Trade openness degree as technology spillover carrier[1]

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ABSTRACT: This paper addresses commercial openness as a technology transfer channel using a database for 58 countries over a period of 45 years. It is proposed to identify the impact of openness in Total Factor Productivity (TFP) and to verify if the interaction between openness and internal technological efforts impacts productivity. We use a fixed-effect panel model in Instrumental Variables (IV). The results suggest that TFP growth is not affected by long-term openness, although it has temporary positive effects. For developing countries, openness negatively affects TFP, even when variation in the degree of openness interacts with internal technological efforts.
Key-words: Knowledge Spillovers, Trade Openness, Productivity Growth, Developed and Developing Countries.

RESUMO: Este artigo aborda a abertura comercial como um canal de transferência de tecnologia usando um banco de dados para 58 países durante um período de 45 anos. Propõe-se identificar o impacto da abertura na Produtividade Total de Fatores (PTF) e verificar se a interação entre abertura e esforços tecnológicos internos impacta a produtividade. Utilizamos um modelo de painel com efeito fixo em Variáveis Instrumentais (IV). Os resultados sugerem que o crescimento da PTF não é afetado pela abertura a longo prazo, embora tenha efeitos positivos temporários. Para os países em desenvolvimento, a abertura afeta negativamente a PTF, mesmo quando a variação no grau de abertura interage com os esforços tecnológicos internos.
Palavras-chave: Transbordamentos de Conhecimento; Abertura Comercial; Crescimento da Produtividade; Países Desenvolvidos e em Desenvolvimento.

JEL Codes: O10; O33; O47.

Área 9: Economia Industrial e da Tecnologia

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1. Introduction

The discussion about the relationship between trade openness and economic growth commonly arise both theoretical models and empirical works. That is a classical concern in economic theory and currently has become relevant because of the controversial visions on the commercial policy has taken place for the global economy. More specifically, part of the literature proposes openness as a factor determining productivity. For example, Miller & Upadhyay (2000) found that a country's openness has a significant and robust positive effect on total factor productivity (TFP). Therefore, the question is what the mechanism to lead openness to affect productivity growth. To answers this, the literature also identifies the trade as a likely channel of knowledge diffusion among countries and consequently considering the possibility to be a factor that influences the TFP growth.

The theoretical assumption behind the international trade as a channel of technological diffusion is that "international trade of tangible commodities leads to an exchange of intangibles ideas" (GROSSMAN & HELPMAN, 1990), more specifically, these commodities, are understood as capital and intermediate goods. As Eaton & Kortum (2001), Grossman & Helpman (1991), and Caselli & Wilson (2004) stated, countries with more openness in machinery and equipment imports tend to take advantage from external knowledge efforts to improve their growth in total factor productivity (TFP).

However, there are also opposing visions such as those that empirical findings have shown up to now. Theoretical models show ambiguous results between trade openness and growth. For example, there is evidence of a positive relationship between both variables along with the idea that learning by doing is a key issue in the accumulation of human capital (LUCAS, 1993). Furthermore, a positive and significant correlation has been found between the openness variable and long-run economic growth (ULAȘAN, 2012). Nonetheless, another work state that trade openness is negative for developing countries because these countries would produce goods of a very low learning rate (YOUNG, 1991). Additionally, in other recent paper McMillan, Rodrik and Verduzco-Gallo (2014) argue that an intensified globalization process for developing countries have represented a disadvantage, even more, if those countries are revealed with comparatives advantages in natural or primary commodities. They explain that it is due to mobility frictions on the labor market founding evidence that workers have dislocated from higher productivity sectors for the lower ones.

Thus, there seem to be certain differences when we refer to technology spillovers between developing and developed countries. Moreover, Xu & Chiang (2005) argue that the literature has focused on industrialized countries and this, indeed, represents a serious limitation, due to the structural differences between both types of countries. In addition, Ang & Madsen (2013) state that almost all available studies on knowledge spillovers have focused exclusively on the mature OECD countries. Hence, it is convenient to identify at least two groups of countries, since results obtained from a sample of mature industrialized countries do not necessarily extend to developing ones.

An important exception is a work by Coe, Helpman, & Hoffmaister (1997), who investigate the influence on the productivity of knowledge spillovers through the channel of imports from OECD countries to 77 developing countries. Their study focused mainly on the following aspect: knowledge spillovers through the channel of imports from North to South. However, they did not consider the effect on the productivity of domestic knowledge in developing countries, international knowledge transmission through channels other than imports, and knowledge spillovers among developing countries. However, there are not many works that consider the fact that openness defined by imports plus exports to gross domestic product (as a single variable) could have some relationship with TFP growth, in a technology-spillover sense, with exception of Madsen (2009, 2008) that consider openness like a determinant of productivity growth, but only for OECD countries. However, this author states that the interaction between the propensity to import, understood as openness, and its influence on the growth of research intensity in developing countries has not been tested so far. That is, it is not clear what

connection this openness holds to a country's own productivity and technological efforts. Therefore, we start from the hypothesis that trade openness might be a channel of knowledge transmission but with the purpose of potentiating/optimizing internal efforts to impact on TFP growth. Madsen (2009) also argued that one of the main problems faced by developing economies is that they do not yet have the educational and research capacity to exploit effectively the technology that has been developed elsewhere.

Thus, the contribution of this paper is summarized as follow. We associate openness to growth considering the possibility that openness is a carrier of technology spillovers. This is the key issue under investigation here: finding out the link between these two variables and proving the hypothesis mentioned above, proposing to go beyond that countries of OECD limitation, including a sample with developed and developing countries to test our hypothesis not just for High-income countries, but also for other categories of countries by income criteria. Furthermore, two additional objectives are proposed: first, to investigate the long-run and short-run effects of openness in TFP growth, using the cointegrated equations approach. Second, to verify the positive relationship between foreign knowledge stock like technology spillover on productivity growth, for a large sample, including developed and developing countries. In order to answer these questions, we use the knowledge spillovers approach across countries using openness as an added variable to pick up the trade relationship degree, beyond the typical spillovers variables build from resident patents data. Our results for the short-run analyses show that in general for the countries intensify trade relations enhance its productivity in technological terms but in the long-run not seems to have a clear link. However, when we able the interaction of openness with domestic patent data, it prejudices the internal knowledge productivity, even in the short-run. That finding suggests being in line with the capacity to absorption theory, which variance depends on the features of each country in terms of economic structure, and cultural or law institutions. Finally, we find a very strong influence in the short-run of imports from more close countries of technological frontier over productivity growth.

The rest of the paper is presented as follow: Information on the database and methodological issues are presented in Section 2. The results, discussion, and the sensitivity analysis are carried out in Section 3 and 4, respectively. Finally, Section 5 concludes this work. An appendix section is included to present the construction of the variables and additional tests for the estimated models.

2. Data and Methodology

2.1 Database

The dataset covers the period from 1969 to 2014 and comprehends 58 countries: Argentina, Australia, Austria, Belgium, Bolivia, Brazil, Canada, Switzerland, Chile, China, Colombia, Costa Rica, Germany, Denmark, Dominican Republic, Ecuador, Egypt, Spain, Finland, France, United Kingdom, Greece, Guatemala, Hong Kong, Honduras, Indonesia, India, Ireland, Iran, Iceland, Israel, Italy, Japan, Kenya, Republic of Korea, Morocco, Mexico, Malaysia, Nigeria, Nicaragua, Netherlands, Norway, New Zealand, Panama, Peru, Philippines, Portugal, Paraguay, Romania, Singapore, Sweden, Thailand, Tunisia, Turkey, Uruguay, United States, Venezuela, and South Africa.

Data on TFP, GDP, trade and national accounts, and human capital (hc) were obtained from the Penn World Table 9.0 (PWT 9.0). Data on patent applications by resident and non-resident were obtained from the World Bank (WB) Database, which uses the World Intellectual Property Organization (WIPO) as the source. All data but labor – which is measured as an annual average of worked hours by employees – are in US$ million at constant 2011 prices and transformed into natural logarithm form (ln), except for TFP and openness, which are expressed as indexes. From the previous descriptions, Table 1 specifies the variables used in this study, the expected sign and the data source.

Table 1. Description of the main variables of the model

Variable		Description	Expected sign	Source
Explained Variable	*tfp*	Total Factor Productivity Index		PWT 9.0
Explanatory Variables	*O*	Openness Index	+/-	PWT 9.0
	Sd	Domestic Stock of Knowledge	+	WIPO/WB
	Sf	Foreign Stock of Knowledge	+	WIPO/WB
	hc	Human Capital Index	+	PWT 9.0

Source: Author's elaboration.

2.2 Empirical strategy

The empirical strategy followed in this work is based on the data panel techniques. The estimates make through Fixed Effect (FE) or Random Effect (RE). Furthermore, the Instrumental Variable (IV) is used to solve possible endogeneity effects of country productivity on the trade variable. Lastly, estimate via robust errors is used to obtain correct standard errors through heteroskedastic panels.

Based on the specification of Coe & Helpman (1995) and Madsen (2009), the first basic model to be estimated is:

$$\Delta ln\ tfp_{it} = \beta_0 + \beta_1^d\left(\Delta ln\ S_{it}^d\right) + \beta_2^f\left(\Delta ln\ S_{it}^f\right) + \beta_3^o(O_{it}) + \beta_4^{od}(O_{it})\left(\Delta ln\ s_{it}^d\right) + \beta_5^{hc}(hc) + \beta_6^{hc^2}(hc^2) + \beta_7^I(I_{it}) + \varepsilon_{it}, \quad (1)$$

where *tfp* is total factor productivity, S^d is the domestic knowledge capital, S^f is the foreign stock of knowledge spillovers through the trade channel, O is the level of trade openness, $O(S^d)$ is the interaction between openness and domestic knowledge stock, *hc* is a human capital index, I is a vector of selected instrumentals variables, and ε is an error term. Δ is the first difference operator, the subscripts i and t signify country and time, respectively, and β is the respective coefficient.

The term $O(\Delta \ln S^d)$ is constructed in order to test the hypothesis that openness associated with domestic R&D efforts positively affects *tfp* in the long run. It is expected to be positive if the trade of product varieties between advanced and less developed countries improves innovative activities provided that the existence of absorptive capacity in less developed countries. The opposite case could be evidence for supporting the argument of Rodríguez & Rodrik (2000), who state that the presence of some trade barriers may be good for the internal development of knowledge and technology.

Additionally, we also are interested in observing the short-term effects of openness on productivity. For this purpose, we include two more variables: openness in first difference, ΔO, and interaction with domestic knowledge, $\Delta O(\Delta ln\ S^d)$. Thus, we have a second equation to estimate:

$$\Delta \ln tfp_{it} = \beta_0 + \beta_1^d\left(\Delta \ln S_{it}^d\right) + \beta_2^f\left(\Delta \ln S_{it}^f\right) + \beta_3^o(\Delta O_{it}) + \beta_4^{od}(\Delta O_{it})\left(\Delta \ln s_{it}^d\right) + \beta_5^{hc}(hc) + \beta_6^{hc^2}(hc^2) + \beta_7^I(I_{it}) + \varepsilon_{it}, \quad (2)$$

Two brief comments are needed at this point. First, it is not possible to include both variables of openness in the same equation, for methodological reasons. That is because the estimation would present collinearity since we consider openness to be probably endogenous and we use openness lagged and in differences as instruments in order to exclude such endogeneity.

Second, the first difference operator (Δ) is included to capture the influences of economic cycles. About this, the literature in micro studies has generally shown a positive association between increased exports and productivity growth. However, the relationship between imports and productivity growth is often negative. That observed pattern is likely to be since countries tend to export goods in which they have a comparative advantage and to import goods in which they do not, which generates inability to distinguish between the expected positive effect of imports on TFP growth in the long run and the fact that imports are drawn to low productivity sectors where a country does not have an international advantage. In addition, the observed relationships could also be explained by the well-known pro-cyclical nature of productivity growth: this tends to be higher when output is growing and falls during recessions or low-growth periods. Therefore, if greater import penetration is accompanied by a contraction of the domestic industry, productivity growth is expected to fall as well. This is known as the simultaneity problem (HARRISON, 1996).

To solve this issue, some authors, such as Quah & Rauch (1990), use trade shares as a proxy for openness to decompose the short- and long-run effects of openness on economic growth and take out the trend component of the series. They find that most of the observed positive relationship between openness

and growth is due to short-run cyclical fluctuations. Furthermore, the choice of the model makes through the Sargan-Hansen test, which is applied by the IV. The null hypothesis says that the overidentifying assumptions are valid. That is, it tests the validity of the used instruments.

2.3 Descriptive statistics analyses

The descriptive statistical analysis of the data is now presented. Table 2 shows the mean and standard deviation of the main variables used in the model, organized by a group of countries, and each variable denotes Domestic Knowledge Capital, S^d_{it}, Foreign Knowledge Spillover, $S^f_{it,}$ and Openness, O_{cit}. Moreover, the last column presents the percental distribution of the sample by country category.

Due to characteristic differences between countries, which may affect the knowledge transmission among developed and developing economies through intermediate varieties imports, we use a classification suggested by Ghimire, Kapri & Rahman (2018). According to the World Bank convention, countries with per capita income (in US dollars) below 1,025 are defined as lower-income economies, per capita income between 1,025 and 4,035 defines lower-middle-income economies, upper-middle-income economies have per capita income between 4,035 and 12,475, and countries with per capita income above 12,475 are defined as high-income economies. The correlation matrix (presented in the appendix) shows the main variables in this study. We also include the control variable and instruments used in section 3. Such variables are explained by solving endogeneity problems of openness. The most important object here is to observe any possible collinearity relation between the explanatory variables. However, as the table shows, this problem does not seem to exist because the correlation coefficients do not exhibit high values. In addition, the correlation coefficient among the explanatory and the explained variable, TFP, states how strong the relation between them is. In this case, the Foreign Knowledge Stock, *Sf*, has the strongest correlation, in addition to showing a positive sign, followed by the Unemployment Rate Growth and Openness in First Difference, with negative and positive signs, respectively.

Table 2. Summary statistics

Countries Category	Domestic Knowledge		Foreign Knowledge		Openness		Percent (%)
	Mean	***Std***	***Mean***	***Std***	***Mean***	***Std***	
High-income	10.180	1.648	12.778	0.977	0.526	0.309	29.82%
Emerging-income	7.368	2.902	11.643	1.101	0.763	0.928	21.05%
Middle-income	6.360	2.024	10.444	1.072	0.614	0.373	33.33%
Low-income	3.019	2.044	9.357	1.036	0.657	0.298	15.79%

Source: Author's elaboration.

Additionally, Figures 1 and 2 show the scatterplot for TFP and Openness. In the first figure, we can observe a positive trend for the annual average variation. However, there is a clear presence of outliers in both directions, as the case of Hong Kong or Singapore, which are countries with a very high openness volume and, at the same time, increasing productivity rates. In contrast, we find that Iran is in a very opposite situation, with a negative productivity growth rate and the lowest rate for openness in the sample. In Figure 2, nevertheless, there seems to be no clear relationship between the TFP annual average growth rate and the annual average of the openness level. This could suggest that TFP and Openness are more closely linked in the short-run, which is also supported by the coefficient between $\Delta ln\ tfp$ and ΔO presented in the correlation matrix.

3. Estimation Results

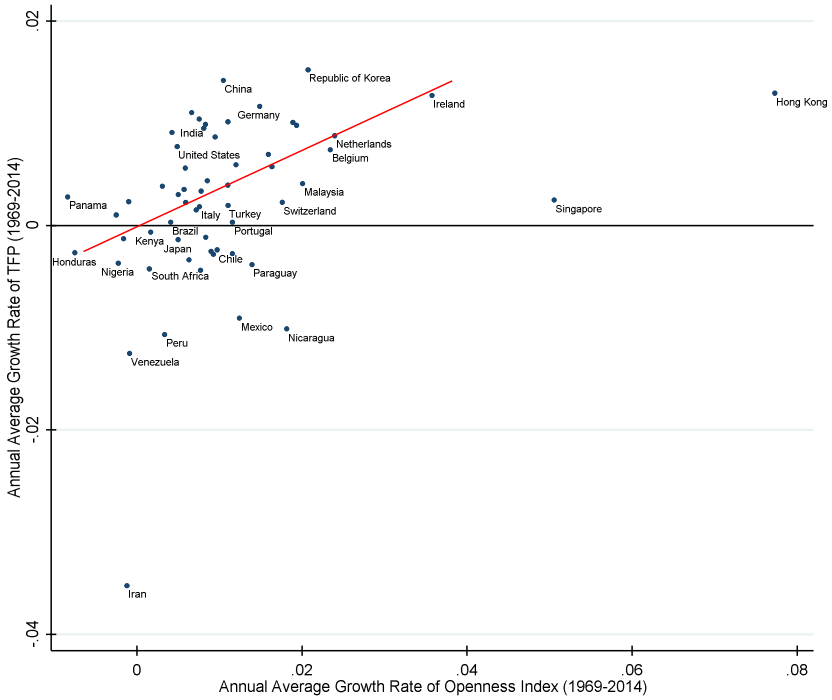
Table 3 shows the coefficients for the entire period (1969-2014). The tests for instruments overidentification do not reject the null hypothesis that the instruments are exogenous at 10% significance level. *Openness* (O) is measured by import plus export to GDP, the estimated coefficients of this variable in level are statistically insignificant, except for the estimates when the *Openness Variation* (ΔO) is

considered. In general, these results suggest that openness has no permanent effects on productivity growth but may have direct temporary positive effects on growth.

In turn, when we analyze the interaction variable, $\Delta O^{*}\Delta ln\ S^{d}$, there is a significant negative coefficient. This result is an interesting finding because, although the openness itself does not seem to be clearly related to the growth of productivity, and even the openness change rate is positive and highly significant, it suggests that higher openness could decrease TFP even when the domestic knowledge efforts are considered, at least in the short-run. This result is in line with what is suggested by Rodriguez and Rodrick (2000). According to these authors, there is a conceptual distinction between quantity and quality effects of trade policies on growth.

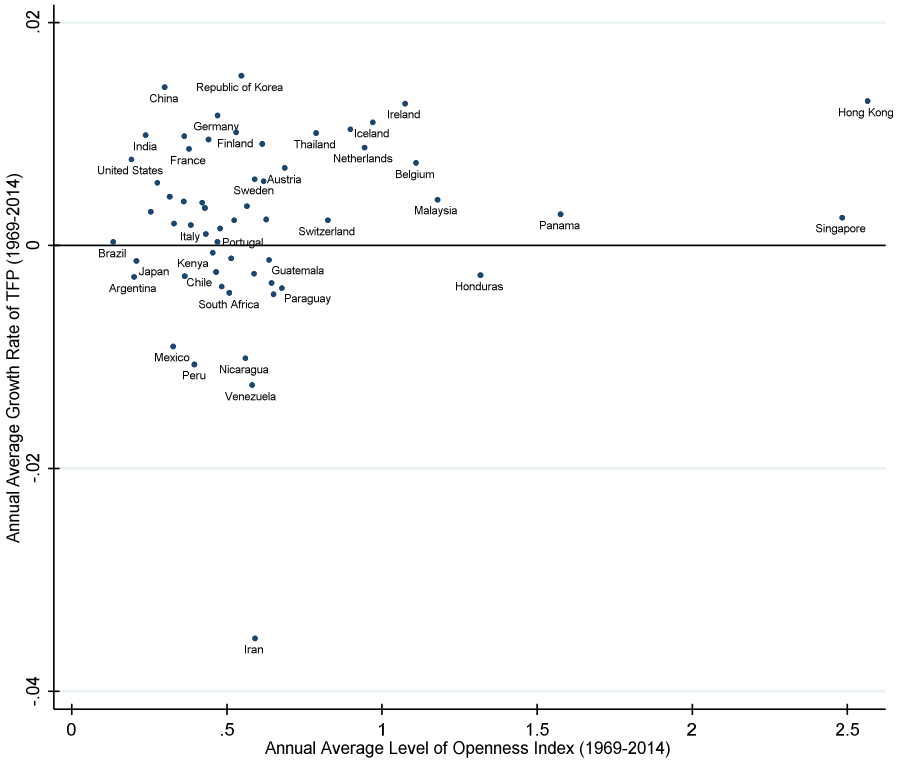
That is, openness influences higher volume of trade, but it does not necessarily improve productivity growth in the same sense or directions, because the volume of trade may also be influenced by other factors, like changes in world demand or geographical relations, which in turn affect growth. Then, when we investigate openness as one possible channel that affects the internal knowledge progress, we find results that suggest a negative link among these variables in the sense to affect productivity. Moreover, this interaction term is tested for different categories of countries, keeping the negative relation in Middle and Low-income countries, but only being significant in emerging countries. In High-income countries, however, the relationship is positive but not significant. The estimated coefficients of *Foreign Spillovers (ΔlnSf)* are consistently positive and highly significant.

Figure 1. The relationship between the annual average growth rate of TFP and Openness (1969-2014)



Notes: Each point represents a country of the sample. The annual average measures the growth rate of TFP and the Openness index in level between 1969 and 2014.
Source: Author's elaboration.

Figure 2. The relationship between the annual average growth rate of TFP and Openness in level (1969-2014)



Notes: Each point represents a country of the sample. The red line is a trend line around observations. The annual average growth rate measures the variation of TFP and Openness index between 1969 and 2014.
Source: Author's elaboration.

Because $\Delta lnSf$ is based on the interaction between import penetration and foreign stock of knowledge, this result suggests that openness has temporary growth effects, provided that the country trades with countries that have increasing knowledge stocks.

About the control variables, we find that the *Human Capital* is slightly significant and has a negative link with the growth rate of productivity, but when we take the square of this variable, it appears to be positively related and significant. This implies that *Human Capital* (*hc*) performs better as a quadratic form, that is, the more investment and development in human capital, the more productivity grows at a proportionally higher rate. In addition, a set of instrumental variables to openness are involved as indicated by the last section. Although most of these variables are not significant, it is important to include them in order to solve endogeneity issues.

Table 4 shows the results for the same regression, for the first half of the period, from 1969 to 1991. We chose this period because, after it, the global geopolitical order changed due to the fall of the Union of Soviet Socialist Republics (USSR), which could have affected the international trade flow. *Openness*, in this case, is significant and positive in relation to productivity growth, whereas its *variation* is mostly positive and significant. These results suggest that openness was important for productivity growth in this period, but that the beneficial effects of openness come from knowledge, as is demonstrated by the growth rate of the *Foreign Spillovers* coefficient, which is positive and strongly significant.

Table 3. Drivers of Total Factor Productivity by Categories of Countries (1969-2014). Estimations Based on Instrumental Variables (IV).

Variable	IV			
	1	2	3	4
Openness (O)	0.034	0.037		
ΔO			0.204***	0.204***
Δln Domestic Knowledge Stock (Sd)	0.003	0.003	0.001	0.000
Δln Foreign Knowledge Stock (Sf)	0.088***	0.089***	0.065***	0.065***
O*Δln Sd	-0.004			
O*Δln Sd (High income)		0.018		
O*Δln Sd (Emerging income)		-0.007***		
O*Δln Sd (Middle income)		0.000		
O*Δln Sd (Low income)		-0.007		
ΔO*Δln Sd			-0.099**	
ΔO*Δln Sd (High income)				0.226
ΔO*Δln Sd (Emerging income)				-0.102***
ΔO*Δln Sd (Middle income)				-0.020
ΔO*Δln Sd (Low income)				-0.097
Human Capital (hc)	-0.045**	-0.044**	-0.052**	-0.052**
Square of Human Capital (hc^2)	0.007*	0.007*	0.010**	0.010**
ln population (pop)	0.064***	0.065***	0.055***	0.055***
population density (pop_den)	-0.000	-0.000	-0.000	-0.000
unemployment rate (unemp_rate)	0.000	0.000	0.000	0.000
Δunemp_rate	-0.001**	-0.001**	-0.002***	-0.002***
inflation (π)	-0.001	-0.001	-0.001	-0.001
Time Dummy (TD)	yes	yes	yes	yes
N	1046	1046	1046	1046
r2	0.352	0.353	0.255	0.255
Hansen J statistic Prob > chi2	0.80	0.78	0.84	0.83
Underidentification test Prob > chi2	0.00	0.00	0.00	0.00

Legend: * p<.1; ** p<.05; *** p<.01

Notes: The Hansen J statistic is the overidentification test for all instruments. The following instruments are used for openness: the human capital index, the population in logarithmic form, population density, rate of unemployment, changes in the rate of unemployment, inflation, and all years' time dummies. As excluded instruments, we use the first difference of openness and the agricultural GDP growth. For these results, we take out China; however, similar results are obtained if China is included in the models.

Besides, when we observe the interaction between both variables for Openness and the Domestic Knowledge Stock, it is positive although not significant, but, if we explore within countries by income categories, we find that for it is positive and strongly significant for low-income countries. This suggests that openness had positive temporary and permanent effects, along these two decades, on the internal efforts of this type of countries.

Table 4. Drivers of Total Factor Productivity by Categories of Countries (1969-1991). Estimations Based on Instrumental Variables (IV).

Variable	IV			
	1	2	3	4
Openness (O)	0.064**	0.044		

ΔO			0.092*	0.100**
Δln Domestic Knowledge Stock (Sd)	-0.004	-0.006	-0.001	-0.001
Δln Foreign Knowledge Stock (Sf)	0.075***	0.075***	0.071***	0.073***
O*Δln Sd	0.004			
O*Δln Sd (High income)		-0.07		
O*Δln Sd (Emerging income)		-0.006		
O*Δln Sd (Middle income)		0.006		
O*Δln Sd (Low income)		0.424***		
ΔO*Δln Sd			0.201	
ΔO*Δln Sd (High income)				-1.856
ΔO*Δln Sd (Emerging income)				0.017
ΔO*Δln Sd (M income)				0.225
ΔO*Δln Sd (Low income)				2.079**
Human Capital (hc)	-0.12	-0.159*	-0.047	-0.047
hc2	0.021	0.031	0.009	0.01
ln population (pop)	0.074	0.129**	0.004	0.006
population density (pop_den)	0.000	0.000	0.000	0.000
unemployed rate (unemp_rate)	0.001	0.002*	0.001	0.001
Δunemp_rate	-0.006***	-0.006***	-0.006***	-0.006***
inflation (π)	-0.001	-0.001	-0.001	-0.001
Time Dummy (TD)	yes	yes	yes	yes
N	295	295	295	295
r2	0.39	0.45	0.40	0.40
Hansen J statistic Prob > chi2	0.97	0.90	0.84	0.75
Underidentification test	0.04	0.04	0.05	0.05

Legend: * p<.1; ** p<.05; *** p<.01.
See notes to Table 3.

Finally, consider the results for the last 22 years of the sample in Table 5. The level of Openness does not have significance, but its variation rate is strongly significant and positive in relation to productivity growth. However, specifically, when we analyze the interaction in differences regarding knowledge internal efforts, ΔO*ΔSd, it has a negative and significant relation.

In the estimation, by categories of countries, we can see a positive but not significant relation for the High-income countries, while the relation is highly significant but negative for the Emerging-income countries. This result suggests that, while openness may have been beneficial for developed countries in terms of their knowledge productivity, high degrees of openness does not seem to be suitable for developing emerging economies. However, for the rest of the countries categories, Middle and Low-income, the coefficients are also negative but do not present significance for the openness-knowledge link. In general, this may suggest that, although trade relations among countries have intensified in the last two decades in contrast to the estimation of previous years, the result has been positive for developed countries as opposed to developing countries, that is, openness has had temporary negative effects for the latter along the last two decades.

For these results, we can analyze that the *variation rate* of the openness itself has a direct relationship with productivity growth, but when we test this specifically in relation to internal knowledge efforts, the trade becomes a negative factor for countries' internal development of knowledge and technology, even more so for developing economies. That may suggest that a lower openness degree would be good for such economies. Thus, according to these first results, the hypothesis that trade leads

to knowledge spillovers between countries in terms of internal development efforts is only confirmed for the High-income category along nearly the last three decades. In contrast, for the rest of the countries evaluated in the present study, this hypothesis is not confirmed, because openness is either negative or not significant.

Table 5. Drivers of Total Factor Productivity by Categories of Countries (1991-2014). Estimations Based on Instrumental Variables (IV)

Variable	IV			
	1	2	3	4
Openness (O)	0.028	0.027		
ΔO			0.139*	0.139*
Δln Domestic Knowledge Stock (Sd)	0.005	0.004	0.001	0.001
Δln Foreign Knowledge Stock (Sf)	0.096***	0.096***	0.074***	0.074***
O*Δln Sd	-0.007***			
O*Δln Sd (High income)		0.014		
O*Δln Sd (Emerging income)		-0.009**		
O*Δln Sd (Middle income)		0.003		
O*Δln Sd (Low income)		-0.011		
ΔO*Δln Sd			-0.081**	
ΔO*Δln Sd (High income)				0.237
ΔO*Δln Sd (Emerging income)				-0.080***
ΔO*Δln Sd (Middle income)				-0.075
ΔO*Δln Sd (Low income)				-0.112
Human Capital (hc)	-0.044**	-0.045**	-0.041*	-0.041*
hc2	0.008*	0.008*	0.007*	0.007*
ln population (pop)	0.085**	0.083**	0.064***	0.064***
population density (pop_den)	0.000	0.000	0.000	0.000
unemployed rate (unemp_rate)	0.000	0.000	0.000	0.000
Δunemp_rate	-0.001	-0.001	-0.001	-0.001
inflation (π)	-0.001	-0.001	-0.001	-0.001
Time Dummy (TD)	yes	yes	yes	yes
N	722	722	722	722
r2	0.34	0.35	0.29	0.29
Hansen J statistic Prob > chi2	0.88	0.86	0.77	0.77
Underidentification test	0.06	0.06	0.06	0.04

Legend: * p<.1; ** p<.05; *** p<.01.
See notes to Table 3.

4. Sensitivity Analyses

To test the sensitivity of the results, model specification in Equation (1) and (2), is extended to allow for the interaction between openness and foreign knowledge spillovers. The following two equations are estimated:

$$\Delta ln\ tfp_{it} = \beta_0 + \beta_1^d(\Delta ln\ S_{it}^d) + \beta_2^f(\Delta ln\ S_{it}^f) + \beta_3^o(O_{it}) + \beta_4^{od}(O_{it})(\Delta ln\ s_{it}^d) + \beta_5^{of}(O_{it})(\Delta ln\ s_{it}^f) + \beta_6^{hc}(hc) + \beta_7^{hc^2}(hc^2) + \beta_8^I(I_{it}) + \varepsilon_{it}, \quad (3)$$

$$\Delta ln\ tfp_{it} = \beta_0 + \beta_1^d(\Delta ln\ S_{it}^d) + \beta_2^f(\Delta ln\ S_{it}^f) + \beta_3^o(\Delta O_{it}) + \beta_4^{od}(\Delta O_{it})(\Delta ln\ s_{it}^d) + \beta_5^{of}(\Delta O_{it})(\Delta ln\ s_{it}^f) + \beta_6^{hc}(hc) + \beta_7^{hc^2}(hc^2) + \beta_8^I(I_{it}) + \varepsilon_{it}, \quad (4)$$

Following the seminal work of Coe and Helpman (1995) and the strategy used by Madsen (2009), as well as the related empirical literature, we include such interaction term. Coe and Helpman (1995) interacted *O* and ΔlnS^f to capture the role of international trade. They reasoned that, although S^f constructs by the import-weighted stock of knowledge, these weights are fractions that add up to one and, therefore, do not implies necessarily openness. In this study, we use the weights like Lichtenberg and de la Potterie (1998) to construct *Sf*, whose weights do not add up to one, but are influenced by imports. Madsen (2009) states that the importance of making the interaction between *O* and *lnSf* is to investigate whether knowledge spillovers through the openness channel influence growth in a non-linear way.

The results for this analysis, presented in Table 6, show that the estimated coefficients of $\Delta O^*\Delta lnSf$ are not significant, which suggests that, for most of the countries in the sample, a higher openness index does not influence the country's capacity to absorb knowledge. However, the estimated coefficients of $\Delta lnSf$ keep positive and strongly significative, which suggests that, for these countries, the quality of their imports is more important than the openness degree of the economy. In other words, knowledge spillovers are more efficient in improving productivity when imports come from countries closer to the technological frontier.

A second sensitivity test is presented, as suggested by Coe and Helpman (1995). Below, we allow the initial model of the equations (1) and (2) to be extended by turning it into a production function:

$$ln\, Y_{it} = \beta_0 + \beta_1^K(ln\, K) + \beta_2^L(ln\, L) + \beta_3^d\left(\Delta ln\, S_{it}^d\right) + \beta_4^f\left(\Delta ln\, S_{it}^f\right) + \beta_5^o(O_{it}) + \beta_6^{od}(O_{it})\left(\Delta ln\, s_{it}^d\right) + \beta_7^{hc}(hc) + \beta_8^{hc^2}(hc^2) + \beta_9^I(I_{it}) + \varepsilon_{it}, \quad (5)$$

$$ln\, Y_{it} = \beta_0 + \beta_1^K(ln\, K) + \beta_2^L(ln\, L) + \beta_3^d\left(\Delta ln\, S_{it}^d\right) + \beta_4^f\left(\Delta ln\, S_{it}^f\right) + \beta_5^o(\Delta O_{it}) + \beta_6^{od}(\Delta O_{it})\left(\Delta ln\, s_{it}^d\right) + \beta_7^{hc}(hc) + \beta_8^{hc^2}(hc^2) + \beta_9^I(I_{it}) + \varepsilon_{it}, \quad (6)$$

Table 7 shows the estimated results of this test. Both capital and labor coefficients are significant, with the elasticity of the labor being larger than the elasticity of the physical capital. That could suggest that most of the countries in the sample have more share of the labor factor than capital. That is, it is probable that the developing countries involve more labor-intensive processes while developed countries are more capital-intensive. For the rest of the essential variables in the present study, although they lose significance, the main results of the coefficient signs are not modified.

Table 6 Drivers of Total Factor Productivity by Categories of Countries (1969-2014). Estimations Based on Instrumental Variables (IV).

Variable	IV			
	1	2	3	4
ΔO*Δln Sf	0.063	0.073	-0.354	-0.393
Openness (O)	0.026	0.028		
ΔO			0.248*	0.252*
Δln Domestic Knowledge Stock (lnSd)	0.003	0.002	0.000	-0.002
Δln Foreign Knowledge Stock (lnSf)	0.088***	0.088***	0.064***	0.064***
O*Δln Sd	-0.007***			
O*Δln Sd (High income)		0.019		
O*Δln Sd (Emerging income)		-0.007**		
O*Δln Sd (Middle income)		0.001		
O*Δln Sd (Low income)		-0.006		
ΔO*Δln Sd			-0.089**	
ΔO*Δln Sd (High income)				0.294
ΔO*Δln Sd (Emerging income)				-0.096***
ΔO*Δln Sd (M income)				0.071

ΔO*Δln Sd (Low income)				-0.005
Human Capital (hc)	-0.045**	-0.044**	-0.054***	-0.054***
hc2	0.007*	0.007*	0.010**	0.010**
ln population (pop)	0.060**	0.061**	0.056***	0.055***
population density (pop_den)	-0.000	-0.000	-0.000	-0.000
unemployed rate (unemp_rate)	0.000	0.000	0.000	0.000
Δunemp_rate	-0.001**	-0.001**	-0.002***	-0.002***
inflation (π)	-0.001	-0.001	-0.001	-0.001
Time Dummy (TD)	yes	yes	yes	yes
N	722	722	722	722
r2	0.35	0.36	0.22	0.21
Hansen J statistic Prob > chi2	0.87	0.87	0.76	0.74
Underidentification test	0.00	0.00	0.00	0.00

Legend: * p<.1; ** p<.05; *** p<.01.
See notes to Table 3.

The variable Δ*O* appears to be not significant for the output but keep its positive sign. Moreover, the principal finding of this test is observed by the elasticity of the interaction between Openness (*O* and Δ*O)* and Domestic Stock of Knowledge (Δ*lnSd*), which confirms its negative relation, such as one of our main results of the original model indicates, even when we observe the countries by category.

Table 7 Drivers of GDP by Categories of Countries (1969-2014). Estimations Based on Instrumental Variables (IV).

Variable	IV			
	1	2	3	4
ln K	0.028**	0.028**	0.029**	0.028**
ln L	0.673***	0.669***	0.671***	0.671***
Openness (O)	-0.037	-0.033		
ΔO			0.110	0.095
Δln Domestic Knowledge Stock (lnSd)	0.040**	0.061*	0.026*	0.029*
Δln Foreign Knowledge Stock (lnSf)	0.085	0.087	0.063	0.064
O*Δln Sd	-0.015			
O*Δln Sd (High income)		-0.180*		
O*Δln Sd (Emerging income)		-0.021		
O*Δln Sd (Middle income)		-0.026		
O*Δln Sd (Low income)		-0.075		
ΔO*Δln Sd			-0.052	
ΔO*Δln Sd (High income)				0.554
ΔO*Δln Sd (Emerging income)				-0.036
ΔO*Δln Sd (M income)				-0.572
ΔO*Δln Sd (Low income)				0.166
Human Capital (hc)	-0.025	-0.031	-0.089	-0.092
hc2	0.019	0.020	0.032	0.033
ln population (pop)	0.867***	0.871***	0.908***	0.916***
population density (pop_den)	0.000***	0.000***	0.000***	0.000***

unemployed rate (unemp_rate)	-0.004	-0.004	-0.004	-0.004
Δunemp_rate	-0.001	-0.001	-0.002	-0.002
inflation (π)	-0.001***	-0.001***	-0.001***	-0.001***
Time Dummy (TD)	yes	yes	yes	yes
N	648	648	648	648
r2	0.93	0.93	0.93	0.93
Hansen J statistic Prob > chi2	0.81	0.81	0.76	0.74
Underidentification test	0.01	0.01	0.00	0.00

Legend: * p<.1; ** p<.05; *** p<.01.
See notes to Table 3.

5. Conclusions

This article provides an empirical study on the influence that trade openness has on the growth of TFP in the sense that it is a channel of transmission of knowledge spillovers that affect the countries' technological capacity. The focus of this paper was to extend this discussion to a sample that also includes developing countries. Therefore, it aimed not only to study openness as a channel of spillovers but also to investigate how it influences the domestic generation of knowledge and the productivity of the economies by categories of countries.

The results reveal that the degree of openness does not have a permanent effect on TFP growth, although its variation rate shows a significant and positive impact on TFP, which implies that, in the short-run, a higher openness degree leads gains of TFP growth. This result is supported by all estimates. Another variable that presents a very important influence on TFP growth is the Foreign Stock of Knowledge that countries receive from others with higher levels of technological development. For the countries that are more distant from the technological frontier, it is important, in the short term, to contact those countries that have technologically developed intermediate and finals goods because this implies savings in terms of time and resources when it is necessary to carry out any productive or industrial process. However, it does not necessarily imply that these technologies are developed internally by developing economies. It is necessary to associate imports of capital and intermediate goods to active learning strategies such as domestic technological efforts.

The main idea investigated in this study was the interaction between openness (in level and in first difference) and the Domestic Stock of Knowledge, finding a significant negative link for the entire sample in most of the estimates. This suggests that more openness may impede productivity gains even domestic technological efforts are present. The reason could be associated with the predatory competition that does not allow the development of infant industries. Therefore, in order to present new evidence on this issue, both with theoretical and policy implications, we proposed to also test this hypothesis by categories of countries. We found that the level of openness, when interacted with domestic R&D efforts, has a positive but not significant impact on TFP in high and middle-income countries. For the rest of countries, the relationship is negative, being significant for emerging-income, both related to temporary and permanent effects. Hence, according to these results, these countries' performance is in line with Rodriguez and Rodrick's (2000) hypothesis, which is that countries with a large share of commodities in their GDP tend to specialize in this type of market to the detriment of their domestic technology industries.

Nevertheless, another interesting finding of our research is that the interaction between openness and domestic knowledge is positive and significant only for the low-income countries in the first two decades of the sample, from 1969 to 1991. We can note in the figures of descriptive statistics that after the 1990s trade relations among countries intensified through financial integration and trade agreements. The results suggest that the liberalization of trade after these two decades has been little beneficial for developing countries because, in the estimate for the second half of the period, 1991-2014, the scene

changes drastically, the coefficients turn negative and insignificant. In general, we conclude that in, in the short run, openness is effectively a carrier of technological spillover that improves productivity growth but does not have a permanent effect in the long run, which corroborates the results of the literature. Nevertheless, when we test how the economies react internally in industrial and technological terms, openness has negative effects on productivity in developing countries, as exposed above. Finally, we performed the sensitivity analyses, finding slight or no changes in the main results for the research purposes. It is important to make a final comment. Although these results have been tested by different robustness tests, for future work is recommended contrasting such results using other measures of openness and stock of knowledge.

6. Appendix

Tests and Diagnostics

In this section, we proceed to do some tests on the prior estimations in order to identify several econometrics issues related to panel data methodology, following the guide proposed by Torres (2007). First, we prove if Fixed Effects (FE) is the appropriate model for this panel data through the Breusch-Pagan Lagrange multiplier (LM), which helps in the choice between a FE regression or a simple Ordinary Least Square (OLS) regression. The null hypothesis in the LM test is that variances across entities are zero. This is, there is no significant difference across units and, therefore, no panel effect. In our case, table A1 shows the results for the LM test. For the *p-value* at a significance level of 95%, we reject the null hypothesis and conclude that FE is appropriate. I.e., there is evidence of significant differences across countries, so a simple OLS regression cannot be run.

Table A1. Breusch-Pagan Lagrange multiplier Test for random effects

	Var	sd = sqrt(Var)
d_tfp	.0092519	.0961865
e	.0066519	.0815589
u	.0010521	.0324363
chibar2 (01)	828.33	
p-value	0.0000	

where d_tfp(country, time) = Xb + u(country) + e(country, time)

The following test proves the presence of heteroskedasticity in the estimated model. The null hypothesis is homoskedasticity or constant variance. It is expected that this hypothesis will not be confirmed, because there are likely to be differences in variance between countries. Table A2 shows the results for this test. The p-value is < 0.05, so we can reject the null hypothesis of constant variance and, therefore, the model has the presence of heteroskedasticity.

Table A2. Heteroskedasticity Test

dtfp	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
dsd	-.0006193	.002743	-0.23	0.821	-.006001	.0047624
dsf	.0550964	.0057441	9.59	0.000	.0438264	.0663664
do_sd	-.0228886	.0307539	-0.74	0.457	-.0832277	.0374505
trade	.011789	.0056387	2.09	0.037	.0007259	.0228522
dtrade	.0496176	.0159012	3.12	0.002	.0184195	.0808158
hc	-.0059929	.0143125	-0.42	0.675	-.0340739	.0220881

sqr_hc	-.0023812	.0026949	-0.88	0.377	-.0076686	.0029062
ln_pop	.0163464	.0074146	2.20	0.028	.0017989	.0308938
pop_den	-5.18e-06	4.07e-06	-1.27	0.204	-.0000132	2.81e-06
unemp_rate	.0002075	.0002412	0.86	0.390	-.0002657	.0006806
dunemp	-.0029374	.0005206	-5.64	0.000	-.0039588	-.0019161
infl	-9.21e-06	1.24e-06	-7.45	0.000	-.0000116	-6.78e-06
cons	-.0272194	.0196551	-1.38	0.166	-.0657827	.011344
sigma_u	.02751737					
sigma_e	.02463524					
rho	.55509512	(fraction of variance due to u_i)				

F test that all u_i=0: F(52, 1169) = 2.21 Prob > F = 0.0000

Modified Wald test for groupwise heteroskedasticity in fixed effect regression model	
chi2 (53)	3029.35
p-value	0.0000

where H0: sigma(i)^2 = sigma^2 for all i

One possible solution for this issue is to use the robust option into the FE and RE models to obtain heteroskedasticity-robust standard errors, also known as Huber-White estimators. For this reason, Section 4 only presented estimates for the models in their robust version.

Table A3 shows the results from the first-stage instrumental variable regressions. Most of the instruments used for trade in level are significant and the r2 is of high value, which suggests that such instruments are valid and suitable to include into the model. The r2 are lower in the regressions side in which ΔO are dependent variables, and most of the estimated coefficients are insignificant. These results suggest that the instruments used for ΔO are not of high quality and that they may potentially give misleading coefficient estimates of ΔO. We conclude that the openness lagged 1 year and the agricultural GDP (gross domestic product) are valid instruments, supported also by the Sargan-Hansen tests.

Table A3. Instruments for trade. Twostep

Variable	O	Δ*O*
ln_pop	0.478***	-0.003
pop_den	0.001***	-0.000**
unemp_rate	-0.001	0.001**
Δunemp	-0.004*	-0.001
π	-0.000*	0.000
Δagr	0.004	-0.001
_cons	2.405***	0.099*
N	1010	1010
R^2	0.81	0.19

legend: * p<.1; ** p<.05; *** p<.01

Notes. pop_den = population density, ln_ pop = population in ln, unemp_rate = the rate of unemployment, agr = agricultural production, π = inflation rate, Δ = year difference estimator. Time-dummies and fixed effects are included in the regressions but not shown.

In order to test de cointegration revised in section, we proceed to apply the Wooldridge (2003) test for autocorrelation and the Kao (1999) and Westerlund (2005) tests of cointegration on a panel dataset. In the case of the Wooldridge test, there is the null hypothesis of no first-order autocorrelation. For the case of Kao and Westerlund tests, there is the common null hypothesis of no cointegration. The alternative hypothesis of the Kao test is that variables are cointegrated in all panels, while the Westerlund test supposes that the variables are cointegrated in some of the panels. This implies more constraint in the Kao test because it assumes a stronger hypothesis in relation to the other test.

When the first difference of a nonstationary process is stationary, the process is said to be integrated of order one, denoted *I* (1). When a linear combination of several *I* (1) series is stationary, the series are said to be cointegrated (ENGLE & GRANGER, 1987). We test for cointegration because cointegration implies that the *I* (1) series are in a long-run equilibrium; they move together, although the group of them can wander arbitrarily. In our case, we are interested in observing the long-run relationship between the growth rate of productivity and the openness in level, which is a nonstationary series, since it contains a unit root as proved by the Levin-Lin-Chu test and the Breitung test in section 3.4. From the p-value results of Tables A5 and A6, we cannot reject the null of the Autocorrelation test (for α=5%), and we reject the null of the Cointegration test. Hence, we conclude that the series is cointegrated and the inclusion of the variable openness in level is valid.

Table A4. Wooldridge Test for first-order Autocorrelation

Model of Equation (1) without countries category	F(1, 51) = 3.786 Prob > F = 0.0572
Model of Equation (1) with countries category	F(1, 51) = 3.555 Prob > F = 0.0651

Table A5. Tests for Cointegration

	Kao Test	Westerlund Test
Model of Equation (1)	Unadjusted modified Dickey-Fuller t -32.3908 P-value 0.0000 Unadjusted Dickey-Fuller t -23.2661 P-value 0.0000	Variance ratio -3.5899 P-value 0.0002

Table A6 shows the correlation matrix of the variables used in this study. That analysis is done in Section 2.3.

Table A6. Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Δ*ln tfp*	1														
2 Δ*ln Sd*	-0.0128	1													
3 Δ*ln Sf*	0.4228	0.0177	1												
4 *O*	0.0178	0.0834	0.0781	1											
5 Δ*O*	0.2237	0.077	0.3418	0.1744	1										
6 *O**Δ*Sd*	-0.0244	0.8006	0.0194	0.2477	0.1602	1									
7 Δ*O**Δ*Sd*	0.0118	0.3956	0.0669	0.1562	0.2798	0.6826	1								
8 *hc*	0.1021	-0.0787	0.0096	0.0395	0.0082	-0.042	-0.011	1							
9 *hc2*	0.1006	-0.0772	0.0038	0.029	0.0035	-0.047	-0.0166	0.9916	1						
10 *ln pop*	-0.0116	0.0311	0.0059	-0.4207	-0.052	-0.0629	-0.0541	-0.0281	-0.0133	1					
11 *pop den*	0.0221	0.0759	0.0327	0.7367	0.1421	0.2363	0.1567	0.0163	0.0158	-0.2185	1				
12 *unemp rate*	-0.0799	-0.016	-0.0817	-0.1384	-0.0104	-0.0519	-0.0281	-0.0701	-0.0864	0.0292	-0.1867	1			
13 Δ*unemp rate*	-0.2399	0.0369	-0.2929	-0.0324	-0.024	0.0345	0.0065	0.0084	0.004	0.0122	-0.0159	0.1977	1		
14 *inflation*	-0.0969	-0.0304	-0.0575	-0.0533	0.0023	-0.0185	-0.0084	-0.0543	-0.0555	-0.0057	-0.0224	0.0657	0.0908	1	
15 Δ*agr gdp*	-0.0196	-0.0224	-0.0933	0.0242	-0.0213	0.0025	-0.0078	0.0699	0.0731	-0.0214	0.0197	0.0562	0.0179	-0.0506	1

Source: Author's elaboration

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