The Evidence of the Comparative Advantage in R&D

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Abstract:

This paper examines the effect of the relative endowment with skilled labor on the return of R&D expenditure in total factor productivity. To overcome the shortage of the data, this paper applies two approaches on the estimation. The first one is the pooled estimator and the second one is the model of co-integration. These two approaches show similar results in that the interaction between R&D expenditure and skilled-labor ratio is found to be positive and significant only in developed countries but not in developing countries. This suggests that the economy with abundant in skilled labor has the comparative advantage in R&D.

Introduction:

Most of the empirical literatures on economic growth have shown that by using the Cobb-Douglas production function, the variation in physical capital and human capital explains only about half of the differences in income per worker across countries. On the other hand, the rest of the variation in the output per worker is attributed to the variation in the total factor productivity (TFP) or the Solow residual. Indeed, the frontier technology may not be non-rival[1] (Jaffe *et al*, 1993) and depend on the research and development (R&D) expenditure and the stocks of human capital in the country. Therefore, R&D does have a beneficial effect on the

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[1] Empirical evidence shows that the knowledge spillover of R&D tends to be geographically concentrated.

growth of economy. Lichtenberg (1996) and Eaton and Kortum (1996) both find the number of national scientists and engineers and the level of R&D expenditure have significant and positive effect on the income level of the country. However, it does not mean that countries can rapidly accelerate their technology growth by investing heavily in R&D. If R&D resources are not used efficiently, the additional investment might not stimulate the growth (Wang and Huang, 2007). Coe and Helpman (1995) indicate that the returns of R&D on technology are different across countries and that R&D has stronger effect on growth of TFP for large countries. Engelbrecht (1997) also shows the same result after controlling for the human capital. Then, what causes the difference in the returns of R&D across countries?

Some of the relative literature suggests that not all technologies are equally suited to every country, and countries use their own appropriate technology that depends on the different relative factor endowment. As R&D uses skilled-labor intensively, an economy with an abundance of skilled-labor will conduct a great deal of this kind of investment (Grossman and Helpman, 1994). Indeed, Caselli and Coleman (2006) show that the rich countries are more efficient at using skilled labor than poor countries because skilled-labor is abundant in most of high-income countries. They also state that the technology frontiers depends more on the technology that complements skill-labor than the technology that is efficient on using unskilled-labor. Jerzmanowski (2007) also suggest the one-third of variation in the TFP is due to the different appropriate technology. If the developing countries have the same mix of input as the United States, the gap of the TFP is smaller.

Based on these arguments, it is reasonable to assume that the higher stock of human capital increases the returns of R&D in developed country rather than developing country since developed country uses skilled labor more efficiently. In this paper, due to the limitation of the data, two approaches are applied to overcome the shortage: The pooled estimator and the co-integration. The first approach involves using the World Bank's data that includes 103 countries over the period 1996 to 2009 but has many missing values. I then apply the model of co-integration by using the strongly balanced dataset from the OECD. This paper is organized as follows. Section 2 is the literature review. In section 3, I describe the econometrical model. The data are introduced in section 4. Section 5 is the regression results. The last section is the conclusion.

Literature review:

Coe and Helpman(1995) show that effect of accumulated spending on R&D in the G7 countries is almost twice larger than that in the smaller OECD countries. Also, Schneider (2005) finds that the effect of R&D expenditure on the innovation rate is positive and significant in developed countries but insignificant in developing countries.

Arrow (1962) and the Nelson-Phelps model provide a possible explanation and argue a more educated workforce makes the adoption of new technologies easier. Grossman and Helpman (1994) state that the country that is skilled-labor abundant have the comparative advantage in R&D since it specializes relatively in skilled-labor-intensive production. Grossman and Helpman (1990) construct a dynamic theoretical model of trade and growth with endogenous technology progress, which also shows that the cross-country difference in efficiency at R&D is critical to the growth of the economy. Torstensson (1998) shows that the relative endowments with skilled labor affect net export in R&D intensive industries, which also suggests that high level of national R&D expenditure stimulates growth if the country is skilled labor abundant. Wang and Huang (2007) use the data envelopment analysis (DEA) and indicate proficiency in English increases the efficiency of R&D performance since it is the most important language used in academic circles. Wolff (2000) estimates effect of human capital on the returns of R&D in the labor productivity growth model by using 24 OECD countries over the period 1950 to 1990. He compares the results measured by different sources of educational data and concludes that the interaction effects between schooling and R&D were not found to be significant determinants of labor productivity growth. However, it does not mean that the Nelson-Phelps model is incorrect or the relative endowment with skilled labor has no effect on the returns of R&D in technology growth. This effect should be stronger since R&D mainly contributes to technology progress especially in developed countries.

Empirical model:

My empirical equations build on some theoretical models of economic growth. The aggregate production function can be expressed as:

$$y = Ak^{\alpha}h^{1-\alpha}$$

where y denotes the output per worker, k represents the physical capital per worker, and h is the efficient unit or the human capital per worker. The share of physical capital in GDP is represented by α. The technology growth can be measured by using the total factor productivity:

$$\log A = \log y - \alpha \log k - (1-\alpha) logh = F$$

The growth of technology depends on foreign direct investment (FDI), human capital, R&D expenditure, and the relative endowment with skilled worker. Therefore, the empirical model can be shown by:

$$F_{it} = \beta_0 + \beta_1 R\,\&\,D_{it} + \beta_2 HC_{it} + \beta_3 GDP_{it} + \beta_4 FDI_{it} + \delta R\,\&\,D * Skill_{ti}$$

where $R\&D_{it}$ is the ratio of R&D expenditure to GDP in country i, HC_{it} is the human capital estimated by the average years of schooling in country i, GDP_{it} is the ratio of real Gross Domestic Product per worker in country i to the real GDP per worker in the United State, FDI_{it} measures inflows of foreign direct investment into country i, and $Skill_{it}$ is the relative endowment of skilled labor in country *i* which is measured by the percentage of population having completed primary school. The expected signs of β_1, β_2 , and β_3 are positive based on the previous empirical study made by Coe, Helpman and Engelbrecht. Since Schneider (2005) shows that the effect of FDI is insignificant on the innovation rate when the data includes both developed and developing countries and negative and significant when using the data for only developed countries, I expect similar results for the effect of FDI. Caselli and Coleman (2006) suggest that a rich country uses skilled labor more efficiently than a small country because the skilled-labor is abundant in high-income country. Based on the hypothesis, the coefficient of the interaction is expected to be positive and significant in developed country and insignificant in developing country. To estimate the parameter, this paper has two approaches: pooled estimator and the co-integration in panel data. The pooled estimator is consistent and unbiased if the time and number of countries are large enough. However, to minimize the effect of business cycles, the irregular intervals have to be used and the size of the dataset shrinks. Also, if any unobserved factor varies across countries then the fixed effect estimator cannot be used to correct the pooled estimator if the number of intervals is too small for a large number of countries. The second approach is to estimate equations by using co-integration. The basic idea of co-integration is that if there is a long-run relationship between two or more trended variables, the co-integrating equation will have a stationary error term (Granger and Newbold, 1974). To confirm that the variables are all non-stationary, Levin and Lin (1992,1993) provide the unit root tests on panel data and show that the power of the test increases when cross-section dimension increases. However, the unit root test requires strongly balanced dataset. Therefore, the method is only available for few countries. In this paper, due to the limitation of data, I use two different dataset and compare the results of these two approaches.

Data:

The data on the ratio of FDI to GDP and real GDP in constant dollars (2000) come from the World Bank development indicators. The human capital is estimated by the average years of schooling from Barro and Lee (2010). The skilled-labor ratio is measured by the percentage of population having completed primary education, which also comes from Barro and Lee (2010). I use primary education to distinguish skilled and unskilled-labor because it shows more qualitative difference between the two groups (Caselli and Coleman, 2006).

The ratio of R&D expenditure to GDP comes from the World Bank development indicators and the OECD dataset. The World Bank data has more countries but also a lot of missing values, while the OECD data are more complete but the number of countries is limited. Based on that, I use the dataset from the World Bank for the pooled estimator and the OECD's dataset for the co-integration. After merging the R&D data with the data of other variables, there are 103 countries over period 1996 to 2009 in the World Bank's dataset and 10 developed countries[2] over year 1983 to 2009 and 12 developing countries[3] over year 1996 to 2007 in OECD's data.

Results:

Table 1 is the results for using the pooled estimator. I use average annual data for four separate sub-periods: 1996-1997, 1998-2001, 2002-2005, and 2006-2009. The first model uses only three variables: the R&D expenditure, human capital and GDP. All the coefficients are positive and significant as expected. In the second model, I include the FDI into the model. All the coefficients of the three variables maintain the same magnitude. The result for FDI inflows appears insignificant in the regression, which is possible because the effect of FDI is different between developed and developing countries. Schneider (2005) also finds the similar results showing that the effect of FDI on the innovation rate is insignificant as using the data includes all countries but negative and significant for developed countries. In the third model, I add the interaction between R&D expenditure and the skilled-labor ratio. The interacted term is positive and significant, which shows that the return of R&D expenditure increases as the relative

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[2] The ten developed counties are Austria, Canada, Denmark, France, Germany, Italy, Japan, Spain, United Kingdom, and United States.

[3] The twelve developing countries includes Argentina, Bulgaria, China, Colombia, Costa Rica, Cuba, Ecuador, India, Malaysia, Mexico, Mongolia, Pakistan, Panama, Romania, Singapore, Thailand, and Turkey.

endowment with skilled labor increases. The coefficient of R&D becomes negative and insignificant after including the interacted term. It appears that the efficiency of R&D depends on the skilled labor ratio, which is consistent to the argument of Arrow (1962) and the Nelson-Phelps model. To show the difference in the returns of R&D between rich and poor countries, I use the developed dummy variable equaling to 1 if it is a developed country and zero otherwise. The R&D*Dev is the interaction with R&D expenditure and the developed dummy. The last column is the results after including the R&D*Dev. It shows that the effect of R&D itself becomes negative and significant. Also, the return of R&D increases dramatically if the country is developed. Comparing with the third and fourth equation, the effect of skilled labor on the return of R&D is lower than the effect of income level. It is possible that the relatively higher skilled labors increase the efficiency of R&D only for developed country, since developed country uses skilled labor more efficiently (Caselli and Coleman, 2006). Therefore, the effect of relative endowment with skilled labor is lower since this dataset includes both developed and developing countries. To further confirm this hypothesis, I estimate the same model for developed and developing country separately. The results are shown in the Table 2.

Table1: Pooled cross-section, time-series regression of the total factor productivity. (All countries)

Pooled	(1)	(2)	(3)	(4)
R&D	0.12***	0.12***	-0.0003	-0.40***
	(0.02)	(0.03)	(0.05)	(0.11)
HC	0.088***	0.085***	0.094***	0.07***
	(0.01)	(0.01)	(0.01)	(0.01)
GDP	0.33***	0.32***	0.32***	0.3***
	(0.01)	(0.01)	(0.02)	(0.02)
FDI		0.018	0.02	0.02
		(0.02)	(0.02)	(0.02)
R&D*Skill			0.005***	
			(0.00)	
R&D*Dev				0.52***
				(0.11)
Adj R-squared	0.88	0.80	0.86	0.87
F-test	660.84	310.86	258.63	278.21
Observations	277	204	204	204

*** 1% significant, **5% significant, *10% significant

The results in Table 2 show that the effect of R&D is insignificant in both developed and developing country. On the other hand, the coefficient of GDP remains positive and significant in both equations. The interaction has a positive and significant effect only in developed country, which is consistent with the hypothesis. Since developed country is skilled labor abundant, it specializes relatively in skilled-labor production. As R&D use this factor intensively, developed country has the comparative advantage in R&D and the technology grows faster in developed country. However, since the information for R&D expenditure is very incomplete in the World Bank dataset, the regression of developing country only has 53 observations. The pooled estimator could be biased due to the limited information. Therefore, I use the co-integration and the R&D data from OECD to estimate the effect of skilled-labor again and compare the results of these two approaches.

Table 2:
Pooled cross-section, time-series regression of the total factor productivity

	Developed	Developing
R&D	0.02	-0.14
spe	(0.05)	(0.27)
HC	0.09***	0.02
	(0.01)	(0.02)
GDP	0.31***	0.31***
	(0.02)	(0.03)
FDI	-0.014	0.1***
	(0.02)	(0.04)
R&D*Skill	0.003*	-0.02
	(0.002)	(0.02)
Adj R-squared	0.83	0.87
F-test	146.4	72.1
observations	151	53

*** 1% significant, **5% significant, *10% significant

Before turning into the estimation results, we have to check that the TPF and at least one independent variable are non-stationary. However, since there are only 27 periods for each country, the power of the augmented Dicky-Fuller test is very low when done separately on the time series for each country. Levin and Lin (1993) provide the other unit root test on panel data and show that it has more power when there is larger number of panels. Table 3 reports the result of Levin and Lin's pooled unit root test. It shows that all the variables are non-stationary in the data of developed countries. In the data for developing countries, the R&D expenditure, human capital and skilled labor rate are stationary. Next, I apply the model with co-integration for the developed and developing countries. The results are reported in Table 4.

Table 3:
Pooled unite-root tests (annual data 1983-2009 for 10 developed countries and 1996-2007 for 17 developing countries)

Lavin & Lin	Developed	Developing
TFP	5.9548	6.0336
RD	1.0095	-6.0691*
GDP	5.8445	6.1004
FDI	2.5241	2.4829
HC	1.5075	-12.9364*
Skill	-0.3895	-32.3314*
Number of panels	10	17
Number of time	27	12

Ho: Panels contain unit roots
Ha: Panels are stationary
* =Reject the null hypothesis as 5% significant level

Table 4 shows similar results as using the pooled estimator. In the developed countries, the return of R&D is higher when there are relatively more skilled workers. In the developing countries, the increase in relative endowment with skilled-labor has no beneficial effect on the efficiency of R&D expenditure. The result is consistent with Caselli and Coleman's argument that high-income country is more efficient on using skilled labor because this factor is abundant in the country. Since the efficiency of R&D expenditure is affected by the skilled labor rather than unskilled labor, the high-income country has the comparative advantage in R&D.

Table 4:
Total factor productivity estimation result (pooled data 1983-2009 for 10 developed countries and 1996-2007 for 17 developing countries)

	Developed	Developing
RD	-0.06	0.01
GDP	0.73	0.16
FDI	-0.01	0.004
HC	0.032	-0.03
RDSkill	0.002	-0.06
Adj R^2	0.97	0.88
Levin & Lin	-2.35	-3.41
P-value	0.0003	0.0093

Conclusion:

This paper examines the effect of the relative endowment with skilled labor on the return of R&D in developed and developing countries. As R&D uses skilled-labor intensively, the economy that are skilled-labor abundant should have higher growth than those with less human capital. Caselli and Coleman (2006) suggest that most high-income countries are skilled- labor abundant and more efficient at using skilled labor by applying the technology that is "best" for them. It appears that skilled labor intensive technology has high efficiency in R&D investment. Therefore, developed countries have comparative advantage in R&D.

To overcome the limitation of data, this paper uses two approaches: the pooled estimator and the co-integration. Both of the results are consistent with the hypothesis, which shows that the effect of skilled labor is positive and significant on the returns of R&D expenditure only for developed countries, and the effect vanishes in developing countries.

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