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International technology diffusion and economic growth: Explaining the spillover benefits to developing countries

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ABSTRACT

Technology spillovers offer great opportunities for economic growth to developing countries that do little, if any, R&D activity. This paper explores the extent to which these countries benefit from foreign technology, the diffusion mechanisms involved, and the factors that shape their absorption capabilities. Results based on a non-stationary panel of 55 developing countries indicate that the benefits are quite substantial: a ten-percent increase in foreign R&D stock is translated into more than a two-percent increase in aggregate productivity. Of the diffusion channels considered, imports appear to be more conducive to R&D spillover. In addition, developing countries that enjoy larger benefits tend to exhibit larger stock of human capital, more openness to trade and foreign activities, and stronger institutions. These North–South R&D spillovers, although larger than previously suggested, appear less strong than North–North spillovers, adding to the general literature on economic divergence between developed and developing countries.

1. Introduction

The new growth theories developed in the early 1990s that suggest that innovation is the major source of technological advance (which in turn drives economic growth), have sparked a large body of empirical research with the aim to measure the extent to which investment in Research and Development (R&D) promotes sustained expansion of nations' production capabilities. A key finding has been that these investments, which result in new technologies, processes, products, and materials, benefit not only domestic countries which perform such activities, but also their foreign counterparts. For example, Coe and Helpman (1995), focusing on developed countries, have shown that the long run rate of return on R&D investment was 120 percent for the performing countries and an additional 30 percent for their trading partners, in terms of increased total factor productivity (TFP).

International technology spillover, which occurs in part through import and foreign direct investment (FDI) channels (Keller, 2004), offers great opportunities for economic growth to developing countries that do little, if any, R&D activity. These countries seem to be trapped in a vicious circle of insignificant R&D activity that would otherwise fuel the engine of economic growth, and the lack of significant economic progress provides very weak incentives to develop a knowledge production sector. In effect, most of them have been struggling for decades to improve their economic conditions, and often times, the results have been so disappointing that some referred to them as the "economic tragedy of the XXth century" (Vila-Artadi and Sala-i-Martin, 2003). Therefore, one development strategy

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could consist of looking at different ways to enable these countries to benefit from international technology diffusion.

This paper sets out to explore the extent to which developing countries gain from technology spillover, and the factors that explain the potential heterogeneity in their absorption capabilities. The influential work by Coe and Helpman (1995) has generated a fair amount of follow-up research that aimed at deepening the understanding of technology spillover.[1] The literature has been extended into a couple of directions (Coe et al., 2008): the measurement of foreign R&D capital stock to account for the different diffusion channels, the model specification (controlling for additional relevant factors that explain the spillover mechanism), and the econometric techniques used (panel cointegration).

Despite the large body of empirical works, little attention has been paid to developing countries; most of the contributions look at North–North technology spillover. One of the few papers that focus on North–South spillovers is Coe et al. (1997). Using a dataset of 22 developed countries as in Coe and Helpman (1995), along with 77 developing countries, the authors show that the latter can substantially benefit from the stock of knowledge developed in advanced countries. A key finding suggests that a ten-percent increase in the R&D capital stock in developed countries generates a 0.6-percent increase in TFP in developing countries. The only diffusion channel considered is imports of machinery and equipment. The results also suggest important differences in developing countries' gains from foreign R&D: more open countries where trade is more oriented towards developed countries that do more R&D are the ones that tend to gain the most from technology externalities (e.g. Latin American countries vis-a-vis the US).

The paper addresses some limitations to Coe et al. (1997) in studying North–South technology spillover, and to a lesser extent to other papers in the technology spillover literature. First, it considers two of the many diffusion channels, namely imports and FDI, allowing for the determination of which channel is more conducive to R&D spillover. Second, besides openness to trade and human capital, additional sources of heterogeneity in the spillover gains are considered, such as social and economic institutions: the World Bank ease of doing business, the index of patent protection, and the historical origin of the legal systems. Last, the paper considers more advanced econometric techniques in the panel cointegration econometrics, the so-called second generation panel unit root tests and the estimation methods that outperform the regular OLS method by addressing the potential endogeneity of the regressors and the serial correlation in the error term – all of which that were not fully worked out at that time.

A dataset of 55 developing countries and the seven most-industrialized countries (G7) is considered. A panel cointegration model is developed that relates TFP to foreign R&D capital stocks, as well as different interactions to allow for heterogeneity in the absorption and assimilation of foreign technology. Because the paper is interested in import- and FDI-related spillovers, the foreign R&D capital stock is constructed using alternatively bilateral import of machinery and equipment and FDI shares as weights. The statistical inference is based on the Fully Modified Ordinary Least Squares.

The paper suggests the following key results. The R&D spillover gains are quite substantial. Both import and inbound-FDI are significant channels through which technology diffuses from advanced to developing countries, and most of the gains are carried through the first channel. In addition, the benefits are more substantial than the results from Coe et al. (1997) indicate, but less than the results from North–North technology spillover. Furthermore, the differences in the spillover gains among developing countries appear to be attributable to factors such as human capital, openness, and institutions.

The remainder of the paper is organized as follows. The next section introduces the empirical model. Section 3 describes the data and some key features derived from them. Section 4 presents both the test results related to the use of non stationary panel and the empirical evidence on how developing countries gain from technology spillover. Section 5 offers a summary and some concluding remarks.

2. Empirical methodology

To measure the extent to which developing countries benefit from R&D activity in advanced countries and analyze the potential sources of heterogeneity in their absorption capabilities of technology spillover, a non-stationary panel model is considered. This technique has become very popular in analyzing issues related to the economic performance of countries in the long run. The next subsection provides some theoretical background on how the benefits of R&D activities spill over onto foreign countries. The empirical model is presented afterwards, and then some details on the panel cointegration techniques (panel unit root testing, cointegration testing, and estimation) are offered.

2.1. Theoretical background

Prior to the early 1990s, which saw the emergence of the so-called "new" growth theory, technology was also viewed as a major source of economic growth not only for countries that experience its development, but also foreign countries because of the externalities it generates. But the treatment of this major component of growth was quite unsatisfactory in early growth theories. For instance, in the neoclassical growth model developed in the 1950s, technology progress was considered as exogenous, therefore providing no room for economic policy that would aim at increasing the domestic knowledge stock either by encouraging a domestic R&D sector or by developing the absorption capacity of foreign ideas.

[1] This literature is based on the foundations of the endogenous growth theories. However, economists have long recognized and well documented the importance of international R&D spillovers, especially in the context of economic convergence. Some key contributors to the early literature include Z. Griliches, M. Abramovitz, P. Mohen, F. Scherer, to name but a very few.

Nevertheless, the importance of R&D spillovers was recognized in explaining for instance why developing countries were not catching up to technologically advanced ones. The idea of R&D spillover refers to the benefits gained by a country or an industry from "process-oriented" innovation or "product-oriented" innovation of its foreign partners. While the type of innovation typically lowers the unit costs of production of a given good, the second type aims at producing either new goods or better quality varieties of already existing goods. Following this typology, Griliches (1979) suggested two types of R&D spillover: "rent spillover" and "knowledge spillover". The former comes about when knowledge-embodied inputs are purchased at a price that does not fully reflect their quality improvement (i.e. an improved price–quality ratio). It therefore has more to do with price determination, and is not circumscribed to capital equipment and materials. What are considered as true spillovers are knowledge spillovers. This is the case when an industry or a country benefits from research results from another industry or country, and it does not necessarily involve a purchase of productive inputs. More generally, two types of knowledge spillovers can be distinguished. The first is "imitation-enhancing," referring to the case in which imperfectly protected codified knowledge ends up being obtained and imitated by other innovators. The second is "idea-creating," and is based on the premise that the accumulated knowledge stock is an important input in the production of new knowledge or ideas.

In practice, however, it can prove difficult to disentangle between rent spillover and knowledge spillover. One example would be a firm purchasing an input that embodies newly developed technology at less than its full "quality" price. The firm has benefited from both types of R&D spillover, but sorting out the two is a difficult empirical task, especially when considering the issue at the aggregate level. Fortunately, the evidence seems to suggest that most of R&D activity is "product-oriented," and subsequently, most of the R&D spillovers are "knowledge spillovers", especially to the extent that "process innovation" has a larger propensity to get protected than "product innovation" (see Los and Verspagen, 2007, for an in-depth discussion). By technology spillovers, this paper primarily refers to knowledge-type spillovers, more specifically imitation-enhancing spillovers which play a major role in productivity growth. But due to many difficulties in separating the different types of spillovers, the paper also recognizes that the results may be "contaminated" (to a lesser extent, hopefully) by the effects of rent spillovers.

In order to benefit from foreign R&D activities, a country must develop a strong "absorptive capacity" (Cohen and Levinthal, 1989), which refers to the same "absorbing social capability" (Abramovitz, 1986) that explains both why backward countries lag behind the technology frontier and why they fail to assimilate and exploit foreign technology. The learning capability of a country depends greatly on factors such as social institutions (Abramovitz, 1986), technical competencies or the level of education (Baumol et al., 1989), the level of infrastructure and capital intensification of the economy (Verspagen, 1991), the economic similarities between the sartorial activities in both leading and following countries (Pasinetti, 1981), and the political, commercial, industrial, and financial institutions (Abramovitz, 1986).

One important implication of these views is that if foreign backward countries do not have significant and relevant absorption capabilities of new knowledge, technology will not spill over among countries. This is in sharp contrast to the implicit intuition that underlies the convergence hypothesis as inspired by the neoclassical growth theory, which assumes that international technology diffusion takes place automatically. Such an assumption is viewed as heroic (Dosi, 1988). The success of diffusion depends critically upon receiving countries investing in human and institutional capital (Westphal et al., 1985). The well-documented divergence in relative productivity levels and living standards between advanced capitalist countries and less developed countries (Pritchett, 1997) tells a lot about the relatively weak capability of the latter to assimilate technological knowledge developed by the former. One reason why backward countries fail to develop significant absorption capacity and catch up is that incumbent political elites may actually oppose any sources of major change and block economic development if it erodes their advantages (see Gerschenkron, 1962, for a historical perspective, and Acemoglu and Robinson, 2006, for a political perspective).

The advent of the new growth theories offers a renewal of interest in the R&D spillover literature. By considering technology development as an endogenous process, they suggest a more interesting framework for analyzing how countries manage to generate new knowledge, and how newly developed technology diffuses to their economic partners. Helpman (2004) provides a detailed review of these theoretical innovation-driven growth models. Some of the key channels through which technology diffusion takes place are trade and foreign direct investment. International trade makes available new goods that embody foreign knowledge. One theoretical approach analyzing these spillover benefits through the import channel suggests the quality ladder assumption (Aghion and Howitt, 1991): investments in new knowledge improve the quality of the existing intermediate inputs or capital goods, which then become vertically differentiated. Consequently, by importing these knowledge-embodied inputs, the economy can enjoy an increase in the aggregate productivity (TFP).

A second approach puts forth the love of variety assumption (Romer, 1990). It suggests that the R&D efforts lead to an increase in the amount of horizontally differentiated inputs. Again, by importing these newly developed goods from the R&D performing countries, a country will be able to increase its production possibilities.

As for the FDI diffusion channel, it enables a host country to develop a contact with more technologically advanced partners. By so doing, it provides a platform for learning opportunities through which the economy gets access to more efficient production processes. One way the technology gains could occur is through the increased competition that comes with the arrival of foreign firms. In this new intense competition environment, domestic firms will then have to come up with a response strategy to the technology differential, which could be either to imitate the foreign firms' production processes, or acquire the technology-embodied inputs they use (Holmes and Schmitz, 2001). Another way FDI can generate technology spillover is through labor turnover. Former workers in technology-advanced foreign firms or their domestic affiliates (e.g. R&D employees) bring with them their new skills and know-how to the domestic firms. In the context of relatively strong mobility in the domestic labor market, these gains can quickly spread to a significant part of the economy, hence benefiting to a large extent the economy as a whole in terms of increased productivity.

Other channels are also considered in the literature. As far as North–South R&D spillovers are concerned, knowledge transmission can occur via migration between developing and developed countries. It is expected that a country in the South can greatly benefit from workers or students they send to the North. This could be the case when, for instance, those workers or students return and actively participate in the economic development process. A perfect illustration is Meiji Japan between 1868 and 1912 when the country embarked into an international quest for knowledge, and later became a modern economic power. Other possible knowledge transmission channels are scientific exchanges (professional conferences, academic exchange program, etc.), and patent documents.[2] However, due to the many difficulties to trying to measure knowledge spillover gains through these channels (availability of reliable data on returning skilled migrants, the workforce involvement in scientific exchanges, etc.), the paper will focus solely on trade and FDI channels of international technology diffusion.

It is reasonable to expect different effects of import- and FDI-related spillovers on developing countries' TFP, with respect to the very same factors that shape their absorption capabilities. Differences in their international trade patterns, as well as the extent to which they are successful in attracting FDI could be translated into different levels of gains. In addition, as discussed above, one might also expect the heterogeneity in the spillover gains to depend upon differentials in human and institutional capital (Westphal et al., 1985). Human capital can be proxied by the level of education. As for countries' institutional framework, it can be approached through some of its key components, such as property rights protection or the legal traditions.

2.2. Empirical model

Empirical analyses of international technology diffusion are based on the concept of foreign R&D capital stock. The latter is defined as the weighted average of the domestic R&D capital stocks of the trading partners. The weighting scheme reflects the diffusion channel considered. In Coe et al. (2008), the weights are the bilateral import ratios, and they allow capturing trade-related R&D spillovers. As for the FDI-related spillovers, Van Pottelsberghe de la Potterie and Lichtenberg (2001) suggest using (inbound) FDI ratio as weights.

Some important empirical contributions that build on Coe et al. (1997) include Engelbrecht (1997) who points to the crucial role of human capital both as a source of productivity growth (directly affecting aggregate productivity) and as a determinant of countries' absorption capacity. Furthermore, Coe et al. (2008) showed that differences in institutions across (developed) countries determined to a large extent the absorption of technology spillover.

In line with these empirical developments, a series of specifications are considered. The first, dubbed the baseline specification, is as follows:

$$\log TEP_{it} = \alpha + \theta_t + \alpha^M \log S^M_{it} + \alpha^F \log S^F_{it} + \alpha^H \log H_{it} + \varepsilon_{it,} \quad (1)$$

where TFP_{it} stands for the total factor productivity of developing country i at time t, θ_t time-specific effects (common to all countries), S^M_{it} and S^F_{it} the stocks of foreign R&D available through the import channel and the FDI channel, respectively, H_{it} human capital (average years of schooling), and ε_{it} a well behaved error term. The functional form of the model (logarithmic) allows one to interpret the coefficients as elasticities, and it comes from the non linear Cobb-Douglas production function.

Foreign R&D capital stocks that account for each channel are constructed as follows:

$$S^M_{it} = \sum_{j=1}^{J} \frac{ME_{ijt}}{M_{it}} * S^d_{jt} \quad \text{and} \quad S^F_{it} = \sum_{j=1}^{J} \frac{FDI_{ijt}}{I_{it}} * S^d_{jt},$$

where S^d_{jt} is the domestic R&D capital of developed country j, ME_{ijt}, bilateral imports of machinery and equipment, M_{it}, total imports of goods and services, FDI_{ijt}, bilateral inbound FDI, and I_{it}, total physical investment. The domestic R&D stock in developed country j is constructed using the perpetual inventory method and allowing for depreciation:

$$S^d_{jt} = (1-d)S^d_{jt-1} + I^{RD}_{jt},$$

with d the depreciation rate (set to five percent), and I^{RD}_{jt} total R&D expenditures in country j.[3] The rationale behind this process of knowledge accumulation stems from the idea that newly developed knowledge improves our understanding of the economic process as well as our ability to stretch the aggregate production domain. The inclusion of the depreciation recognizes that over the course of technology development, new ideas can make prior ones obsolete or less valuable, and the resulting effect is a lower marginal gain.

To analyze why some developing countries may gain more than others from foreign R&D spillovers, namely the

[2] The well-known survey by Levin et al. (1987) on US firms identified some seven sources of knowledge diffusion. Some of these channels are linked to knowledge spillovers (reverse-engineering allowed for instance by international trade on knowledge-embodied goods, labor mobility that is related to FDI), and others not (e.g. licensing, independent R&D).

[3] It is customary to set the depreciation rate under 15 percent, and evidence tends to suggest that the empirical results are robust to changes in the rate (see Helpman, 2004).

differences in the absorption capacities, the baseline model (1) is expanded in different ways. The potential sources of heterogeneity in the spillover gains to be explored are trade and FDI intensities, human capital accumulation, and institutional quality (e.g. ease of doing business, property rights protection, and legal origins). Let Z_{it} denote one of these conditions. Then the following expansion of specification (1) is considered:

$$\begin{aligned}\log\, TFP_{it} &= \alpha + \theta_t + \alpha^M \log S_{it}^M + \alpha^F \log S_{it}^F + \alpha^H \log H_{it} \\ &\quad + \alpha^{MZ}\left(Z_{it} * \log S_{it}^M\right) + \alpha^{FZ}(Z_{it} * \log S_{it}^F) \\ &\quad + \alpha^Z Z_{it} + \varepsilon_{it}. \qquad (2)\end{aligned}$$

The estimated coefficients on the multiplicative interaction terms would tell whether spillover gains are conditional upon countries characteristics. Following the methodological requirements that apply to models with interaction terms, all constitutive terms are included in the model specifications (whenever possible), and substantively meaningful estimates of the marginal effects and their standard errors are provided (Brambor et al., 2006). Conditional variables that are time invariant such as EDB_i and $LEGALBR_i$ are not included as stand-alone explanatory variables (it is even impossible to apply the IPS and LLC stationarity tests).

In a more general case of models with one multiplicative interaction term with the following specification: $y = \beta_0 + \beta_1 X + \beta_2 Z + \beta_3 XZ + \varepsilon$, the conditional marginal effect is $\partial y/\partial X = \beta_1 + \beta_3 Z$, and the variance is $\sigma^2_{\partial y/\partial X} = Var(\beta_1) + Z^2\, Var(\beta_3) + 2Z\, Cov(\beta_1 \beta_3)$. As specified, both the marginal effect and the standard error depend on the values of the modifying variable Z. Therefore, one needs to compute both statistics for all possible values of Z. In such circumstances, a graph showing the prediction of the marginal effect as well as its confidence interval would be more informative, at least for continuous modifying variables (i.e. import and FDI stock ratios, human capital, and index of patent protection). For discrete modifying variables (ease of doing business and legal tradition), the conditional marginal effects and the standard errors are computed for each modality (0 and 1).

2.3. Empirical methods

The econometrics of panel cointegration involves first testing for unit root process and cointegrating relationships, and then estimating the model. Recent developments in the cointegration literature have led to what is known as the second generation panel unit root tests. By far the most commonly used test procedures are Levin et al. (2002, LLC henceforth), and Im et al. (2003, IPS henceforth). These tests generalize the times series ADF equation to panel data. Both LLC and IPS tests assume that all series are non stationary under the null hypothesis. They differ in how they define the alternative hypothesis: while LLC imposes the same dynamics across the units, the IPS procedure allows for heterogeneity in the short run dynamics. Because of these different treatments of the cross sectional units, LLC is known as a homogeneous test, and IPS a heterogeneous test.

If the data-generating process of the variables turns out to be a panel unit root, then the next step is testing for panel cointegration. If the variables have a long run relationship, the residuals from the estimation of this relationship have to be stationary. Running a regression based on non-cointegrating relationships leads to spurious estimations. In such a case, the correlation generated by the regression is due to other variables (confounding or lurking variables) that influence those in the model, instead of a real causal relationship. Various panel cointegration tests have been suggested, and they are based on their time series counterparts. Pedroni (1999, 2004), Kao (1999), and Larsson et al. (2001) extended the Engle and Granger (1987) time series framework to panel data. They are residual-based tests.

Comparison among the panel cointegration tests is often based on the time length of the data. For example, Gutierrez (2003) has demonstrated that, in the case of small (high) time dimension, Kao test has higher (lower) power than the Pedroni test, and both tests show higher power than the Larsson et al. test. In addition, while the Pedroni tests can only be applied to a number of series no greater than six, the Kao test is more general. The latter also assumes individual specific intercept terms and homogenous coefficients in the first stage. Under the null of no cointegration, the test statistic is shown to converge asymptotically to the standard normal distribution. Results from both panel unit root and cointegration tests determine the variables to be considered in the model; that is, the cointegrating relationship.

When developing an estimator for a panel-cointegration model, two issues generally arise: a potential endogeneity of the regressors, and a heterogeneity of the variance–covariance matrix (e.g. serial correlation). As a consequence, the regular OLS method tends to generate biased coefficient estimates, and the standard test statistics (e.g. t-statistics or F-statistic) become irrelevant. One of the estimators that have been suggested as an alternative is known as the Fully Modified Ordinary Least Squares (FMOLS). It was first developed, as it is often the case, in the times series context. Pedroni (1996) first generalized it to panel data framework.[4] The central theme of the FMOLS estimation strategy was to "pool only the information concerning the long run relationship", and "allow the short run dynamics to be potentially heterogeneous." Three versions of this estimator have been developed: residual-FM, adjusted-FM, and group-FM. While the first two pool the data along the within dimension, the latter does so along the between dimension. Based on their performance in finite samples, the group-FMOLS has more desirable properties, and it is associated with lower size distortion. Phillips and Moon (1999) have proposed a version which asymptotic properties are derived from joint limits, in contrast to the previous estimators that are based on sequential limits.

[4] The time series counterpart was proposed by Phillips and Hansen (1990) as a way to deal with the same issues of inefficiency and inconsistency. The former is brought about by serial correlation, while the latter is a consequence of endogeneity.

This estimator has been opposed in the econometric literature to the Dynamic OLS (DOLS) estimator. While FMOLS uses a non-parametric technique, the DOLS estimator is essentially a parametric approach, and the model specification basically adds lags and leads of the independent variables. Furthermore, both FMOLS and DOLS estimators have the same limiting distribution, but they perform differently in finite samples. The DOLS estimator appears to improve the properties of the simple OLS more so than the FMOLS does. But a main drawback is its higher sensitivity to the leads and lags of the regressors. More importantly, in a panel setting with relatively small time dimension and many regressors, a large number of lags and leads are synonymous of significant loss of degrees of freedom. In that sense, the use of the DOLS estimator appears to be more conditional on the length of the data.

3. Data and variables

The data collected cover 55 developing countries: 21 from Africa, 19 from Latin America, and 15 from Asia and the Pacific region. Data availability is the main constraint to the choice of countries in the sample. The developed countries considered are the seven most industrialized ones (G7). These technologically advanced countries account for a large part in the world R&D activity. Among the 21 OECD countries that the literature often uses to study spillover within the developed world, the G7 countries accounted for about 70 percent of total R&D expenditures in 2004.[5] In addition, they have developed a dense web of economic ties with a larger range of developing countries, which ensure more availability of data for developing countries, especially with respect to bilateral imports and FDI, and foreign R&D capital stock. The time period spans from 1980 to 2006.

The TFP variable is computed using the common approach known as the development or growth accounting method.[6] It assumes a functional form for the production function (e.g. Cobb-Douglas), and then computes TFP as a residual:

$$\log TFP_{it} = \log Y_{it} - \alpha \log K_{it} - (1-\alpha)\log L_{it}.$$

Y_{it} represents real GDP of developing country i in year t, K_{it}, the physical capital stock, L_{it}, the labor force, α, the capital income share in GDP (set to one third). The capital stock is obtained through the perpetual inventory procedure:

$$K_{it} = (1-\delta)K_{it-1} + I_{it}.$$

δ is the depreciation rate (set to one tenth), and I_{it} the gross fixed capital formation.

Human capital is measured as the average years of schooling of people over 25 years old. Barro and Lee (2000) provided quinquenial statistical information on schooling for many countries up to 2000. Interpolation is used to fill in both the years in between each 5-year segment and to forecast for the most recent years (2001–2006). This interpolation assumes constant rate of growth over a given sub-period, and the rate in the 1995–2000 period is used for the post-2000 years.

Institutional variables include the ease of doing business, the index of patent protection, and the historical origin of the legal systems. The World Bank index that summarizes the ease of doing business includes a large variety of factors that could possibly influence the economic decisions along with the performance of both domestic and foreign firms, with actual or potential ties with the economy. Launched in 2003, the index is a comprehensive measure of a wide range of jurisdictions that tell about government regulations. It covers among others trade across borders, protection of investors, and registration of properties. The updated index of patent protection by Park (2008) offers a measure of the strength of intellectual property rights protection. For the origin of the legal systems, about 96 percent of the countries in the sample have either the British or the French (or more generally Roman) legal tradition. So the variable will allow a comparison between the British common law and the French civil law. Except for the index of patent protection, the other two variables are time invariant. For the ease of doing business, the ranking in 2004 is considered.

Tables 1 and 2 provide some descriptive statistics. While the first summarizes the evolution and structure of the domestic R&D stock of the G7 countries, the latter describes the data for the 55 developing countries.

Over the period 1980–2006, advanced countries have been investing a significant amount in the production of new knowledge. For countries like Canada, Italy, Japan, and the US, total spending on R&D has more than tripled. In most of the countries, this effort in the production of new ideas is so important that the resulting increase in the domestic R&D capital has outpaced the increase in the physical capital (in all countries except France). Furthermore, the business sector, which is more oriented to applied research, accounts for more than two-thirds of the investment effort. In countries like Japan and the US, business R&D represents more than 70 percent of the total investment. In addition, the business and high education sectors are the ones that have enjoyed the highest increased over the period.

These features of the R&D activities in developed countries may have some implications in terms of the magnitude of the spillover gains. It could be more beneficial to strengthen the economic ties (e.g. trade and FDI) with countries that devote more effort to the development of new technology. Because most of the R&D expenditure is performed by the business sector, it could be more rewarding to find ways to attract those firms that are involved in the production of new knowledge.

In Table 2, the descriptive statistics show, for each variable, the average across each one of the three regions, as well as the figures for the whole sample. Overall, the foreign technology stock has increased everywhere from 1980 to 2006. This is an indication of the combined efforts by developed countries to invest more in new technology and by developing countries to open up their economies to international trade and foreign activities. In addition, the increase in the foreign stock is more pronounced through the FDI channel, with a factor of more than three on

[5] Own calculation from OECD data.

[6] Abramovitz (1956) was the first to suggest this methodology, but Solow (1957) made it a powerful empirical instrument.

Table 1
Domestic R&D capital stock of the G7 countries: evolution and structure.

	Business		Government		High education		All sectors	
	S^d_{06}/S^d_{80}	*Share*	S^d_{06}/S^d_{80}	*Share*	S^d_{06}/S^d_{80}	*Share*	S^d_{06}/S^d_{80}	*Share*
Canada	4.76	55.19	1.83	14.07	1.40	30.39	4.00	100.00
France	2.93	61.66	2.74	19.61	2.48	17.55	2.82	100.00
Germany	2.48	68.65	2.07	14.10	1.66	17.42	2.27	100.00
Italy	3.14	52.00	1.98	20.98	5.88	26.60	3.26	100.00
Japan	5.45	70.35	1.95	9.70	1.94	17.23	3.98	100.00
U.K.	1.65	63.01	0.48	23.11	2.57	18.67	1.44	100.00
U.S.	3.27	70.63	1.75	13.99	4.01	12.09	3.05	100.00
Sample	3.57	68.11	1.84	14.28	3.10	15.63	3.09	100.00

Source: OECD.
Notes: The evolution is measured by the ratio of the value in 2006 to the value in 1980. The structure is given by the percentage share in the total R&D for each sector in a given country for the year 2006. A fourth sector (Private Non-Profit Organizations) is not considered due to lack of data.

average, against two for the import channel. However, in level terms, foreign R&D stock available through the import channel is much higher than foreign stock available through the FDI channel.

African countries appear to have gained less both in terms of increase in and level of foreign R&D. This has gone hand in hand with a lower performance in terms of economic growth, with an increase in TFP by less than two percent, most of which occurring after the mid-1990s. The largest improvement in human capital has more to do with the lower starting point of the countries than real social or economic achievements. In such a case, small increases tend to be magnified in terms of larger rates of growth.

Latin American countries have enjoyed the largest increase in their foreign R&D capital, both through the FDI and the import channel (by factors of 3.02 and 4.18, respectively), but in level terms, Asian countries have done better. These large increases can be explained by the effort to open up their economies. In effect, the import ratio has increased by 89 percent over the period, and most importantly, their FDI stock has very significantly increased by a factor of more than 21, which corresponds to almost 2100 percent. The large increase in foreign R&D stocks could also reflect their technology proximity to the center of the world technology, namely the US. In effect, in 2006, total R&D investment effort of the latter was larger than the combined effort of the other advanced countries (3.8 percent higher), and it accounts for nearly half of the G7 countries' R&D stock (48 percent), from only about 14 percent in the early 1980s.

As for Asian and Pacific countries, their quite remarkable economic performance (more than 62-percent increase in TFP, on average) has been accompanied by significant efforts to improve the quality of their institutions. The strength of the property rights' protection has increased significantly, which has contributed to a good ranking according to the World Bank ease of doing business (more than 70 percent of the developing countries in the top half are from that region). Additionally, more than half of them have the British common law legacy, which is generally viewed as more oriented towards better market outcomes than the French civil law.

These stylized facts suggest some hypotheses about some of the explanations of why some developing countries may have benefited more than others from technology spillover. First, one may expect the effects of trade- and FDI-related technology spillovers on domestic TFP to differ with respect to their trade and inbound FDI patterns. Second,

Table 2
Summary statistics for developing countries, by regions.

	Africa	Latin America	Asia-Pacific	Sample
TFP	1.019	1.056	1.623	1.197
S^M	1.633	3.015	1.683	2.097
	(1.31E+08)	(1.76E+09)	(3.66E+09)	(1.66E+09)
S^F	2.649	4.175	3.652	3.449
	(9.44E+05)	(1.75E+07)	(1.12E+07)	(9.46E+06)
Human capital	2.479	1.378	1.189	1.747
	(3.19)	(6.18)	(4.78)	(4.66)
Import ratio	1.484	1.892	2.181	1.815
	(33.78)	(37.55)	(43.90)	(37.32)
FDI stock ratio	9.102	21.771	7.143	12.944
	(158.57)	(211.58)	(215.43)	(192.38)
IPP	1.578	2.811	1.637	2.020
	(2.76)	(3.40)	(3.03)	(3.06)
EDB	21.053	57.895	73.329	100.00
LEGALBR	42.105	5.263	53.334	32.44
Count	21	19	15	55

Notes: Figures represent the ratio of the value in 2006 to that in 1980, and those between parentheses the levels in 2006, except for *EDB* and *LEGALBR* that show the percentage of countries within the region that are ranked in the top half according to the index of the ease of doing business, and the percentage of countries with the British legal tradition, respectively.

Table 3
Panel unit root test results.[a]

	IPS		LLC	
	W[*t*-bar]	*P*-value	*t*-Star	*P*-value
log *TFP*	2.055	0.980	−0.176	0.429
log S^M	−1.239	0.108	−1.145	0.126
log S^F	−0.544	0.293	−0.179	0.429
log *H*	−1.418[*]	0.079	−0.343	0.366
m_gdp	−1.359[*]	0.087	−0.554	0.290
fdistok_gdp	4.557	1.000	−0.169	0.433
IPP	−1.168	0.122	−1.292[*]	0.098

Notes: Columns IPS report the Im et al. (2003) weighted *t*-bar statistic (also known as Psi-bar), and LLC the Levin et al. (2002) *t*-star statistic, as well the corresponding *P*-values. Under the null hypothesis of non-stationary data-generating process, both test statistics are distributed standard.

[a] All interaction variables considered in the different specifications also show a panel unit root.

[*] Denotes a significance at 10% level.

Table 4
Estimation results for the baseline model.[a]

	Coefficients
log S^M	0.1858[***]
	(0.009)
log S^F	0.0513[***]
	(0.008)
log *H*	0.0389[*]
	(0.023)
Intercept	2.6885
	(0.154)
N	1485
F-Stat.	342.44

Notes: The dependent variable is log *TFP*. The standard errors are in parentheses.

[a] The issue of the sources of funds for the R&D activities (business, government, and high education) is dropped following a suggestion made by one referee. Although business R&D tends to be more applied, the results in a previous draft indicate no clear answer as to which of the three types of R&D is associated with more spillover benefits.

[*] Significance at 10%.

[**] Significance at 5%.

[***] Significance at 1%.

more open countries can be expected to gain more, especially from the import channel. Third, while countries with larger human capital and much easier framework for business activities may benefit more through both channels, countries with stronger patent protection could mainly gain through the FDI channel.

4. Results

Table 3 provides the results of the LLC and IPS panel unit root tests. As the results show, both test procedures point to the conclusion of panel unit root. Where conflicting results do exist, only one barely fails to reject the null of the panel unit root process. The next step then consists of testing for panel cointegration.

The cointegration tests broadly reject the null hypothesis of no cointegration (results are shown in Appendix A). Few conflicting results do exist between the seven statistics of the Pedroni tests and the Kao ADF statistic. But in most cases, more than half of the tests point to the same favorable conclusion: that the series do share a common trend in the long run.

4.1. Technology spillover: the baseline estimation

The results of the baseline model in Table 4 first indicate that the spillover gains are quite substantial. The import channel is associated with an (unconditional) elasticity of more than 0.18, meaning that a ten percent increase in a developing country's foreign R&D stock is translated into more than 1.8 percent increase in its aggregate productivity. These gains are quite large compared to Coe et al. (1997) which find no significant direct gains through the import channel; all of the benefits being conditional upon some openness to trade. The differences could be due in part to the estimation techniques, as the panel cointegration techniques were not fully worked out at that time. Another possible reason is their regression analysis they used might suffer from an omission bias. In fact, the authors considered only one diffusion channel (namely imports) and ignored the FDI channel.

Compared to North–North R&D spillovers, these North–South gains appear smaller though. For instance, in Coe et al. (2008), the elasticity of TFP with respect to foreign R&D capital is estimated to be 0.30. Despite differences in the approaches used in the construction of foreign R&D stocks and the statistical inferences, one would expect such a result. In effect, trade ties among advanced countries are in general much stronger than those between developed and poor developing countries. Consequently, advanced countries tend to exhibit larger stocks of foreign R&D and, more importantly, stronger absorption and assimilation capabilities than their developing counterparts.

Table 4 shows the estimation results for the baseline model. The results for the extended specifications models that include interaction terms are shown in Appendix A, as well as the plots showing the conditional marginal effects of foreign R&D capital (log S^M and log S^F) on aggregate productivity (log *TFP*).

As for the FDI channel, the associated gains are modest, with a corresponding elasticity of 0.05. As suggested in the early discussion of the spillover mechanisms, FDI constitutes a vector of knowledge transmission to the extent that workers that learn from foreign technologically advanced companies bring their knowledge and know-how to domestic firms. This mechanism assumes significant labor mobility. The small gains could however be an indication that labor turnover is not a significant feature in (most) developing countries' labor market.

Another key determinant of TFP is human capital. Countries with more educated labor force gain directly in terms of stronger economic performance. This finding is consistent with some approaches that treat human capital as an explicit argument in the production function (Mankiw et al., 1992), and others that consider an increase in human capital as an innovation that occurs outside the R&D sector (Engelbrecht, 1997).

4.2. Technology spillover: role of import and FDI intensities

Given that developing countries gain from foreign knowledge through both channels, this part of the empirical model explores whether more trade openness and more inbound-FDI are translated into larger gains. As the results indicate, more openness is associated with more R&D spillover gains through the import channel. In effect, as the import ratio increases, so too does the increase in TFP consecutive to a rise in foreign R&D capital available through the import channel, and the result is significant over the entire range of the import share. This result could reflect the availability of larger varieties of new products to more open economies. A broader base of new foreign technologies is more likely to benefit a country at a given level of learning and assimilation capabilities.

The results for FDI-related spillover also indicate a significant positive effect, although of a lower magnitude. In effect, the spillover gains associated with an increase in foreign R&D capital available through the FDI channel increase by only 0.0002 point as the FDI stock ratio increase by one percentage point. This result could indicate that a relatively small number of foreign companies are necessary to bring the bulk of foreign technology new to the domestic economy and from which local firms can learn. As FDI keeps increasing, any new foreign activities will not add very much to the existing stock, and will more likely bring redundant knowledge or ideas, which the economy has already absorbed and assimilated.

4.3. Technology spillover: role of human capital

Education is rightfully viewed as a key factor that shapes countries' abilities to absorb new technology. The results provide a strong support for that view. The effect of R&D spillover on aggregate productivity conditional on human capital not only rises as the latter increases, but it gets more and more significant, for both diffusion channels. For instance, as far as the import channel is concerned, a one percent increase in human capital raises the elasticity of TFP with respect to foreign R&D stock by 0.03 through the import channel, and by 0.02 through the FDI channel.

This strong result contrasts with Coe et al. (1997) who find that education has no significant effect on North–South technology spillover, despite the identical way of proxiing human capital, i.e. average years of schooling. This could be attributable to the sample differences (time period, and countries involved), the model specification and the estimation technique, or simply the way the conditional marginal effect is obtained. In Coe et al. (1997), unconditional marginal effects are wrongly interpreted as conditional marginal effects.

This result points to the well-documented crucial role of human capital in technological knowledge acquisition. Knowledge is not like any other public good, with respect to the non-excludability property. In effect, learning from others' research outcome often requires specific skills in the field or specialized knowledge. This "tacitness of knowledge" (Polanyi, 1966) often determines how far its diffusion can go. An important factor that contributes to strengthening country's learning skills is education. As suggested by the results, the larger the stock of human, the more able the labor force is in assimilating foreign knowledge.

An issue that often arises in measuring human capital is the accuracy of the proxy. Just counting the years of schooling may not precisely reflect the real ability of the labor force. An alternative approach, still focusing on education attainment, would be to also consider the quality of the educational systems. Coe et al. (2008) follow such a strategy in the context of developed countries, and show that human capital is indeed a key factor that strengthens the absorption capacity. This type of statistical information, when available for developing countries, would be more descriptive of the direct and indirect effect of human capital on aggregate productivity.

4.4. Technology spillover: role of institutions

Three institutional quality indicators are considered: the ease of doing business, the index of patent protection, and the historical origin of the legal system. Although they may not be viewed as totally separate, considering one at a time allows one to capture either the overall quality (ease of doing business), or to single out one aspect of the institutional framework which is of vital interest to technology diffusion (patent protection), or simply to analyze how the actual, broad social and economic institutions are shaped by the historical legacy.

4.4.1. Ease of doing business

This first institutional variable appears to play a significant role in technology diffusion. The results indicate that a developing country that guarantees a friendlier institutional environment to business activities is also the one that benefits the most from foreign technology spillover. As the conditional marginal effects show, the marginal gain is almost a 0.03 percent increase in TFP for countries that are ranked in the top half. All of these gains occur through the FDI channel. Of the ten sub-indices that make up the ease of doing business, only one is (at least directly) related to international trade, that is, "Trading across borders." The other elements ("Employing workers," for instance) tell about the strength of incentives provided to attract foreign investment (and the subsequent foreign technology), and, more importantly, the ease with which the labor force could move from foreign to domestic firms, contributing to the spread of new knowledge to the rest of the economy.

The ease of doing business has also been found to play a significant role in North–North technology diffusion, as in Coe et al. (2008). But since the authors do not account explicitly for the other channel, e.g. FDI, one may not conclude that the magnitude of the effect of this institutional variable is the same for both developed and developing countries. We could reasonably expect a larger payoff to a developing country from an improvement in its overall institutions. The developing world is characterized both by the lower quality of and larger heterogeneity in the institutional setting. While the G7 countries and other OECD members generally have a high ranking and tend to form a more homogenous group, the developing countries in contrast are more dispersed along any of the institutional sub-indices, and with a very few exceptions, most of them are in the bottom half. This suggests that developing countries may have more to gain than developed countries from a given improvement in the institutional quality. One may then hypothesize that augmenting the Coe et al. (2008) by accounting directly for the FDI channel would generate an R&D spillover effect lower than the one found here for developing countries.

4.4.2. Property rights protection

Strengthening property rights protection significantly contributes to countries' abilities to benefit from foreign technology through both import and FDI channels. The conditional marginal effects indicate that a one-point increase in the index of patent protection is translated into an additional marginal import-related spillover gain of 0.05 percentage point and an additional FDI-related spillover gain of 0.03 percentage point.

The literature that looks closely at the effect of property rights on knowledge production and diffusion often points to some non-linearities (Mazzoleni and Nelson, 1998). As far as following countries are concerned, one of the benefits of strong property rights protection is that, by encouraging a viable domestic R&D sector ("invention motivation" theory), it contributes to developing strong absorption capabilities of foreign ideas. In effect, the more domestic firms are engaged in R&D activities, the more able they are to assimilate and make a better use of foreign research proceeds, especially when the research areas are complementary. However, there are some costs associated with stronger property rights protection, one of which being the difficulty to copying or imitating foreign technology. But given the actually low level of protection offered by most of developing countries, the (net) positive effect from the estimation results could be interpreted as an indication that, on average, an increase in the index has delivered more good than harm. Despite some noticeable effort by some developing countries to actually provide more formal protection to patents, the enforcement may not be that effective in putting an end to copying and imitating, which could suggest that the actual cost, if any, may not be significant.

4.4.3. Legal traditions

This final part of the estimations explores the potential role of the historical origin of the legal systems in explaining the differences in the absorption capabilities of developing countries. The way in which the legal origin variable enters the model and the fact that most of the countries in the sample are either of British or French systems, allow one to compare between these two historical legacies, which also turn out to represent the most distinct approaches to laws and regulations. As the results clearly indicate, countries with the British legal origin appear to benefit more from technology spillover than countries with French legal origin. The gain differential is about 0.03 percentage increase in TFP, and it occurs only through the FDI channel.

The empirical evidence all too often points to the economic superiority of the common law system (originating in British law) over the civil law system (originating in Roman law). The Legal Origins Theory, when opposing these two legal families, describes French civil law as being associated with a "heavier hand of government ownership and regulation" than British common law, therefore more prone to generate "adverse effects on markets" (La Porta et al., 2007). British common law seems to be associated with better investor protection, lighter government ownership and regulation, and less formalized and more independent judicial system, all of which are in turn associated with more favorable economic outcomes. The positive result for the common law could be an indication that it influences more favorably the mechanisms that underlie technology diffusion and adoption, such as factor mobility, than the civil law does.

5. Summary and conclusion

The literature that searches for R&D spillover has suggested that the return on investment in new technology is not confined within the performing countries, but that some benefits spill over to foreign countries with relatively strong economic ties. Consequently, international knowledge spillover could offer growth opportunities to developing countries that do little, if any, R&D activity, provided that they develop significant absorption capabilities in order to reap the subsequent benefits.

This paper asked how and why some developing countries may exhibit stronger absorption capabilities of knowledge spillover (rather than rent spillovers) than others. The main contributions to the North–South R&D spillover literature are threefold. First the paper considered two of the many diffusion channels, namely imports and FDI. Second, it considered additional sources of heterogeneity that have been proven to play a significant role in technology spillover among developed countries, e.g. economic and social institutions. Last, the paper used an improved panel cointegration technique that was not fully worked out a decade ago.

Some key answers based on a sample of 55 developing countries along with the G7 countries and using the FMOLS estimation technique first suggested that the spillover gains are quite substantial: a ten percent increase in a developing country's foreign R&D capital stock leads to more than a two percent increase in its total factor productivity. Much of this spillover gain occurs through the import channel. The results also suggested significant heterogeneity in the spillover gains. Cross-country differences in the absorption and assimilation capacity have to do with the openness to international trade and FDI, the stock of human capital measured by the average years of schooling, and the quality of the institutions (e.g. ease of doing business, property rights, legal traditions). As for policy implications, developing countries wanting to benefit from international technology diffusion definitely have to design policies that not only take into account the diffusion channels, but also the right set of domestic institutions.

Table A.1
Detailed estimation results.

	(I)	(II)	(III)	(IV)	(V)	(VI)
$\log S^M$	0.1858***	0.1724***	0.1584***	0.0847**	0.0494*	0.0463***
	(0.009)	(0.021)	(0.035)	(0.043)	(0.028)	(0.011)
$\log S^F$	0.0513***	0.0485***	0.0687***	0.0343***	0.0378	0.0419***
	(0.008)	(0.009)	(0.024)	(0.013)	(0.025)	(0.010)
$\log H$	0.0389*	0.7230***	0.0648*	0.0546	0.0428*	0.6996***
	(0.023)	(0.030)	(0.034)	(0.033)	(0.023)	(0.031)
$\log S^M{*}Z_1$		0.0006**	0.0312*	−0.0159	0.0463***	−0.0067
		(0.0003)	(0.016)	(0.104)	(0.014)	(0.009)
$\log S^F{*}Z_2$		0.0002	0.0225*	0.0283*	0.0276***	0.0312**
		(0.0004)	(0.013)	(0.016)	(0.009)	(0.015)
Z_1		0.0143**			0.6713***	
		(0.007)			(0.245)	
Z_2		−0.0005				
		(0.0004)				
Intercept	2.6885	2.190335	3.5128	2.6303	3.7746	2.7959
	(0.154)	(0.349)	(0.386)	(0.166)	(0.480)	(0.149)
N	1485	1485	1485	1485	1485	1485
F-Stat.	342.44	202.84	363.01	260.73	247.15	328.81
Panel ν-Stat.	−1.26		2.10**	−1.77*	2.23**	−0.69
Panel rho-Stat.	5.58***		4.79***	6.66***	4.47***	3.14***
Panel PP-Stat.	−5.11***		−1.98*	0.76	6.71***	1.14
Panel ADF-Stat.	6.03***		−4.43***	3.53***	−3.96***	−2.89***
Group rho-Stat.	5.94***		6.17***	5.66***	j 24***	5.93***
Group PP-Stat.	−4.91***		3.66***	−2.30**	−8.12***	−1.32
Group ADF-Stat.	2.98***		−2.17**	−6.68***	−6.35***	−2.79***
Kao ADF t-Stat.	−2.16**	.2.41***	−1.51*	−1.47*	−2.52***	−1.63*

Notes: In column (I), the baseline model estimates are shown. The remaining columns show the results for different specifications with multiplicative interaction terms: in column (II), $Z_1 = m\_gdp$ and $Z_2 = fdistock\_gdp$; in column (III), $Z_1 = Z_2 = \log H$; in column (VI), $Z_1 = Z_2 =$ EDB; in column (V), $Z_1 = Z_2 = IPP$; and in column (VI), $Z_1 = Z_2 = LEGALBR$. The last rows provide the Pedroni and Kao panel cointegration test results. The standard errors are in parentheses. The Pedroni tests could not performed for the eight series included in specification (II).

* Significance at 10%.
** Significance at 5%.
*** Significance at 1%.

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Appendix A. Detailed estimation results

More details about the different estimations are offered below. The various estimations and cointegration test results are shown in Table A.1. The following graphs and tables illustrate the conditional marginal effects of the foreign R&D capital available through each diffusion channel on TFP (Tables A.2 and A.3) (Figs. A.1–A.6).

Table A.2
Conditional marginal effects with the ease of doing business.

$\partial \log TFP/\partial \log S^M$	$0.0847 - 0.0159^{*} EDB$
Value at EDB = 1	0.0688
Value at EDB = 0	0.0847**
Difference	−0.0159
	(0.032)
$\partial \log TFP/\partial \log S^F$	$0.0343 + 0.0284^{*} EDB$
Value at EDB = 1	0.0627***
Value at EDB = 0	0.0343***
Difference	0.0284***
	(0.009)

Notes: EDB is the ease of doing business. The ranking in 2004 is considered, and the variable takes on the value of 1 for countries that are in the top half, and 0 for the rest. The standard errors are in parentheses.

* Significance at 10%.
** Significance at 5%.
*** Significance at 1%.

Table A.3
Conditional marginal effects with the legal origins.

$\partial \log TFP/\partial \log S^M$	$0.0463 - 0.0067^{*} LEGALBR$
Value for LEGALBR = 1	0.0395
Value for LEGALBR = 0	0.0463***
Difference	−0.0067
	(0.016)
$\partial \log TFP/\partial \log S^F$	$0M19 + 0.0312^{*} LEGALBR$
Value for *LEGALBR* = 1	0.0731***
Value for *LEGALBR* = 0	0.0419***
Difference	0.0312**
	(0.015)

Notes: *LEGALBR* is a dummy variable that takes the value of 1 if the country's historical legacy is British common law, and 0 otherwise. The standard errors are in parentheses.

* Significance at 10%.
*** Significance at 1%.
** Significance at 5%.

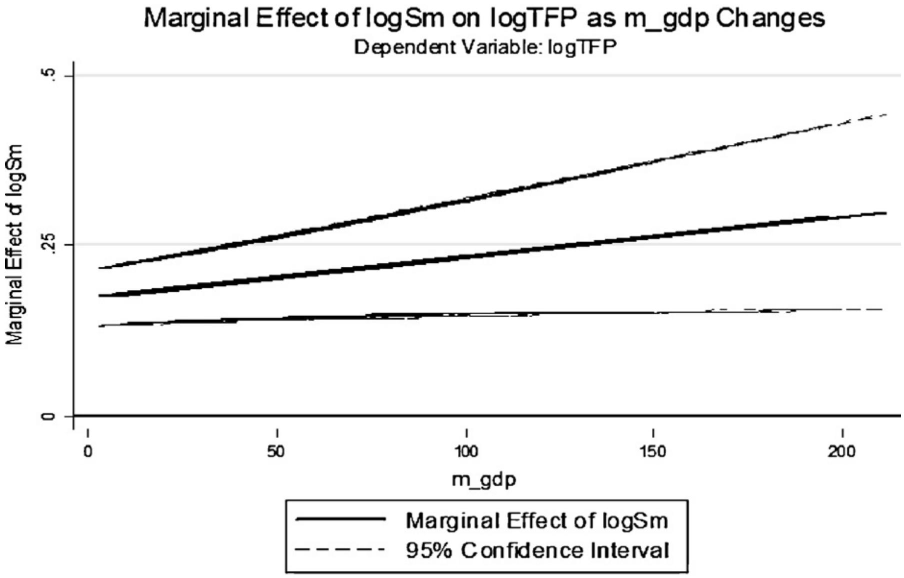

Fig. A.1. Conditional marginal effect of $\log S^M$ with import intensity.

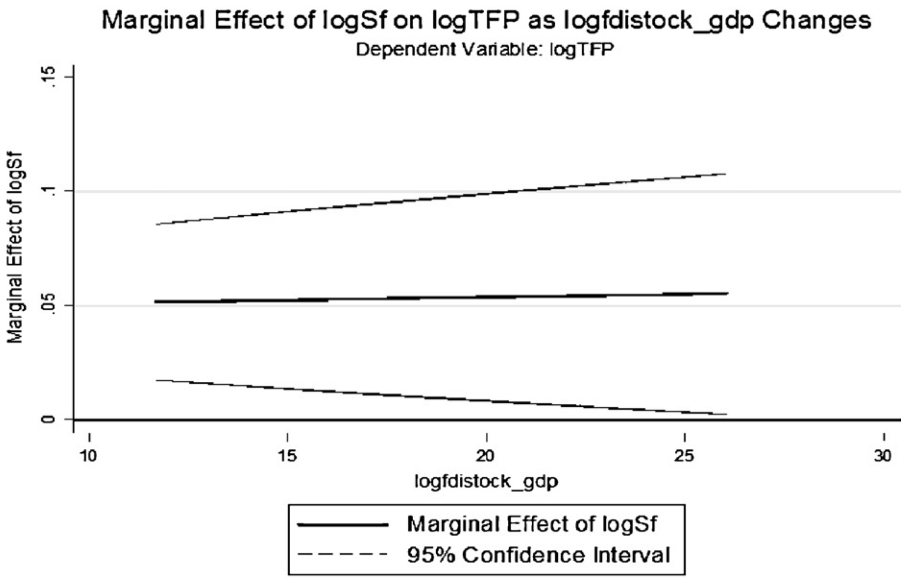

Fig. A.2. Conditional marginal effect of $\log S^F$ with FDI intensity.

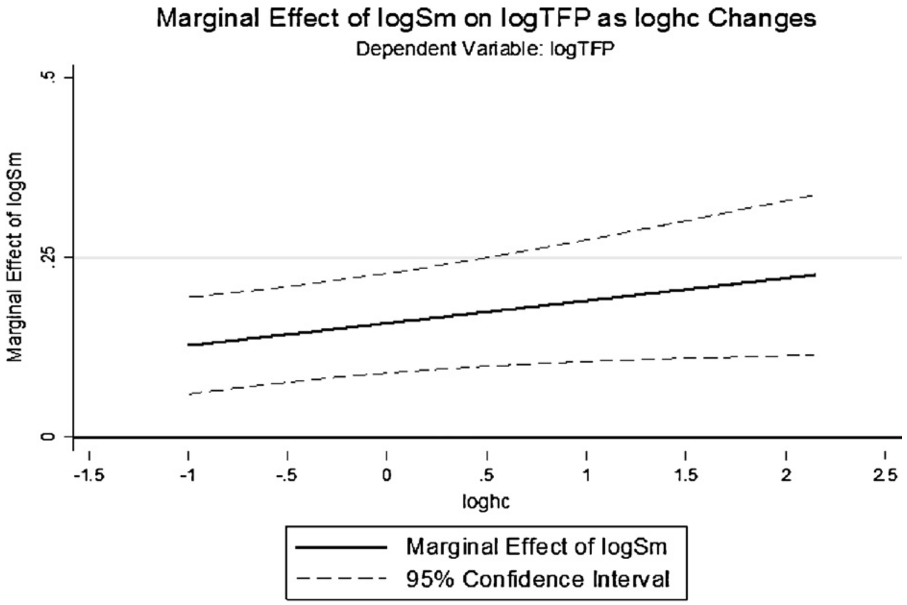

Fig. A.3. Conditional marginal effect of $\log S^M$ with human capital.

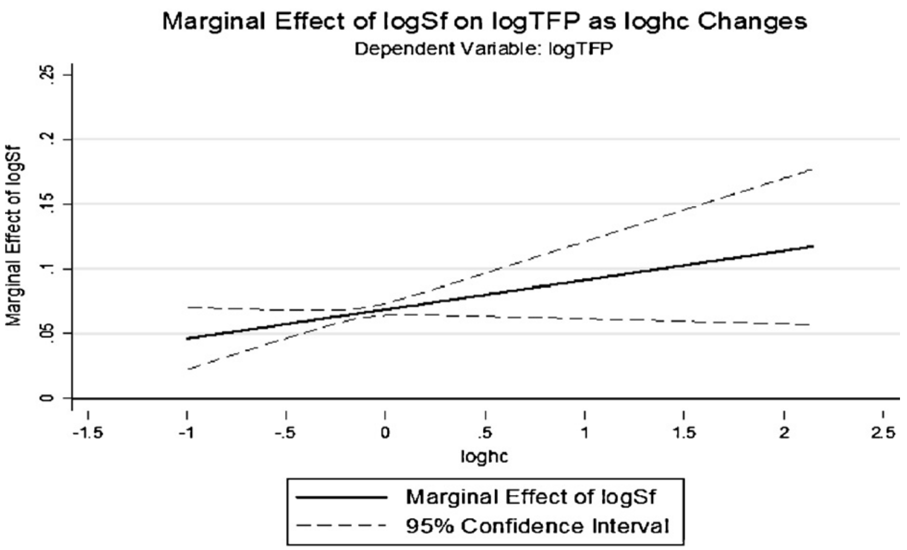

Fig. A.4. Conditional marginal effect of $\log S^F$ with human capital.

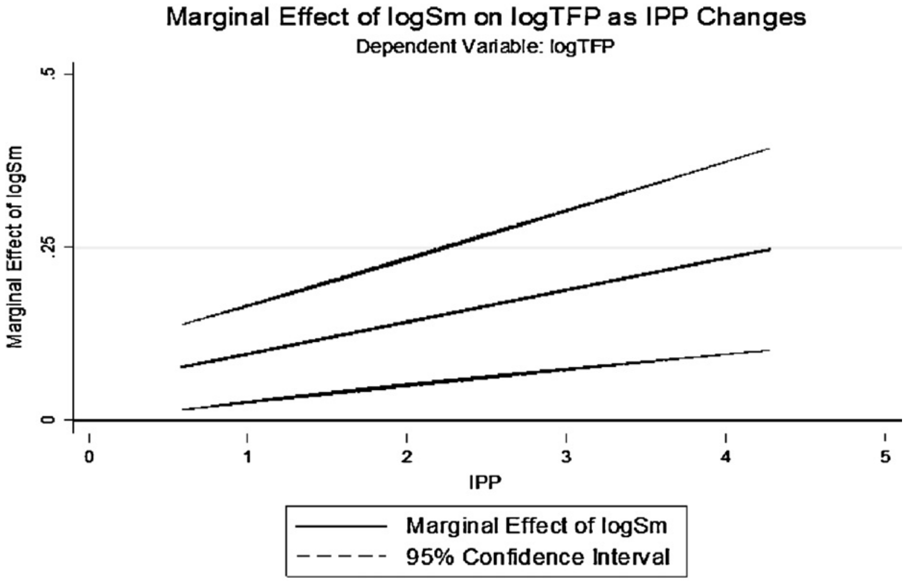

Fig. A.5. Conditional marginal effect of log S^M with patent protection.

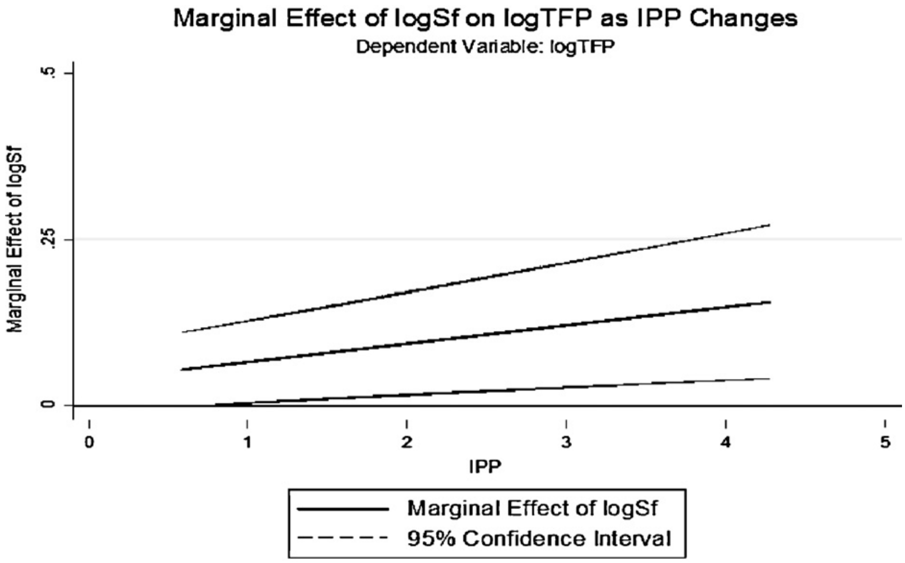

Fig. A.6. Conditional marginal effect of log S^F with patent protection.

Appendix B. Data sources

Data used in this paper come from a variety of commonly used sources. Most of the macroeconomic data are from the World Bank (World Development Indicators, 2008): GDP, gross fixed capital formation, labor force, and total imports of goods and services. Data on bilateral imports of machinery and equipment come from OECD, as well as data on R&D expenditures in the G7 countries, both the total and by sectors. The bilateral FDI flows are obtained from UNCTAD. The average years of schooling up to 2000 are from Barro and Lee (2000).[7] The Index of Patent Protection is obtained from Park (2008).[8] The Ease of Doing Business index for the year 2004 is from the World Bank.[9] Data on the historical origin of the legal systems come from La Porta et al. (2007).

[7] http://www.nber.org/pub/barro.lee/.
[8] http://www.american.edu/cas/econ/faculty/park.htm.
[9] http://www.doingbusiness.org/economyrankings/.

Appendix C. List of developing countries in the sample

Table C1 shows the sample of 55 developing countries. Constraints on data availability were an important motive for country selection.

Table C1
List of developing countries.

Africa	Latin America	Asia-Pacific
Benin	Argentina	Bangladesh
Cameroon	Bolivia	China
Central Afr. Rep.	Brazil	Fiji
Congo	Chile	Hong Kong
Dem. Rep. of Congo	Colombia	India
Egypt	Costa Rica	Indonesia
Ghana	Dominican Rep.	Jordan
Kenya	Ecuador	Korea
Malawi	El Salvador	Malaysia
Mali	Guatemala	Nepal
Mauritius	Guyana	Pakistan
Niger	Honduras	Papua New Guinea
Rwanda	Mexico	Philippines
Senegal	Panama	Thailand
Sierra Leone	Paraguay	Vietnam
South Africa	Peru	
Sudan	Trinidad & Tob.	
Tanzania	Uruguay	
Togo	Venezuela	
Zambia		
Zimbabwe		

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