The Phases of Economic Development,

Technology in R&D Spillovers and Education

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Abstract

This paper observes R&D spillovers from North to South using micro-based data. Secondly, medium-high technology has played largest role in R&D spillovers, but R&D spillover in high technology sector is larger in higher income group. These results support the hypothesis that foreign R&D stocks of different levels of technology will be different effect on productivity, depending on the stages of development. Third, higher education has stronger effect in R&D spillovers relative to secondary education. Finally, the distance to partner matters in the R&D spillovers, but this pattern may not hold for a specific level of technology. Foreign R&D stock from the United States is more effective in relatively higher level of technology and foreign R&D from other countries is stronger in relatively lower level of technology.

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1. Introduction

Endogenous growth model puts an emphasis on innovation and trade as engines for technological progress as well as growth (Rivera-Batiz and Romer, 1991; Grossman and Helpman, 1991). In endogenous model introducing intermediate goods, productivity depends on both domestic research and development (R&D) capital stock and international R&D spillovers. R&D activity can lead to the improvement of existing manufactured techniques (innovation) and to the creation of new technologies (invention). The former is related to quality-ladder growth model and the latter is related to varieties growth model.

However, within the OECD countries, the G-7 countries account for more than 90% of the world's R&D spending in 1991 (Coe, Helpman and Hoffmaister, 1997). This fact implies that developing countries can adopt new technologies through international trade with advanced countries, foreign direct investment or patent licenses rather than through their own R&D spending activity. Therefore, especially international R&D spillovers in developing countries cannot be negligible because developing countries can indirectly experience the outcomes of R&D activity occurred in developed countries, and thus the foreign R&D spent in developed countries will have an effect on productivity of developing countries.

Most studies on international R&D spillovers have focused on overall effect of the foreign R&D capital stock on domestic total factor productivity. One of the weaknesses of these studies is in the identification of the relationship between the stages of economic development and technology source. In the initial stage of development in developing countries, relatively lower level of technology may be more adoptable and thus low level of technology will play a central role in technical progress. With trade opened, developing country tends to specialize in low-technology goods, and developed country tends to specialize in high-technology goods (Young, 1991; Stokey, 1991). Dynamic learning by doing intensifies the initial pattern of comparative advantage unless learning displays spillovers among goods.

However, in the process of development, developing countries will adopt higher level of technology with learning by doing or investment in human capital. Lau and Wan (1993) point out that the benefits from efforts in borrowing technology vary across countries, depending on the technical capability and the opportunity for borrowing. The high growth economies like Japan and the East Asian countries are possible for technology followers, in their middle phase of development. Chuang (1998) emphasizes the importance of trade-induced technology spillovers. Learning allows a country to produce new goods, and hence enables to export refined goods. Exports of refined goods subsequently may lead to absorption of new technology and experience. Finally, this export generates the demand for new technology that is helpful for further higher domestic technology. Based on these theoretical background, this paper attempts to examine the role of R&D spillovers of different levels of technologies in total factor productivity. This will be the main contribution of this paper.

The second issue dealt with in this paper is about the localization or globalization of R&D spillovers. Using fourteen OECD countries for twelve industries, Keller (2000) found that technological knowledge has become more global over the sample period, 1970-95, but knowledge spillover is geographically localized in the sense that the effect of foreign R&D on productivity declines with the geographic distance between trade partners. Coe, Helpman and Hoffmaister (1995) found that there are regional difference in R&D

spillovers. Generally, R&D activity of the United States has been more effective in productivity of Latin America because Latin American countries trade more with the United States, while the Japanese R&D stock is more effective in Asia because Asian countries trade more with Japan. The present paper will examine what level of technology of which country's R&D stock has relatively stronger effect on productivity in developing countries by separating the foreign R&D stocks into three regions by technology level: the United States and Canada, Japan and 11 European countries. Coe, Helpman and Hoffmaister (1995) examine the overall R&D spillovers by trade partner, but there would be different R&D spillovers by technology level from trade partners, even though, for example, R&D in the United States are, as a whole, more effective in Latin America.

The third difference in the present paper from the previous empirical studies is in the construction of foreign R&D capital stocks. The previous empirical studies (Coe et. al, 1995; Coe et. al, 1997; Engelbrecht, 1998) uses aggregated average import shares as weight for the analysis period. In this case, R&D stock of high technology sector will be included into the construction of the foreign R&D stocks, even though there has been no trade with trade partners in this sector, and thus the foreign R&D stocks may not be correctly constructed. To avoid this problem, the present paper constructed foreign R&D capital stocks on the basis of industry-based data on trade and R&D capital stocks using the methods of Coe and Helpman (1995) and Lichtenberg and de la Potterie (1998).

One of the main findings is that R&D spillovers from North to South occurred mainly in medium-high technology sector. Second, as income per capita increases, relatively higher level of technology is more important to R&D spillovers. These results support that there may exist relationship between the phases of economic development and technology level of R&D spillovers. Third, higher education increases total elasticity of total factor productivity with respect to foreign R&D stock relative to secondary education level in every technology level. Lastly, distance matters in R&D spillovers from North to South, but the R&D stock of the United States is more important in high-technology sector and the Japanese R&D stock plays relatively more important role in R&D spillovers of relatively lower level of technology.

The paper is organized as follows. The next section presents the hypothesis to be examined for the relationship between the stages of economic development and technology levels in R&D spillovers. The third section describes the empirical framework. The fourth section will explain the data sources and construction of variables and section 5 is for some descriptive summary of data. The empirical results will be presented in section 6 and the last section is for conclusion.

2. Hypothesis Testing

Coe et al. (1997) examined R&D spillovers from North to South through trade using bilateral machinery and equipment import shares with 21 OECD countries plus Israel as weights. Coe and Helpman (1995) also examined R&D spillovers within 21 OECD countries plus Israel. These two papers using aggregated data found that the foreign R&D capital stocks played a substantial role in total factor productivity. Even in developed countries, foreign R&D stock is positively associated with productivity as much as domestic R&D stock. Engelbrecht (1998) confirms the results of Coe and Helpman (1995) by adding human capital into their preferred empirical models. Keller (2002) also investigated the effects of R&D spillovers on total factor productivity within eight OECD countries using thirteen industry-level data basically according to the method used in Coe and Helpman (1995). However, Lichtenberg and Potterie (1998) argue that the method of Coe and Helpman (1995) for constructing the foreign R&D capital stock has an aggregation bias and an indexation bias. Alternatively, they propose an alternative measure of foreign R&D stock that is much less sensitive to the level of data aggregation. In the construction of the foreign R&D capital stock, they use trade partner's export share in production rather than import share of importing country as weight.

Most empirical studies on R&D spillovers are for R&D spillovers within advanced countries. On the other hand, Madden and Savage (2000) investigate R&D spillovers among 15 OECD countries and 5 Asian economies (India, Indonesia, Singapore, South Korea and Thailand). They extend the empirical models of Coe and Helpman (1995) by considering the role of trade of information technology and telecommunications in R&D spillovers.

However, there have been few empirical studies on the relationship between the phases of economic development and technology levels in R&D spillovers. In the progress of economic development, developing countries will adopt high level of technology with learning by doing or investment in human capital, starting with specialization in low technology because developing countries have insufficient physical capital or knowledge stocks in the initial stage of development. Learning allows a country to import a product employing high-level technology and produce new goods, and hence enables to export refined goods. Exports of refined goods subsequently may lead to absorption of new technology and experience. 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 technologies will play a different role in productivity, depending on different stages of development that each country faces.

In the beginning stage of development, a country will specialize in labor-intensive and low technology products and thus the foreign R&D stock of low technology sector will play relatively stronger role in productivity compared with that of high technology sector because trade with developed countries occurs mostly in relatively lower level of technology sectors. Later, learning by doing of technology experience through trade will generate the demand for new technology that is helpful for further higher domestic technology. In this stage, the foreign R&D spillovers will become relatively stronger in high-technology sector relative to in low-technology sector.

For this hypothesis test, developing countries are separated into three groups based on the classification of the World Bank (2002). World Bank (2002) divides 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. Four countries (Hong Kong, Singapore, Taiwan and Israel) classified into developing countries here are high-income group, but these four countries are included in upper-middle-income group. This classification may not exactly represent the degree of economic development and we have to consider some other variables related to economic development. However, because of data limitation, we will use this classification as a proxy for the stages of economic development.

3. Empirical Framework

Using the classification based on per capita income level, the present paper assumes that different income group represents different stage of development and as income per capita rises, the economy will experience the foreign R&D spillovers in relatively higher technology sector. The simple regression model is as follows:

$$lnTFP_{it} = \alpha_i + \alpha_t + \alpha_E EDU_{it} + \alpha_M IMPSH_{it} + \alpha_F lnR\&D^F_{it} + \varepsilon_{it} \quad (1)$$

where α_i and α_t are country and year dummies to be estimated. Thus this empirical model is two-way fixed effect model for panel data. $lnTFP_{it}$ is the natural logarithm of TFP of country i at year t. EDU is education variable such as average years of secondary or higher education of population aged 15 and above, IMPSH is import share of manufacturing sector from 14 OECD countries in developing country GDP, and $lnR\&D^F$ is the natural logarithm of foreign R&D capital stock. ε_{it} is disturbance, which is not captured by country and time specific effects.

Education variable as a proxy for human capital and the import share from developed countries in developing country GDP will be introduced into the empirical model. Coe et. al (1997) and Engelbrecht (1997) show that human capital plays an important role in productivity in both developing and developed countries. Therefore, education variables are also taken into consideration: average years of secondary and higher education of population aged 15 or above. These different levels of education will be combined with different levels of technologies to investigate the role of education in technology spillovers.

The larger import share from industrial countries implies the economy opens more to advanced countries and thus the larger is the foreign R&D capital stock. On the other hand, the larger import share also implies that a country with larger import share is less competitiveness in the world market and this country is less productive. In this case, import share will have a negative effect on productivity.

However, since larger import share implies that the country imports more foreign R&D stock indirectly through trade, the interaction term between import share and foreign R&D stock may be positively associated with domestic productivity. Similarly, for 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 Coe et. al (1997). Thus, the second model to be estimated is given by

$$\begin{aligned} \ln TFP_{it} &= \alpha_i + \alpha_t + \alpha_E EDU_{it} + \alpha_M IMPSH_{it} + \alpha_F \ln R\&D^F_{it} \\ &\quad + \alpha_{MF} IMPSH_{it} * \ln R\&D^F_{it} + \alpha_{EF} EDU_{it} * \ln R\&D^F_{it} + \varepsilon_{it} \qquad (2) \end{aligned}$$

where $IMPSH_{it} * \ln R\&D^F_{it}$ and $EDU_{it} * \ln R\&D^F_{it}$ are interaction terms of import share and education with the log of foreign R&D capital stock, respectively. Other variables are the same as in equation (1).

The main purpose in this paper is to identify the relationship between R&D spillovers by level technology and the stages of economic development and the role of education in R&D spillovers. Therefore, equation (2) will be examined by income group and technology level for different levels of education.

For the next empirical test on geographic R&D spillovers by trade partner, developing countries are separated into five groups by geography: East Asia, South Asia, Middle East and North Africa, Sub-Sahara Africa, and Latin America. The foreign R&D stocks are also decomposed into three groups: the foreign R&D stocks from the United States and Canada, Japan, and 11 European countries by technology level. The empirical framework is the modified one of equation (1):

$$\begin{aligned} \ln TFP_{it} &= \alpha_i + \alpha_t + \alpha_E EDU_{it} + \alpha_M IMPSH_{it} + \alpha_{US} \ln R\&D_{it}^{USA} \\ &\quad + \alpha_{JP} \ln R\&D_{it}^{JPN} + \alpha_{EU} \ln R\&D_{it}^{EUR} + \varepsilon_{it} \qquad (3) \end{aligned}$$

where $R\&D_{it}^{USA}$ is the foreign R&D stock from the United States and Canada, $R\&D_{it}^{JPN}$, the foreign R&D stocks from Japan, and $R\&D_{it}^{EUR}$, the foreign R&D stocks from 11 OECD countries. Using equation (3), we can examine the sources of R&D spillovers by region and technology level.

4. Data

The data for the estimation of total factor productivity are taken from the preliminary version of Penn World Table 6. (Heston and Summer, 2001, PWT 6). When I combine education and trade variables with PWT6, only 83 countries are available in common. Among 83 countries, 61 ones are classified as developing countries and 22 countries 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 61 developing countries.

The data of real output are calculated by multiplying real per capita GDP of 1996 prices (RGDPCH) by population reported in PWT 6. The number of workers is also implicitly calculated 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 in PWT 6 and R&D expenditure from the ANBERD database (OECD, 2000), respectively. Following Coe and Helpman (1995), these two capital stocks are calculated as follows.

$$K_t = I_{t-1} + (1 - \boldsymbol{d})K_{t-1} \qquad (4)$$

where $\boldsymbol{d}$ is the depreciation rate, which is assumed to be 10 percent. The initial capital stocks of both are estimated with the procedure used in Coe and Helpman (1995):

$$K_0 = I_0 /(g + \boldsymbol{d}) \qquad (5)$$

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. 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, nominal R&D expenditures of 14 OECD countries[1] are deflated by each country's price index of business investment of 1996 basis year. These real R&D expenditures in terms of national currency is converted into international constant values using each country's purchasing power parity exchange rate of 1996 to obtain the internationally comparable data of R&D expenditures.[2]

Using real R&D expenditures of twenty-two industries of fourteen OECD countries, R&D capital stocks are estimated over 1973-1996 using a perpetual inventory method discussed above, and the foreign R&D stocks by industry for each country of 75 countries are constructed based on the method of Lichtenberg and de la Potterie (1998). In Coe and Helpman (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 Lichtenberg and de la Potterie (1998), the foreign R&D stock of industry *i* at time *t*, S_{it}^{f}, is calculated as follows:

$$S_{it}^{f} = \sum_{j=1}^{14} S_{ijt}^{f} = \sum_{j=1}^{14} \frac{m_{ijt}}{y_{ijt}} S_{ijt}^{d} \qquad \text{for industry } i \text{ at year } t \tag{6}$$

where S_{ijt}^{d} is the domestic R&D stock of industry *i* of trade partner *j*, m_{ijt} is the flow of imports of industry *i* from trade partner *j*, and y_{ijt} is the output level of industry *i* of trade

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

partner j. Lichtenberg and de la Potterie (1998) argued that the procedure in Coe and Helpman (1995) is not invariant to the level of data aggregation, while their formulation reflects both the intensity and direction of international R&D spillovers. Therefore, the foreign R&D capital stocks are constructed followed by the method of Lichtenberg and de la Potterie (1998).

Output data by industry of 22 industries used in equation (7) are taken from the STAN database (OECD, 2000) and the trade data used in calculating the bilateral trade shares of 22 industries are from the World Trade Flows Database CD-ROM (Feenstra et al., 1997; Feenstra, 2000). The industry code of trade data is the 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.[3] Then, according to Hatzichronoglou (1997), 22 manufacturing industries are reclassified into four different levels of technologies: high-technology (4 industries), medium-high-technology (6), medium-low-technology (8) and low-technology industries (4).

Based on overall R&D intensity, Hatzichronoglou (1997) classified 22 manufacturing industries into four technology categories. The OECD ANBERD and STAN databases also can be classified into these categories and trade data (Feenstra et. al, 1997 and Feenstra, 2000) of SITC Rev. 2 are matched with the industry codes of ISIC Rev. 2.

The source of education data is Barro and Lee (2000). Since these data are reported every 5-year, the interpolation method is applied to estimate annual data between two periods.

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[2] The deflators of business investment and purchasing power parity exchange rates of 14 OECD countries are downloadable from http://www.oecdsource.org.

Total factor productivity of each country *i* is estimated by the traditional Solow residual using the growth-accounting approach, which imposes conventional values for factor shares. These are given by

$$lnTFP_{it} = lnY_{it} - \alpha lnK_{it} - (1-\alpha)lnL_{it} \tag{8}$$

where α is the capital's share in GDP which is assumed to be 0.35 or 0.4. lnY_{it}, lnK_{it}, and lnL_{it}, are the natural logarithms of output, physical capital stock and workers, respectively.

5. Descriptive Summary

Table 1 shows average annual growth rates of TFP, GDP per worker, physical capital and labor force by income group, by region and by some select individual countries. In general, over the entire period 1961-1998, upper-middle income group and East Asian countries have achieved the highest growth rates in TFP, GDP per worker and physical capital stocks. However, there is no significant difference in the growth rate of labor force across income groups and regions except for high-income group. Especially, the average annual growth rate of physical capital in East Asian countries is 9.02% and this growth rate is distinct from those of other regions.

In the comparison across individual countries, among East Asian countries, Hong Kong achieved the highest growth rate of TFP and Korea has the lowest growth rate of TFP. These countries have accumulated physical capital stock by around 10% per year, while the

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[3] See Appendix B for more details.

annual growth rates of labor force lie in the range between 1.87% and 3.48%. These East Asian countries including China, Korea suffered relatively severe economic pain with Hong Kong from financial crisis in 1997.

Table 2 presents the trends of educational attainment for the population aged 15 and over by education level across income groups, regions and individual countries. Following the suggestion of Barro and Lee (2000)[4], this paper uses the education attainment of population over 15 aged and over. The first three columns indicate the enrollment rate of each education level and the last three columns denote the average years of schooling at each education level. To observe the trends over time, Table 2 shows two years, 1970 and 1995, and its relative ratio defined as the value of 1995 to the value of 1970. Since average years of schooling are used in regression models, explanation will be focused on these variables.

In the comparison of education attainment across groups by income per capita, low-income group shows relatively higher growth in primary and secondary education, but its absolute levels are still further behind from those of other groups. When compared the absolute values of developing countries with those of high-income countries (OECD countries), as per capita income increases, the average years of each schooling level have become closer to those of high-income countries, but the gap of average years of higher education between low-income group and high-income group in 1995 is 12 times, the gap between lower-middle-income group and high-income group is 2.5 times, and the gap between upper-middle-income group and high-income group is around 1.8 times.

[4] They pointed out that the group of population over 15 aged and over would be better measure for the labor force for many developing countries.

In the comparison across regions with high-income countries, as a whole, the growth rates of three types of schooling of five regions are larger than those of high-income countries except the growth rate of higher education of South Asian countries. Especially, there has been a catch-up in average years of primary schooling, but developing countries still need more investment in secondary and higher education to get closer to those of high-income countries. For example, the average years of primary and secondary schooling of East Asian countries in 1995 are really close to those of high-income countries, but average year of higher education of East Asian countries (0.32) is almost twice less than that of high-income countries (0.60).

In comparing across individual countries, in general, four East Asian countries have larger average years of schooling relative to three Latin American countries in secondary and higher education. In particular, average years of three schooling levels of Korea in 1995 are larger than those of Japan in 1995 with higher growth of education relative to other countries, and average years of primary and secondary schooling of Korea are closer to those of the United States, but average years of higher education of Korea (0.65) in 1995 is still twice less than that of the United States (1.33).

Table 3 represents average annual import and export shares of each income group by technology level based on trade of each group with 14 high-income countries. First of all, most trade has occurred within OECD countries. For example, during 1985-1996 the portion of imports within OECD countries is 75.81% and its export share is 79.24%. Second, in trading by technology level, medium-high technology has the highest trade share in every income group and the second highest is in medium-low technology sector. Third, in low- and lower-middle income groups, import share of high-technology sector increased in the second period, while those of other technology sectors as well as overall import shares decreased in the second period relative to the first period. On the other hand, import share of all technology sectors except for medium-low technology sector of upper-middle income group increased in the second period.

These trends of import shares across income groups are similar with those of export shares. In the comparison of export shares, the overall export shares of low and lower-middle income groups remain relatively stable between two periods, but there is difference in export shares across technology levels. Export shares of high technology of these two groups grow fast relative to other technology sectors, while export shares of other technology sectors has decreased or increased a little.

However, the overall export shares of upper- middle income group has increased by 4.87 percent points from 10.84% in the first period to 15.71% in the second period, and the main source of its increase is from the increase in the export shares of high and medium-high technology sectors and from the decrease of the overall export share of high-income group. 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. And the overall export share of high-income group decreased by 6.07 percent points from 85.31% to 79.24%.

Table 4 denotes average annual shares of import and export of each region by technology level and by trading partner by breaking down 14 high-income group into 3 groups based on their geographic location: 11 European countries including Australia

(EUR), Japan (JPN), and the United States and Canada (USC).[5] First, import share of each technology sector of each region is highest with trading partner that is closer to them. For example, East Asian countries have imported more from Japan rather than from other countries, and Latin American countries have imported more from the United States and Canada rather than from other countries. However, there are some exceptions. The import share of high technology from the United States of East Asian countries is a little bit larger than that from Japan: 0.26% from Japan and 0.29% from the United States in the first period and 0.65% from Japan and 0.74% from the United States in the second period.

In general, the trends in Table 4 indicate that distance matters in bilateral trade. These trends also hold for market shares of exports in trading partners except East Asian countries. For these countries, the most important market for their exports is the United States rather than Japan.

6. Empirical Results

6.1 Empirical Results by Income Group

Two-way fixed-effect method (considering country-specific and time-specific effects) has been employed for the annual panel data of 61 developing countries over 1973-1996. The regression models are to examine R&D spillovers from North to South in terms of the stages of economic development and technology levels. For the purpose, 61 developing countries are broken down into three groups based on per capita income: low-income group (20 countries), lower-middle-income group (23), and upper-middle-income group including four high-income countries (18). In order to test the role of education in each technology level, secondary and higher education are considered separately.

Table 5 shows the regression results of the simple model without the distinction of foreign R&D stock by technology level. First, the estimates of the (log of) $R\&D^F$ have all positive signs and are statistically different from zero at a 1% significance level in every regression model ranging from 0.091 in low- income group to 0.196 in upper-middle-income group. Second, as per capita income increases, the estimates of $R\&D^F$ are increase. This implies that higher income group has experienced larger R&D spillovers from North.

Third, when the variable HYR, average years of higher education, was used in the model, the estimates of foreign R&D stock become a little larger relative to when SYR was used, and the coefficients of SYR and HYR are positively and statistically significant from zero in the whole sample, but these are not consistent in the models of each income group. Lastly, as we expected, the coefficients of import share are negative and statistically significant from zero. These results are consistent with those of Coe, Helpman and Hoffmaister (1997).

In Table 6, two interaction terms of education and import share with foreign R&D stock are introduced into the regression models in Table 5. These two interaction terms are positive (except the interaction term of education in lower-middle-income group) and statistically significant from zero mostly at a 1% level. The coefficients of these two interaction terms become larger in higher education level relative to in secondary education level.

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[5] It would be more reliable to put Australia and Japan together, but trading of Asian

Table 6 also reports total elasticity of total factor productivity with respect to foreign R&D stock considering two interaction terms. Table 6 shows that the total elasticity becomes larger with higher income for the same education level and total elasticities in higher education are larger than those in secondary education except in lower-middle-income group.

The main purpose in the present paper is to test R&D spillovers of different technology levels with different stages of economic development. Table 7 displays the empirical results from four different technology levels for three income groups. First, the estimated coefficients of foreign R&D capital stock are positive and statistically significant from zero in every income group and in every technology level, but the magnitude of these estimates are different for different technology levels within a group and across income groups.

In the comparison of the coefficients across technologies within a group, the estimates of foreign R&D stock in medium-high-technology sector are highest. This result is also supported from the comparison of total elasticity of total factor productivity with respect to foreign R&D stock of each technology level. In each income group, the total elasticity in medium-high technology is largest compared with others.

Second, in the comparison of the total elasticities in the same technology level across income groups, upper-middle-income group has the largest total elasticities in high-technology and medium-high-technology sectors, and lower-middle-income group is in the second largest for these two elasticities. On the other hand, the total elasticities in both medium-low-technology and low-technology sectors are the largest in lower-middle-

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countries with Australia is relatively small.

income group, and low-income group has the second largest elasticity in medium-low-technology.

Third, higher education increases total elasticity relative to secondary education level in the same technology model except for the lower-middle-income group.

In summary, from the results of Table 7, all foreign R&D stocks of four levels of technologies have a positive effect on total factor productivity and the foreign R&D stock of medium-high technology sector has the strongest effect on TFP in all income groups. Third, as income rises, relatively higher level of technology plays more important role in R&D spillovers. This finding supports the hypothesis in the paper. In addition, higher education increases the total elasticity of TFP with respect to foreign R&D stock relative to secondary education used. This implies that higher education is necessary to obtain more R&D spillovers from North.

6. 2 Empirical results by region

Coe, Helpman and Hoffmaister (1997) found that there are important regional differences in R&D spillovers. In Latin America, the main source of R&D spillovers is from the United States because countries in America trade more with the United States. Because of the similar reason, total factor productivity of countries in Asia is more influenced by the foreign R&D stock from Japan. In order to examine the technology source in R&D spillovers by trading partners, developing countries are broken down into five groups by their geographic location: East Asian, South Asia, North Africa and Middle East Asia, Sub-Saharan Africa, and Latin America. In addition, the foreign R&D stocks of these regions are decomposed into three groups for every technology level: from the United States and Canada, Japan, and other eleven OECD countries.

Table 8 shows the empirical results by region.[6] Since the empirical models do not include the interaction terms between education and foreign R&D stock or between import share and foreign R&D stock, the outputs reported in Table 8 are chosen from the results using three different education levels, which have a positive sign on education variable. Other variables other than education are insensitive to the changes in education levels.

In Table 8, the column, total, in each region is the total foreign R&D stock by trading partners without the distinction of technology level. Other columns indicate that foreign R&D stocks of each technology for three trade partners are used in the regression model. First, we can confirm the findings in Coe, Helpman and Hoffmaister (1997). For example, the foreign R&D stock from Japan plays more important role in productivity of East Asian countries and the foreign R&D stock from the United States and European are more effective in productivity of Latin American countries.

However, there are some exceptions on these trends for R&D spillovers in each level of technology. In case of East Asian countries, the estimated coefficient of foreign R&D stock from European countries is a little bit larger than that from Japan in high technology sector. For the level of medium-low technology in Latin America, foreign R&D stock from Japan is more effective relative to those from the United States and European countries. In countries in Sub-Saharan Africa, the foreign R&D stock of low technology only from Japan is positive and significant.

[6] In the present paper, the empirical result of South Asian countries is not reported for simplicity. The result is available upon request.

Second, from the comparison of coefficients of the foreign R&D stock within the same trade partner across technologies, the foreign R&D stocks from the United States have played more important role in relatively higher technology levels, European R&D stocks are more effective in relatively medium level of technology, and the Japanese R&D stock is more effective in relatively lower level of technology.

Lastly, the effect of education level on productivity is different across regions. For example, in countries in East Asia, higher education has a positive effect on productivity in higher level of technology and secondary education has a positive role in relatively lower level of technology. On the other hand, primary education is more effective on productivity in countries in Latin America.

7. Conclusion

The present paper confirms international R&D spillovers from North to South using micro-based data. Secondly, medium-high technology has played largest role in R&D spillovers, but the R&D spillover of high technology is larger in higher income group. Therefore, the stage of economic development matters in technology level in R&D spillovers. Third, different levels of education play different role in different technology level. The present paper finds that higher education increases total elasticity of productivity with respective to the foreign R&D stock. Finally, the distance with trading partner matters in R&D spillovers, but this pattern may not hold in a specific level of technology.

The present paper focuses on the R&D spillovers from North to South by technology level and the role of education in the R&D spillovers as the determinants of total factor productivity of developing countries. However, some other factors may be concerned in the world trade: foreign direct investment, patent citation, protection of intellectual property rights and so on. These may suggest a broader empirical study on the determinants of technical progress for the sustainable economic growth in developing countries.

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Table 1: Average annual growth rates of TFP, GDP per worker, capital and workers

Period / Country	TFP (α = 0.4)					GDP per worker					Capital					Workers				
	61-98	61-72	73-84	85-96	97-98	**61-98**	60-72	73-84	85-96	97-98	**61-98**	60-72	73-84	85-96	97-98	**61-98**	60-72	73-84	85-96	97-98
Simple average by income per capita																				
low (20) [1]	**-0.26**	0.52	-0.59	-0.80	0.31	**0.35**	1.76	0.38	-1.10	0.55	**4.12**	5.25	4.71	2.56	3.09	**2.58**	2.15	2.27	3.33	2.48
lower middle (23)	**0.71**	1.53	-0.02	0.73	-0.06	**1.63**	2.91	1.47	0.66	0.79	**4.89**	5.84	6.38	2.60	4.05	**2.59**	2.40	2.67	2.78	1.94
Upper middle(18)	**1.31**	2.10	0.39	1.70	-0.33	**2.69**	3.81	2.03	2.45	1.32	**5.78**	6.86	6.76	3.72	5.70	**2.31**	2.57	2.65	1.85	1.58
High(13) [2]	**1.21**	1.78	0.64	1.21	1.33	**2.33**	3.73	1.47	1.79	2.28	**3.88**	6.22	3.29	2.29	2.90	**1.10**	1.35	1.21	0.85	0.52
Simple average by region																				
East Asia (9)	**1.60**	1.77	1.55	2.65	-5.32	**4.25**	4.49	4.41	4.99	-2.54	**9.02**	9.53	10.00	7.62	8.60	**2.40**	2.72	2.85	1.76	1.66
South Asia (5)	**0.67**	-0.07	0.44	1.65	0.65	**2.06**	2.39	1.67	2.16	1.82	**5.55**	8.41	5.32	3.02	4.87	**2.07**	2.25	2.25	1.73	1.93
Middle East (7)	**0.95**	2.14	0.56	0.25	0.41	**2.28**	3.86	2.99	0.25	0.76	**6.11**	6.89	8.91	3.01	3.14	**2.79**	2.59	2.85	3.02	2.29
C. America (10)	**0.37**	1.74	-0.68	-0.18	1.79	**1.15**	3.18	0.32	-0.31	2.65	**4.48**	6.20	5.32	2.00	4.01	**2.55**	2.61	2.84	2.31	1.86
S. America (11)	**0.76**	1.87	-0.63	1.05	0.76	**1.05**	2.47	0.15	0.39	1.84	**3.19**	3.66	4.36	1.37	4.34	**2.49**	2.15	2.41	3.03	1.64
Africa (19)	**-0.11**	0.78	-0.61	-0.63	0.83	**0.29**	1.70	0.23	-1.13	0.84	**3.54**	4.45	4.34	2.00	2.41	**2.54**	2.15	2.25	3.24	2.39
Individual country																				
Hong Kong	**3.26**	5.08	2.52	3.60	-5.24	**5.64**	7.22	4.65	6.50	-3.05	**7.83**	7.97	8.83	6.58	8.37	**1.87**	2.62	3.49	-0.66	2.89
Korea	**1.88**	1.91	1.94	3.39	-7.59	**5.20**	4.85	5.44	6.97	-4.71	**10.50**	10.42	11.23	10.22	8.17	**2.21**	3.07	2.48	1.28	0.96
Singapore	**2.14**	2.91	1.52	2.60	-1.48	**5.17**	7.95	4.42	3.73	1.63	**11.05**	15.86	11.24	6.28	9.72	**3.48**	3.26	3.99	3.45	1.93
Taiwan	**2.56**	2.73	1.60	3.47	1.81	**6.06**	6.85	5.31	6.24	4.78	**10.94**	13.21	11.87	8.19	8.34	**2.19**	2.91	2.59	1.28	0.90
China	**1.64**	0.96	1.78	2.38	0.40	**3.69**	1.96	3.66	5.44	3.71	**7.13**	4.57	7.08	9.38	9.25	**1.99**	2.06	2.37	1.73	0.96
Argentina	**0.53**	0.76	-0.70	1.06	3.41	**1.05**	2.37	0.23	0.01	4.40	**2.92**	5.39	3.26	-0.01	3.73	**1.62**	1.35	0.95	2.61	1.27
Brazil	**1.44**	3.25	-0.23	1.49	0.38	**2.48**	4.59	1.72	1.42	0.75	**5.10**	6.43	7.87	1.48	2.25	**2.51**	3.09	2.99	1.65	1.33
Mexico	**0.75**	1.68	0.15	0.04	3.10	**1.48**	3.37	1.07	-0.32	3.44	**4.70**	7.17	5.94	1.36	2.51	**2.88**	2.94	3.64	2.25	1.66
Japan	**1.45**	3.19	0.59	1.23	-2.49	**4.18**	7.94	2.77	2.74	-1.17	**7.79**	13.50	6.31	4.27	3.56	**0.96**	1.63	0.85	0.51	0.26
USA	**0.89**	1.47	0.33	0.75	1.65	**1.71**	2.27	1.06	1.56	3.07	**3.77**	3.89	3.77	3.44	5.04	**1.73**	1.88	1.93	1.43	1.49
Sample Mean	**0.68**	**1.44**	**0.04**	**0.64**	**0.22**	**1.67**	**2.96**	**1.31**	**0.82**	**1.13**	**4.72**	**6.00**	**5.48**	**2.81**	**4.01**	**2.26**	**2.19**	**2.30**	**2.36**	**1.73**

Source: The author's calculation using PWT 6.

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

(2) The group of high income is the same as OECD countries.

Table 2: Trends of Education Attainment

Year / Country	Primary			Secondary			Higher			Years of primary			Years of secondary			Years of higher		
	1970	1995	Ratio[1)]	1970	1995	Ratio	1970	1995	Ratio	1970	1995	Ratio	1970	1995	Ratio	1970	1995	Ratio
Simple average by income per capita																		
low	23.47	33.11	1.41	5.16	15.23	2.95	0.68	1.69	2.50	1.31	2.33	1.77	0.26	0.73	2.85	0.02	0.05	2.40
lower middle	42.35	41.39	0.98	13.39	26.89	2.01	1.83	8.09	4.41	2.53	3.78	1.49	0.61	1.47	2.41	0.05	0.24	4.51
upper middle	48.42	40.92	0.84	21.98	35.62	1.62	3.60	11.51	3.20	3.61	4.79	1.33	1.10	2.13	1.93	0.10	0.33	3.24
High (14)[2)]	49.55	27.86	0.56	39.04	48.09	1.23	8.89	21.49	2.42	5.04	5.38	1.07	2.27	3.63	1.60	0.25	0.60	2.43
Simple average by region																		
East Asia	43.63	35.43	0.81	21.72	37.99	1.75	3.13	11.03	3.52	3.39	4.63	1.37	1.11	2.38	2.15	0.09	0.32	3.59
South Asia	32.74	31.86	0.97	12.22	29.26	2.39	1.78	3.04	1.71	2.40	3.61	1.50	0.56	1.41	2.51	0.06	0.09	1.59
M. East	24.66	30.74	1.25	14.24	29.49	2.07	2.70	10.69	3.96	2.24	3.86	1.72	0.63	1.70	2.70	0.07	0.30	4.07
C. America	53.77	46.61	0.87	11.67	24.80	2.13	2.25	8.48	3.77	2.72	3.82	1.41	0.60	1.41	2.35	0.06	0.25	3.85
S. America	55.04	48.27	0.88	18.19	28.41	1.56	3.02	10.98	3.64	3.41	4.39	1.29	0.92	1.65	1.79	0.09	0.32	3.74
Africa	23.31	34.74	1.49	7.04	16.27	2.31	0.46	1.68	3.64	1.41	2.45	1.74	0.30	0.74	2.51	0.01	0.05	3.48
Individual country																		
Hong Kong	41.00	25.50	0.62	32.50	50.40	1.55	2.60	12.20	4.69	4.07	4.92	1.21	2.18	4.00	1.84	0.07	0.36	5.13
Korea	39.10	13.90	0.36	25.30	57.20	2.26	4.60	22.20	4.83	3.47	5.58	1.61	1.30	4.34	3.34	0.15	0.65	4.48
Singapore	29.70	40.80	1.37	33.90	34.50	1.02	1.90	7.30	3.84	3.36	4.47	1.33	1.64	2.05	1.25	0.05	0.20	4.08
Taiwan	38.90	27.00	0.69	28.80	45.20	1.57	5.80	16.70	2.88	3.73	4.98	1.34	1.43	2.93	2.05	0.15	0.45	2.97
China	26.37	34.30	1.30	29.18	43.20	1.48	0.80	2.40	3.00	2.88	4.16	1.45	1.18	1.87	1.59	0.03	0.09	3.04
Argentina	69.30	48.10	0.69	19.30	31.60	1.64	4.40	16.10	3.66	5.15	6.05	1.17	0.93	1.96	2.11	0.12	0.45	3.67
Brazil	47.40	64.00	1.35	13.50	11.60	0.86	1.70	6.70	3.94	2.47	3.55	1.44	0.80	0.70	0.88	0.05	0.20	4.26
Mexico	56.70	42.50	0.75	10.60	36.40	3.43	2.50	9.60	3.84	3.01	4.56	1.51	0.60	2.13	3.53	0.07	0.27	3.94
Japan	47.30	29.60	0.63	42.90	50.40	1.17	7.90	19.80	2.51	5.13	5.51	1.07	2.10	3.12	1.49	0.23	0.61	2.63
USA	32.60	8.10	0.25	45.60	47.10	1.03	20.30	44.20	2.18	5.80	5.84	1.01	3.15	4.72	1.50	0.58	1.33	2.29
Sample mean	**40.12**	**36.54**	**0.91**	**18.04**	**29.83**	**1.65**	**3.27**	**9.70**	**2.97**	**2.93**	**3.93**	**1.34**	**0.94**	**1.83**	**1.94**	**0.09**	**0.28**	**3.01**

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

Notes: (1) Ratio is the value of the column of 1995 divided by the column of 1970 in each category of education.

(2) 14 countries are 13 OECD countries in Table 1 plus Germany and other groups are the same as in Table 1.

Table 3: Average annual import and export shares in 14 OECD trade partners by per capita income (%)

Country Group	Industry	Import share 1973-84	Import share 1985-96	Export share 1973-84	Export share 1985-96
Low income (20)	Hi Tech	0.24	0.25	0.01	0.03
	Med. Hi Tech	1.55	1.26	0.05	0.08
	Med. Low Tech	0.62	0.41	0.67	0.43
	Low Tech	0.45	0.23	0.95	1.02
	sub total [a]	2.87	2.15	1.69	1.56
Lower-Middle Income (23)	Hi Tech	0.53	0.76	0.02	0.21
	Med. Hi Tech	3.87	3.65	0.30	0.51
	Med. Low Tech	1.74	1.22	0.64	0.89
	Low Tech	1.04	0.83	1.21	1.89
	sub total [b]	7.18	6.46	2.16	3.49
Upper-Middle Income (18)	Hi Tech	1.23	2.08	0.82	2.54
	Med. Hi Tech	8.08	8.94	1.61	4.10
	Med. Low Tech	2.93	2.73	3.41	3.79
	Low Tech	1.72	1.84	4.99	5.27
	sub total [c]	13.97	15.58	10.84	15.71
High income (14)	Hi Tech	6.54	10.34	7.33	10.81
	Med. Hi Tech	36.56	39.10	41.05	40.87
	Med. Low Tech	15.76	12.18	17.70	12.73
	Low Tech	17.12	14.19	19.23	14.83
	sub total [d]	75.98	75.81	85.31	79.24
	Total [=a+b+c+d]	100.00	100.00	100.00	100.00

Source: The author's calculation from trade data of Feenstra et. al (1997) and Feenstra (2000).

Table 4: Average annual import and export shares in the 14 OECD trade partners by region (%)

Region	Industry	trading partner	Import share 73-84	Import share 85-96	Export share 73-84	Export share 85-96	Region	Import share 73-84	Import share 85-96	Export share 73-84	Export share 85-96
East Asia (9)	Hi Tech	EUR	0.19	0.36	0.23	0.89	Latin America (21)	0.23	0.18	0.02	0.04
		JPN	0.26	0.65	0.05	0.19		0.11	0.07	0.01	0.01
		USC	0.29	0.74	0.46	1.35		0.25	0.45	0.06	0.21
	MH Tech	EUR	1.29	2.12	0.35	0.99		1.68	0.99	0.19	0.25
		JPN	2.33	3.68	0.20	0.50		0.45	0.35	0.03	0.02
		USC	1.08	1.78	0.64	1.63		2.18	1.83	0.34	0.92
	ML Tech	EUR	0.59	0.77	0.56	0.82		0.54	0.27	0.49	0.27
		JPN	1.26	1.22	0.54	0.68		0.43	0.30	0.11	0.12
		USC	0.22	0.33	0.82	1.31		0.51	0.46	0.95	0.77
	Low Tech	EUR	0.37	0.56	1.59	1.74		0.35	0.20	0.89	0.53
		JPN	0.45	0.40	1.19	1.39		0.03	0.01	0.07	0.08
		USC	0.28	0.40	1.52	2.44		0.48	0.53	0.65	0.72
Sub total [a]			**8.60**	**13.01**	**8.15**	**13.92**	[d]	**7.24**	**5.64**	**3.81**	**3.94**
South Asia (5)	Hi Tech	EUR	0.06	0.08	0.01	0.01	N. Africa & Middle East Asia (7)	0.21	0.20	0.01	0.03
		JPN	0.01	0.01	0.00	0.00		0.03	0.03	0.00	0.00
		USC	0.04	0.04	0.00	0.00		0.09	0.10	0.01	0.05
	MH Tech	EUR	0.35	0.30	0.02	0.03		1.71	1.28	0.07	0.14
		JPN	0.13	0.16	0.00	0.00		0.23	0.21	0.00	0.01
		USC	0.11	0.10	0.01	0.02		0.33	0.22	0.03	0.07
	ML Tech	EUR	0.18	0.16	0.05	0.07		0.76	0.47	0.20	0.26
		JPN	0.08	0.05	0.02	0.05		0.19	0.07	0.07	0.04
		USC	0.03	0.02	0.04	0.11		0.08	0.04	0.13	0.19
	Low Tech	EUR	0.11	0.06	0.30	0.32		0.42	0.36	0.26	0.36
		JPN	0.02	0.01	0.09	0.08		0.03	0.01	0.01	0.01
		USC	0.08	0.03	0.13	0.17		0.12	0.08	0.04	0.06
Sub total [b]			**1.19**	**1.02**	**0.66**	**0.85**	[e]	**4.20**	**3.07**	**0.82**	**1.22**
Sub-Saharan Africa (19)	Hi Tech	EUR	0.16	0.12	0.01	0.01	OECD (14)	3.23	4.93	5.25	7.28
		JPN	0.02	0.02	0.00	0.00		1.30	2.54	0.41	0.63
		USC	0.04	0.04	0.00	0.00		2.01	2.87	1.67	2.89
	MH Tech	EUR	1.20	0.58	0.06	0.08		24.11	24.95	29.49	27.22
		JPN	0.19	0.14	0.01	0.01		4.20	6.76	1.40	1.68
		USC	0.24	0.09	0.01	0.02		8.25	7.40	10.16	11.98
	ML Tech	EUR	0.36	0.17	0.41	0.24		12.18	9.64	13.26	9.23
		JPN	0.06	0.02	0.12	0.08		1.56	0.96	0.46	0.57
		USC	0.04	0.01	0.21	0.12		2.02	1.58	3.98	2.94
	Low Tech	EUR	0.36	0.21	0.36	0.23		14.08	12.01	13.72	10.59
		JPN	0.05	0.01	0.02	0.02		0.51	0.27	1.20	1.16
		USC	0.07	0.03	0.04	0.03		2.53	1.91	4.31	3.08
Sub total [c]			**2.78**	**1.46**	**1.25**	**0.84**	[f]	**75.98**	**75.81**	**85.31**	**79.24**
Total =[a+b+c+d+e+f]								100.00	100.00	100.00	100.00

Source: See Table 3.

Table 5: Empirical results without distinction of technology levels (1)

Sample	Whole sample (61)	Low income (20)	Lower-middle income (23)	Upper-middle income (18)

	SYR	HYR	SYR	HYR	SYR	HYR	SYR	HYR
Edu	.087*** (4.93)	.274*** (3.54)	.162*** (3.65)	-.017 (0.03)	.028 (1.00)	-.287*** (2.78)	.024 (1.08)	.069 (0.61)
Impsh	-.324*** (6.57)	-.340*** (6.89)	- .262*** (3.28)	-.287*** (3.53)	-.392*** (3.55)	-.390*** (3.55)	-.389*** (5.14)	-.400*** (5.28)
$lnR\&D^F$	.148*** (21.09)	.155*** (22.78)	.091*** (7.01)	.113*** (9.06)	.158*** (14.27)	.159*** (14.46)	.191*** (13.03)	.196*** (14.01)
R^2	.9306	.9300	.8548	.8504	.9213	.9224	.8016	.8012
F value	157.83	157.50	56.77	49.53	127.30	130.73	32.91	36.85

Notes: (1) The figures in parentheses of Sample row are the number of countries in each group.

(2) The figure in parentheses in each variable is absolute t-statistic and F value is for the hypothesis test on no two-way fixed effect.

(3) F value is for the hypothesis test on no two-way fixed effect for panel data.

(4) ***, ** and * indicate the significance levels at a l%, 5% and 10%, respectively.

Table 6: Empirical results without distinction of technology levels in model (2)

Sample / EDU	Whole sample		Low income		Lower-middle income		Upper-middle income	
	SYR	HYR	SYR	HYR	SYR	HYR	SYR	HYR
Edu	-.690*** (7.77)	-4.142*** (7.24)	-2.716*** (7.87)	-32.945*** (7.59)	.504** (2.23)	2.045 ** (2.08)	-.651*** (4.67)	-3.673*** (4.35)
Impsh	-1.921*** (4.45)	-2.645*** (6.34)	- 1.904 (1.59)	-2.988** (2.46)	-3.192** (2.39)	-4.465*** (3.41)	-3.263*** (4.52)	-4.019*** (5.73)
$\ln R\&D^F$	.101*** (12.84)	.118*** (15.79)	.034** (2.48)	.051*** (3.59)	.174*** (7.79)	.151*** (9.87)	.090*** (4.59)	.107*** (5.87)
Impsh * $\ln R\&D^F$	.085*** (3.83)	.122*** (5.70)	.094 (1.45)	.149** (2.26)	.143** (2.05)	.211*** (3.09)	.137*** (4.07)	.176*** (5.39)
Edu * $\ln R\&D^F$	.036*** (8.89)	.205*** (7.67)	.145*** (8.41)	1.722*** (7.69)	-.024** (2.12)	-.116 ** (2.43)	.030*** (4.96)	.173*** (4.58)
Total elasticity ($\overline{M}, \overline{E}_S, \overline{E}_H$)[1)]	0.153	0.163	0.121	0.124	0.166	0.160	0.167	0.179
	(0.15, 1.09, 0.13)		(0.14, 0.51, 0.03)		(0.13, 1.11, 0.16)		(0.19, 1.71, 0.22)	
R^2	.9368	.9352	.8769	.8699	.9230	.9246	.8281	.8265
F value	163.72	160.29	68.05	58.03	107.17	107.77	37.05	35.31

Note: 1) The total elasticity of TFP with respect to foreign R&D stock ($R\&D^F$) = $\alpha_F + \alpha_{MF}\overline{M} + \alpha_{EF}\overline{E}$ where $\overline{M}$ and $\overline{E}$ are sample mean of import share and education, respectively. This formula is the same in the following Table 7.

Table 7: Empirical results by technology level: whole sample

lnR&D^F / EDU	High technology		Medium-high tech		Medium-low tech		Low technology	
	SYR	HYR	SYR	HYR	SYR	HYR	SYR	HYR
Edu	-.504*** (5.91)	-2.483*** (4.78)	-.612*** (6.84)	-3.859*** (6.90)	-.622*** (8.58)	-4.157*** (8.32)	-.579*** (7.69)	-3.670*** (7.07)
Impsh	-19.735*** (6.73)	-25.666*** (9.19)	- 4.170*** (4.66)	-5.415*** (6.35)	-5.117*** (4.72)	-5.601*** (5.10)	-8.310*** (3.96)	-10.124*** (4.71)
$\ln R\&D^F$	.077*** (10.72)	.099*** (14.95)	.114*** (13.79)	.129*** (16.39)	.091*** (12.24)	.108*** (15.45)	.060*** (7.15)	.081*** (9.82)
Impsh * $\ln R\&D^F$	.874*** (5.97)	1.174*** (8.47)	.188*** (4.03)	.253*** (5.71)	.246*** (4.29)	.264*** (4.54)	.442*** (3.25)	.550*** (3.96)
Edu * $\ln R\&D^F$	.030*** (7.38)	.133*** (5.27)	.033*** (7.84)	.198*** (7.27)	.039*** (10.10)	.244*** (8.91)	.042*** (9.65)	.237*** (7.71)
Total elasticity **	.123	.134	.164	.173	.142	.149	.120	.129
R^2	.9337	.9307	.9359	.9348	.9320	.9302	.9266	.9230
F value	157.34	149.68	158.80	157.17	153.27	151.66	138.39	129.27

** Sample means of import shares of each technology in nominal GDP, the average years of secondary and higher education are ($\overline{M}_{HI}, \overline{M}_{MH}, \overline{M}_{ML}, \overline{M}_{LW}, \overline{E}_S, \overline{E}_H$) = (.015, .072, .035, .031, 1.092, .131).

Table 7: low-income group (continued)

lnR&D^F / EDU	High technology		Medium-high tech		Medium-low tech		Low technology	
	SYR	HYR	SYR	HYR	SYR	HYR	SYR	HYR
Edu	-2.181*** (6.82)	-23.319*** (5.94)	-2.680*** (7.90)	-31.834*** (7.52)	-1.844*** (7.60)	-20.434*** (6.85)	-1.311*** (4.06)	-10.414*** (2.64)
Impsh	6.269 (0.49)	-8.670 (0.67)	- 3.130 (1.09)	-7.369** (2.58)	-4.969 (0.98)	-9.272* (1.79)	-10.419*** (2.81)	-12.062*** (3.08)
$\ln R\&D^F$	.022 (1.56)	.053*** (3.67)	.050*** (3.70)	.061*** (4.41)	.049*** (3.81)	.065*** (4.98)	-.0001 (0.01)	.037** (2.44)
Impsh * $\ln R\&D^F$	-.443 (0.61)	.341 (0.47)	.154 (0.97)	.383** (2.42)	.270 (0.83)	.537 (1.62)	.626** (2.56)	.722*** (2.80)
Edu * $\ln R\&D^F$	.126*** (7.46)	1.298*** (6.13)	.146*** (8.35)	1.706*** (7.55)	.123*** (8.31)	1.309*** (6.96)	.107*** (4.92)	.770*** (2.91)
Total elasticity *	.086	.097	.125	.143	.112	.123	.079	.091
R^2	.8691	.8584	.8775	.8718	.8741	.8659	.8550	.8384
F value	60.96	49.54	67.94	58.11	64.86	54.53	56.50	44.16

* ($\overline{M}_{HI}, \overline{M}_{MH}, \overline{M}_{ML}, \overline{M}_{LW}, \overline{E}_S, \overline{E}_H$) = (.013, .063, .026, .039, .511, .034).

Table 7: lower-middle-income group (continued)

EDU \ lnR&D^F	High technology		Medium-high tech		Medium-low tech		Low technology	
	SYR	HYR	SYR	HYR	SYR	HYR	SYR	HYR
Edu	.489*** (2.69)	2.804*** (3.33)	.769*** (3.45)	1.877* (1.94)	-.098 (0.54)	.522 (0.66)	.323 (1.49)	1.852* (1.93)
Impsh	-24.708*** (2.76)	-36.827*** (3.94)	- 5.545** (2.52)	-8.518*** (3.79)	-14.236*** (3.01)	-13.412*** (2.91)	-6.273 (1.45)	-7.921* (1.84)
lnR&D^F	.138*** (8.26)	.117*** (10.08)	.215 ** (8.98)	.166*** (9.86)	.128*** (6.52)	.155*** (9.44)	.171*** (7.60)	.169*** (10.79)
Impsh * lnR&D^F	1.061** (2.21)	1.758*** (3.49)	.244** (2.03)	.413*** (3.38)	.773*** (2.66)	.700** (2.47)	.257 (0.97)	.363 (1.39)
Edu * lnR&D^F	-.023** (2.47)	-.155*** (3.65)	-.038** (3.33)	-.116** (2.37)	.008 (0.71)	-.054 (1.18)	-.018 (1.34)	-.137** (2.29)
Total elasticity **	.125	.115	.189	.177	.148	.173	.171	.149
R^2	.9174	.9190	.9237	.9248	.9158	.9181	.9107	.9126
F value	109.01	110.55	113.01	109.77	101.93	103.70	99.12	105.15

** ($\overline{M}_{HI}, \overline{M}_{MH}, \overline{M}_{ML}, \overline{M}_{LW}, \overline{E}_S, \overline{E}_H$) = (.012, .067, .026, .029, 1.111, .146).

Table 7: upper-middle-income group (continued)

EDU \ LnR&D^F	High technology		Medium-high tech		Medium-low tech		Low technology	
	SYR	HYR	SYR	HYR	SYR	HYR	SYR	HYR
Edu	-.790 *** (5.86)	-4.458*** (6.21)	-.325** (2.27)	-3.205*** (4.42)	-.796*** (6.46)	-6.559*** (7.98)	-.799*** (7.58)	-3.750*** (5.89)
Impsh	-23.133*** (4.80)	-34.198*** (7.64)	- 8.934*** (5.22)	-9.423*** (6.05)	-9.695*** (4.69)	-8.410*** (4.09)	-29.721*** (6.29)	-36.301*** (7.69)
lnR&D^F	.043** (2.58)	.068*** (4.39)	.145*** (6.68)	.144*** (7.71)	.011 (0.63)	.033** (2.18)	.026* (1.76)	.055*** (3.77)
Impsh * lnR&D^F	1.012*** (4.53)	1.544*** (7.50)	.374*** (4.73)	.399*** (5.55)	.476*** (4.52)	.407*** (3.89)	1.477*** (5.13)	1.870*** (6.49)
Edu * lnR&D^F	.039*** (6.55)	.211*** (6.32)	.016** (2.41)	.144*** (4.19)	.044*** (7.00)	.343 ** (8.12)	.046*** (8.03)	.218*** (6.04)
Total elasticity *	.130	.146	.205	.211	.102	.131	.142	.150
R^2	.8079	.8001	.8340	.8400	.8071	.8120	.8507	.8398
F value	32.38	30.45	40.51	40.47	32.18	34.86	46.88	44.18

* ($\overline{M}_{HI}, \overline{M}_{MH}, \overline{M}_{ML}, \overline{M}_{LW}, \overline{E}_S, \overline{E}_H$) = (.020, .087, .055, .025, 1.713, .221).

Table 8: Regression results for each technology level by region

Region	East Asian					Latin America				
	Total	High Tech	Med. High	Med. Low	Low	Total	High Tech	Med. High	Med. Low	Low
	HYR	HYR	HYR	SYR	SYR	PYR	PYR	PYR	PYR	PYR
EDU	.392** (2.60)	.402** (2.47)	.470*** (3.22)	.049* (1.93)	.021 (1.18)	.091*** (5.10)	.081*** (4.17)	.098*** (5.49)	.081*** (4.15)	.066*** (3.35)
Impsh	-.304*** (2.76)	.014 (0.03)	-.642*** (3.22)	-1.380*** (3.00)	-3.571*** (3.74)	-.172** (2.15)	-1.931*** (2.72)	-.786*** (3.56)	-.122 (1.09)	-.498 (1.53)
lnR&D^{USA}	.005 (0.43)	.014 (0.56)	.016 (1.53)	.003 (0.40)	-.025*** (2.60)	.049*** (4.00)	.037*** (2.84)	.045*** (2.85)	.001 (0.10)	.023 (1.32)
lnR&D^{JPN}	.207*** (7.72)	.046*** (3.36)	.244*** (9.86)	.189*** (7.67)	.145*** (7.46)	.051*** (4.24)	.021*** (3.61)	.076*** (6.84)	.051*** (6.32)	.025*** (3.78)
lnR&D^{EUR}	.023 (1.07)	.055*** (3.55)	-.004 (0.21)	.027* (1.78)	.091*** (4.28)	.053*** (3.72)	.053** (4.77)	.078*** (5.61)	.021* (1.92)	.050*** (4.26)
R^2	.9716	.9590	.9730	.9701	.9708	.8846	.8658	.8846	.8719	.8665
F value	79.92	57.05	84.56	58.83	75.74	61.57	53.88	61.44	59.34	50.28

Region	Sub-Saharan Africa					Middle East Asia and North Africa				
	Total	High Tech	Med. High	Med. Low	Low	Total	High Tech	Med. High	Med. Low	Low
	SYR	SYR	SYR	SYR	SYR	HYR	HYR	HYR	HYR	HYR
EDU	.081 (1.61)	.102** (2.05)	.082 (1.61)	.140*** (2.74)	.128** (2.47)	.699*** (3.18)	.944*** (3.33)	.573*** (2.70)	.483** (2.02)	.875*** (3.97)
Impsh	-.225*** (2.78)	-2.107*** (2.70)	-.402** (2.08)	-1.823*** (4.11)	-1.037*** (4.16)	-1.036*** (3.70)	-7.484*** (3.25)	-1.501*** (3.09)	-3.625*** (2.93)	-5.841*** (3.99)
lnR&D^{USA}	.008 (0.79)	.020 ** (2.49)	-.008 (0.56)	-.010 (1.12)	-.015 (1.30)	.031** (2.40)	.045*** (3.75)	.031* (1.81)	.045*** (3.61)	.021** (2.31)
lnR&D^{JPN}	.035 ** (2.50)	.024*** (3.68)	.010 (0.77)	.001 (0.09)	.035*** (4.56)	.079*** (3.49)	.015 (1.03)	.079*** (3.87)	.043** (2.26)	.049*** (3.93)
lnR&D^{EUR}	.052 ** (2.56)	.074*** (5.48)	.091*** (4.56)	.155*** (7.37)	.007 (0.36)	.069* (1.75)	.077** (2.56)	.109*** (3.32)	.101*** (3.05)	.049 (1.53)
R^2	.9111	.9220	.9147	.9178	.9105	.7803	.7390	.8006	.7530	.7832
F value	71.94	73.40	61.00	59.90	66.15	7.42	5.78	8.91	6.00	6.14

Appendix A: Country List (75)

country	income	country	income	country	income
Sub-Saharan Africa (19)		Singapore *	3	Chile	3
Benin	1	Taiwan *	3	Uruguay	3
Cameroon	1			Venezuela	3
Gambia	1	**South Asia (5)**			
Ghana	1	India	1	**Mid East Asia and N. Africa (7)**	
Guinea-Biss	1	Pakistan	1	Algeria	2
Kenya	1	Sri Lanka	2	Egypt	2
Malawi	1	Fiji	2	Iran	2
Mali	1	Papua N. Guine	2	Jordan	2
Mozambique	1			Syria	2
Senegal	1	**Latin America (21)**		Israel *	3
Sierra Leone	1	Nicaragua	1	Turkey	3
Togo	1	Dominican Rep.	2		
Uganda	1	El Salvador	2	**OECD (14)**	
Zaire	1	Guatemala	2	Canada	4
Zambia	1	Honduras	2	USA	4
Zimbabwe	1	Jamaica	2	Japan	4
Tunisia	2	Costa Rica	3	Denmark	4
Mauritius	3	Mexico	3	Finland	4
South Africa	3	Panama	3	France	4
		Trinidad&Tobago	3	Germany	4
East Asia (9)		Bolivia	2	Italy	4
Indonesia	1	Colombia	2	Netherlands	4
China	2	Ecuador	2	Norway	4
Philippines	2	Guyana	2	Spain	4
Thailand	2	Parguay	2	Sweden	4
Hong Kong *	3	Peru	2	U.K.	4
Korea	3	Argentian	3	Australia	4
Malaysia	3	Brazil	3		

Notes: (1) In the column, income, 1, 2, 3, and 4 indicate low-income, lower-middle-income, upper-middle-income, and high-income

(2) Countries with * belongs to high-income countries (4) based on World Bank’ s classification.

Appendix B: Industry code by technology level in manufacturing

Industry description	ISIC Rev .2	SITC Rev. 2
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.