R&D and Economic Growth

—— Panel Data Analysis in ASEAN+3 Countries

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Abstract: Most literature suggests that roughly half of cross-country differences in economic growth are driven by differences in Total Factor Productivity, generally associated with technological progress. This study investigates the long-run relationship between R&D expenditure and economic growth using a panel data set comprising of 8 ASEAN+3 economies, over the period of 1994 to 2003. first, Begin with the Cobb-Douglas production function; we focuses on the contribution of R&D by estimating the social rates of return to R&D. Then,we develop the patterns of the evolution of R&D expenditure over the course of economic growth. In the last part ,we use the PLS model to explores the determinants of R&D for every ASEAN+3 members.

Keywords: R&D expenditure economic growth ASEAN+3

Introduction

Facing with the trends of unprecedented rapid technological advances, accelerating globalization and regional integration will serve as the basic framework for the formation of the global economic order in the new era. The "ASEAN+3 " bringing together ASEAN, Korea, Japan and China with a view to promoting regional economic cooperation in East Asia is now truly under way. With ample natural resources and economic cooperation, "ASEAN+3" countries are closing the gap with the developed countries. However, it is a painful fact that with the exception of Japan, these countries as a whole were slow to wake up to industrialization, and therefore failed to become developed countries. Enhancing competitiveness (according to the World Economic Forum, is a nation's ability to achieve sustained high rates of growth in per capita income as measured by per capita Gross Domestic Product in constant prices.) is still great challenges for "ASEAN+3" countries.

A large theoretical and empirical literature has suggested that R&D plays a corel role as an engine of growth. however, recent work in innovation also stresses that adopting existing technology is not without cost. Countries need to develop an "absorptive" or "national learning" capacity which, in turn ,are hypothesized to be functions of spending on R&D.

The purpose of this study is to provide a view to understanding the link between the R&D and economic growth in ASEAN+3 countries over the 1994-2003 period. The major questions it addresses are the following:

— What is the contribution of technology to productivity growth in ASEAN+3 countries?

— Do ASEAN+3 countries engage in too much or too little R&D?

— What are the determinants of R&D across countries and over time?

— To what extent do these determinants influence cross-country differences in R&D?

The rest of the paper is organized as follows. Section 2 focuses on the contribution of R&D by estimating the social rates of return to R&D .Section 3 then develop the patterns of the evolution of R&D expenditure over the course of economic growth . To explain cross-country differences in R&D, Section 4 uses the PLS model to explores the determinants of R&D for every ASEAN+3 members. Section 5 summarizes the main findings.

The rate of return to R&D

There are different types of R&D and the effect of R&D on productivity may take various channels. In order to capture the links between R&D and productivity it is necessary to take these aspects into account. R&D performed by business results in new goods and services, in higher quality of output and in new production processes. These are factors of productivity growth at the firm level and at the macroeconomic level. Government and university research have a direct effect on scientific knowledge and public missions, they generate basic knowledge. To avoid the measurement problem of the R&D capital stock, we estimate the rate of return to the R&D to measure the

contribution of R&D to productivity.

Based on the above framework, we estimate the contribution of technical change to productivity growth. We distinguish the two sources of technical change: business and public sources. We also take into account business-cycle effects that strongly influence productivity in the short run. The model on which the estimated equation is based is a simple Cobb-Douglas production function.

$$Y_{it} = Exp(\phi_i + \varphi_t + \varepsilon_{it}) L_{it}^{\lambda_l} K_{it}^{\lambda_k} BRD_{it-1}^{\lambda_{brd}} PRD_{it-1}^{\lambda_{prd}} U_{it}^{\lambda_u}$$

The variables (for country *i* and time *t*) are defined as follows:

Y is the level of output

K is the level of physical capital

L the labor stock

BRD is the business performed R&D capital stock

PRD is total public R&D capital stock implemented in the higher education and public laboratories.

A range of control variables is included in all the regressions, ***U*** is intended to capture the business cycle effect: it is equal to 1 minus the unemployment rate.

ϕ_i is an individual country fixed effect, φ_t is a sample-wide time effect, and ε_{it} is a country and time specific effect.

The model can be rewritten as:

$$d\ln(Y_{it}) = r_k (I/Y)_{it} + r_{brd} (BRD/Y)_{it-1} + r_{prd} (PRD/Y)_{it-1} + \lambda_l d\ln(L_{it}) + \lambda_u d\ln(U_{it}) + \phi_i + \varphi_t + \varepsilon_{it}$$

by using the fact that

$$\lambda_x d\ln(X) = r_x (\frac{\dot{X}}{Y}) = r_x (x)$$

Here r_x is the rate of return on factor X ,x is the share of investment in X over Y, λ_x is the output elasticity of factor X .

One important type of omitted variable bias might be induced by the correlation of unobserved country-specific factors and the variables of interest; $E(\phi_t, x_{it})$ may be large. Casselli, Esquivel and Lefort (1996), for instance, pointed out that the difference with respect to the highest level of income in the sample of countries acts as a proxy of the

country-specific effect in cross sectional regressions, and thus the resulting estimates are inconsistent. Here we use the lagged dependent variable(the initial level of GDP per capita) as instrument for endogenous variables. Nevertheless, if the lagged dependent variable is included in the model to account for endogeneity between variables, the coefficients obtained from the fixed effects analysis are no longer consistent. The GMM estimator takes into account both country fixed effects and the endogeneity problem by using the first differences of the variables and including the lagged dependent variable as an instrument in the analysis.

Table 1 presents estimated returns to R&D for the panel of countries that had sufficient consecutive observations (at least three) required for the GMM system estimator.

Table 1 Returns to R&D

Dependent Variable: Growth of GDP (PPP)				
Methodology : GMM System Estimator				
	All Countries	**ASEAN +3**	**EU**	**G7**
Explanatory Variable				
Ln(gdp per capita)t-1	0. 2089 (2. 6)	0.6868 (2.58)	0.1069 (2.33)	0.7128 (3.43)
Investment /GDP	0.03016 (2.87)	0.1553 (2.88)	0.0173 (2.04)	0.0135 (2.97)
Labor growth	0.3749 (3.46)	0.3076 (2.36)	1.0151 (4.17)	0.9076 (3.55)
BRD/GDPt-1	0.2273 (2.66)	0.7328 (2.66)	0.0337 (2.14)	0.2295 (2.86)
PRD/GDPt-1	0.227 (2.45)	4.1391 (1.68)	0.0295 (2.12)	0.2189 (1.91)
Control Variable				
ln(Unemployment)	-1.1656 (-4.01)	-2.6123 (-4.37)	0.00057 (0.00)	-0.3299 (-0.53)
R-squared	0. 6273	0. 5735	0. 5299	0. 4769
Observations	457	80	130	70
Countries	49	8	13	7

The conclusions from table 1 are that:

Compared with physical capital, the expenditures on R&D have more contribution to economic growth.

Comparing the returns to R&D of All Countries, ASEAN+3 , EU and G7, we find that ASEAN+3 is the most attractive region for Investment, either in R&D capital or in physical capital.

In contrast to other region, R&D implemented by government has morn contribution to economic growth than R&D implemented by business in ASEAN+3 countries. The coefficient of PRD is 4.1391, while the coefficient of BRD is only 0.7328.

The control variable (for the business cycle) is of the expected sign and is significant. The employment rate has a large impact on GDP growth.

As a whole ,for ASEAN+3 countries, technological effort (measured by R&D) is one of the most important drivers to upgrade their competitiveness .Furthermore, it is urgent for these countries to exert more indigenous technological effort (proxied by Business R&D) .

To learn more about the R&D behavior of the ASEAN+3 members ,we have a look at their innovation trajectories.

Innovation Trajectories

Following Daniel Lederman and William F. Maloney(2003), we develop the patterns of the evolution of R&D expenditure over the course of economic growth using the panel data set including 8 ASEAN+3 countries constructed by IMD(1994-2003).we use OLS and Fixed Effects model to estimate the regression of the ratio of total R&D expenditures to GDP on log GDP per capita and its squared term. The estimated coefficients are presented in the Table 2.

Table 2 innovation trajectory

Dependent Variable	**R&D/GDP**	**R&D/GDP**
Estimation Method	OLS	FEONE
Explanatory Variables:		
Log GDP per capita	-6.2995 (-6.047)	-2.79698 (-2.24)
Log GDP per capita squared	0.3898 (6.834)	0.159141 (2.35)
Adjusted R-squared	0.4553	0.8566
F-test of Significance of No Fixed-Effects(p-value)		

country	-	<0.0001
year	-	0.0649
Observations	80	80
Countries	-	8

Note: all coefficients are significant at 99%.

It is shown ,from OLS and FEONE estimated results ,that there is a positive relationship between R&D effort and log GDP per capita and the rate of increase also rises with GDP per capita in ASEAN+3 countries. The fixed effects estimates indicate that, though the R&D effort is partly a function of the log transformation of GDP per capita within countries, there is not an exclusive feature of the cross-country variations(for the F-test of significance of No-Country-Fixed-Effects less than 0.0001).

Figure 1 plots the observed levels of R&D as a share of GDP as function of the log GDP per capita for 8 ASEAN+3 countries (including Korea, Japan ,Singapore, Malaysia, Thailand, Indonesia, Philippines and China) and compares these innovation trajectories with the so-called "general innovation trajectory" generated by a panel data set of all countries. Impressively, through depicting the specific trajectories of 8 ASEAN+3 countries, we classify these countries into five categories:

High Growth and High R&D : Japan and Korea

High growth but Low R&D : Singapore

Medium growth but Low R&D: Malaysia and Thailand

Low growth but High R&D :China

Low growth and Low R&D: Indonesia and Philippines

What is immediately striking is Korea and Japan show substantial "take offs" relative to the "general innovation trajectory". And China appear to be a follower in the footsteps of the "take offs".

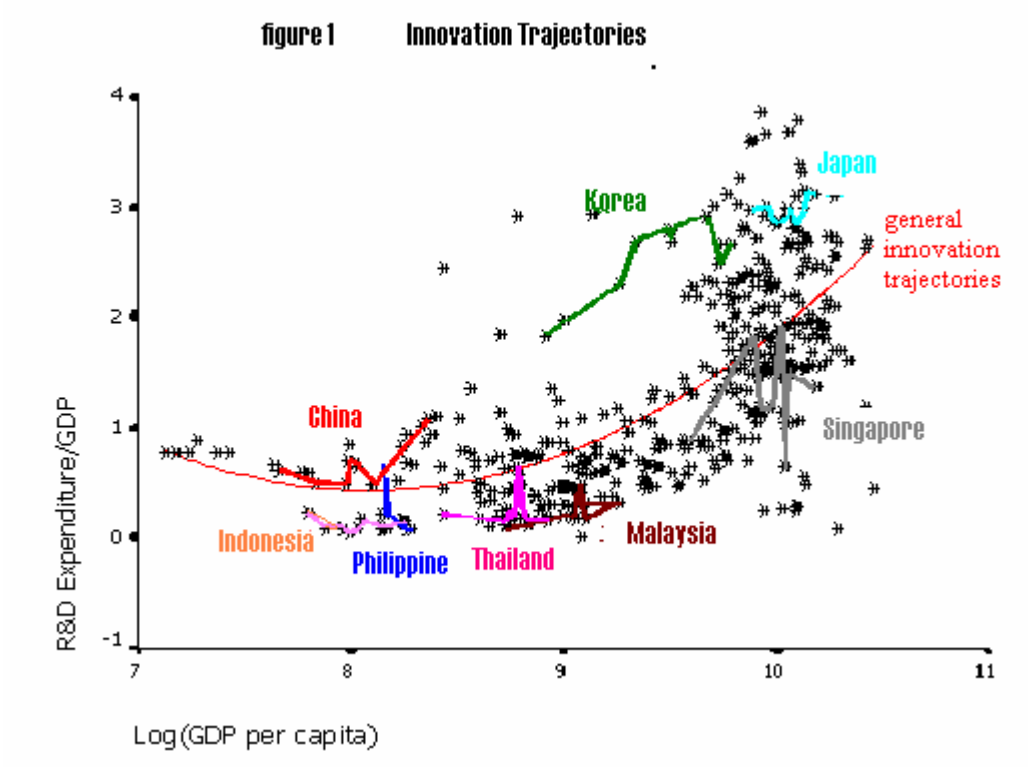


Figure 1 provides us with another way (more explicit)to tell the same story: the level of development is not the only reason to explain the R&D expenditure, there are some other reasons to determine the R&D expenditure for a country.

Determinants of R&D Propensity

There are very few studies of the determinants of R&D across countries. Two such studies (Varsakelis 2001; Bebczuk 2002) suffer from small samples and, as result, inconsistent estimates due to inability to deal with country-specific effects and endogeneity of the explanatory variables. And Daniel Lederman and William F. Maloney (2003)apply the GMM system estimator to their larger sample. Here we want to use PLS(partial least squares) regression to explain why there is various on R&D expenditure among ASEAN+3 countries.□PLS□regression is a recent technique that generalizes and combines features from principal component analysis and multiple regression. It is particularly useful when we need to predict a set of dependent variables from a (very) large set of independent variables.

As to determinates of R&D expenditure, there are some views as follows (Daniel Lederman and William F. Maloney 2003):□

First, We imply the real interest rate which we presume reflects the opportunity cost of investment as well as other factors pertaining to the investment climate.

Second, we include a measure of credit market depth measured as index of credit flows easily from banks to businesses to proxy for the availability of credit at the reported interest rate.

Third, to capture risk associated with long term investments. we include the variance of GDP growth which he found correlated with physical investment.

Fourth, We also include a measure of intellectual property rights that would also affect the expected quasi rents derived from innovation. Although the impact of IPR is theoretically ambiguous (Horstmann et. al 1985), Arora, Ceccagnoli and Cohen (2003) using US manufacturing survey data find that patent protection stimulates R&D across almost all industries.

Fifth, for the fact that we are using a series of total R&D expenditures, which includes private and public financing of R&D, we include a measure of overall government spending over GDP as a measure of the government's capacity to mobilize resources.

Sixth, as possible further constraints on investment, we include measures of the availability of complementary innovation-related institutions that may also put binding constraints on new R&D projects. We include the subjective indicators on the quality of research institutions (universities, public research centers, etc) and the extent to which these collaborate effectively with the private sector. These considerations may also constrain the number of national innovation projects.

Finally, we include as control variables GDP growth to capture cyclical or accelerator effects, and the log of GDP/capita which we know from section 2 is positively associated with the R&D effort.

Based on the above framework, we specificity the model to explore the determines of R&D propensity:

Table 3 Determinants to R&D: PLS regress results

Dependent Variable: R&D/GDP										
country		Control Variable		Response Variable						
		x1	x2	x3	x4	x5	x6	x7	x8	x9
Philippine	Coef.	0.04	0.20	−0.03	0.26	−0.11	0.01	0.77	0.14	0.19
	VIP	0.16	1.07	1.08	1.59	1.24	1.09	2.87	1.13	1.48
Korea	Coef.	−0.25	−0.34	−0.02	0.07	−0.37	0.12	0.28	0.29	0.11
	VIP	1.10	1.55	0.10	1.34	1.42	1.46	1.75	1.76	1.25
Malaysia	Coef.	0.07	0.21	−0.39	0.16	−0.19	0.36	0.69	0.04	0.45
	VIP	0.89	0.71	1.31	1.58	1.37	1.64	2.34	1.17	1.99
Japan	Coef.	0.36	0.16	−0.18	0.00	−0.09	0.12	0.20	0.43	0.09
	VIP	1.97	0.89	1.67	0.49	0.92	0.63	1.77	2.38	1.35
Thailand	Coef.	−0.16	−0.08	−0.01	0.18	−0.06	0.02	0.44	0.26	0.17
	VIP	0.87	0.97	1.04	1.61	1.01	0.22	2.41	1.45	1.67
Singapore	Coef.	−0.21	−0.06	0.15	0.15	−0.01	0.40	−0.51	0.10	0.13
	VIP	1.03	0.45	1.42	1.07	0.94	2.07	2.91	0.78	1.24
Indonesia	Coef.	0.00	0.02	0.17	0.31	−0.01	0.42	−0.24	0.18	0.33
	VIP	1.15	1.03	1.06	1.91	0.37	2.28	1.20	1.59	1.56
China	Coef.	0.39	0.07	−0.08	0.09	−0.27	0.06	0.31	0.14	0.15
	VIP	2.35	0.48	0.40	0.50	1.84	0.43	1.74	0.78	1.33

Note: all coefficents are significant at 10%
VIP means *variable importance for projection*

Here :

x_1-log(GDP per capita), x_2- GDP growth, x_3-Real Interest Rate x_4-Credit Index, x_5-Sd Growth, x_6-IPR Index, x_7-Gov.Cons./GDP, x_8- Quality of Edu., x_9-Collaboration

For Philippine, Malaysia, Japan, Indonesia and China, column3 and 4 shows level of development and the GDP growth variable, positive and significant .the negative coefficient in Korea, Thailand and Singapore imply that there are some reduction on R&D expenditure relative to the GDP level.

The real interest rate (column 5)has the expected negative sign in all but Singapore and Indonesia . following investment literature (see Serven 2003) ,the overall impression is that higher borrowing costs do lead to lower investment in R&D.

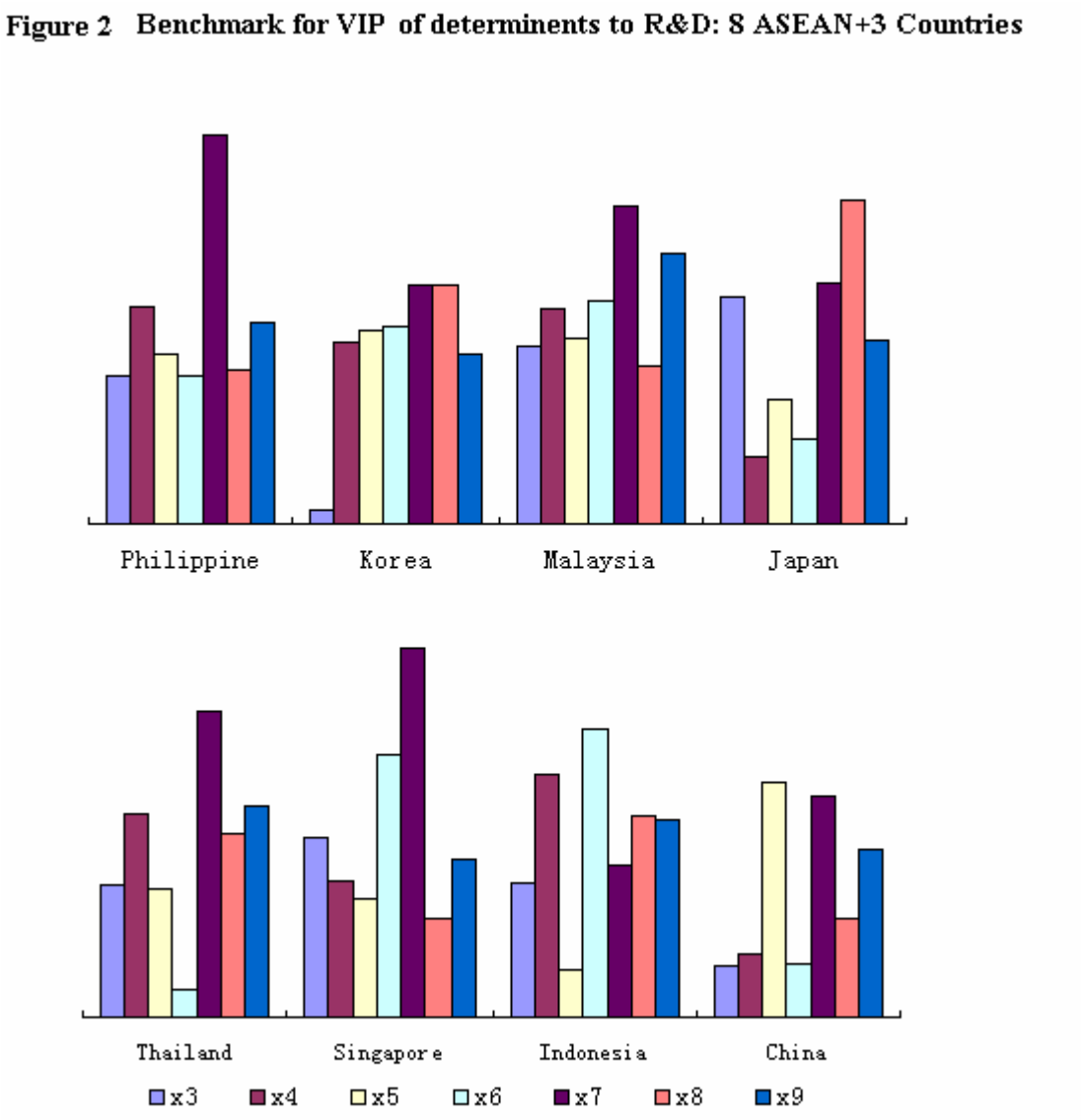
Credit Index(column 5) for 8 ASEAN+3 countries enters with the predicted positive sign indicating that deeper capital markets facilitate R&D investments. Among the measures of risk(column 6), the standard deviation of growth enters with the expected negative sign . For 8 ASEAN+3 countries, the IPR protection index(column 7) has the expected positive and very significant coefficient. Excepting Singapore and Indonesia, the government's ability

to mobilize resources(column 8) has positive contribution to R&D effort.

Both measures of complementary research capacity(column 9 and 10) enter strongly significantly and with predicted sign in 8 ASEAN+3 countries.

Figure 2 provides us with benchmark on important of determinants for every country.

Figure 2 Benchmark for VIP of determinents to R&D: 8 ASEAN+3 Countries



Note:only for respose variables

The top 3 determinants have been arranged based on their contribution to R&D

Philippine: Gov.Cons./GDP, Credit Index, Collaboration

Korea: Gov.Cons./GDP, Quality of Edu, IPR Index

Malaysia: Gov.Cons./GDP, Collaboration, IPR Index

Japan: Quality of Edu,Gov.Cons./GDP, Real Interest Rate

Thailand: Gov.Cons./GDP,Collaboration,Credit Index

Singapore: Gov.Cons./GDP, IPR Index, Real Interest Rate

Indonesia: IPR Index, Credit Index, Quality of Edu

China: Sd Growth, Gov.Cons./GDP, Collaboration

Summary

Through the preceding three sections ,we found that there is an interactive relationship between R&D expenditure and economic growth. Focusing on the ASEAN+3 countries, R&D expenditure play a more efficient role than that of other region. By tracing the innovation trajectory of these countries, it is illustrated that R&D expenditures mainly depends on the level of their development ,but the deviation from the "general innovation trajectory" implies it is also affected by several other elements. In the last section, we attempted to lay out these elements and found that Government ability to mobilize resource, credit market depth and the technological cooperation have more effect on R&D for ASEAN+3 countries.

Every country ,which aims to upgrade their competitiveness(sustainable economic growth), should increase their R&D expenditure.

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