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	317.242000	0.0000**
LOG(s_K)	0.094919	0.011264	8.426686	0.0000**
n	0.004040	0.004027	1.003285	0.3166
OPEN	0.000200	0.000111	1.794905	0.0737*

Table 3a Fixed effects estimation result (semi-endogenous)

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	1.468840	0.324306	4.529179	0.0001
LOG(y_{-1})	0.742577	0.049776	14.918420	0.0000**
LOG(s_K)	0.122726	0.053036	2.314001	0.0260**
N	-0.158959	0.040345	-3.940030	0.0003**
LOG(RD= $s_R Y^*$)	0.069741	0.030049	2.320912	0.0256**

Table 3b Fixed effects estimation result (semi-endogenous)

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	0.462460	2.333899	0.0250
LOG(y_{-1})	0.792449	0.029134	27.200040	0.0000**
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

In the semi-endogenous growth model, per capita output is proportional to the population of world economies, *L(t)*, along a balanced growth path.[50] Changes in research intensity only affect the long-term level of income, not the growth rate.[51] The estimate of β' in a model with linear R & D intensity is 0.742 (speed of convergence, λ =0.298 from $\beta' = e^{-\lambda t}$) (see equation 4, Table 3a). The regression suggests somewhat significant

[50] 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).
[51] This leads to an increase in the rate of short-term income growth by the principle of transition dynamics.

convergence.[52]

The estimate of β' in model with product term of trend and R & D is 0.792 (λ =0.233) (see equation 5, Table 3b).[53] The coefficients for the determinants of steady-state income, $RD^*(trend)$, are significant and have the expected sign.[54] From these results, we can examine the fit of the semi-endogenous growth model and infer that the model explains well why one countries in East Asia grow much faster than others (see equation 6, Table 3c).[55]

Table 3c Fixed effects estimation result (semi-endogenous)

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	1.994350	0.0533
LOG(y_{-1})	0.657365	0.086376	7.610550	0.0000**
LOG(s_K)	0.076839	0.065070	1.180866	0.2450
n	-0.127306	0.047965	-2.654114	0.0115**
LOG(RD)	0.177062	0.094031	1.883016	0.0674*
LOG(s_R)	-0.086420	0.071794	-1.203717	0.2361

3.3 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.

$$y(t) - y(t-1) = \beta' [y(t-1) - y(t-2)] + \gamma'[X(t) - X(t-1)] + [u(t) - u(t-1)] \quad (11)$$

However, this equation still has endogeneity problems, and the (difference of) lagged income per capita may be correlated with the composed error term.[56] The (pooled) instrumental variables(IV) estimation results show the estimates for the determinants of steady-state income (see Table 4). The coefficient for the multiplicative term of R&D expenditure and TREND is significant and has the expected sign.[57]

Finally, since the fixed effects problem is serious, we can consider Arellano and Bond's (1991)[58] GMM estimation.[59] But, Bond, et al (2001) assert that if the time series are "short", the first-differenced GMM estimator

[52] 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.
[53] The regression suggests slower significant convergence. The value of the implied speed of convergence is λ of 23.3%, a lower rate of convergence.
[54] These results also show that in an augmented Solow model, there may be biased estimation from the omission of R & D related variables.
[55] 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.
[56] Additionally, one component of the steady-state income and the function of R & D can be determined endogenously. In this case, we can use a 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 $[y(t-1) - y(t-2)]$.
[57] We omit the second term in the right hand side of the regression equation because of a problem with insufficient degrees of freedom.
[58] 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.
[59] 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.

is not good due to the weak instruments problem.[60] We postpone this analysis for future research.

Table 4 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**

Table 5 Summary: Effects of R & D efforts

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

Notes: ++: positively significant, --: negatively significant, +: positively insignificant, -: negatively insignificant.

Table 5 shows many coefficients for research efforts seem to have significant positive values.[61] The contribution of this paper is that it explicitly consider R & D-related variable in growth regression for Asian countries.[62] 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), as in Jones' semi-endogenous growth model, across Asian countries.[63]

4. Economic growth and unemployment

4.1 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 nonstationary (see Table 6)[64]. 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

$$y_{it} = \rho_i \, y_{it-1} + \gamma X^*_{it} \, \gamma_i + \varepsilon_{it})^{65} \tag{12}$$

[60] 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.

[61] These partially coincides with the implication of semi-endogeneous growth theory. The increase in research input causes the steady-state income to increase and then, the growth rate of income.

[62] In convergence regression, income growth is regressed on initial income and steady-state income levels.

[63] 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.

[64] 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.

[65] Firstly, the persistence parameters are common across cross-sections so that ρi = ρ for all *i*. Alternatively, one can allow *ρi* 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 6 Pool unit root test statistics (4 Asian countries and regions)

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 & Chut*	-3.22014	0.0006**
Null: Unit root (assumes individual unit root process)					
Im, Pesaran and Shin W-stat	-1.69365	0.04520**	Im, Pesaran and Shin W-stat	-2.31906	0.01020**
ADF - Fisher Chi-square	11.80960	0.06640*	ADF - Fisher Chi-square	15.91770	0.01420**
PP - Fisher Chi-square	11.34750	0.07820*	PP - Fisher Chi-square	15.06650	0.01970**

Notes: ** 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 (see Table 7)[66].

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.[67] Most criteria show that optimal lag length is one.[68] More precisely, a structural form is expressed as:[69]

$$BY_t = AY_{t-1} + E_t{}^{70} \tag{13}$$

where Y t =(IP t, U t)'.

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 countries and regions (see Fig 5).[71]

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 countries and regions.

[66] It is better to consider the role of R&D again, in the spirit of semi-endogeneous model, in analyzing unemployment. But, we only focused only on growth and unemployment.
[67] Lag lengths in a VAR is determined by log-likelihood, likelihood ratio or information criteria.
[68] An (reduced-form) VAR (1) is expressed as: $x_t = \alpha(1) + \beta(1)\, x_{t-1} + \theta(1) y_{t-1} + e_t$, $y_t = \alpha(2) + \beta(2)\, x_{t-1} + \theta(2) y_{t-1} + e_t$
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.
[69] If B is not an identity matrix, the elements (errors) in V are weighted functions (averages) of the elements in *E*.
[70] We impose long-run restriction so that the shocks in unemployment have no effect on production growth in the long-run.
[71] 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.

Table 7 The effects of (Production) growth on unemployment (4 Asian countries and regions)

Dependent variable: U - fixed effects				
Sample (adjusted): 2000M02 2008M09				
Total pool (unbalanced) observations: 217				
Variable	Coefficient	Std. error	t-statistic	Prob.
C	3.888054	0.024140	161.062800	0.0000
ΔLOG(IP)	-0.080797	0.458408	-0.176255	0.8603

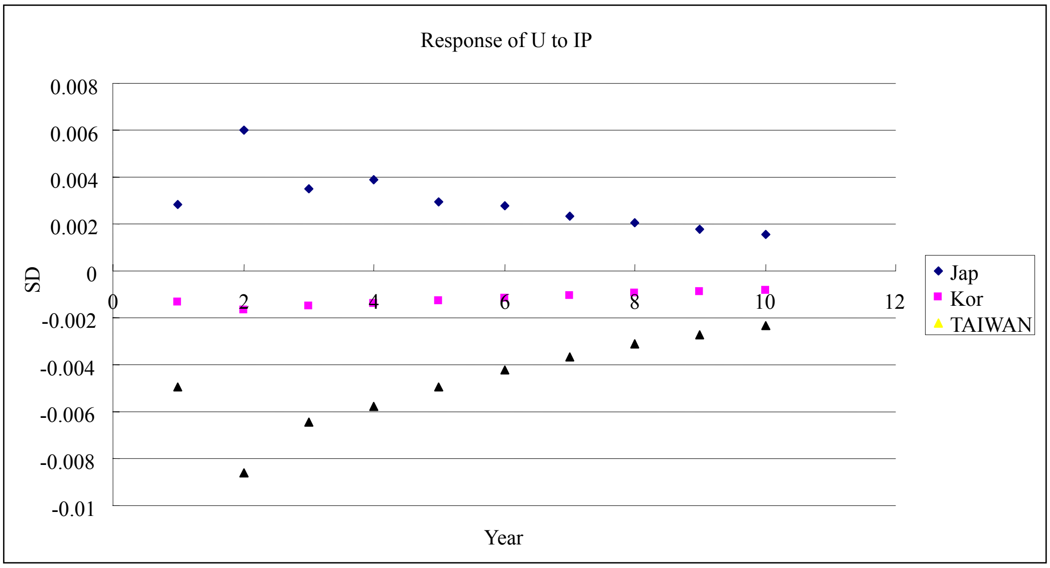

Fig. 5 Estimation results for impulse response functions (3 Asian countries and regions)[72]

5. Summary and conclusion

Aghion and Howitt (1998) analyzed the relationship between economic growth and unemployment with endogeneous 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 countries and regions.

In this paper, we also showed that "direct creative destruction"(increasing unemployment) is not the only effect of faster productivity growth.[73] 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 & Howitt, 1998). We showed that the empirical evidence is in favor of both effect from production growth, across three Asian countries and regions. We can infer that due to high industrialization and developed economic structure, and Japan has "creative destruction" effect of economic growth on unemployment.

[72] We omitted the data for China due to unavailability of IP data.

[73] 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 & Howitt, 1998).

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Appendix:

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.[74]

We apply the same tools to test endogenous growth theory.[75] According to Cellini (1997), y, n, and s_K are all non-stationary

[74] 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.

[75] We insert the trend variable into the ADF test equation.

series with unit roots.[76] Thus, we applied augmented Dickey-Fuller unit root tests (see Table 1). These results show that almost all the variables have unit roots.[77]

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	1.70	0.71	1.70	0.71
KOR	-0.44	0.98	-2.35	0.39	-2.41	0.36

The Johansen (1988, 1992) approach starts with setting a reduced VAR model.[78] 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 (see Table 2).

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-endogeneous	y	s_K	n	Trend	RD
JAP	1	-4.46	3.04		2.33
KOR	No Cointegration				
Johansen cointegartion method(3) semi-endogeneous	y	s_K	n	Trend	RD^2
JAP	1	-3.53	2.55		0.08
KOR	No Cointegration				

Johansen cointegartion method(4) semi-endogeneous	y	s_K	n	Trend*RD
JAP	1	-0.380	-0.090	-0.002
KOR	1	0.215	-0.053	-0.005

We can set up the ECM (equilibrium correction model).[79] Estimation results show that only the Japanese economy shows significant error correction mechanisms (see Table 3).[80]

Table 3 ECM estimation result for Japan

Dependent Variable: ΔLOG(y_JAP)				
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$_{-1}$)	0.075030	0.087559	0.856912	0.4059
ΔLOG(RD_JAP$_{-1}$)	0.028765	0.035836	0.802696	0.4356

(to be continued on Page 63)

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[76] The non-stationarity means that the variables have mean which change over time.

[77] To effectively use DF test, we need to have a lot of observations, and this is not very common in panel data sets.

[78] The null hypothesis that there are less than *r* co-integrating vectors is tested using the trace test statistic.

[79] This error correction model shows how much Δy responds (converges) to the co-integrating error.

[80] $\Delta y_t = c + \pi(s_K)\, s_{K\,t-1} + \pi(n) n_{t-1} + \pi(RD) RD_{t-1} + \Sigma_{i=1}^{p-1} \psi'_i (\Delta y_{t-i}, \Delta s_{K\,t-i}, \Delta n_{t-i}, \Delta RD_{t-i})' + \delta' (\Delta y_t, \Delta s_{K\,t}, \Delta RD_t) + u_t$.