DISCUSSION PAPERS IN ECONOMICS

Working Paper No. 02-13

**Phases of Economic Development,
Technology Differentiation in R&D Spillovers, and Human Capital**

Changsuh Park
Department of Economics, University of Colorado at Boulder
Boulder, Colorado

October 2002

Center for Economic Analysis
Department of Economics

University of Colorado at Boulder
Boulder, Colorado 80309

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http://www.colorado.edu/Economics/CEA/papers02/wp02-13

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Abstract

This paper investigates the types of technology in international R&D spillovers and a relationship between technology levels and stage of economic development, which have not been identified in previous empirical studies. It also examines the role of human capital in R&D spillovers. The results of this paper show that medium-high technology is the main source of technology diffusion in developing countries, and high technology is more important in advanced countries. Furthermore, the second important technology in R&D spillovers is different across different stages of economic development: medium-low technology in the low-income group and high technology in the middle-income group. Third, the role of high technology in R&D spillovers becomes larger as per capita income rises. These findings suggest that stage of economic development matters in the type of technology diffusion. Finally, education is also a major factor in R&D spillovers and it plays more important role in relatively higher technology level with higher stage of economic development.

JEL classification: F1, O1, O3, O4

Keywords: Technology Differentiation, R&D spillovers, Economic Development, Human Capital.

* I would like to thank Keith Maskus for his decent provision of the ANBERD and STAN databases. A previous version of this paper was presented in the conference on “Korea and the World Economy” in Seoul, Korea, July 2002. I would like to thank professors Frank S. T. Hsiao, Murat Iyigun, John Y. T. Kuark, Keith Maskus and Robert McNown for their valuable comments. Trade data were purchased by a grant from the Beverly Sears Graduate Student Grants, the University of Colorado at Boulder, 2001-2002.

* Department of Economics, Campus Box 256, University of Colorado at Boulder, Boulder, CO 80309-0256. Tel: (303) 492-7116. Fax: (303) 492-8960. Email address: changsuh.park@colorado.edu

Contents of the Paper

1. Introduction

Endogenous growth models put an emphasis on innovation and trade as engines for technological progress as well as growth (Rivera-Batiz and Romer, 1991; Grossman and Helpman, 1991b). In the endogenous growth literature that introduces horizontally or vertically differentiated intermediate products, technological progress depends on both domestic research and development (R&D) capital stock and international R&D spillovers. R&D activity can lead to improvement of existing manufacturing techniques and to the creation of new technologies. The former is related to the quality-ladders growth models and the latter is related to the varieties growth models.

However, among advanced countries, the G-7 countries accounted for more than 90% of the world's R&D spending in 1991 (Coe, Helpman and Hofmaister, 1997, henceforce CHH). This suggests that developing countries can adopt new technologies through the channels of international trade with advanced countries, foreign direct investment, or patent licenses, rather than through their own R&D activity. Therefore, international R&D spillovers from developed countries to developing countries cannot be negligible. Developing countries can indirectly experience the outcomes of R&D activity performed in developed countries, and thus the R&D outlays spent in developed countries will have an effect on the productivity of developing countries through trade.

Most studies on international R&D spillovers have focused on the *overall* effect of the foreign R&D capital stock on domestic total factor productivity (Coe and Helpman, 1995, henceforth CH; CHH, 1997). As such, it does not explain the relationship between stage of economic development and technology differentiation. In the initial phase of development, relatively lower technology level may be more adoptable and will thus play a more important role in technological progress. In the product cycle framework, with trade opened, a developing country tends to specialize in exporting low-technology goods, and a developed country tends to specialize in exporting high-technology goods (Krugman, 1979; Grossman and Helpman, 1991c).

However, in the process of development, developing countries will adopt higher levels of technology through learning-by-doing or investment in human capital. Lau and Wan (1993) point out that the benefits from attempting to borrow technology vary across countries, depending on their technical capabilities and their opportunities for borrowing. The high-growth economies like Japan and the East Asian countries are in a position to be technology followers, in their middle phase of development. Based on this theoretical background, this paper attempts to examine the sources of differentiated technology in R&D spillovers from North to South and within the North.

The second contribution of this paper is in constructing the foreign R&D capital stock. Previous empirical studies (CH, 1995; CHH, 1997) use aggregated average import shares as weight, and R&D data are also aggregated. In this case, R&D stock of the high-technology sector will be included in the construction of the foreign R&D stock, even though there has been no trade in this sector with advanced countries. Thus, foreign R&D stock may not be correctly constructed. To reduce this problem, the present paper constructs foreign R&D capital stock from the actually realized industry-based trade and R&D capital stock of advanced countries.

One of the main findings is that R&D spillovers from North to South occur mainly in the medium-high-technology sector, followed by the medium-low- and the high-technology sectors. There is a relatively weak R&D spillover in the low-technology sector. The product cycle models may explain this. In the product cycle literature, a developing country tends to specialize in low-technology goods and to export them. Thus, R&D spillovers in the low-technology sector from the North may not be substantial. Second, as per capita income increases, relatively higher levels of technology are involved in R&D spillovers. These results may support a relationship between phase of economic development and technology differentiation in R&D spillovers. Furthermore, human capital has a positive effect on productivity when it interacts with foreign R&D capital stock. It plays a stronger role in R&D spillovers from the high-technology sector in upper-middle- and high-income groups.

The paper is organized as follows. The next section presents the hypothesis to be examined. Section 3 describes the framework of analysis and empirical specification. The fourth section explains the data sources and construction of variables, and Section 5 provides a descriptive summary of the data. The empirical results will be presented in Section 6, and the last section is the conclusion.

2. A Testable Hypothesis

CH (1995) examined R&D spillovers within 21 OECD countries plus Israel. On the other hand, CHH (1997) investigated R&D spillovers from North to South through trade, using weighted bilateral machinery-and-equipment import shares among 21 OECD countries plus Israel. These two papers, using aggregated data, found that foreign R&D capital stock plays a substantial role in total factor productivity. Even in developed countries, foreign R&D stock is positively associated with productivity to the same extent as domestic R&D stock. Keller (2002) also investigated the effects of R&D spillovers on total factor productivity within eight OECD countries using thirteen industry-level data. He found strong productivity effects both from own R&D expenditures and foreign R&D stock. Engelbrecht (1998) confirmed the results of CH (1995), adding human capital into their preferred empirical models. Lichtenberg and Potterie (1998, henceforth LP) proposed an alternative measure of foreign R&D stock that was much less sensitive to the level of data aggregation than that used by CH (1995). In order to reduce the bias of data aggregation, they used trade partner's export share in production rather than import share of importing country as a weight in constructing the foreign R&D capital stock.

Most empirical literature on R&D spillovers examines spillovers among advanced countries. Madden and Savage (2000), however, focused on R&D spillovers from 15 OECD countries to 5 Asian economies (India, Indonesia, Singapore, South Korea and Thailand). They extended the empirical model of CH (1995) and considered the role of trade of information technology and telecommunications in R&D spillovers. Schiff et al. (2002) explored trade-related R&D spillovers between North-South and South-South. They found that high R&D-intensive industries benefited mainly from North-South R&D flows, while low R&D-intensive industries benefited mainly from South-South R&D flows. They used only two types of R&D intensity. This classification of technology is too broad to identify the sources of specific technology levels in international R&D spillovers. In addition, there have been few empirical studies on the relationship between phases of economic development and technology differentiation in R&D spillovers.

In the initial stage of development, developing countries may have insufficient physical capital or knowledge stock. As economic development progresses, however, they will adopt higher levels of technology through learning-by-doing or investment in human capital, starting with specialization in low technology. Flam and Helpman (1987) developed a model of North-South trade in which the North exports high-quality products and the South exports low-quality products.

In order for the South to export low-quality products, it is not necessary to import machinery and equipment in which high technology is embodied, because producing low-quality products may not require high-technology machinery and equipment. In addition, the level of per capita income in the South is low, especially in the beginning stage of economic development, so that they cannot afford to import high-quality products. In this case, R&D spillovers from the North will occur in the low-technology sector rather than in the high-technology sector.

However, learning allows a country to import a product employing high-level technology and to produce new goods, and hence to export refined goods. Exports of refined goods subsequently may lead to absorption of new technology (Chuang, 1998). In addition, as per capita income rises with economic development, the South can afford to import high-quality products from the North. Thus, in this stage of development, a relatively high-technology sector will be more involved in R&D spillovers from the North. Therefore, the hypothesis to be tested here is as follows:

> *In the process of economic development, the foreign R&D capital stocks of different levels of technology will play different roles in productivity, depending on the different stage of development of each country.*

The World Bank (2002) divides world economies into four income groups according to gross national income per capita of 2000. The groups are (1) low income with US$ 755 or less, (2) lower-middle income with US$ 756-2,995, (3) upper-middle income with US$ 2,996-9,265, and (4) high income with US$ 9,266 or more.

To test the above hypothesis, groups (1)-(4) are separated into three groups: Groups (1) and (2) will be classified as the first stage of economic development, group (3) will be considered the middle stage of development, and group (4) is considered to be in the last stage of development. Four countries (Hong Kong, Israel, Singapore and Taiwan) belong to the high-income group on the basis of the World Bank, but these countries are included in the group (3) here, because these countries are usually classified as developing countries. The classification for stages of economic development may not exactly represent the degree of economic development and we may have to consider some other variables related to economic development. However, because of data limitations, we will use this classification as a proxy for stages of economic development.

3. Framework of Analysis

In traditional growth theory, exogenous technology shock is necessary for sustainable economic growth. In the new theory of endogenous growth (Romer, 1990; Grossman and Helpman, 1991a, 1991b and 1991c), technological progress is determined endogenously, and sustainable long-run growth can be obtained without exogenous technology shock. There are two types of endogenous growth models: the varieties growth model (or horizontally differentiated model), and the quality-ladders growth model (or vertically differentiated model), both of which model the relationship between technological change and R&D outlays.

In the framework of the varieties model (Romer, 1990; Grossman and Helpman, 1991b, Ch.3), a simple specification of output, *Y*, is given as a Dixit-Stiglitz (1977) production function,

$$Y = AL^{\alpha} d^{1-\alpha}, \quad 0 < \alpha < 1, \tag{1}$$

where *A* is a positive constant, *L* is labor input, and *d* is a composite input consisting of horizontally differentiated goods *x* of variety *i*:

$$d = \left(\int_0^v x(i)^{1-\alpha} \, di \right)^{1/(1-\alpha)} \tag{2}$$

The variety *v* denotes the number of varieties of intermediate products that are currently known and employed. In equilibrium, each intermediate is employed at the same level, $\bar{x}$, together with a linear production technology that converts one unit of output into one unit of any of the intermediates. Thus capital stock at any point or the total quantity of intermediate inputs employed is given by $K = v\bar{x}$. Solving this for $\bar{x}$ and substituting it into equations (2) and (1) gives rise to

$$Y = Av^{\alpha} L^{\alpha} K^{1-\alpha} \tag{3}$$

Even though the underlying production function (1) is homogeneous of degree 1 in *L* and

d, this reduced form (3) is homogeneous of degree (1+α) in v, L and K.

An alternative endogenous growth model for a model of North-South interactions is the quality-ladders model, in which the number of intermediate inputs is fixed and technological progress arises from improvement in the quality or productivity of these intermediate goods (Aghion and Howitt, 1992; Grossman and Helpman, 1991b).

To test the hypothesis in this paper, we assume there are two different types of intermediates: high R&D-intensive intermediate inputs, or high-quality inputs, d_H, and low R&D-intensive intermediate inputs, or low-quality inputs, d_L, but the intermediate goods are horizontally differentiated within each R&D intensity.[1] Thus, two vertically differentiated intermediate inputs as well as horizontally differentiated intermediate inputs within each sector are explicitly introduced into the production function.

Suppose now that the production function is modified from equation (1).

$$Y = AL^{\alpha} d_H{}^{\beta} d_L{}^{1-\alpha-\beta}, \quad 0 < \alpha < 1 \text{ and } 0 < \beta < 1, \tag{4}$$

This production function is homogeneous of degree 1 in L, d_H, and d_L. Composite inputs, d_H and d_L, consisting of horizontally differentiated goods x of variety i in high R&D-intensive and low R&D-intensive sectors, respectively, are defined as

$$d_H = \left(\int_0^{v_H} x_H(i)^{\beta} di \right)^{1/\beta} \tag{5-1}$$

$$d_L = \left(\int_0^{v_L} x_L(i)^{1-\alpha-\beta} di \right)^{1/(1-\alpha-\beta)} \tag{5-2}$$

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[1] Hereafter, the subscripts H and L denote high R&D-intensive and low R&D-intensive sectors, respectively.

In equilibrium, each intermediate is employed at the same level, $\bar{x}_H$ and $\bar{x}_L$, in each sector. Thus capital stock in each sector at any point or the total quantity of intermediate inputs employed is given by $K_H = v_H \bar{x}_H$ and $K_L = v_L \bar{x}_L$. Solving those for $\bar{x}_H$ and $\bar{x}_L$ and substituting them into equations (5), then

$$d_H = K_H (v_H)^{(1-\beta)/\beta} \tag{5-1$'$}$$

$$d_L = K_L (v_L)^{(\alpha+\beta)/(1-\alpha-\beta)} \tag{5-2$'$}$$

Substituting equations (5-1)′ and (5-2)′ into equation (4) leads to

$$Y = A (v_H)^{1-\beta} (v_L)^{\alpha+\beta} L^{\alpha} K_H^{\beta} K_L^{1-\alpha-\beta} \tag{6}$$

In practice, if we have only aggregated capital stock in an economy, then we can assume that $K_H = K_L = K$. Thus, the above equation finally will be

$$Y = A (v_H)^{1-\beta} (v_L)^{\alpha+\beta} L^{\alpha} K^{1-\alpha} \tag{6$'$}$$

If total factor productivity is defined as $TFP \equiv Y / L^{\alpha} K^{1-\alpha}$, we can derive the following equation from equation (6)′:

$$\log TFP = \log A + (1\text{-}\beta) \log v_H + (\alpha+\beta) \log v_L \tag{7}$$

Since the new varieties of intermediate product employed, v_H and v_L, can be realized from the R&D effort, v_H and v_L represent the current state of the endogenously determined technology and thus TFP is positively related to high R&D-intensive and low R&D-intensive outlays, respectively. However, the own R&D expenditures of developing countries were less than 10% of the world's R&D spending in 1991 (CHH, 1997). There are also data limitations to collecting the R&D data of developing countries. For these reasons, the present paper assumes that v_H and v_L are dependent on the trade-related spillovers of the foreign R&D stock.

Based on the derivation of equation (7), a simple regression specification for the panel data is as follows:[2]

$$lnTFP_{ct} = \alpha + \alpha_c + \alpha_t + \sum_r \alpha_r lnR\&D_{ct}^{F-r} + \varepsilon_{ct} \tag{8}$$

where $r = \{HI, MH, ML, LW\}$, which denote four different types of technology: high (HI), medium-high (MH), medium-low (ML) and low (LW) technologies. $lnR\&D^{F-r}$ is the natural logarithm of the foreign R&D capital stock of each technology level r. α, α_c and α_t are constant term, country and year dummies to be estimated. $lnTFP_{ct}$ is the natural logarithm of TFP of country c at year t. ε_{it} is disturbance, which is not captured by country- and time-specific effects.

One possible extension of the above model is to introduce human capital, in which human capital is technology-specific. Human capital is introduced as follows:[3]

$$d_H = \left(\int_0^{v_H} [x_H(i) \bullet \exp(H_H)]^{\beta} di \right)^{1/\beta} \tag{9-1}$$

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[2] For simplicity, we use only two different types of R&D intensity. However, we can easily extend this into four different types of R&D intensity.

[3] This is the modified version of Jaumotte (2000).

$$d_L = \left(\int_0^{v_L} [x_L(i) \bullet \exp(H_L)]^{1-\alpha-\beta} di \right)^{1/(1-\alpha-\beta)} \tag{9-2}$$

where H_H and H_L are assumed to be skilled and unskilled human capital employed in high R&D-intensive and low R&D-intensive sectors, respectively, or they are assumed to be the same quality of human capital that is employed in each sector. Then, with the similar procedure above, we can easily derive the following production function.

$$Y = AH^{1-\alpha}(v_H)^{1-\beta}(v_L)^{\alpha+\beta} L^{\alpha} K^{1-\alpha} \tag{10}$$

where $K_H = K_L = K$ and $H_H = H_L = H$ are assumed. Thus, the final equation with human capital can be derived as follows:

$$\log TFP = \log A + (1\text{-}\alpha)H + (1\text{-}\beta) \log v_H + (\alpha+\beta) \log v_L \tag{11}$$

A regression model based on (11) can be expressed as follows:

$$lnTFP_{ct} = \alpha + \alpha_c + \alpha_t + \alpha_E EDU_{ct} + \sum_r \alpha_r lnR\&D_{ct}^{F}{}_{-r} + \varepsilon_{ct} \tag{12}$$

where *EDU* as the proxy for human capital is the education variable of the sum of average years of secondary and higher education of the population aged 15 and above, and other variables are the same as in (8). CHH (1997) and Engelbrecht (1997) show that human capital plays an important role in productivity in both developing and developed countries. Thus, the education variable is used as a proxy for human capital in (12). In the interaction of education with foreign R&D capital stock, the effect of foreign R&D capital stock on productivity will be larger the more educated is the domestic work force, as pointed out in CHH (1997). Thus, another model is given by

$$\begin{aligned} lnTFP_{ct} &= \alpha + \alpha_c + \alpha_t + \alpha_E EDU_{ct} + \sum_r \alpha_r lnR\&D_{ct}^{F-r} \\ &+ \sum_r \alpha_{Er} EDU_{ct} lnR\&D_{ct}^{F-r} + \varepsilon_{ct} \end{aligned} \tag{13}$$

where $EDU_{ct}lnR\&D_{ct}^{F-r}$ is the interaction term of education with the log of foreign R&D capital stock of technology level *r*.

The main purpose in this paper is to identify the relationship between stages of economic development and different technology levels in R&D spillovers. Therefore, equations (8), (12) and (13) will be examined by different income group for four different technology levels of the foreign R&D stocks. This is a critically different approach from the current literature on the international R&D spillovers.

4. Data

The data for total factor productivity are taken from the preliminary version of Penn World Table 6. (Heston and Summer, 2001, PWT 6). When we combine the education variable with PWT6, only 90 countries are available. Among these 90 countries, 68 are classified as developing countries and 22 are advanced ones. However, R&D data are available only for 14 OECD countries so that this paper concentrates on these 14 OECD countries and the 68 developing countries.[4]

The data of real output are calculated by multiplying real per capita GDP of 1996

[4] Germany is excluded in the regression model because of discontinuous data in PWT 6.0 after her unification, but German R&D data are used in calculating the foreign R&D stocks. Therefore, the final data set is for 81 countries. See Appendix A for more details.

prices (RGDPCH) by population reported in PWT 6. The number of workers is also calculated implicitly using real GDP per worker, population and RGDPCH available in PWT 6. Physical capital stock and R&D capital stock are estimated by a perpetual inventory approach using investment data in PWT 6, and R&D expenditure data from the ANBERD database (OECD, 2000), respectively. Following CH (1995), the current physical and R&D capital stocks, K_t, are determined as follows:

$$K_t = I_{t-1} + (1 - \delta)K_{t-1} \tag{14}$$

where δ is the depreciation rate, which is assumed to be 10 percent, and I_{t-1} and K_{t-1} are investment and capital stock at previous period in an economy, respectively. The initial capital stocks of both, K_0, are estimated by the procedure used in CH (1995):

$$K_0 = I_0 / (g + \delta) \tag{15}$$

where g is the average annual growth rate of per capita income for initial physical capital stock and the average annual growth rate of R&D expenditures for initial R&D capital stock over the period available, and I_0 is initial investment available. Initial physical investment data are available from 1950 or 1960 and initial R&D expenditures are available since 1973 in the ANBERD database.

In the ANBERD database, nominal R&D expenditures of 14 OECD countries[5] are deflated by each country's price index of gross domestic products at 1996 base year. These real R&D expenditures in national currency are converted into international constant values using each country's purchasing power parity exchange rate of 1996 to obtain the

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[5] These countries are Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, the United Kingdom and the United States.

internationally comparable data of R&D expenditures.[6]

Using real R&D expenditures of twenty-two industries[7] in fourteen OECD countries, R&D capital stocks are estimated over 1973-1996 using the perpetual inventory method discussed above, and the foreign R&D stocks by industry for each of 81 countries are constructed based on the method of LP (1998). In CH (1995), the foreign R&D capital stock is defined as the import-share-weighted average of the domestic R&D capital stocks of trade partners. On the other hand, in the method of LP (1998), the foreign R&D stock of industry *i* in country *c* at time *t*, S^f_{cit}, is calculated as follows:

$$S^f_{cit} = \sum_{j=1}^{14} S^f_{cijt} = \sum_{j=1}^{14} \frac{m_{cijt}}{y_{ijt}} S^d_{ijt} \qquad \text{for industry } i \text{ of country } c \text{ at year } t \qquad (16)$$

where $i = \{1, 2, \ldots, 22\}$. S^d_{ijt} is the domestic R&D stock of industry *i* of trade partner *j*, m_{cijt} is the flow of imports of industry *i* in country *c* from trade partner *j*, and y_{ijt} is the output level of industry *i* of trade partner *j*. LP (1998) argued that the procedure in CH (1995) is not invariant to the level of data aggregation, while their formulation reflects both the R&D intensity and direction of international R&D spillovers. In this paper, the foreign R&D capital stocks are constructed on the basis of the method of LP (1998).[8]

The production data of 22 industries used in equation (16) are taken from the STAN database (OECD, 2000) and the trade data used in calculating the bilateral trade shares of 22 industries come from the World Trade Flows Database CD-ROM (Feenstra et al., 1997;

[6] The data of the deflators of gross domestic products and purchasing power parity exchange rates of 14 OECD countries are downloadable from http://www.oecdsource.org.
[7] See Appendix B for the industry classification used for R&D and trade data.
[8] If the present paper follows the Coe and Helpman method (1995), total imports from 14 trading partners for each industry will be used instead of y_{ijt}. That is, m_{cit} = sum of m_{cijt} over trading partner *j* for each industry *i*.

Feenstra, 2000). The industry code of trade data is SITC (Standard International Trade Classification) Rev. 2, but the R&D data are based on ISIC Rev. 2. Therefore, the 4-digit SITC is matched to the 3-digit ISIC.[9] Then, according to Hatzichronoglou (1997), 22 manufacturing industries are reclassified into four different levels of technology: high-technology (4 industries), medium-high-technology (6 industries), medium-low-technology (8 industries), and low-technology industries (4 industries).

Since the OECD ANBERD and STAN databases are matched with the classification in Hatzichronoglou (1997), trade data (Feenstra et. al, 1997 and Feenstra, 2000) of SITC Rev. 2 are matched with the industry codes of ISIC Rev. 2. Finally, the source of education data is Barro and Lee (2000). Since these data are reported every five years, the interpolation method is applied to estimate annual data between two periods.

The total factor productivity of each country c is estimated by the traditional Solow residual, which imposes conventional values for factor shares. These are given by

$$lnTFP_{ct} = lnY_{ct} - \alpha\, lnK_{ct} - (1\text{-}\alpha)\, lnL_{ct} \tag{17}$$

where α is the capital's income share in GDP which is assumed to be 0.35 or 0.4. lnY_{ct}, lnK_{ct}, and lnL_{ct} are the natural logarithms of output, physical capital stock, and the number of workers, respectively. These data are taken from PWT 6.

5. Descriptive Summary

In the present paper, one of the main issues is how to classify the sample countries

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[9] See Appendix B for more details.

into different stages of economic development. Because of data limitations, the present paper uses classification by per capita income from World Bank (2002), as mentioned before. However, this classification may not exactly represent the degree of economic development. Some countries may shift from the first stage to a higher stage of development, or *vice versa* over the long term. Therefore, we first rank the sample of 81 countries by per capita nominal income for 1973, 1978, …, 1993, and 1996, and calculate the correlation coefficient for these ranks in Table 1 to examine the fluctuation of the ranks over time.

The correlation coefficients in Table 1 are positively significant at the 1% level. In general, the correlation coefficients are relatively smaller between two periods which are longer, but the minimum correlation coefficient is .891 between the ranks of 1973 and 1996. This implies that there is some fluctuation of the ranks by country, but it is not really a significant change over time.[10] Therefore, this paper uses the classification of per capita income as the proxy for phases of economic development.

Table 1. Correlation coefficient of rank of nominal GDP per capita

	rank73	rank78	rank83	rank88	rank93	rank96
rank73	1					
rank78	0.956	1				
rank83	0.929	0.960	1			
rank88	0.909	0.932	0.950	1		
rank93	0.899	0.917	0.934	0.967	1	
rank96	0.891	0.912	0.928	0.958	0.989	1

Note: Nominal GDP per capita came from PWT 6.0 for 1973, 1978, …, and 1996.

[10] The correlation coefficient of the ranks for real GDP per capita also shows the similar results as in nominal GDP per capita. Since the classifications of countries are based on nominal income per capita, we only report the results for nominal income per capita.

Figures 1a to 1e represent a distribution between foreign R&D stock per worker and real GDP per worker, for total foreign R&D stocks and by technology levels in 1996. The figures indicate a very strong linear relationship between these two variables in terms of logarithm. The slopes are positive and become smaller when technology level becomes lower. In this simple regression, for the 1% increase in real GDP per worker, foreign R&D stock of high technology increases by 1.56%, while foreign R&D stock of low technology increases by 1.30%.

These may be related to the elasticities of demand for the high-technology and low-technology products. The elasticity of demand for the high-technology product may be larger than that of the low-technology product. The values of R^2 also decline with lower levels of technology. This may imply that there is a relatively stronger linear relationship between the foreign R&D stock and per capita income in higher level of technology rather than in relatively lower level technology.

In the comparison of overall foreign R&D stock per worker in 81 individual countries, Singapore (SGP) has the highest foreign R&D stock per worker, followed by Hong Kong (HKG). The foreign R&D stocks per worker of the USA and Japan are almost the same (The logs of the foreign R&D stock are 12.88 and 12.56, respectively.). We can observe these trends in the individual technology level of the foreign R&D stock.

In general, the foreign R&D stocks per worker of four East Asian economies (TWN, Taiwan; KOR, Korea) are larger than those of Latin American countries (MEX, Mexico; ARG, Argentina; BRA, Brazil), while China (CHN) is located in the middle group and Zaire (ZAR) has the smallest foreign R&D stock except foreign R&D stock of the low technology. India (IND) has the smallest foreign R&D stock of low technology in 1996.

Figure 1a. Total foreign R&D stock vs. real GDP per worker (1996)

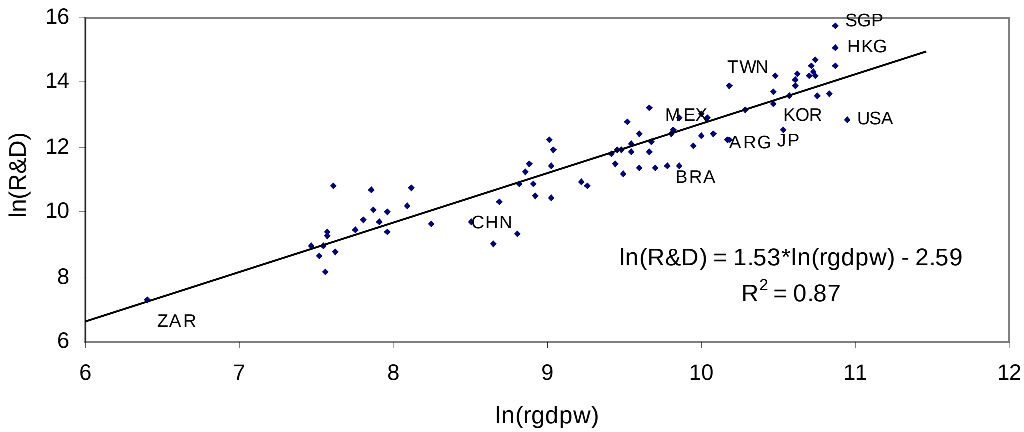


Figure 1b. Foreign R&D stock of high-tech

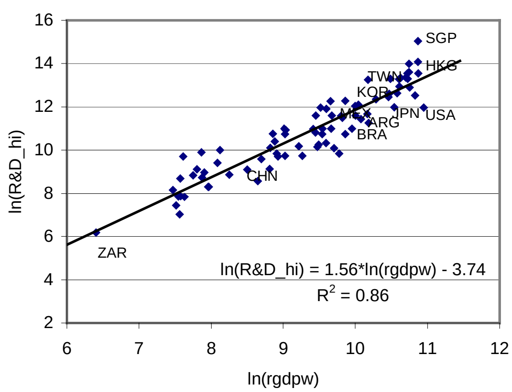


Figure 1c. Foreign R&D stock of med.-hi-tech

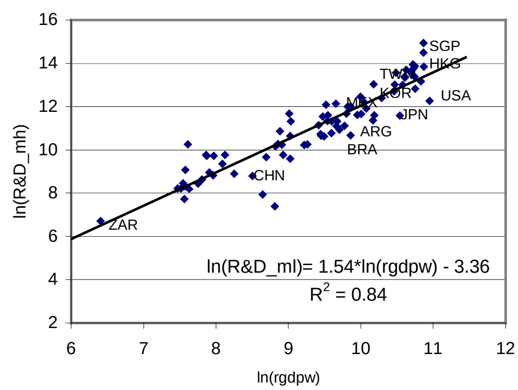


Figure 1d. Foreign R&D stock of med.-low-tech

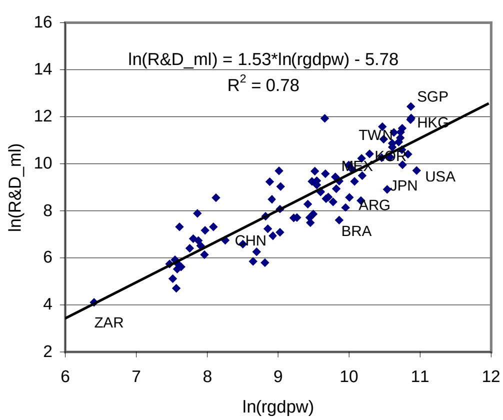
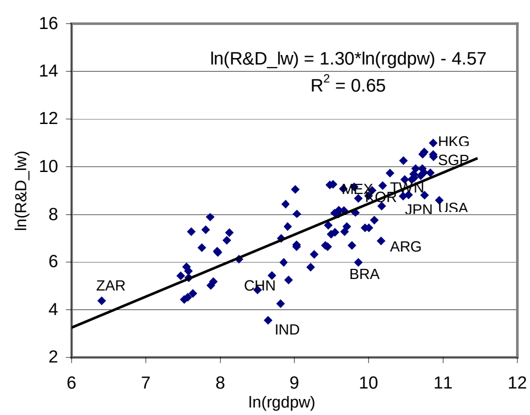


Figure 1e. Foreign R&D stock of low-tech



This result may come from different trade pattern between these countries. Especially, Hong Kong and Singapore have very high trade shares in GDP.

Table 2 shows average annual growth rates of TFP, GDP per worker, physical capital stock and labor force by income group and by some selected individual countries of our data. In general, over the entire period of 1973-1996, the upper-middle-income group has achieved the highest growth rates in TFP, GDP per worker and physical capital stocks, but this may result from the performance of East Asian countries. In the comparison across individual countries, among East Asian countries, Hong Kong achieved the highest growth rate of TFP, and the performance of East Asian economies is distinct from those of Latin American economies except in the growth rates of the labor force. On the other hand, the annual growth rate of TFP in the low-income group is negative for the entire period. However, there is no significant difference in the growth rate of the labor force across income groups except in the high-income group.

Table 3 presents the trends of educational attainment for the population aged 15 and over by education level across income groups and individual countries in 1973 and 1996, with its relative ratio of the average years of 1996 to the average years of 1973.[11] In the comparison of education attainment across income groups, the low-income group shows relatively higher growth in primary and secondary education, but its average years of education are still far behind from those of other income groups.

In the comparison of the average years of schooling of developing groups with those of high-income group, with higher per capita income, the average years of schooling

[11] Barro and Lee (2000) point out that the part of the population aged 15 and over would be a better measure for the labor force for many developing countries.

Table 2: Average annual growth rates of TFP, GDP per worker, capital and workers

	TFP ($\alpha = 0.35$)			TFP ($\alpha = 0.40$)			GDP per worker			Capital stock			Workers		
Period	73-96	73-84	85-96	73-96	73-84	85-96	73-96	73-84	85-96	73-96	73-84	85-96	73-96	73-84	85-96
By income group															
Low (25) [1]	-0.52	-0.19	-0.83	-0.56	-0.31	-0.78	-0.28	0.66	-1.14	3.36	4.64	2.19	2.68	2.24	3.09
Lower-middle (25)	0.48	0.01	0.90	0.39	-0.17	0.91	1.06	1.30	0.84	4.27	6.28	2.44	2.60	2.59	2.61
Upper-Middle (18)	1.18	0.51	1.80	1.04	0.31	1.70	2.21	1.93	2.45	5.14	6.69	3.72	2.22	2.63	1.85
High (13)	0.92	0.53	1.28	0.84	0.43	1.21	1.51	1.20	1.79	2.69	3.12	2.29	1.01	1.19	0.85
Sample	**0.40**	**0.14**	**0.63**	**0.31**	**-0.01**	**0.61**	**0.97**	**1.23**	**0.74**	**3.93**	**5.36**	**2.62**	**2.29**	**2.27**	**2.31**
Select individual countries															
China	2.44	2.08	2.76	2.13	1.85	2.38	4.63	3.74	5.44	8.27	7.05	9.38	2.01	2.32	1.73
Hong Kong	3.21	2.38	3.96	2.89	2.10	3.60	5.45	4.30	6.50	7.73	8.98	6.58	1.32	3.48	-0.66
Korea	2.89	1.86	3.84	2.44	1.41	3.39	6.05	5.04	6.97	10.85	11.54	10.22	1.84	2.45	1.28
Singapore	2.28	1.76	2.74	2.04	1.43	2.60	3.93	4.15	3.73	8.41	10.74	6.28	3.68	3.93	3.45
Taiwan	2.84	1.78	3.82	2.45	1.33	3.47	5.61	4.93	6.24	9.82	11.59	8.19	1.91	2.59	1.28
Argentina	0.17	-0.65	0.92	0.19	-0.75	1.06	0.04	0.08	0.01	1.44	3.02	-0.01	1.81	0.93	2.61
Brazil	0.49	-0.59	1.48	0.38	-0.82	1.49	1.24	1.05	1.42	4.42	7.62	1.48	2.27	2.95	1.65
Mexico	0.00	0.00	-0.01	-0.04	-0.12	0.04	0.23	0.84	-0.32	3.56	5.96	1.36	2.88	3.57	2.25
Japan	1.06	0.66	1.42	0.84	0.41	1.23	2.57	2.39	2.74	5.01	5.81	4.27	0.69	0.88	0.51
USA	0.56	0.24	0.85	0.46	0.15	0.75	1.22	0.85	1.56	3.54	3.65	3.44	1.66	1.90	1.43

Source: The author's calculation using PWT 6.

Note: (1) Figures in the parentheses indicate the number of countries in each group.

Table 3. Trends of average years of schooling for population aged 15 and over

Income groups \ Education	Primary			Secondary			Higher		
	1973(a)	1996(b)	(b)/(a)	1973(c)	1996(d)	(d)/(c)	1973(e)	1996(f)	(f)/(e)
Low	1.37	2.28	1.66	0.33	0.73	2.21	0.02	0.05	2.50
Lower middle	2.85	3.92	1.38	0.87	1.62	1.86	0.06	0.26	4.33
Upper-middle	3.75	4.80	1.28	1.20	2.15	1.79	0.12	0.34	2.83
High	5.13	5.45	1.06	2.25	3.55	1.58	0.31	0.63	2.03
Sample mean	**2.96**	**3.86**	**1.30**	**1.00**	**1.77**	**1.77**	**0.10**	**0.27**	**2.68**
Some Individual countries									
Hong Kong	4.07	4.96	1.22	2.18	4.06	1.87	0.07	0.39	5.60
Korea	3.47	5.59	1.61	1.30	4.48	3.45	0.15	0.77	5.30
Singapore	3.36	4.54	1.35	1.64	2.23	1.36	0.05	0.27	5.55
Taiwan	3.73	5.08	1.36	1.43	3.15	2.20	0.15	0.53	3.48
China	2.88	4.29	1.49	1.18	1.97	1.68	0.03	0.10	3.50
Argentina	5.15	6.13	1.19	0.93	2.14	2.30	0.12	0.56	4.59
Brazil	2.47	3.91	1.59	0.80	0.75	0.94	0.05	0.22	4.74
Mexico	3.01	4.68	1.55	0.60	2.25	3.74	0.07	0.30	4.36
Japan	5.13	5.54	1.08	2.10	3.25	1.55	0.23	0.68	2.94
USA	5.80	5.82	1.00	3.15	4.77	1.52	0.58	1.45	2.49

Source: The author's calculation from Barro and Lee (2000).

have become closer to those of the high-income group, but the gap of average years of higher education between the low- income and the high-income groups in 1996 is 12 times (= .63/.05), while the gap between the lower-middle-income and the high-income groups is 2.4 times, and the gap between upper-middle-income and high-income groups is around 1.9 times.

In comparing the average years of education of individual countries, in general, four East Asian countries except China have larger average years of secondary and higher education schooling relative to three Latin American countries. In particular, the average years of the three schooling levels of Korea in 1996 are higher than those of Japan in 1996, with higher growth of education relative to other countries. The average years of primary and secondary schooling of Korea are closer to those of the United States, but the average years of higher education of Korea (0.77) in 1996 are still almost half those of the United States (1.45).

Table 4 shows the average annual import and export shares of each income group by technology level within the total imports and exports of the 14 high-income countries. First, most trade has occurred within high-income countries. For example, during 1985-1996, the portion of imports within 14 advanced countries is 75.62% and the export share is 79.15%. Second, in trading by technology level, medium-high technology has the highest import share in every income group, while medium-low technology has the second highest import share except in the high-income group. The export share is largest in the low technology sector in three income groups, but not in the high-income group. These trends explain the trade pattern between the North and the South. The North exports high-quality products and the South exports low-quality products (Flam and Helpman, 1987). But the main technology that the South imports from the North is medium-high technology rather than high technology.

The import shares of the high-technology sector of low- and lower-middle-income groups from the high-income group have remained unchanged (.25 → .26) or increased (.54 → .77) in the second period, while those of other technology sectors as well as overall import shares have decreased in the second period relative to the first. On the other hand, import shares of all technology sectors except the medium-low technology sector of the upper-middle income group have increased in the second period.

Table 4: Average annual Import and export shares in 14 OECD trade partners by income group(%)

Group	Industry	Import Share		Export Share	
		1973-84	1985-96	1973-84	1985-96
Low income (25)[1]	Hi Tech (4)[2]	0.25	0.26	0.01	0.03
	Medium Hi Tech (6)	1.62	1.31	0.05	0.10
	Medium Low Tech (8)	0.66	0.43	0.68	0.43
	Low Tech (4)	0.49	0.25	1.00	1.10
	sub total [a]	**3.02**	**2.25**	**1.74**	**1.67**
Lower-middle income (25)	Hi Tech	0.54	0.77	0.02	0.21
	Medium Hi Tech	3.92	3.70	0.30	0.51
	Medium Low Tech	1.77	1.25	0.64	0.89
	Low Tech	1.08	0.87	1.22	1.90
	sub total [b]	**7.31**	**6.59**	**2.18**	**3.50**
Upper-middle income (18)	Hi Tech	1.23	2.07	0.82	2.54
	Medium Hi Tech	8.06	8.91	1.61	4.10
	Medium Low Tech	2.93	2.72	3.41	3.79
	Low Tech	1.72	1.83	4.98	5.26
	sub total [c]	**13.94**	**15.53**	**10.82**	**15.69**
High income (14)	Hi Tech	6.52	10.31	7.32	10.80
	Medium Hi Tech	36.45	39.01	41.02	40.82
	Medium Low Tech	15.70	12.15	17.69	12.72
	Low Tech	17.07	14.15	19.22	14.81
	sub total [d]	**75.74**	**75.62**	**85.25**	**79.15**
total [=a+b+c+d]		100.01	99.99	99.99	100.01

Source: The author's calculation from trade data of Feenstra et. al (1997) and Feenstra (2000).
Notes: (1) The figures are the number of countries in each income group.
(2) The figures are the number of industry in each technology classification.

These trends of import shares across income groups are similar to those of export shares. The overall export shares of low- and lower-middle-income groups remain relatively stable between the two periods, but there is a difference in export shares across technology levels. Export shares of high technology of these two groups grow faster relative to other technology sectors, while export shares of other technology sectors do not show significant differences.

The overall export share of the upper- middle-income group has increased by 4.87 percent points from 10.82% in the first period to 15.69% in the second period, and the main source of its expansion is the increase in the export shares of the high- and medium-high-technology sectors. Its export share of high technology increased by 1.72 percent points from 0.82% to 2.54%, and its export share of medium-high technology increased by 2.49 percent points. By contrast, the overall export share of the high-income group decreased by 6.10 percent points from 85.25% to 79.15%.

In summary, Table 4 shows that most imports of developing countries from advanced countries are in the medium-high technology sector, and thus R&D spillovers from advanced countries will be the same as the import pattern.

6. Empirical Results

A fixed-effect model for the panel data (considering country-specific effect) has been employed for 68 developing countries plus 13 developed countries over 1973-1996.[12] In order to reduce any possible simultaneity bias between TFP and the foreign R&D stock, the data are selected from the initial observations of every 5-year period since 1973; that is, the initial observations of 1973, 1978, 1983, 1988, 1993 and 1996 for every country are chosen for regression.[13]

The purpose of the regression models is to examine the international R&D spillovers from the North to the South in terms of stage of economic development and technology differentiation. For this purpose, 81 developing countries are broken down into three groups based on per capita income as of 2000 according to World Bank (2002). The

[12] We have considered the time-specific effects by introducing time dummy variables in the regression model. However, these time dummies are not significantly different from zero. Thus, the year dummies are excluded from the regression models.

[13] For the four countries in the low-income group, Central African Rep., Congo, Rep. of, Niger and Rwanda, there are missing data for 1973. Therefore, the total sample size is 482 for 81 countries over 6 periods.

first group is combined from the low-income (25 countries) and lower-middle-income groups (25 countries). Hereafter this combined group is called the low-income group, and it is suggested to reflect the beginning stage of economic development. The second group consists of the upper-middle-income countries and four high-income ones (18 countries). We assume this second group is in the middle stage of development. Lastly, 13 developed countries are considered to represent the last stage of development.

Table 5 shows the regression results of a simple model without the distinction of foreign R&D stock by technology levels. Since we are mainly concerned with R&D spillovers of developing countries in the present paper, the first three columns only show developing countries, excluding the high-income group. The estimation results show that there exist R&D spillovers from the North to the South. The coefficient of foreign R&D stock is .142, statistically significant from zero at the 1% level.

The first column in each income group has only the education variable. This education variable has positive signs and is statistically significant at the 1% or 5% level. The coefficient is the largest in the upper-middle-income group (.201), followed by the high-income group (.107).

The second column in each group tests the foreign R&D spillovers only. The estimates of the (log of) $R\&D^F$ are all positive and statistically different from zero at the 1% significance level in every regression model ranging from .125 in the low-income group to .193 in the upper-middle-income group. These results suggest that we observe R&D spillovers from North to South and within the North. The R&D spillovers from the North to the upper-middle-income group are larger than the R&D spillovers within the North, but the spillovers from the North to the low-income group are smaller than within

Table 5: Empirical results without distinction of technology levels

Sample	Developing countries (68, 404)[1)]			Low and Lower-middle Income Group (50, 296)		
EDU	.119 ***		-.442 ***	.058 **		-.553***
	(5.57)		(4.19)	(2.02)		(2.60)
$LnR\&D^F$		.142***	.089 ***		.125***	.092***
		(8.69)	(4.62)		(6.43)	(4.14)
$lnR\&D^F$ *EDU			.041 ***			.050***
			(5.09)			(2.81)
Adj. R^2	.8914	.9120	.9189	.8718	.8969	.8997
F value	31.25	24.06	24.78	30.73	25.11	24.50

Sample	Upper-middle income group (18, 108)			High-income group (13, 78)		
EDU	.201 ***		-.571***	.107***		.030
	(7.43)		(3.07)	(8.34)		(0.14)
$LnR\&D^F$		.193***	.026		.151***	.028
		(7.53)	(0.73)		(7.58)	(.067)
$lnR\&D^F$ *EDU			.052***			.004
			(4.02)			(.030)
Adj. R^2	.6257	.6577	.7306	.8433	.7531	.8438
F value	8.28	8.18	10.72	21.34	19.95	18.88

Notes: (1) The figures in parentheses in the Sample row are the number of countries and no. of obs. in each group. (2) The coefficients of constant and country dummies are estimated, but not reported here for simplicity. (3) The figures in parentheses below coefficients are absolute value of t-statistics. t-stat is calculated from robust standard errors. F value is for the hypothesis test on no fixed effect. No fixed effect has been rejected. (4) ***, **, * and # indicate the significance levels at l, 5, 10, and 15%, respectively.

the North. However, when human capital is introduced into the model, spillovers to the low-income group from the North become the largest.

The last column in each group pools education, foreign R&D stocks and their interaction term together. The education variable itself is negative and statistically significant except in the high-income group, but its interaction term is positive. This may imply that education plays a more important role in technology diffusion when it interacts with foreign R&D stock rather than itself. Foreign R&D stock in the low-income group plays a positive role in TFP, but to play this role, it needs human capital stock.

In general, the results of overall R&D spillovers from the North to the South are consistent with those of CHH (1997). However, one of the main purposes of the present paper is to examine the technology sources of R&D spillovers by different stages of economic development. For this purpose, the foreign R&D stocks used in Table 5 are decomposed into four different levels of technology.

Table 6: Empirical results by pooling four technology levels

Dep. Var \ Sample	Developing Countries		Low & lower-middle		Upper-middle		High-income	
	Eq. 8	Eq. 12	Eq. 8	Eq. 12	Eq. 8	Eq. 12	Eq. 8	Eq. 12
EDU		.074 *** (3.79)		.037 (1.43)		.100 *** (3.02)		.075 *** (3.82)
$lnR\&D^{HI}$	.052 *** (3.41)	.037 ** (2.36)	.031 * (1.79)	.026 # (1.52)	.116 *** (3.52)	.062 * (1.97)	.171 *** (7.26)	.084 *** (3.52)
$lnR\&D^{MH}$	.155 *** (4.53)	.166 *** (4.69)	.140 *** (3.63)	.147 *** (3.74)	.229 *** (2.85)	.224 *** (3.03)	.041 (0.90)	.059 (1.41)
$lnR\&D^{ML}$	.046 * (1.77)	.044 * (1.69)	.097 *** (3.20)	.093 *** (3.08)	-.101 ** (2.13)	-.090 ** (2.14)	-.128 *** (2.94)	-.123 *** (3.00)
$lnR\&D^{LW}$	-.113 *** (4.32)	-.119 *** (4.54)	-.149 *** (4.99)	-.151 *** (5.01)	-.068 (1.31)	-.058 (1.18)	-.009 (0.20)	-.005 (0.13)
Adj. R^2	.9184	.9216	.9090	.9094	.6912	.7205	.8351	.8771
F value	23.11	23.10	26.71	25.49	5.92	6.84	29.40	24.04

Note: See notes in Table 5.

Table 6 displays the empirical results of the breakdown of four different technology levels for three income groups without education or with education in each regression model, using the derived equations (8) and (12). First, in the whole sample of developing countries, all foreign R&D stocks are statistically different from zero at the 1% or 10% significance level, and three coefficients are positive, although the coefficient of low technology is negative. Second, in the comparison of coefficients, the estimated coefficients of medium-high technology ($lnR\&D^{MH}$) and medium-low technology

($lnR\&D^{ML}$) are not sensitive to the inclusion of the education variable.

Third, with the inclusion of education the coefficient of high technology ($lnR\&D^{HI}$) is reduced by 28.8 % from .052 to .037. These trends are observed in upper-middle-income and high-income groups as well. (They decline by 46.6% from .116 to .062 and by 50.9% from .171 to .084, respectively)

Fourth, in the column with education included, the coefficient of medium-high technology is the largest, and the coefficient of high technology is third after that of medium-low technology. From these results, we can observe the main contributor of R&D spillovers in developing countries is medium-high technology rather than high technology.

However, the foreign R&D stock of high technology plays a more important role in TFP as per capita income rises. The coefficients of the foreign R&D stock of the high-technology sector become larger with higher income groups. The coefficient is .026 in the low-income group, .062 in the middle-income group, and .084 in the high-income group.

Lastly, the coefficient of medium-low technology is positively significant from zero only in the whole developing sample and low-income group. This coefficient is negative and significant in other two income groups. However, these negative signs do not imply that the foreign R&D stock of low technology does not have a positive effect on productivity, because in the separate regression model for each technology level of foreign R&D stock it has a positive sign and is statistically significant.[14] The negative signs here may imply that the foreign R&D stock of low technology is relatively less important, compared with other technology levels of foreign R&D stock.

In summary, the results of Table 6 support the hypothesis in the present paper that

[14] For simplicity, we do not report the empirical results of the separate regression for each technology level.

foreign R&D capital stocks of different levels of technology play different roles at different stages of economic development. In the relatively beginning stage of economic development, the lower level of technology plays a more important role in R&D spillovers from the North, but as an economy shifts to further stages of development, higher technology becomes more important in R&D spillovers from the North. This finding supports the theoretical findings on the trade pattern of North-South in the product cycle model: North exports high-quality products and South exports low-quality products (Flam and Helpman, 1987).

Table 7: Regression only on interaction terms between education and technology

	Developing Countries		Low & lower-middle		Upper-middle		High-income	
EDU		-.839 *** (7.02)		-1.273 *** (5.75)		-.634 *** (3.22)		.174 (1.44)
$\ln R\&D^{HI}$ *EDU	.026 ** (2.06)	.036 *** (3.05)	.016 (1.07)	.044 *** (3.03)	.053 ** (2.41)	.062 *** (3.92)	.014 ** (2.14)	.012 * (1.73)
$\ln R\&D^{MH}$ * EDU	-.035 * (1.95)	.066 *** (3.16)	-.044 * (1.97)	.097 *** (3.21)	-.048 # (1.60)	.016 (0.44)	.020 * (1.81)	.010 (0.82)
$\ln R\&D^{ML}$ * EDU	.037 * (1.92)	.021 (1.36)	.104 *** (3.56)	.069 *** (2.83)	-.021 (1.23)	-.022 (1.43)	-.041 *** (3.55)	-.048 *** (3.80)
$\ln R\&D^{LW}$ *EDU	-.012 (0.75)	-.057 *** (3.11)	-.066 *** (2.93)	-.107 *** (4.82)	.038 * (1.73)	2.E-5 (0.00)	.009 (0.85)	.016 (1.31)
Adj. R^2	.8984	.9096	.8798	.8992	.6881	.7426	.8729	.8747
F value	30.53	33.64	29.27	29.54	6.79	7.55	25.49	25.83

Note: See notes in Table 5.

Table 7 examines the role of education in the different levels of technology of R&D spillovers by introducing its interaction terms with technology levels. When we run the equation (13), there may exist multicollinearity because of four similar variables with their interaction terms. In order to reduce this problem, the regression models are regressed only on interaction terms. According to the results of Table 7, education plays a different role across income groups.

In the low-income group, education has a relatively stronger effect on R&D spillovers of medium-high and medium-low technology. Its coefficients of interaction terms are .044 in high technology, .097 in medium-high technology, and .069 in medium-low technology, and these coefficients are statistically significant from zero at the 1% level. On the other hand, it is more important to high technology in upper-middle- and high-income groups. The coefficients of interaction terms between education and high technology are .062 in the upper-middle-income group and .012 in the high-income group. These findings suggest that secondary and higher education plays an important role in technology spillover and it has a stronger effect on high technology in higher income groups.

7. Concluding Remarks

Recent literature on endogenous growth models has identified international R&D spillovers from North to South and with the North. However, the sources of technology in R&D spillovers have not been identified. This paper investigates the types of technology in international R&D spillovers and a relationship between technology levels and stage of economic development.

The results of this paper show that medium-high technology is the main source of technology diffusion in developing countries, and high technology is more important in advanced countries. Furthermore, the second important technology in R&D spillovers is different across different stages of economic development: medium-low technology in the low-income group and high technology in the middle-income group. Third, the role of high technology in R&D spillovers becomes larger as per capita income rises. These findings suggest that stage of economic development matters in the type of technology diffusion. Finally, education is also a major factor in R&D spillovers and it plays more important role in relatively higher technology level with higher stage of economic development.

The present paper focuses on technology differentiation in international R&D spillovers, with phases of economic development and the role of education in R&D spillovers as the determinants of total factor productivity. However, some other factors in international technology spillovers may be considered in an open economy, such as foreign direct investment, patent citation, protection of intellectual property rights, and so on. This suggests a possibility of further empirical studies on the determinants of technological diffusion for sustainable economic growth in developing countries.

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Appendix A: Country lists in the sample used

Country name	Income	Country name	Income	Country name	Income
Sub-Saharan Afr. (23)		Korea	3	Argentian	3
Benin	1	Malaysia	3	Brazil	3
Cameroon	1	Singapore *	3	Chile	3
Central African Rep	1	Taiwan *	3	Uruguay	3
Congo, Rep. of	1			Venezuela	3
Gambia	1	**South Asia (6)**			
Ghana	1	Bangladesh	1	**Mideast Asia & N. Afr. (8)**	
Guinea-Biss	1	India	1	Algeria	2
Kenya	1	Pakistan	1	Cyprus	2
Malawi	1	Sri Lanka	2	Egypt	2
Mali	1	Fiji	2	Iran	2
Mozambique	1	Papua N. Guine	2	Jordan	2
Niger	1			Syria	2
Rwanda	1	**Latin America (22)**		Israel *	3
Senegal	1	Nicaragua	1	Turkey	3
Sierra Leone	1	Barbados	2		
Togo	1	Dominican Rep.	2	**OECD (14)**	
Uganda	1	El Salvador	2	Canada	4
Zaire	1	Guatemala	2	USA	4
Zambia	1	Honduras	2	Japan	4
Zimbabwe	1	Jamaica	2	Denmark	4
Tunisia	2	Costa Rica	3	Finland	4
Mauritius	3	Mexico	3	France	4
South Africa	3	Panama	3	Germany	4
		Trinidad&Tobago	3	Italy	4
Asia (9)		Bolivia	2	Netherlands	4
Indonesia	1	Colombia	2	Norway	4
China	2	Ecuador	2	Spain	4
Philippines	2	Guyana	2	Sweden	4
Thailand	2	Parguay	2	U.K.	4
Hong Kong *	3	Peru	2	Australia	4

Notes: (1) In the income column, 1, 2, 3, and 4 indicate low-income, lower-middle-income, upper-middle-income, and high-income groups, respectively.
(2) Countries with * belongs to high-income countries (4) based on World Bank's classification.

Appendix B: Industry code by technology level in manufacturing sector

Industry description	ISIC Rev .2	SITC Rev. 2 for trade data
High- technology industry		
1. Aerospace	3845	792 (7925).
2. Computers, office machinery	3825	75 (7518).
3. Electronics-communications	3832	76.
4. Pharmaceuticals	3522	54 (5419).
Medium-high-technology industry		
5. Scientific instruments	385	5419, 87 (8748), 88 (882, 883), 8974, 8996.
6. Motor vehicles	3843	713 (7131), 71XX, 78 (7822, 785, 786), 7XXX.
7. Electrical machinery	383-3832	716,77 (7732, 7784), 81 (8121, 8122), 8748, 8983.
8. Chemicals	351+352-3522	23 (2332), 266 (2667), 267 (2672), 2783, 2873, 4314, 5 (54, 5119, 5921), 6517, 882, 883.
9. Other transport equipment	3842+3844+3849	7131, 714, 7493, 7822, 785, 786, 791, 79XX, 8941.
10. Non-electrical machinery	382-3825	6954, 6973, 712,7138, 7139, 718 (7187), 72, 73, 74 (7492, 7493), 7518, 7784, 8946, 9510.
Medium-low-technology industry		
11. Rubber and plastic products	355+356	2332, 62, 8482, 893.
12. Shipbuilding	3841	793 (7933, 79XX, 7XXX).
13. Other manufacturing	39	667, 6993, 89 (892, 893, 8941, 8946, 8951, 8960, 8974, 8983, 8996), 9610.
14. Non-ferrous metals	372	68, 6999, 9710.
15. Non-metalic mineral products	36	2771, 66 (667), 7732, 8122.
16. Fabricated metal products	381	6770, 69 (6954, 6973, 6993, 6999, 6XXX), 711, 7187, 7492, 8121, 8951.
17. Petroleum refining	353+354	323, 334, 335.
18. Ferrous metals	371	67 (6748, 6770).
Low-technology industry		
19. Paper printing	34	25, 64, 892, 9916.
20. Textile and clothing	32	2633, 2634, 2667, 2672, 2686, 2687, 2690, 61 (6130), 65 (6591), 6XXX, 8310, 83XX, 842, 843, 844, 84 (8482), 8510, 8XXX.
21. Food, beverages and tobacco	31	01, 02 (0251, 025A, 025X), 03, 042 (0421), 0460, 0470, 048, 0546, 056, 058, 06 (0611, 0616), 0712, 0722, 0723, 08(0811), 09, 0XXX, 11, 122, 12XX, 1XXX, 211, 2239, 2632, 4 (4314), 5921.
22. Wood and furniture	33	24 (2440), 634, 63XX, 6597, 82.

Note: The codes in the parentheses are excluded in that classification.