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Full Length Research Paper

Research and Development (R&D) spillovers and economic growth: Empirical validation in the case of developing countries

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The aim of this paper is to study the effects of the domestic and foreign Research and Development (R&D) on the total factor productivity (TFP) in the case of the developing countries. In other words, it is to determine the important role of the R&D externalities through the commercial opening in the TFP of these countries and the necessary conditions to enable them absorb the technological transfer. To achieve this, we apply a static and non-stationary (FMOLS and DOLS) panel data model of 24 developing countries, on data covering the period from 1996 to 2007. According to the estimates, it seems that the impact of the foreign R&D is greater than that of the domestic one. Therefore, technology transfer has a positive role in economic growth in the developing countries, namely in the economies where the human capital is so important that it helps adapt and assimilate foreign technology.

Key words: Research and Development (R&D), economic growth, panel data, developing countries.

INTRODUCTION

Technological development is uprooted in the primacy of the national effort of Research and Development (R&D). The lack of such an effort in the developing countries explains the dependence of these countries on the outside. This dependence widens their technological gap and hinders their economic and social development. Under these conditions, the implementation of national technological policies should be regarded as a necessary condition leading these countries towards growth. However, the implementation of such policies has several limitations which are considered to be the real challenges of the technological growth in these countries.

Moreover, a country's openness to the world trade is justified by its international specialization which depends on its technological level or the abundance of its resources. According to this principle, the developed countries would export more manufactured goods, while the developing countries would specialize in goods produced by unskilled labor.

Therefore, since the efforts in the R&D of the developing countries remain weak, these countries can benefit from global technology only through the import of intermediate goods and equipment. Actually, many countries have adopted a liberal policy while awaiting the knowledge transfer by foreign companies which can be transferred to local businesses. In this context, several empirical studies (Coe and Helpman, 1995; Eaton and Kortum, 1996; Keller, 1998, 2002) show the important role of technological spillovers as a major source of technical progress for both the developing and the developed countries.

In this context, the technology transfer and adoption have much concern among the economists of economic growth. Some of them have focused on the developed countries which innovate and export technology, while others were interested in the developing countries that import and imitate. The latter ones, which have a low technology, can generally catch up technologically only if they are able to accumulate foreign technology, either by encouraging direct capital transfer, or by opening to

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foreign trade.

The objective of this paper is based particularly on the following question: have the R&D externalities been the key factor of economic growth in the developing countries in the recent years?

To answer this question, we are to apply the following approach. First, we will focus on the relationship between economic growth and technological transfer mediated by international trade. We will then examine an econometric estimation of the interaction of the different stocks of the R&D and the TFP by presenting the main tools of the recent econometric panel data dealing with this problem.

The empirical study applied will typically cover 24 developing countries over the period 1996 to 2007. The choice of this sample of countries and the study period is due to the scarcity of data regarding the expenditure in the R&D.

THEORETICAL AND EMPIRICAL ASPECTS OF THE RELATIONSHIP BETWEEN EXTERNALITIES OF R&D AND ECONOMIC GROWTH

Recent theoretical developments of endogenous economic growth, which are based on the R&D, provided a useful framework to dealing with the problems of long-term international transfer of technology and its adoption. Indeed, the impact of trade openness and economic integration on the domestic technological change is studied by several authors such as Rivera-Batiz and Romer (1991a, b), Grossman and Helpman (1991), Keller (1996) and Aghion and Howitt (2000). Others, such as Coe and Helpman (1995) and then Coe et al. (1997), have attempted to explore the benefits of externalities (spillovers) from the diffusion of technological knowledge on TFP. They show that the positive externalities of R&D are not limited to the industrialized countries which implement them, by devoting considerable expenses, but also to those which affect their partners in the exchange.

Technology transfer: Factor changing the nature of the specialization and productivity growth

The endogenous growth theory emphasizes that trade openness can lead to specialization of countries in non-carrier sectors (low potential for economies of scale and low international application). This specialization will reduce the expected gains from free trade.

To do this, this theory emphasizes the positive role of technology transfer, which will allow the exporting country to be adapted to global demand and to upgrade its trade structure to the intra-industry, thus maximizing the gains from free trade. If this type of exchange between two countries is growing, this means that they have a closer and closer demand structure and therefore closer and closer levels of development. Thus, trade openness can be a source of convergence for developing countries to the development levels of developed countries under certain conditions including the acquisition and adaptation of foreign technology required for the upgrade of local industry.

The main change is to move up the value chain and to specialize in activities with high added value (OCDE, 2007), to break away from traditional specializations in industries facing strong competition from countries that have a competitive advantage through very low production costs.

According to Bensidoun et al. (2001), the adaptation of specialization in international demand can stimulate growth by specializing in goods that promote “learning by doing” or a specialization in high quality or high technology. In addition, specialization in primary products will suffer a negative price trend and high variability in prices will lead to low growth rates.

Busson and Villa (1997) note that there are two cases in which openness promotes growth: if the country manages to position itself in areas where global demand is strong, this specialization will, initially be of, inter-industry type with the country’s economic development, and tends to be more and more of intra-industry nature. In this case, this specialization will allow countries to have a greater variety of intermediate goods and equipment and this will encourage growth through the increase in TFP. This is confirmed by authors such as Trotignon and Abdelkmalki (2001) or Blecker and Razmi (2008) who talk about “fallacy composition” (that is, a fall in demand by developed countries due to strong competition through prices exerted by other developing countries). In this case directed countries that export more goods of low value and whose technological expertise is more towards traditional products (textiles, for example) happen to be in competition with other developing countries rather than developed countries.

In contrast, developing countries are recommended to ensure the transition of their export structures from the primary sectors to others where global demand is high that is, intensive sectors in human capital and technology. In this context, the import of goods of high technology as well as the technology spillovers via foreign direct investment (FDI) causes the structures of countries to converge and choose an intra-industry trade which brings growth.

The technological externalities conveyed international trade

Besides the impact of openness on the specializations and rhythms of accumulation of factors of production, trade integration can promote technology transfer and accelerate the development of the economies lagging. The views of economists are very diverse face to the treatment of this subject. A first group shows that international trade alters the allocation of resources in an economy, while a second focuses on the role of trade in the international transmission of technology.

The endogenous growth models have presented theoretical justifications for the interdependent relationship between the positive open trade and economic growth in the developing countries. On the one hand, Rivera-Batiz and Romer (1991a, b) and Grossman and Helpman (1991) explain these effects by the existence of an intensified research activity conducted by business partners and mainly the importance of knowledge promoted by international trade flows between the developed countries.

Under these conditions, international contacts facilitate the copying of foreign technologies and their adjust must to household use. At the same time, they increase the productivity of a country in the development of new technologies or the imitation of production techniques. Thus Grossman and Helpman (1991) point out that international trade seems to be a development strategy and knowledge acquisition.

On the other hand, Stokey (1991) and Young (1991) sought to explain the link between openness to trade and growth through a process of “learning by doing”. Young has led to a conclusion noting that the developed countries are making high levels of technical progress at the expense of the underdeveloped countries. Stockey has also shown that openness to trade has a negative impact on the economic growth in the developing countries, reflected, according to Lucas (1988), by the intensification of the initial structure of the comparative benefits and the dynamics of specialization between developed and under developed countries.

Indeed, in the context of trade, movement of specialization makes some countries unable to produce knowledge and found themselves skilled in areas bearing little in terms of technology. Under these conditions, technology transfer through imports of capital goods is the only source of knowledge accumulation (Romer, 1990).

Externalities in international trade can then break with the findings of Lucas, since models based on R&D show that new products result from new ideas, trade goods can lead to international transmission of knowledge. It is a central idea of several growth models of open economies studying the relationship between trade and growth.

Parente and Prescott (1994) have emphasized the importance of barriers to technology adoption in determining the differences in per capita incomes in different countries. They showed that any firm can access technology in the global economy but the cost of such access may differ through countries. This difference is due to legal factors, political and social issues which are not the same in all the countries. Indeed, Parente and Prescott suggested that trade can affect growth by reducing barriers to technology adoption.

Coe and Helpman (1995) are the first to provide evidence of the importance of trade in the international diffusion of technology. They tried to measure international technological spillovers, conveyed through trade, using aggregate data for 22 developed countries. Estimates have shown that for the group of seven, the level of the total factor productivity is determined primarily by the efforts of the home R&D, while for smaller countries, the international technological externalities embedded in goods and services sold play a much more important role than those of domestic origin, with higher effects for the countries most open to trade. As a result, a significant interaction was observed between the propensity to import and the ability to benefit from foreign R&D.

Several studies, following the paper of Coe and Helpman, criticized the constructed variables and assumptions developed by the pioneer authors. Critics have focused on the construction of the capital stock of R&D abroad. Lichtenberg and De la Potterie (1996, 1998) have proposed extensions by estimating the same equations with an additional explanatory variable expressing foreign externalities. Their results show that the more a country imports from other countries the more advanced it is in terms of R&D, the more it benefits from technological externalities. They confirm the hypothesis of existence of a positive correlation between the level of openness to trade and spillovers of foreign R&D appropriate for each country.

Keller (1998) attempted to test the statistical validity of the relationship between international trade and technological externalities. In the construction of the capital stock of foreign R&D, he proceeded with the construction of dummy weights calculated by Monte Carlo simulations instead of weights based on the proportions of real imports. The more statistically significant results and higher coefficients have questioned the estimates of Coe and Helpman (1995) and therefore the relationship between technological externalities and trade. However, Keller was himself criticized by Coe and Hoffmaister (1999) for the random weights he used.

These discussions led Lumenga-Neso et al. (2005) to think differently about it. They built a new variable that explains the technological externalities, namely, the international spillovers of R&D indirectly related to trade. The results of these authors verified the importance of trade in the transmission of knowledge at the international level, but contradict the ideas of Coe and Helpman about the dependence on the flow of foreign R&D of a country with its structure of trade.

More recently, Connolly (2003) confirmed the role of imports of high-tech goods in the international diffusion of technology. She concludes that the domestic imitation of innovation depends absolutely on high-tech imports from developed countries. She also suggests that less developed countries rely more on trade in goods to access foreign technology.

To sum up, we can say that although the theoretical studies has dealing with the problem of technology transfer carried out by international trade have failed to decide on a favourable or unfavourable effect of openness on economic growth, the empirical ones have resulted, in most cases, in consistent results indicating a positive effect of openness on growth. However, these studies have shortcomings related to the indicators used to measure the opening and to used the econometric methods do not allow a rigorous control of the bias associated with individual heterogeneity.

The role of absorption capacity

The increased capacity to absorb technology has an important role in investment in the R&D. According to Cohen and Levinthal (1989), absorption capacity is defined as the ability of the company to select, assimilate and exploit the dissemination of foreign knowledge. The concept of absorption capacity was also determined by Abramovitz (1986) or by Temple and Johnson (1998) who has adopted the expressions of “social capability” and “technological capability”. According to these authors, the social capacity covers the general levels of education and financial, commercial, and industrial institutions while the technological capacity in line with the country is specific skills to assimilate, in an efficient way, the advanced technologies.

The process of capacity development to absorb new technologies is not necessarily the same for all the countries. It widely depends on the country is specific factors. Therefore, the development policies of the absorption capacity must be modulated with respect to the technological heritage of the country. However, despite the specificity of R&D, there are factors somehow standard for all the countries which influence the technological development such as foreign sources of knowledge, human capital, public policy and institutional framework.

The channels of technology transfer are the largest sources of development of absorption capacity. Indeed, the R&D depends mainly on the links with the outside. Several studies have focused on showing the importance of the transferred technology in the development of domestic research.

In this framework, Grossman and Helpman (1991) have established a direct relationship between trade openness and technology transfer. They found that the flow of technological knowledge from abroad is associated with the intensification of foreign trade. They showed that the increase of international trade in tangible goods facilitates the exchange of intangibles ideas. Indeed, in a situation of free trade the R&D sector depends not only on domestic knowledge, but also on those coming from abroad.

Thus, Rivera-Batiz and Romer (1991a) as well as Dalgaard and Kreiner (2001) showed that the import of capital goods results in an increase of knowledge that stimulates the performance of the R&D sector by reducing the cost of innovation and accelerating the rate of knowledge accumulation.

This is the “lab-equipment model” in which the expansion of domestic R&D is only possible through the exchange of goods. Barro and Sala-i-Martin (1997) also showed that imports of intermediate goods boosts the likelihood of imitation in the South.

At the empirical level, many studies have shown that the import of capital and intermediate goods is an effective way of acquiring new technology (Coe and Helpman, 1995; Coe et al., 1997; Savvides and Zachariadis, 2005; Moskalyk, 2009).

New technologies can also be transmitted through exports. Indeed, international competition forces companies to meet export quality standards and encourages efficiency. Feder (1982) presented the theoretical foundations of the relationship between exports and productivity growth. He shows that the export sector is more productive than the protected area to the extent that it is subject to more intense competition. In addition, the export sector generates externalities that enhance productivity in the protected sector.

On the other hand, the empirical studies, which have sought to examine the role of exports in technology transfer, have focused on confirming the bidirectional links between exporting and productivity. In other words, it is to check whether exporting firms are more efficient (assuming self-selection) and to highlight the effects of learning-by-exporting, that is to say that companies perform better after starting to export.

Wagner (2007), based on a literature review covering 45 empirical studies conducted at the micro level from data of 33 countries and performed during the period 1995 to 2006, concludes that the hypothesis of self-selection is often verified, while exports do not necessarily contribute to productivity improvement. It is obvious that the author has come to a general conclusion from heterogeneous data from several countries. It is more important to focus on the experience of individual countries to identify the mechanisms that lead to the effects of learning-by-exporting.

Another channel through which new technologies can be transferred is the IDE. The relationship between the FDI and technology transfer is complex in that it depends on the nature of the investment behaviour of multinational firms and the technological absorption capacity of the host country.

Findlay (1978) showed that the technology gap is present for backward countries as an opportunity to benefit from technological externalities from FDI. By cons, Kokko (1994) and Glass and Saggi (1998) hold that FDI can be an effective technology transfer if the host country is characterized by a technological gap and a low capacity to absorb a well developed technology.

Moreover, the assimilation of new technologies depends on the availability of skilled labour. According to Lucas (1988), human capital is an important source of externalities and technological progress. Pissarides (1997), by extending the model of Romer (1990), showed that the rate of imitation in the South depends on the interaction between the quantity of available human capital and trade openness.

Keller (1996) also showed that the import of new technology by itself can not increase the growth rate of long-term, it must be associated with an accumulation of human capital at a rate relatively higher that in autarky situation. The author stressed the importance of human capital in developing the capacity to absorb technology.

According to UNCTAD (2007), three types of policies are needed to improve the capacity absorption of technology. First, it requires an effort of education and training to increase the amount of skilled labour. Second, we must provide incentives to promote the implementation of systematic mechanisms of technological learning and innovation in domestic firms. Third, to create a new set of institutions to develop the dissemination of knowledge between the home firms, subsidiaries of foreign companies and local businesses, and with the rest of the world.

In what follows, we will empirically analyze the state of R&D in the developing countries all over the world while making an estimate panel data econometrics.

EXTERNALITIES OF R&D AND ECONOMIC GROWTH: EMPIRICAL EVALUATION OF PANEL DATA

Our objective is to study the impact of the externalities of R&D on economic growth and examine the role of public investment in human capital in order to explain why some developing countries benefit more than others from externalities in international R&D of advanced countries. To do this, it is necessary to choose a suitable and appropriate model to achieve this objective.

Thus, our survey is based on two types of studies: First, those of Coe and Helpman (1995) which explore the link between technology transfer and the opening on the outside, via international trade. On the other hand, the article by Borensztein et al. (1998) which examines the role of human capital in technology transfers.

Coe and Helpman (1995) have attempted to show that the TFP of a country depends not only on its own capital accumulation in the form of R&D but also on the stock of R&D of its trading partners. In practical cases, where only a portion of intermediate goods is imported, changes in TFP are explained by both domestic and foreign stocks of R&D. Coe and Helpman propose to calculate the stock of foreign R&D taking into account both the structure of imports from the various partners and the level of imports. Thus,

$$Log\,TFP_i = \alpha_i + \alpha_i^d\,LogS_i^d + \alpha_i^f m_i\,LogS_i^f \qquad (1)$$

Where: $S_i^f = \sum_{i\neq j} \frac{M_{ij}}{M_i} S_j^d$, i and j: Indices of country; TFP: The total factor productivity; S^d : The stock domestic capital in R&D; S^f : The foreign stock capital in R&D; m_i : The share of imports in GDP of country i; α^d : elasticity of TFP with respect to the stock of domestic R&D; α^f : the elasticity of TFP with respect to the stock of foreign R&D and M_{ij} : imports of country i from country j.

Lichtenberg and De La Potterie (1998, 2001) extend the work of Coe and Helpman in two directions. First, they highlight an “aggregation bias” in the calculation of stocks of foreign R&D of previous authors and propose an alternative measure theoretically less biased and which yields better empirical results. On the other hand, they show, by an econometric study, that FDI is a vector of transfer of technology beyond the borders. Their contribution is about testing the previous Equation by integrating different measures of the stock of foreign R&D, two of which correspond to our problem:

$$Log\,TFP_i = \alpha_i + \alpha_i^d\,LogS_i^d + \alpha_i^f\,LogS_i^f \qquad (2)$$

Where $S_i^f = \sum_{i\neq j} \frac{m_{ij} S_j^d}{y_j}$

However, Borensztein et al. (1998) investigate the effect of FDI on economic growth. Their empirical study, which was carried out in 69 developing countries during the two decades, the eighties and nineties, is rooted in an endogenous growth model in which the main determinant of long-term growth is the technological change generated by the introduction of new varieties of goods constituting the capital.

However, the application of advanced technologies requires the presence of a sufficient level of human capital in the host country. As it is for Nelson and Phelps (1966) and Benhabib and Spiegel (1994), the stock of human capital limits the absorption capacity of the developing countries. With an illustrative model similar to that proposed by Barro and Sala-i-Martin (1995), they empirically test several variants of the basic relationship as follows:

$$g = \beta_0 + \beta_1 IDE + \beta_2 IDE * HK + \beta_3 HK + \beta_4 Y_0 + \beta_5 A \qquad (3)$$

Where g: The rate of income growth, FDI: FDI flows from OECD countries, HK: The stock of human capital captured by the initial level of the schooling average of men in high school is an indicator proposed by Barro and Lee (1993); Y_0: Gross domestic product (GDP) per capita and initial A: A set of other variables that affect economic growth and that are frequently introduced as determinants of growth in cross-sectional studies (Cross Country).

However, based on these two theoretical models, we examine the role of public investment in human capital and openness to explain why some developing countries benefit more than others from the international externalities of the R&D of the advanced countries. That is to say, we study the impact of human capital and the opening rate on the degree of spillovers from R&D and capital contribution of domestic R&D to TFP, allowing heterogeneity in parameter estimates. This step contributes to the broader growth literature stressing the importance of these two indicators for economic growth.

Moreover, owing to the relevance of certain variables for economic activity, but also the availability of data about countries of interest, we selected and estimated the following empirical model (Equations 4, 5 and 6) based on theoretical models listed previously (Equation 2 and 3) by expanding as follows:

$$Log\,TFP_{it} = \alpha_i + \alpha^h HK_{it} + \alpha^{ouv} OPEN_{it} + \alpha^{rdn} LogSNRD_{it} + \alpha^{rdf} LogSFRD_{it} + \varepsilon \quad (4)$$

$$Log\,TFP_{it} = \alpha_i + \alpha^h HK_{it} + \alpha^{rdn} LogSNRD_{it} + \alpha^{ouvf} OPEN_{it} * LogSFRD_{it} + \varepsilon_{it} \quad (5)$$

$$Log\,TFP_{it} = \alpha_i + \alpha^h HK_{it} + \alpha^{rdn} LogSNRD_{it} + \alpha^{hrdf} HK_{it} * LogSFRD_{it} + \varepsilon_{it} \quad (6)$$

Where i and t: The respective indices of developing countries and annual periods, TFP: The total factor productivity; OPEN: The open rate; HK: Human capital; SNRD: The stock of domestic capital devoted to R&D and SFRD: the stock of foreign capital devoted to R&D embodied in imports.

Presentation of variables and their sources

The variables that are collected will be presented for a panel of 24 developing countries over the period 199 to 2007. The variables in our study are: total factor productivity growth as endogenous variable (TFP), the stock of human capital (HK), the stocks of Domestic (SNRD) or foreign R&D (SFRD), the open rate (OPEN) and the terms of interaction or crossed (Appendix 1).

The dependent variable (TFP)

TFP is measured by the method of growth accounting in which TFP stands for technical progress. In other words, TFP is simply the share of growth not explained by the physical quantities of two traditional factors (capital and labour). For each of the country sample, TFP is calculated from a Cobb-Douglas constant return to scale as follows:

$$TFP_t = \frac{Y_t}{K_t^{\beta} L_t^{1-\beta}}$$

Where, Y_t, K_t and L_t are respectively the real gross domestic product, the stock of physical capital and the working population at time t. Since the contribution of TFP depends on the elasticity of output with respect to physical capital, TFP was calculated assuming a value of 0.4 for β that is often used in empirical work (Mankiw et al., 1992; Coe et al., 1997; Senhadji, 2000). Thus, the stock of physical capital is calculated by the perpetual inventory method:

$$K_t = Inv_t + (1-\delta)K_{t-1}$$

Where Inv is the gross fixed capital formation (GFCF) and δ the depreciation rate of physical capital (δ = 6%) (Hall and Jones, 1999). At t = 0, the initial stock of physical capital is $K_0 = \frac{Inv_0}{g+\delta}$, with Inv_0 is the initial investment and (g) is the annual growth rate of investment.

In addition, we used TFP to calculate respectively the real GDP, the GFCF and the active employed population. The data for all the 24 countries in our sample, relating to this variable are retrieved from the CD-Rom of the World Bank, "World Development Indicators" (WDI), in its 2009 version.

The stock of human capital (HK)

The work of Coe et al. (1997), Levin and Raut (1997), suggest that the developing countries must have a skilled workforce that is human capital capable of assimilating foreign technology. Based on the work of Mankiw et al. (1992), we use the gross enrolment rate in high schools as a "proxy" of human capital. The data are taken from the World Bank Indicators (2009) and the UNESCO Institute for Statistics (2009).

The variables related to R&D

Two indicators of R&D are used in our empirical analysis, namely the domestic R&D and the foreign R&D:

Stock of domestic R&D (SNRD): The data on domestic R&D are obtained from the CD-ROM of the World Bank in its 2009 version or the ISU (2009). Indeed, we call the domestic R&D or the home research expenditure and development (GERD). It corresponds to the R&D performed on the national territory (SNRD) whatever of the source of funds. All these data are in million current PPP $.

Stock of foreign R&D (SFRD): The stock of foreign R&D measures the diffusion of technology coming from advanced countries is not without effect on the growth of the host countries. Before constructing the variables, it is necessary to calculate the capital stock of domestic R&D of each country (j), a partner in the exchange with the countries in our sample. For each recipient country, the stock of foreign R&D is the sum of stocks of domestic R&D of the seven advanced countries, weighted by the share of bilateral trade conducted with each country.
Therefore, it is necessary to calculate in advance the R&D stocks of the domestic advanced countries. The method used is that of perpetual inventory. Thus, the stock of R&D in year t is equal to its value in t-1, adjusted by a depreciation rate to which we add the investment in year t, measured by the internal expenditure on R&D.

$$SNRD_t = R\&D_t + (1-\delta)R\&D_{t-1}$$

Where $R\&D_t$ represents the investment in R&D in year t and the depreciation rate δ. Inspired by Coe and Helpman (1995), we retain for this rate the value of 5%. According to the specification of Griliches (1980), the stock of the initial R&D (SRD_0) is equal to the initial $R\&D_0$ investment divided by the sum of the annual growth rate g, investment in R&D ($R\&D_t$) and the depreciation rate R&D.

$$SRD_0 = \frac{R\&D_0}{(g+\delta)}$$

The data flow of expenditure on R&D (percentage of GDP) is taken from the database of the OECD (Indicators of Science and Technology 2009).

From the R&D stocks of the seven advanced countries, we can determine the variable representing the dissemination of the research results towards countries by following the approach of Coe and Helpman (1995) who retain the following measure:

$$SFRD_{it} = \sum_{j=1}^{7} m_{ijt} \frac{SNRD_{jt}}{m_{it}}$$

Where $SFRD_{it}$ is the stock of foreign R&D from country i at time (t), m_{ijt} represents the imports of capital goods from country i to advanced country j at time (t), m_{it} denotes the total imports of country i at time (t). The database CHELEM (2009) describing in details the trade relations between countries helps to calculate the stock of foreign R&D.

The open rate (OPEN)

Coe et al. (1997) note that the developing countries will have a higher rate of productivity when it is more open to trade with developed countries that have extensive experience in R&D. This implies that countries the most open to trade will benefit from foreign R&D and the country whose stock of foreign R&D is the largest gains more productivity of a marginal increase in its imports. This idea according to which international trade is an important vector of transmission of the technology or R&D spillovers from one country to another is also confirmed by Keller (2002).

Moreover, the openness indicator is the ratio of exports beside the imports on GDP. Barro (2000) estimates that, being calculated so, this ratio tends to be larger for small countries. He therefore made a correction of the indicator by taking into account the size of the population and the country is area. Trade openness, being calculated so, has a positive effect on growth. Finally, this variable is extracted from the database of the World Bank (WDI, 2009).

The cross terms or interactions

$OPEN_{it} * LogSFRD_{it}$: The first variable that identifiers the absorption capacity of the host country is measured by the degree of openness. The introduction of this variable is to get the role of openness in the transmission of foreign technology, particularly through the importation of capital goods.

$HK_{it} * LogSFRD_{it}$: A second variable that identifies the absorption capacity of the host country is measured by the level of local human capital which is considered as a determinant factor of assimilation and absorption of foreign technology by the host country.

Missing values were completed assuming an average constant annual growth rate between the two periods indicated. Finally, the missing data of the estimation period were calculated by assuming an average constant annual growth rate and identical to the one obtained over the past five years.

ESTIMATION RESULTS

We present, in this part, the estimation results of the equations presented above using different methods. We first offer conventional estimators in the context of panel data models such as fixed or random effects which, not taking into account the presence of unit roots in the series, provide biased estimates and statistical tests which do not follow a usual Student's t-test. This is why we offer an analysis of integration-cointegration panel, using the methods of the fully modified ordinary least squares (FMOLS) and the dynamic ordinary least squares (DOLS).

The method of static panel data

Specification tests: The first step in establishing a sample of panel data is to check the specification of the homogeneous or heterogeneous data generating process. In economic terms, the specification tests whether the return is entitled to assume that the theoretical model studied is exactly the same for all countries or on the contrary, if there are features specific to each country.

We begin by testing the hypothesis of a perfectly homogeneous structure (constant and identical slope). If the statistics associated with Fischer's test of total homogeneity exceeds the Fischer table, we therefore reject this hypothesis. Then we test the presence of individual effects by assuming that the β_i are constant for all i.

After completing both tests, the selected model will be estimated by two heterogeneous panel specifications, where the only source of heterogeneity comes from the individual constants:

$$Y_{it} = \alpha_i + \beta X_{it} + \varepsilon_{it}$$

For this type of model, we distinguish two cases: if the parameters αi is deterministic constant (fixed effects model) and if the parameters αi is performances of explication random variable with a finite variance (random effect model). For this, we conduct an analysis of Hausman specification test.

Hausman test: The Hausman specification test (1978) is a specification test of individual effects. It is used to discriminate between fixed and random effects. The hypothesis tested the correlation between individual effects and explanatory variables:

$$\begin{cases} H_0 : E(\alpha_i \setminus X_i) = 0 \\ H_1 : E(\alpha_i \setminus X_i) \neq 0 \end{cases}$$

Under H_0, the model can be specified with random individual effects and we must retain the generalized least squares (GLS) estimator. Under the alternative hypothesis H_1, the model must be specified with individual fixed effects and thus we must retain the within estimator. The statistics of Hausman test applied to the specification test of individual effects is as follows:

$$H = (\hat{\beta}_{within} - \hat{\beta}_{MCG})' [var(\hat{\beta}_{within} - \hat{\beta}_{MCG})]^{-1} (\hat{\beta}_{within} - \hat{\beta}_{MCG})$$

Under H_0, the H-statistic asymptotically follows a "Chi-square" in K degrees of freedom.

Decision rule: If Prob($H_{exogeneity}$) <10% : therefore, the exogeneity is rejected at 10 and 5%. So, we accept the two-stage least squares (2SLS) estimator and vice versa.

Estimation results: To test the effect of human capital and the open rate on the variables in the model such as the stock of national R&D and the stock of foreign R&D, we estimate Equations 4 to 6 using the classic method of panel data for 24 developing countries over the period 1996 to 2007. The estimation results shown in Table1 appear to confirm the previous theoretical results.

After giving an idea of the main tests and estimators presented in the method of static panel data, we now turn to a presentation of the estimators used in the method of non-stationary panel data.

The method of non-stationary panel data

It is now conventional in macroeconomics to test the presence of a unit root in a time series. The panel versions of these tests have recently been developed to resolve the lack of performance of traditional unit root tests when the number of periods is relatively small.

Unit root tests: In the model estimates, we have not considered the problem of stationarity. This limits the robustness of the results given the bias of parameter estimates associated with the non-inclusion of properties of non-stationarity of the series. Indeed, and to overcome this problem, a series of unit root tests have become a common approach in analyzing the stationarity of the panel series (Appendix 3). The best known tests are those of Levin et al. (2002), Breitung (2000), Im et al. (2003), Maddala and Wu (1999) and finally, Hadri (2000). The most frequently used test, when the time dimension is limited, is that of Im et al. (2003) (IPS) which offers tests helping to detect the presence of unit root in models of type ADF. In this section, we aim to study the order of integration of series and the cointegrating relationships between the variables. To study the non-stationarity, we use the IPS test presented by the following equation:

$$\Delta y_{it} = \rho_i y_{it-1} + \sum_{j=1}^{ki} \varphi_{ij} \Delta y_{it-j} + \mu_i + \delta_i t + \varepsilon_{it}$$

Table 1. Estimate static panel data of TFP.

Variables	Equation 4	Equation 5	Equation 6
	Within	Within	Within
cst	-	-	-
LSFRD	0.0456 (2.05)**	-	-
LSNRD	0.0181 (1.06)	0.0264 (1.07)	0.0232 (1.003)
OPEN	0.0040 (4.92)***	-	0.0041 (5.59)***
HK	0.0671 (2.89)**	0.0362 (2.15)**	-
LSFRD*OPEN	-	0.0042 (0.40)	-
LSFRD*HK	-	-	0.0003 (2.52)**
N. of ob	288	288	288
t-Hausman	9.56	7.94	7.85
P-values	0.001	0.001	0.001

Values in parentheses are Student static. *, ** and *** are the significances respectively 10, 5 and 1%. Stock of human capital (HK), stock of Domestic R&D (SNRD), stock of Foreign R&D (SFRD), the open rate (OPEN).

Where k, the number of lags chosen to eliminate the autocorrelation of the residuals. The IPS test is calculated as the average t-statistics of Dickey-Fuller regressions with and without trend. The alternative t-bar statistic to test the null hypothesis of the unit root for all the individuals ($\beta_i = 0$) is:

$$\bar{t}_{NT}(\rho_i) = \frac{1}{N}\sum_{i=1}^{N} t_{iT}(\rho_i)$$

With $t_{iT}(\rho_i)$: ADF estimated tests, N: number of individuals and T: number of observations.

Im et al. (2003) propose to use the statistical standard as follows:

$$Z_i = (N)^{1/2}(\bar{t}_{NT} - E(\bar{t}_{NT}))/(\mathrm{var}(\bar{t}_{NT}))^{1/2}$$

Where $E(\bar{t}_{NT})$: arithmetic mean; $Var(\bar{t}_{NT})$: Individual ADF statistics variances.

The IPS study shows that this standardized statistics converges weakly towards normal centred and reduced distribution, which helps to compare it with the critical values of N (0.1) distribution. The results of IPS tests (Appendix 3) conducted on our variables in level then in first difference are presented in Table 2:

At the level variables, the w-tbar statistics is all above the critical value of -1.645, so we do not reject at the threshold of 5%, the null hypothesis of the presence of a unit root in each variable. These tests are carried out with three delays on the increased part of the ADF regression. Adding a deterministic trend specific to each country does not change our conclusions.

The IPS tests on the variables taken in first difference, we reject this time the null hypothesis at the threshold of 5%. We therefore conclude that our variables are non-stationary and integrated of order one. In the presence of non-stationary variables, there is a possibility of obtaining dummy regressions between our variables. One way of bypassing this problem is to use the usual techniques of cointegration.

Our relatively small number of observations results in substantial loss of power on the use of cointegration tests developed for the series. This can lead us to accept the null hypothesis of non-cointegration as the alternative hypothesis is true.

Therefore, it is better to implement the cointegration techniques recently developed in the context of panel data. Thus, verification of properties of non-stationarity for all the variables of the panel leads us to study the existence of a long-term relationship between the variables.

Cointegration tests: To investigate the existence of a cointegrating relationship, we refer to the work of Pedroni (1999, 2004), whose null hypothesis is to test the no cointegration based on unit root tests in the estimated residuals. Pedroni developed seven cointegration tests on the panel data. These tests take into account the heterogeneity concerning the cointegrating relationship that is to say that for every individual there is one or more cointegrating relationships, not necessarily identical, for each individual panel.

In addition, Pedroni aggregates the results depending on the intra size (giving rise to cointegration tests called “Panel”) or according to the international dimension (resulting in cointegration tests called “Group”). Statistics“Panel” or “Group” are calculated on the basis of the approach of Augmented Dickey-Fuller (ADF) or the non-parametric approach of Phillips-Perron (PP). The test statistics are then normalized in an appropriate way by

Table 2. The results of the test IPS (2003).

Variables	Sans tendance	Avec tendance
LTFP	I (1)	I (1)
LSFRD	I (1)	I (1)
LSNRD	I (1)	I (1)
HK	I (1)	I (1)
OPEN	I (1)	I (1)
LSFRD*HK	I (1)	I (1)
LSFRD*OPEN	I (1)	I (1)

I (1): Indicates that the series is stationary in first difference.

Table 3. Cointegration tests of the TFP and its determinants (Pedroni, 1999).

Equation	Panel v-stat[(b)]	Panel rho-stat[(b)]	Panel pp-stat[(b)]	Panel adf-stat[(b)]	Group rho-stat[(a)]	Group pp-stat[(a)]	Group adf-stat[(a)]
4	3.52381	-2.28312	-7.84293	-6.17252	-2.03902	-3.84560	-5.85566
5	4.21576	-6.01470	-3.96531	-2.07144	-6.92409	-3.20746	-3.64905
6	3.02800	-5.18633	-7.95300	-2.99039	-6.35852	-2.96556	-2.20417

(a): These tests are based on the size BETWEEN. (b): These tests are based on the size WITHIN.

taking values for the average and the variance published by Pedroni (1999). We obtain various statistics that converge to a standard normal distribution under the null hypothesis of non-cointegration.

Thus, each of the seven statistics follows a standard normal distribution for N and T sufficiently large:

$$\frac{z_{NT} - \mu\sqrt{N}}{\sqrt{\upsilon}} \rightarrow N(0;1)$$

Witch z_{NT}: One of the seven statistics, μ and ν : the values of the moments tabulated by Pedroni. As with the IPS test, the rejection of the null hypothesis is made according to one-tailed test: if the calculated statistic is inferior to -1.645, we reject the null hypothesis of non-cointegration at the threshold of 5%.

The results of Pedroni tests are presented in Table 3; they include, as is the case for the IPS test, the common temporal dummy variables. From the results of the cointegration tests of Pedroni, we note that all statistics (Panel: rho, pp and adf; group: rho, pp and adf) are below the critical value of the normal rule for a threshold of 5%. So, all of these tests confirm the existence of a cointegrating relationship.

Cointegrating relationship: In literature, we identified several approaches to estimate cointegrating vectors for the panel data. As it is for the timing analysis, there is a debate between an estimate on the residues in the logic of Granger or on the contrary, the search for cointegrating vector in line with the work of Johansen.

To estimate systems of cointegrated variables panel data and to identify tests on cointegrating vectors, it is essential to apply an effective method of estimation. At this level, we distinguish several techniques: the fully modified ordinary least squares method (FMOLS) used by Pedroni, the dynamic ordinary least squares method (DOLS) and the generalised method of moments (GMM) method.

Pedroni (1996), Phillips and Hyungsik (2000) and Kao and Chiang (2000) showed that, in the case of panel data, the first two techniques lead to estimators asymptotically distributed according to a standard normal distribution. However, Kao and Chiang (2000), argue that the estimate by OLS in finite sample can be a problem of bias with respect to the FMOLS method. But they also show the superiority of the DOLS method compared with that of FMLOS and consider it the most effective technique in the estimation of cointegrating relationships in panel data. The DOLS estimator can be obtained by adding the delays in the initial model:

$$Y_{it} = \alpha_i + \beta X_{it} + \sum_{j=-r_1}^{r_2} c_{ij} \Delta X_{it-j} + \zeta_{it}$$

Though, the use of the DOLS estimator involves an arbitrary choice of delays which represent an interesting question but goes beyond our objective in this work. We chose to keep the same number of delays for all the countries.

However, the estimation results by both methods are summarized in Table 4.

Table 4. Estimation results for the FM and DOLS methods of TFP.

Variables	FMLOS			DOLS		
	Eq.4	Eq.5	Eq.6	Eq.4	Eq.5	Eq.6
LSFRD	0.02 (3.09)**	-	-	0.82 (5.56)***	-	-
LSNRD	0.33 (0.98)	0.45 (0.65)	0.21 (0.30)	0.23 (0.97)	0.24 (0.27)	0.05 (0.21)
HK	0.07 (4.80)***	0.075 (5.67)	-	0.12 (3.85)**	0.23 (2.77)**	-
OPEN	0.012 (6.10)***	-	0.014 (2.66)**	0.04 (6.98)***	-	0.11 (2.19)**
LSFRD*OPEN	-	0.035 (5.22)	-	-	0.032 (4.23)***	-
LSFRD*HK	-	-	0.026 (4.98)***	-	-	0.05 (4.98)***

Values in parentheses are the Student static. *, ** and *** are the significances respectively at 10, 5 and 1%. Note: DOLS estimators were obtained for r_1 =1 and r_2 = 2.

Estimation results: Estimation results for the FM and DOLS methods of TFP are shown in Table 4.

INTERPRETATION OF RESULTS

From the estimation of these equations in Table 1, we can conclude, a priori, that both the human capital measured by secondary school enrolment level and the opening rate measured by the volume of trade relative to GDP, have a significant and positive effect on the TFP.

In addition, using the specifications of Equation 4, we tested the relevance of the source of technology transfer (LSFRD). Estimates show that technological spillovers conveyed via the flow of imports (stock of foreign R&D) have a positive impact on TFP with a coefficient statistically very significant while the stock of national R&D has an insignificant effect. Indeed, the results are similar to those found by Coe and Helpman (1995). This result confirms the fact that, for the panel of developing countries, the proliferation of industrial economic or technological cooperation programs, with developed countries, provides technology transfer and appears as an effective means of reducing development disparities.

However, the opening of the economies of developing countries to international trade can make a profit, which is also observed through the presence of a positive and significant impact, direct and indirect imports to the panel. This can be explained in several ways.

First, for the developing countries, the exchange with the outside world usually increases the economies of scale. These countries have to increase the amount of traded goods, particularly with Europe which is a major trading partner, to achieve the objective of the minimum efficiency scale. However, the place of these countries in the world compared to the developed countries is related to their ability to produce goods of high quality. For this reason, monitoring and maintaining the quality are among the priorities of most developing countries in acquiring technology.

Second, the developing countries will leverage the foreign technologies advances by adapt more them to the volume growth of trade openness on their industrial partners. This can occur through the importation of capital goods and the use of the technology of the developed countries. This improvement may be motivated by an increased competition in their industry, due to the internationalization of trade. However, the ultimate success depends on the policy measures that accompany this evolution.

However, from the estimation of Equations 5 and 6, we can conclude that, when considering the role of the absorption capacity measured by the level of human capital in the host country and the degree of openness, the effect of technological spillovers, through the import of capital goods on TFP, decline. Indeed, in regression (4), the coefficient on the stock of foreign R&D (SFRD) was in the range of 0.045 and its effect was significant on TFP. In regressions (5) and (6), the coefficient of the variable HK*LSFRD becomes less equal to 0.0003 and remains significant while the variable OPEN*LSFRD also becomes low and equal to 0.00042, especially that its effect is non significant on TFP.

Thus, our results show that the effect of technological spillovers on productivity indicators depends on the absorption capacity of the selected factors namely on the human capital which plays a primordial role in the transfer of foreign technology (De Gregorio, 1992).

In our case, the interaction between openness and foreign research has an insignificant impact on TFP. This reflects that the technology gap accused by the economy is so important that technology absorption is achieved through import of capital goods. Indeed, the technology gap whereas the inputs imported by the developing countries seem insufficiently adapted to their environment. The inadaptation between the national means and the imported technology is a barrier to the competitiveness of its industry. In addition, Teitel (1987) states that foreign competition destroys a part of the productive tissue. It follows that production factors are allocated to agriculture or services leading to the reduction of the TFP. A disappearance technological activities follow and the appearance of an inability to produce capital goods follow. This may be due to the low interest shown by industry in the activities of R&D due to the low profitability of the latter.

Two arguments reinforce this fact. On the one hand, companies suffer from a financial stranglehold, and on the other hand; the activity of R&D is low carrier in terms of productivity gains in the short term. National productions of capital goods do not improve in a competition environment of massive imports coming from the advanced and therefore more efficient than local productions. Then, industry and more specifically, the activities of production of capital goods have only a marginal impact in the added value of the developing countries.

Similarly, the human capital expected role. Its coefficient is positive and significant. As for the effects of interaction between foreign R&D and human capital, the results show that the interactive variable coefficient is positive and significant. This means that countries make more money from the foreign R&D if they have a stock of a relatively high human capital. This result justifies the interest, namely of countries with a technological backwardness in monitoring their educational policies more diverted towards science and technology.

These results are consistent with economic theory according to which the effect of foreign technology on the local industry becomes effective only in the presence of an absorption capacity of local industry and in the reduction of the technology gap between foreign and local companies and in the presence of quality human capital to benefit from foreign technology (Wang, 1990; Coe et al., 1997; Borenstein et al., 1998; Le, 2010).

However, the estimation of these three equations with the FM and DOLS methods indicates that in the long term, for all countries, trade in capital goods has a positive impact on TFP (Equation 4), according to the results of the theoretical literature. When we incorporate the R&D carried out by imports, we can distinguish two effects related to trade: openness has a positive effect on the TFP and the indirect effect of technology transfer, which spread through imports, is clearly positive. It is clear that, in these equations, the R&D for developing countries embodied in imports has a positive impact on the TFP. We meet here the findings of Coe and Helpman (1995), Coe et al. (1997) and Lichtenbergh and De La Potterie (1998) obtained on other groups of countries while the estimated coefficients of domestic R&D are not significant. This result confirms the result of the method of the static panel.

Thus, the estimation of equation 4 shows some interesting results about the effects of the openness on the TFP in developing countries. The opening has a significant and positive impact on the TFP. The introduction of the interaction between openness and foreign research, in Equation (5), shows their necessary complementarity in the acquisition of productivity gains. It can also show two distinct effects: the coefficient attached to the opening is positive and significant while the one associated with the interaction term is positive and also significant. Thus, the effects related to technology transfer exist and improve the TFP of developing countries.

Finally, the positive sign associated with the human capital and the significance of this variable in Equations 4 to 6; confirm the results of the theory of endogenous growth. Indeed, the human capital plays an important role. The direct and indirect coefficients (interactive variables) of this factor are positive and significant. This justifies the policies of investment in human capital adopted by the developing countries since the 60's to promote growth. These policies have created suitable environment to internalize the benefits of foreign research. The interaction variables between the R&D and the human capital have positive and significant coefficients; this confirms the catalytic role of the human capital in these countries. This result is confirmed by Seck (2011).

Similarly, if the indicator of the schooling rate in secondary education is questionable, in the way that schooling an individual does not mean he will join the workforce and his training will be tailored to the needs, it provides a measure of the effort of a country to improve its stock of human capital, and this effort was significant for some developing countries.

Conclusion

This article, following the work of Coe and Helpman (1995), seeks a sample panel of 24 developing countries observed over the period 1996 to 2007, to determine the real extent of the relationship between the different stocks of foreign knowledge, conveyed between countries through trade flows, and the total factor productivity through the human capital and the open rate.

Following the information provided by Lichtenbergh and De la Potterie (1998, 2001), we adopted an alternative formulation for foreign research and in order to appreciate the differences between advanced countries and developing countries, we estimated the model by interacting outside capital stock of R&D, human capital and the opening rate. The estimates were made with a wide variety of methods: "classic" methods in the context of panel data, including models with fixed or random effects as well as those deriving from the application of asymptotic theory of the cointegrated panels developed by Kao and Chiang (2000).

The estimates obtained by these methods are relatively close, although the results of the domestic and foreign research from the two adopted specifications, with and without interactions, have some degree of improvement.

Most economists agree about the fact that a developing country can achieve growth if it follows the most advanced economies and assimilate them. For this reason, the encouragement of the dissemination and technology transfer is preferred.

In addition, it is important to improve the skill level and training of the population to ensure an effective use of this technology. Thus, this technological advance could enable the developing countries to compete in areas other than those that do not require a number of highly qualified labor. Nevertheless, from these empirical results, we can distinguish three important points:

1. Trade openness in itself does not lead to a real increase in productivity and therefore per capita income. Its nature (nature of trade, exchange of intra-industry type) and the conditions of each country can help bring about more profit. As we have seen, the developing countries are wide open. But this opening really does not benefit these countries. The opening should be accompanied by a change in specialization and upscale to qualify for earning dynamics, this can be done by benefiting from the significant foreign technology through the establishment of an industrial policy parallel with the opening for an efficient uptake of this technology to ensure greater diversification of their manufacturing and structure beyond the simple desire to better allocate resources.
2. Developing countries have a negligible level in R&D. The opening allows them access to knowledge and foreign knowledge especially through the importation of foreign goods needed in the process of production such as capital goods and intermediate goods.
3. The absorption capacity of local or nation-specific conditions when the dynamic potential gains from free trade through the establishment of a policy of education and training which allows for a level of human capital of high quality and in line with the market needs and establishes a development policy based on knowledge through the increase of the national effort in the R&D as a part of a national System of developed innovation. This should allow a better assimilation of foreign technology by reducing the technological gap between local and foreign companies through the systematic application of innovation in production.

Finally, most developing countries have not sufficient means to motivate and maintain the activities of the R&D at a significant level. Therefore, they usually turn to foreign technology. Their R&D systems should complement and support the technology acquired by the transfer or by imports of capital goods.

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APPENDIX

Appendix 1. Variables and sources.

Variables	Notations	Sources
Basic variables		
Real GDP per capita	Ln y	WDI (2009) and FMI (2009)
Gross Fixed Capital Formation	LnK	WDI (2009)
Gross enrolment ratio	LnHK	WDI (2009) and UNESCO (2009)
Rate of trade openness	OPEN	WDI (2009) and CHELEM (2009)
Variables related to R&D		
Gross Domestic expenditure on R&D	GERD	WDI (2009), UNESCO (2009) and OCDE (2009)

Appendix 2. List of countries.

Pays	Code Pays	Régions
Armenia	ARM	Europe and Central Asia
Azerbaïdjan	AZE	Europe and Central Asia
Belarus	BLR	Europe and Central Asia
Lithuania	LTU	Europe and Central Asia
Kazakhstan	KAZ	Europe and Central Asia
Latvia	LVA	Europe and Central Asia
Macedonia	MAC	Europe and Central Asia
Bulgaria	BGR	Europe and Central Asia
Poland	POL	Europe and Central Asia
Romania	ROM	Europe and Central Asia
Turkey	TUR	Europe and Central Asia
Ukraine	UKR	Europe and Central Asia
Bolivia	BOL	Latin America and Carïbbean
Brazil	BRA	Latin America and Carïbbean
Chile	CHL	Latin America and Carïbbean
Colombia	COL	Latin America and Carïbbean
Mexico	MEX	Latin America and Carïbbean
Uruguay	URY	Latin America and Carïbbean
Venezuela	VEN	Latin America and Carïbbean
Panama	PAN	Latin America and Carïbbean
Morocco	MAR	Middle East and North Africa
Tunisia	TUN	Middle East and North Africa
Thaïland	THA	East Asia and Pacific
South Africa	ZAF	Sub-saharan Africa

Source: The author's classification of the World Bank.

Appendix 3. Unit root tests (Im et al., 2003).

Variables	In level		In first difference	
	Constant + Trend	Constant	Constant + Trend	Constant
LTFP	2.221 (0.986)	3.300 (0.999)	-4.363 (0.000)	-3.822 (0.000)
LSNRD	-0.321 (0.374)	-1.543 (0.061)	-5.441 (0.000)	-8.859 (0.000)
LSFRD	-0.971 (0.722)	-0.961 (0.486)	-7.320 (0.000)	-13.589 (0.000)
HK	-1.230 (0.012)	-1.018 (0.154)	-6.202(0.000)	-9.930 (0.000)
OPEN	-1.030 (0.151)	1.779 (0.962)	-5.306 (0.000)	-8.025 (0.000)
LSRDF*HK	-1.409 (0.071)	-0.603 (0.256)	-6.175 (0.000)	-11.619 (0.000)
LSRDF*OPEN	-1.238 (0.255)	-0.883 (0.286)	-6.998 (0.000)	-10.882 (0.000)

NB: The test statistic is calculated as the average t-statistics of Dickey-Fuller regressions with and without trend. Values in parentheses are p-values. The tests are performed using Eviews 6.