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The Role of Foreign Direct Investment and Imports of Capital Goods in the North-South Diffusion of Technology

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Abstract

Technology diffusion across industrial countries has been the subject of considerable research. During the last decade economists have measured extensively the extent to which productivity gains are transmitted across countries in the North. However, research on technology diffusion to developing countries has been relatively scarce. This is surprising considering the importance that this source of productivity represents for countries in the South. This paper seeks to fill this gap. The results underline the importance of North-South schemes of integration for technology transfers as long as they lead to larger flows of FDI and trade from developed to developing countries.

• **JEL Classifications:** F15, F21, O40

• **Key words:** Technology diffusion, Productivity, Foreign direct investment, Trade

I. Introduction

For years the economic literature has emphasized the role of technological progress as a source of long-run growth. Since the process by which technological knowledge advances is often related to R&D investment, economists have commonly looked at R&D activity when analyzing sources of efficiency gains for developed nations. Technology diffusion across national borders have also been the subject of considerable research. Economists have not only measured the

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extent to which productivity gains are transmitted from one industrial country to another but they have also analyzed the importance that different mechanisms, like international trade and foreign direct investment, have played in this process. Investment in R&D, however, is highly concentrated in industrialized countries.[1] The lack of R&D investment in developing countries implies that these nations are unlikely to produce their own innovations; therefore, the process of technology diffusion is a relatively more important source of productivity gains for developing than for industrial countries.

Coe and Helpman (1995) pioneered the cross-sectional analysis of international technology diffusion by measuring the size of the efficiency gains generated by the diffusion of technological knowledge among 21 OECD countries plus Israel. The authors related the total factor productivity of each country to the countrys domestic and foreign stocks of technological knowledge. They found that both stocks of knowledge had positive effects on the countrys productivity. They only considered, however, the channel of international trade as a source of technology diffusion. In an effort to control for other transmission mechanisms, Hejazi and Safarian (1996) extended Coe and Helpmans framework to include foreign direct investment into the analysis. They considered the case of technology diffusion from the U.S. to 21 industrial countries and found that both, trade and FDI, were important vehicles for the international transmission of knowledge. Using FDI data from U.S. multinational enterprises, Xu (2000) also found a positive effect of technology transfer on the productivity growth of industrial countries. Hejazi and Safarian (1999) extended their 1996s analysis to include not only the U.S. but also five other major industrial countries as sources of innovation activity. They found again that trade and FDI were important mechanisms for transferring knowledge across national borders. Using a larger sample of industrial countries than Hejazi and Safarin, Xu and Wang (2000) found that the FDI-related spillover effects were associated not with the inward flows of FDI but with the outward flows.

In a cross sectional analysis, Coe, Helpman and Hoffmaister (1997) explore the diffusion of technology in the North-South direction. The study found that countries in the South benefit from the innovation activity that takes place in the North when the former import goods that embody technological knowledge originated in the latter. The study, however, only includes international trade as a channel of diffusion, therefore, nothing can be said about the role of FDI in

[1]According to Coe, Helpman and Hoffmaister (1997), 96% of the worlds R&D expenditures take place in the OECD.

transferring stocks of knowledge from developed to developing countries.

In this paper we consider both, trade and FDI, in measuring the transmission of technological knowledge from industrial to developing countries (the North-South case). We seek to test the relative importance of each of these mechanisms for transferring technology. We also test the role that the level of absorptive capacity in the South has in acquiring foreign technology through each of these channels. According to the results, developing countries benefit from both types of flows with the imports of capital goods showing the strongest effects. It is shown that developing countries with higher levels of absorptive capacity exhibit higher efficiency gains from the adoption of foreign technology through these mechanisms. The absorptive capacity seems to be more important for FDI than for the trade channel and there seems to be a minimum threshold in the level of absorption below which the positive effects of FDI cease to exist. There is no evidence of a minimum level of absorption in the case of imports.

The paper is organized as follows. Section II provides a brief review of the relationship between international trade, FDI and technology diffusion. Section III presents the empirical framework used in this paper as well as the description of the data. The results are showed and discussed in Section IV. Finally, Section V concludes.

II. International Trade, FDI and Technology Diffusion

Technology can be diffused through a variety of channels. Acquiring licenses or patents, reading professional journals, attending foreign seminars, hiring foreign experts, sending students abroad, importing high-technology products, and attracting foreign direct investment are all mechanisms that involve the transmission of new technologies and ideas across countries. In this paper we examine the role of two of these mechanisms, foreign direct investment, as a measure of the inflow of disembodied technology, and imports of machinery and high technology inputs, as a measure of inflow of embodied technology. This section describes briefly how the international trade of capital goods and FDI serve as channels of technology diffusion across countries.

A. International Trade of Capital Goods as a Channel of Technology Diffusion

International trade of capital goods is a form of transferring embodied technology from one country to another. Foreign goods that embody new technology can generate efficiency gains at home from having a vertical or horizontal relation to the domestic goods. On the one hand, innovative products may perform similar functions to those performed by domestic goods, but provide a higher quality (vertical relation). On the other hand, foreign goods can also serve new functions, thereby expanding the variety of differentiated inputs at home (horizontal relation). International trade can thus make available foreign goods that have vertical or horizontal relation with exiting domestic goods generating efficiency gains for the importing country.

International trade of capital goods and specialized inputs can also lead to the propagation of knowledge spillovers. These imports might facilitate learning about a product, which in turn, might spur imitation. Knowledge spillovers have been a common and important form of technology transfers. For example, imitation was an important form of technology acquisition for Japan after the World War II and later for the newly industrialized countries of East Asia (Helpman, 1997).[2] International trade can spur imitation by allowing a large proportion of individuals in a country to be exposed to the new goods. If each person who is exposed to a new good has a given probability to copy it, then the greater the volume of imports of a particular good, the greater the likelihood it will be imitated (Connolly (2002)).

The process of imitation also allows firms to gain insights not only into the particular good being imitated but also into the process of innovation itself. As a firm successfully imitates import varieties it gains insights on how goods are engineered and designed. This improves the skills of the firm for eventually creating new goods. Accordingly, international trade can generate productive efficiency gains in one country not only by making available goods that embody foreign technology but also by making available useful information that would otherwise be costly to acquire expanding the possibilities of imitation and further innovation.

B. FDI as a Channel of Technology Diffusion

When a Multinational Corporation (MNC) decides to enter into another country it must compete against domestic firms that have better knowledge and access to

[2]The existence of knowledge spillovers has to do with the imperfection of the knowledge market. While the creation of new knowledge is often a very expensive process, its reproduction is comparatively cheap. This asymmetry generates incentives for imitation that can only be partially offset by the use of intellectual property rights (IPRs). IPRs, however, are imperfect instruments. For example, Mansfield (1984) reports that about 60% of all patented innovations are imitated within four years.

the domestic market. Therefore, the MNC must enjoy lower costs and higher productive efficiency in order to compensate for the advantages of the national firms. The higher productivity of the MNC is often the result of more advance management skills, a better organization and improved technology. This last element is not surprising since MNCs undertake a major part of the worlds research and development (R&D) efforts and therefore, they control most of the worlds latest technologies. When the MNC enters a country the more advance technology is passed from the firms headquarter into the foreign subsidiaries transferring the technology directly to the host country. The MNC can also establish an R&D center, thereby, inducing knowledge generation in the domestic market.

FDI can also affect the productivity of the recipient country in other ways. For example, workers might migrate to domestic firms after acquiring sufficient training and experience in the MNC. Local linkages might also generate important spillovers at the inter-industry level since MNCs might share a substantial amount of knowledge with their suppliers and buyers increasing productivity in upstream and downstream sectors.[3] MNCs can also increase the productivity in domestic firms through imitation or by forcing local firms in the same industry to cope with better management practices due to the increased competition.

FDI can also lead to important costs in the short-run. A highly efficient MNC can displace the operations of less efficient domestic competitors generating short-run losses in terms of jobs. The entrance of the MNC, however, might imply a better allocation of resources leading to overall benefits in the long term. Even in the short term, the competition of MNC can lead to an increase in the average productivity at the sectoral level since the least efficient firms will shutdown while the surviving competitive firms will increase their market share.

In this paper we are interested in analyzing if developing countries benefit from the innovation activity that takes place in the industrial countries. In spite of all the mechanisms by which imports of capital goods and FDI can transfer technology across countries, the existence of productivity gains from technology diffusion through these channels is ultimately an empirical question. The next section shows an empirical framework developed to address this issue.

III. Econometric Specification and Data Description

Based on Coe and Helpman's empirical framework, the simplest specification

[3]See Kugler (2000) for a discussion on intra-industry and inter-industry spillovers from FDI.

for a panel data setting is given by:

$$\log F_{it} = \alpha_i^0 + \alpha_t^0 + \log S_{it}^d + \alpha_i^m \log S_{it}^m + \mu_{it} \quad (1)$$

where F_{it} is TFP of country *i* at time *t*; α_i^0 and α_t^0 are country and time specific dummy variables; S_{it}^d represents the domestic R&D capital stock; S_{it}^m is the foreign R&D capital stock, and μ_{it} is an error term that is identically independently distributed across countries and time. As explained in the last section, Coe and Helpman measure the foreign R&D capital stock as the bilateral import share weighted sum of the R&D capital stocks of trade partners. This is:

$$S_i^m = \sum_{j \neq i} \frac{M_{ij}}{M_i} S_k^d \quad (2)$$

where M_{ij} represents the bilateral imports of country *i* from country *j*, M_i is country *i*s total imports and S_j^d is the domestic R&D capital stock of country *j*. This specification reflects the *composition* of the trade partners but it does not measure the *intensity* of the imports.[4] According to Coe and Helpman whenever two countries have the same composition of imports and face the same composition of R&D capital stocks among trade partners, the country that imports more should benefit more from foreign R&D. Therefore, in order to include an *intensity* effect, they pre-multiply the log of the foreign R&D capital stock by the ratio of country *i*s total imports to its GDP.

Lumenga-Neso, Olarreaga and Schiff (2001) introduce this ratio of import-to-GDP inside the log of , generating a measure of the foreign R&D capital stock that is equal to:

$$S_i^m = \sum_{j \neq i} \frac{M_{ij}}{Y_i} S_j^d \quad (3)$$

where Y_i is country is GDP. This specification implies that countries that import more relative to their own GDP have a larger foreign R&D capital stock than countries that import less relative to their own GDP.[5] This is the weighting scheme used in this paper.

[4]Lichtembegrg and van Pottelsberghe de la Potterie (1998) argued that the weighting scheme in (2) suffers from an aggregation problem, as the R&D stock distribution is not invariant to mergers between countries. Therefore, they argue that one way to solve this problem is to use a different weighting scheme in which the bilateral imports are divided by the GDP of the exporting country.

[5]Lumenga-Neso, Olarreaga and Schiff argue that their specification is not affected by the aggregation problem raised by Lichtenberg and van Prttelsberghe de la Potterie.

Developing countries also invest in R&D, therefore, they might also obtain productivity gains from accumulating domestic technological knowledge. The problem is that there are no reliable sources of domestic R&D expenditures in developing countries that can be used consistently to construct stocks of R&D valid for international comparisons. For this reason, our specification eliminates the term (log S_{it}^{d} , in equation (1) and focuses exclusively in the diffusion of technology from the industrial countries.

We are interested in exploring not only international trade as a channel of technology diffusion but also the flows of FDI. Accordingly, we include an extra term in equation (1) to capture the effect of the stock of knowledge that is diffused via FDI. Using the same weighting scheme, we define S_i^{fdi} as:

$$S_i^{fdi} = \sum_{j \neq i} \frac{FDI_{ij}}{Y_i} S_j^d \tag{4}$$

This variable enters equation (1) in logarithmic form. Accordingly, our specification becomes:

$$\log F_{it} = \alpha_i^0 + \alpha_t^0 + \alpha_i^m + \log S_{it}^m + \alpha_i^{fdi} \log S_{it}^{fdi} + \mu_{it} \tag{5}$$

where S_i^{fdi} is the "FDI-weighted" foreign stocks of R&D

Absorptive Capacity

It has been argued that a better educated work force will increase aggregate productivity not only directly through more productive workers, but also indirectly through by speeding the adoption of foreign technologies (see, for example, Bils and Klenow (2000)). In our empirical specification we control for the first effect by enhancing the labor force used in the construction of TFP with the returns from years of schooling (see Hall and Jones (1998)). The indirect effect will be captured by introducing an interaction term consisting on the foreign R&D capital stocks multiplied by a measure of the level of education. A positive coefficient on these interaction terms will imply that the effect of the foreign R&D capital stock on productivity is larger the more educated is the labor force. Accordingly, equation (5) becomes:

$$\log F_{it} = \alpha_i^0 + \alpha_t^0 + \alpha_i^m \log S_{it}^m + \alpha_i^{fdi} \log S_{it}^{fdi} + \alpha_i^{mh} h \cdot \log S_{it}^m + \alpha_i^{fdih} h \cdot \log S_{it}^{fdi} + \alpha_i^h h + \mu_{it} \tag{6}$$

Table 1. Pooled Unit Root Tests

log F	-8.53*
$\Delta(\log F)$	-11.58*
$\log S^m$	-0.94
$\Delta(\log S^m)$	-10.31*
$\log S^{fdi}$	-3.47
$\Delta(\log S^{fdi})$	-9.43*
$h \cdot \log S^m$	-1.29
$\Delta(h \cdot \log S^m)$	-10.11*
$h \cdot \log S^{fdi}$	-1.94
$\Delta(h \cdot \log S^{fdi})$	-17.65*
h	-1.81
$\Delta(h)$	-7.89*

An asterisk indicates that the null hypothesis of a unit root is rejected in favor of stationarity.
F = Total Factor Productivity
S^m = Trade-weighted Foreign R&D Capital Stock
S^{fdi} = FDI-weighted Foreign R&D Capital Stock
h = Secondary School Enrollment Ratio

where h is the measure of the educational level.

Order of Integration

ADF tests applied individually to the series of the countries reveal the existence of different orders of integration in the sample. For example, in the case of TFP, the null hypothesis of a unit root could not be rejected in the series of some countries, while for others, the series were clearly stationary. A unit root test for panel data was then used to test for the order of integration of the pooled series.

ADF tests applied individually to the pooled series indicate that the log level of total factor productivity is stationary. On the other hand, the log of the foreign stock of knowledge and the secondary school enrollment rate interacted with the foreign stock of knowledge are nonstationary. This result precludes the use of cointegration techniques to estimate the equation since no statistical evidence was found that the series had a common long-run trend. However, the pooled unit root tests show that the changes of all the variables are stationary indicating that the equation can be estimated in first differences. The test procedure is described in Breitung and Meyer (1994). Table 1 presents the results.

Given that the estimation will be in first differences, we can express equation

(6) as follows:

$$\Delta \log F_{it} = \alpha_t + \alpha_i^m \Delta \log S_{it}^m + \alpha_i^{fdi} \Delta \log S_{it}^{fdi} + \alpha_i^{mh} \Delta (h \cdot \log S_{it}^m) + \alpha_i^h + \Delta h + \mu_{it} \quad (7)$$

Lags in the Diffusion of Technology

Several lags can be expected for a new technology to have an impact over the productivity of a firm. For example, imports of innovative products might require transformations before they can be used successfully under local conditions. On the other hand, process innovations might only be introduced gradually and they might affect only parts of the firms costs structure in the beginning. This implies that the gains in efficiency from acquiring new technologies might not arise immediately. For this reason we estimate equation (7) using 5-year differences.

Conditional Convergence

In the neoclassical growth model where per capita output grows at an exogenous rate, diminishing returns to capital implies the existence of a convergence behavior along the transitional path. This is, if the determinants of the steady-state positions are held fixed, poorer places are predicted to grow faster in per capita terms. This had been described as conditional convergence and has received strong empirical support in many studies. Barro and Sala-i-Martin (1997) have shown that the endogenous models in which growth depends on the discovery of new products and technologies also exhibit conditional convergence due to the increasing costs of adaptation or imitation. The key element is that the cost of invention is typically larger than the cost of adaptation or imitation implying that the typical follower grows relatively fast and tends to catch up to the leaders. Additionally, if some innovations are more productive than others, the larger the set of innovation that the follower country can choose from (that is, the greater the gap), the higher the growth rate that the follower can be accrued from selecting the innovations that are more productive first.

In order to introduce the feature of conditional convergence in our empirical model we include a catchup variable that represent the scope for developing countries to catchup to the productivity levels of the industrial countries. This variable is the logarithm of the ratio of per capita GDP in each developing country to the average per capital GDP of the industrial countries. Including this variable in (7), our final specification becomes:

$$\Delta \log F_{it} = \alpha_t + \alpha_i^m \Delta \log S_{it}^m + \alpha_i^{fdi} \Delta \log S_{it}^{fdi} + \alpha_i^{mh} \Delta (h \cdot \log S_{it}^m) + \alpha_i^{fdih} \Delta (h \cdot \log S_{it}^{fdi}) + \alpha_i^h \Delta h + \alpha_i^c \log(y_i / y_k) + \mu_{it} \quad (8)$$

Data Description

The data on bilateral FDI is taken from the OECD *International Direct Investment Statistics* Database. The information is available for 63 host countries. After excluding the developed nations and revising data availability for other variables, the final sample is restricted to 22 developing countries. The panel is constructed for the years 1980-95. All the variables are in 5-year first differences with the following sub-periods considered: 1980-1985, 1985-1990 and 1990-1995. Accordingly, the panel consists on three points in time for each country for a total of 66 observations.

Total factor productivity is defined as: $F = Y / [K^{\beta} L^{1-\beta}]$ where Y is GDP, K is total stock of capital, and L is total labor force. All the variables are constructed as indices with 1995 = 1. Following Coe, Helpman, and Hoffmaister (1997), the coefficient β (share of capital in GDP) is set equal to 0.4. Y and L are from the *World Development Indicators* of the World Bank and K is constructed from data on fixed capital formation using the perpetual inventory model. The rate of depreciation was set equal to 5% for all the countries.

Measures of TFP can be biased if they are not adjusted for capacity utilization. The problem arises particularly when the capital stock is used to proxy the capital services. If capital utilization is more volatile than the capital stock, then, measuring the capital input as simply the net capital stock will underestimate the volatility of capital. The key is to find a variable that is highly correlated to the utilization of capital. Costello (1993) uses electricity consumption as an indicator of capital services. One advantage of using electricity as a measure of capital usage is that it cannot be easily stored, meaning that the electricity that flows into a process corresponds exactly to the amount used in the process. In this paper we present results using TFP series calculated with electricity consumption (E) as well as with physical capital (K). Electricity consumption is measured in kilowatts per hour and the data are taken from the *World Development Indicators* of the World Bank.

Following the procedure in Hall and Jones (1998), the labor force was augmented by years of schooling to consider the effect of human capital on the level of output. The average years of secondary schooling in total population were taken from the Barro and Lee data set (see Barro and Lee, 2000). Additionally, the measure of the educational level that interacts with the foreign stocks of knowledge is the gross secondary school enrollment. The source is the *World Development Indicators* of the World Bank.

The trade flows refer to machinery and machinery inputs (excluding transport equipment) Data for this variable are obtained from the *OECD's International Trade by Commodities Statistics* (SITC rev.2 Code 7-78-79). Foreign Direct Investment Flows refer to all the direct investment flows from the OECD countries. The source of this database is the OECDs *International Direct Investment Statistics.*

The R&D capital stocks employed in the construction of the foreign R&D capital stocks are taken from 15 OECD countries. The R&D capital stocks for the industrial countries are based on R&D expenditures on business enterprise industry (ISIC 38). The perpetual inventory method was used to construct these stocks. Following Coe and Helpman (1995), the rate of depreciation was assumed to be 5%. Calculations with a rate equal to 10% show similar results. The R&D expenditures data are from the OECD's *Analytical Business Enterprise Research and Development database (ANBERD).*

The 22 developing countries in the sample are: Algeria, Argentina, Brazil, Chile, China, Colombia, Costa Rica, Egypt, Hong Kong, Hungary, India, Indonesia, Kuwait, Malaysia, Mexico, Panama, Phillippines, Portugal, Singapore, Thailand, Turkey and Venezuela. The 15 OECD source countries are: Australia, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherland, Norway, Spain, Sweden, United Kingdom and the United States.

IV. Empirical Results

Table 2 presents the estimations when the TFP is calculated using physical capital stocks. The results from column (2.1) indicate that both channels of diffusion have positive effects on domestic productivity although the coefficient for the foreign R&D capital stock weighted by FDI is only significant at the 10% level. Equation (2.2) includes the catchup variable that represents the scope of developing countries to catchup to the productivity levels of the industrial countries. The theory predicts that the larger the gap between the productivity in country *i* and the productivity in the industrial countries, the faster the TFP growth in country *i*. The results support the theory. The coefficient estimate is negative

Table 2. Estimation Results

Variable	(2.1)	(2.2)	(2.3)	(2.4)	(2.5)
$\Delta(\log S^m)$	0.1078 (4.06)***	0.0932 (3.27)***	0.0869 (3.06)***	0.0702 (2.57)***	0.0989 (3.33)***
$\Delta(\log S^{fdi})$	0.011 (1.90)*	0.0103 (1.69)*	0.0107 (1.93)*	0.0108 (1.91)*	-0.0015 (0.19)
$\log(Y_i/Y_k)$		-0.0391 (1.40)+	-0.0382 (1.27)+	-0.0386 (1.28)+	-0.0387 (1.39)+
Δh			0.3310 (1.40)+		
$\Delta(h\log S^m)$				0.0321 (1.38)+	
$\Delta(h\log S^{fdi})$					0.0212 (1.37)+
R^2	0.20	0.25	0.29	0.29	0.26
R^2 *adjusted*	0.16	0.20	0.23	0.23	0.19
# of obs.	66	66	66	66	66
Threshold.					0.07

The dependent variable is Δ log F. TFP is calculated using physical capital stocks. The equations are estimated using ordinary least squares with Whites heteroscedasticity-consistent covariance estimation method. *t*-statistics in parentheses. ***, **, *, +, indicate statistical significance at the 1%, 5%, 10%, and 15% levels respectively.

implying that when the gap increases, the value of the catchup variable decreases and so the growth rate of TFP increases. The coefficient, however, is only significant at the 15% level in this regression.

Equation (2.3) includes the measure of educational level as an additional variable. The coefficient is not statistically significantly different from zero. This result is not surprising since we have already controlled for the level of human capital in the construction of the TFP series. We are interested, however, in the interaction between the level of education and the foreign R&D capital stocks. If a higher educational level improves the absorption of advance knowledge, then, the higher the level of education in a developing country, the higher the efficiency gains derived from acquiring the technology from abroad. This is done separately in equations (2.4) and (2.5).[6] The interactions variables are both positive and significantly different from zero but only at the 15% level. Therefore, although the results indicate that a more educated labor force enhances the adoption of new

[6]These terms are included simultaneously; however, the estimation encounters strong multicollinearity problems.

Table 3. Estimation Results

Variable	(3.1)	(3.2)	(3.3)	(3.4)	(3.5)
$\Delta(\log S^m)$	0.0923 (3.24)***	0.0760 (2.49)**	0.0702 (2.42)**	0.0525 (2.06)**	0.0848 (2.77)***
$\Delta(\log S^{fdi})$	0.011 (2.55)**	0.0103 (2.27)**	0.0103 (2.63)**	0.0104 (2.58)***	-0.0052 (0.82)
$\log(Y_i/Y_k)$		-0.0533 (1.47)+	-0.0539 (1.40)+	-0.0540 (1.41)+	-0.0511 (1.42)+
Δh			0.3554 (1.23)		
$\Delta(h\log S^m)$				0.0347 (1.20)	
$\Delta(h\log S^{fdi})$					0.0274 (2.12)**
R^2	0.20	0.27	0.32	0.32	0.29
R^2 *adjusted*	0.16	0.22	0.27	0.27	0.23
# of obs.	66	66	66	66	66
Threshold.					0.19

TFP is calculated using electricity consumption to proxy for capital utilization.

technologies, the effect is not very strong in this regression.

It is worth noting that the coefficient for the stock of knowledge diffused through FDI is negative (although insignificant) when the interaction term is included in the regression. Borensztein, De Gregorio and Lee (1998) obtain the same result using a standard economic growth regression. They argue that the negative coefficient is likely to be the result of a linearization of what is probably a nonlinear interaction between FDI and human capital. The authors claim that when the absorptive capacity is very low the effects of FDI are likely to be close to zero but when the level of absorption increases the effects become large very rapidly. Accordingly a linear regression will fail to capture this exponential relationship and so it will give the intercept a negative coefficient for levels of human capital that are equal to zero. What is important from this result, however, is the idea that the flow of advanced technology brought along by FDI can generate efficiency gains only by interacting with the countrys absorptive capacity. In fact, the country needs to exhibit a minimum level of absorptive capacity for enjoying productivity gains from FDI. The values of the coefficients in this regression indicate that all countries with secondary enrollment ratios above 7% will benefit from FDI. It should be noticed that all the developing countries in the sample have a gross secondary enrollment rate higher than 7%.[7]

We now turn to the results in Table 3. This table shows the same set of regressions as in Table 2, but in this case, the TFP series have been calculated using electricity consumption instead of physical capital to correct for capacity utilization. The results are very similar to the ones shown in Table 2 although the fit of the regressions and the levels of the significance improve substantially. One important result from these regressions is seen in columns (3.4) and (3.5). The interaction term of the R&D stock diffused through imports is not different from zero while the interaction term of the R&D stock diffused through FDI is positive and significant. The result seems to suggest that an appropriate level of absorptive capacity is more important for the technology that is diffused through FDI than for the technology that is diffused through the imports of capital goods. Once again, the coefficient for the foreign R&D capital stock weighted by FDI turns negative when the interaction term is included in the regression. This reinforces the thesis of a minimum threshold in the absorption capacity. According to the results, the threshold is equal to 0.19 meaning that the gross secondary enrollment ratio should be equal to 19% or higher for the countries to benefit positively from FDI. Again, all the developing countries in the sample have an enrollment ratio higher than 19%.

So far, we have argued that the amount of technological knowledge in the North is a function of the past and current amount of expenditures in R&D. Therefore, we have used the accumulated sum of R&D expenditures to proxy for the stock of technological knowledge that is originated in the North. For any country in the North, however, an increase in its stock of technological knowledge should be also associated with an increase in its own productivity level. Therefore, the level of TFP in the country should reflect its capacity to innovate and to generate new technological knowledge. For this reason, we are going to use, as an alternative specification, the TFP levels of the industrial countries instead of the stocks of R&D expenditures. In order to do this, equations (3) and (4) are substituted by:

$$S_i^m = \sum_{j \neq i} \frac{M_{ij}}{Y_i} TFP_j \tag{9}$$

$$S_i^{fdi} = \sum_{j \neq i} \frac{FDI_{ij}}{Y_i} TFP_j \tag{10}$$

where refers to the level of TFP of the industrial country *j*. Results are reported

[7]The average of the sample is 55%

Table 4. Estimation Results

Variable	(4.1)	(4.2)	(4.3)	(4.4)	(4.5)
$\Delta(\log S^m)$	0.1065 (3.43)***	0.0936 (2.77)***	0.0844 (2.71)***	0.0661 (2.43)**	0.0981 (2.95)***
$\Delta(\log S^{fdi})$	0.0136 (2.40)**	0.0119 (2.10)**	0.0125 (2.36)**	0.0124 (2.30)**	-0.0061 (0.54)
$\log(Y_i/Y_k)$		-0.0522 (1.37)+	-0.0531 (1.32)+	-0.0531 (1.33)+	-0.0516 (1.37)+
Δh			0.3448 (1.15)		
$\Delta(h\log S^m)$				0.0372 (1.07)	
$\Delta(h\log S^{fdi})$					0.0299 (1.96)**
R^2	0.21	0.28	0.33	0.33	0.29
R^2 *adjusted*	0.17	0.23	0.28	0.27	0.24
# of obs.	66	66	66	66	66
Threshold.					0.20

TFP is calculated using electricity consumption to proxy for capital utilization. The domestic R&D capital stocks of the OECD countries are replaced with the TFP levels of the OECD countries. See equations (9) and (10)

in Table (4). It can be seen that the estimations are very similar to those reported in Table (3). Therefore, the exercise serves to confirm the validity of the previous findings.

Cumulative FDI

Our measurement of foreign R&D stocks, in equation (4), use inflows of FDI as a weight to construct the stock of technological knowledge that is acquired via multinational activity. This specification, although appropriate to capture the stock of R&D that flows during a particular year, does not take into account the stock of knowledge that was captured in previous cumulative FDI. In this section, we seek to control for the overall absorption of foreign technological knowledge that takes place overtime through the accumulation of FDI. Therefore, in the weighting scheme of equation (4), we use cumulative FDI instead of flows. The stock of FDI is constructed using the perpetual inventory method with a depreciation rate equal to 5%.

The results are reported in Table 5. Using FDI stocks instead of flows does not change the outcome from the previous findings in any particular way. All the

Table 5. Estimation Results

Variable	(5.1)	(5.2)	(5.3)	(5.4)	(5.5)
$\Delta(\log S^{m})$	0.1056 (3.68)***	0.0895 (2.88)***	0.0842 (2.87)***	0.0671 (2.73)***	0.0915 (3.08)***
$\Delta(\log S^{fdi})$	0.0110 (1.98)**	0.0096 (1.65)**	0.0094 (1.91)**	0.0094 (1.88)**	-0.0098 (1.13)
$\log(Y_i/Y_k)$		-0.0508 (1.39)+	-0.0510 (1.32)+	-0.0511 (1.33)+	-0.0508 (1.41)+
Δh			0.3472 (1.21)		
$\Delta(h\log S^{m})$				0.0336 (1.19)	
$\Delta(h\log S^{fdi})$					0.0330 (2.50)**
R^2	0.19	0.26	0.31	0.30	0.29
R^2 *adjusted*	0.15	0.21	0.25	0.24	0.23
# of obs.	65	65	65	65	65
Threshold.					0.30

TFP is calculated using electricity consumption to proxy for capital utilization. The FDI-weighted foreign stocks of R&D are calculated using FDI stocks instead of flows.

results reported in Tables 3 and 4 remain essentially the same. The signs of the coefficients are not modified and their magnitude and significance are very similar to those previously reported. This provides further empirical evidence to the FDI channel confirming the previous analysis.

V. Concluding Remarks

This paper uses an econometric estimation based on a theoretical framework that links innovation activity and productive efficiency gains to measures the extent to which flows of foreign direct investment and imports of capital goods from industrialized countries generate productivity gains in developing countries.

The results provide strong evidence that developing countries benefit from the flows of technology that are diffused via imports of capital goods and FDI from developed countries. Although the evidence is stronger for the imports of capital goods, both channels seem to have a positive impact in the productivity of developing countries.

The results provide empirical evidence that developing countries with higher levels of absorptive capacity exhibit higher efficiency gains from the adoption of foreign technology. The absorptive capacity is more important for the technology that is acquired through the flows of FDI than for the technology that is acquired through the imports of capital goods. Moreover, there seems to be a minimum threshold in the level of absorption below which the positive effects of FDI cease to exist. There is no evidence that a minimum level of absorption exists for the case of imports.

The results show the importance of North-South schemes of integration for technology transfers. As long as this type of integration leads to higher volumes of imports of capital goods and larger flows of FDI from developed to developing countries, the countries in the South gain in productive efficiency because through these flows they have access to larger stocks of technological knowledge from the North.

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