Innovation in the Global Economy: Opening-Up Latin American Innovation Systems

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Abstract

Using different country-level datasets, this paper studies the relationship between innovation and economic integration in the global economy. The macroeconomic evidence exploits the fact that different countries liberalized international trade at different moments to look at the evolution of innovation. The evidence indicates that trade reforms have not been relevant to increase country-level innovation outcomes. We found that these results are robust to controlling for other determinants of innovation results. On the other hand, our findings also suggest that integration in the global economy has strong potential for technology transfer but that some explicit complementary innovation policies are needed. We close this paper with some innovation policy recommendations that can be implemented in order to improve the impacts of trade liberalization on LAC innovation systems.

JEL classifications: F02, F23, O33.

Key words: Ideas Production, Schumpeterian Growth Models, International Knowledge Transmission.

1. INTRODUCTION

Since the collapse of the import substitution model, most countries in Latin America and the Caribbean (LAC) have taken increasing steps toward economic liberalization. Early reformers such as Chile, Colombia, and Mexico opened their economies in the early 1970s and 1980s and undertook several structural reforms oriented toward enhancing economic performance. Since then, other countries have followed similar paths. Even though some have since implemented heterodox policies again, openness to international trade has not been reversed.

Several assumptions regarding the potential impacts of trade liberalization on economic performance were taken for granted when these reforms were implemented, especially those justifying the positive results for innovation associated with greater integration into the world economy. Indeed, it was expected that as a result of reductions to trade barriers and restrictions to foreign direct investment, countries would increase innovation through several channels, such as economies of scale through an enlarged market size, better specialization in goods with true comparative advantage, and spillovers from the knowledge frontier through inflows of foreign direct investment, and learning by exporting and importing, among others.

On the other hand, although there are strong reasons to expect a positive outcome of trade reforms on innovation, this is something that cannot be taken for granted. First, economic liberalization was not only a characteristic of LAC countries, it was also a worldwide phenomenon affecting the relative supply and demand of goods and services. In this context, the irruption of China into the world economy and the strong demand for natural resources this entailed might have induced a problem of bad specialization, which may have led developing regions such as LAC to specialize in the supply of commodity products with very low or null technological opportunities. Second, most of the knowledge available in the global economy has tacit components. Given this, taking advantage of growing exposure to the knowledge frontier (through trade, for example) requires countries to have sufficient absorptive capacities to be able to decodify this knowledge. Consequently, it might be the lack of these absorptive capacities which ends up preventing countries from accessing the benefits of globalization. Indeed, market and institutional failures that hinder economic integration may co-exist with other failures, so it might be that the absence of complementary public inputs (universities, public research centers, proper intellectual property right regulations, and human capital) might harm the chances of countries benefiting from international trade.

A third reason why trade liberalization might not necessarily lead to more innovation takes us back to the relationship between innovation and the increased competition induced by trade exposure. This is one of the most studied subjects in the empirical industrial organization literature, and the results are ambiguous so far. From a theoretical point of view, there are at least two different rationales in operation. On the one hand, the so-called Schumpeterian view states that to the extent that increased competition threatens the appropriability of postinnovation rents, more competitive environments could harm innovation efforts. This contrasts with the escape-from-competition approach, according to which competition challenges pre-innovation rents, prompting firms to innovate to escape competition. If trade liberalization induces more competition within domestic markets, this could harm innovation if Schumpeterian effects prevail.

The goal of this paper is to assess how innovation relates to the increased trade liberalization experienced by LAC in recent decades. This paper tries to understand how trade liberalization has been associated with changes in innovation by exploring macroeconomic data across a large set of countries. The paper finds that trade liberalization on its own does not increase the efficiency of a domestic innovation system. Idea generation remains determined by domestic efforts such as investment in R&D, the domestic knowledge stock, and the adoption of knowledge from the international knowledge frontier. We do find, however, some weak evidence that the impact of trade liberalization on innovation seems to be positive but is conditional on investments in human capital, which need to exceed a certain threshold. These results suggest that some sort of explicit innovation policies focusing on creating absorptive capacities might be needed in order to take advantage of the opportunities offered by accessing the international global knowledge frontier.

This paper is structured as follows. In the second section, we discuss the existing literature on the relationship between trade liberalization and innovation. In the third section, we describe the conceptual approach, the main hypotheses, and describe how our main macro data is constructed. In the fourth section, we present our empirical results. In the fifth section, we outline several policy recommendations that could be put forward in order to take advantage of the opportunities of trade liberalization to encourage innovation. The conclusions and policy implications are summarized in the last section.

2. LITERATURE REVIEW

The main reason to expect that trade liberalization will have a positive impact on innovation is that increased market size may generate incentives for innovating and creating new businesses (Desmet, and Parente, 2010; Acemoglu and Linn, 2004). The argument in the literature is that innovation requires an initial investment that needs to be recovered via profits over time. The larger the market, the greater the profits, and thus the more investment in innovation.[1]

This positive effect of market size is most relevant for firms in export-oriented industries, but not for firms facing import competition, which will experience more competition in a market of the same size. In the case of exporters, the first generation of theoretical models with heterogeneous firms assumed exogenous productivity, leaving no room for analysis of the potential impact of increasing export profits on innovation (Melitz, 2003; Bernard et al., 2003). More recent theoretical models, such as Bustos (2011), have studied how trade liberalization may induce technology upgrading. By modeling modern technologies as having higher fixed costs and lower marginal costs than old technologies, she shows that an increase in export profits induces some firms to innovate because they may enter international markets and are able to pay the fixed cost of investing in modern technology. Interestingly, the prediction is that this positive effect on innovation is higher for firms with intermediate productivity. This is because high-productivity firms are already exporters and use the latest technology. On the other hand, in the case of low-productivity firms, the potential profits of exporting are not high enough for firms to enter foreign markets and innovate.

In the case of firms facing import competition for the same market size, Shu and Steinwender (2018) distinguish three mechanisms with different implications for the impact of trade liberalization on innovation. The first of these is the so-called Schumpeterian effect, which states that a key determinant of innovation is the appropriability of innovation rents by the firm, so more competitive environments could harm this, leading to a reduction of innovation efforts. The second is the escape-from-competition approach, which states that the main barrier to innovation is the opportunity cost of a status quo situation. In this context monopolies that get abnormal return rates will have too little incentive to change and to innovate, so in this context import competition could lead to more innovation. A third mechanism is the so-called preference effect, which also predicts a positive relationship between import competition and innovation based on ideas borrowed from the literature of X-inefficiency. The assumption is that when managers are challenged by foreign competitors, they start exerting effort and innovate.

Another important reason why trade liberalization may induce more innovation has to do with international technological spillovers. The main reason for this is that most of the world's technology creation occurs in only a small set of countries (Keller, 2010). Hence it is argued that more open countries may learn from the rest of the world, particularly through international trade and foreign investment. This mechanism has been shown

[1] If we assume that innovation investment leads to process innovation and that process innovation generates cost savings in the production process, then the return on this innovation investment will depend on two things: (a) the size of the cost-savings and (b) the size of the market to which these cost savings will be applied.

to be important for developed countries, where the evidence reveals that TFP growth depends not only on domestic R&D investment but also on trading partners' R&D (Coe and Helpman, 1995; Coe et al., 1997; Lichtenberg and Van Pottelsberge, 1998; Acharya and Keller, 2008; Ang and Madsen, 2013).[2] Related research also finds that there are major tacit components to technology and that international technological spillovers are thus also mediated by geography. In other words, there is significant decay in the impact of R&D by foreign partners that are located relatively far away (Keller, 2002).[3]

Multinationals are also a potentially important channel for international technology transfers. Multinationals operating in a host country normally complete the tasks not imported from their multinational parent through local production. Local workers are hired for these purposes. If workers learn about the multinational's technology either by on-the-job activity or formal training, then once they quit, they may be able to transmit a positive learning effect to a domestic competitor or start their own business. Furthermore, instead of producing everything in-house, the multinational firm may also outsource certain intermediate inputs. If the affiliate buys inputs from local suppliers, there may be so-called vertical technology spillovers. These arise when the multinational affiliate provides technology to its suppliers at a price that is below market value.

From an empirical point of view, the search for spillovers from multinationals has been more difficult to assess due to identification problems and the mechanisms behind the expected relationship, but some evidence indicates that these productivity spillovers are positive for vertically related industries but not necessarily for horizontally related firms (those in the same industries). This may occur because multinationals operating in the same markets might have incentives to avoid these spillovers toward domestic firms (Smarzynska Javorcik, 2004) or because spillovers indeed exist but are overcome by negative competition effects (Aitken and Harrison, 1999). Another relevant aspect from this literature on multinationals' spillovers is that the effect also depends on the absorption capacity of the domestic economy (Görg and Greenaway, 2004) and on the nature of the affiliate subsidiary activity in the host country (Keller and Yeaple, 2009). Consequently, when multinationals have positive effects, it is because the domestic economy has, for example, adequate human capital for internalizing the benefits from new technologies and/or because the subsidiary activity in the host country is knowledge-intensive (e.g., operating an R&D center) rather than a simpler assembly line (e.g., a maquiladora). Finally, one potentially important but far less studied issue relates to FDI spillovers generated by multinationals that go abroad to acquire technological knowledge from other firms or research organizations. Some preliminary research for developed countries suggests that these effects might be important (Branstetter, 2006; Keller, 2010).

In the case of exporters, it is argued that one of the reasons why they are more productive than nonexporters is because they can learn from their experience in international markets. This phenomenon has been called "learning by exporting" and indicates that exporters may increase their productivity after entering international markets. The evidence is, however, controversial. The first papers on this were unable to find consistent evidence of "learning by exporting" (Clerides, et.al. 1998), but more recent evidence finds that firms may learn from exporting (van Biesebroeck, 2005; De Loecker 2013; Park et al., 2010; De Loecker, 2007). One challenge in this literature is identifying the mechanism behind the increase in productivity after exporting. However, some related literature that focuses more closely on innovation rather than on productivity finds that learning from clients after exporting is a major determinant for future innovation (Crespi, et.al. 2005).

A large part of the microeconomic literature on international trade has analyzed the impact of trade liberalization on innovation using plant-level data.[4] In general, the results indicate a positive link between trade integration and innovation. For example, Baldwin and Gu (2004), looking at the effects of unilateral trade

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[2] Keller (1998) is skeptical of these results because when he replaces the trade shares that the authors used to build foreign R&D by randomly generated shares, the results remain the same, suggesting that trade contributes little to technology transfer.
[3] Keller also finds that although the impacts of geographical distance remain significant, they have declined in recent years mostly due to the spread of information and communication technologies.
[4] For a complete discussion on this issue and review of the literature, see Shu and Steinwender (2018).

liberalization on Canadian firms, show that plants moving into export markets increased investment in R&D and training to develop capacities for absorbing foreign technologies and international best practices. They also find that firms entering export markets increased the number of advanced technologies being used and improved their information about advanced technologies. These firms also experienced improvements in the novelty of the innovations that were introduced. Also using Canadian data, specifically looking at bilateral integration with the United States, Lileeva and Trefler (2010) find evidence consistent with the idea that increasing market size increases innovation. Their findings indicate that plants that were induced by tariff cuts to start exporting or to export more eventually engaged in more product innovation and had higher adoption rates for advanced manufacturing technologies.

Regarding developing countries, Bustos (2011) analyzes the impact of Mercosur on technological innovation by Argentinian firms. Their results indicate that a decrease in Brazilian tariffs had a positive effect on technology adoption. The impact is heterogeneous across firms, affecting mostly those in the middle of the productivity range. The explanation is that an increase in export profitability induces upgrading technologies and entering international markets, however, this is not the case for high-productivity firms that already export and employ the new technology or for low-productivity firms because the expected increase in profits is lower than the cost of adopting technology.

There are also studies looking at the impact of integration agreements on the entry of new exporters into new markets. Molina et al. (2011) estimate the impact that trade preferences from the Dominican Republic–Central America Free Trade Agreement have on new exporters and product-market destinations in the Dominican Republic. Their results indicate a positive, albeit small, impact on the number of new exporters and the number of exporters introducing new product-market combinations.

Debaere and Mostashari (2005) study the impact of US trade preferences and show that these have a small but positive effect on the probability of a product being exported. Volpe and Gomez (2010) also find that the US reduction in tariffs has a positive effect for new Colombian exports. Although this evidence is limited to new exporters and new exported products and not directly to innovation, it suggests that integration can have a positive effect on new products and firms, but its magnitude may be reduced in the absence of complementary policies.

There are two examples in Latin America that illustrate how trade reforms have not induced significant improvements in innovation and specialization patterns. First, consider the case of Chile, an early reformer in implementing unilateral trade liberalization and then bilateral agreements covering a large part of its international trade. The evidence shows that in the last decade, the country has experienced poor performance in terms of productivity and innovation. The R&D to GDP ratio has remained constant at a rate of around 0.4%, and TFP growth has been practically zero since the end of the 1990s (IDB, 2013). Even though trade reforms facilitated the incorporation of new exports, this was not accompanied by relevant changes in the innovation path of the economy. The second case is Mexico, where the evidence shows that integration with Canada and the United States has not been as successful as expected in terms of innovation and productivity. Lederman and Maloney (2006) find that NAFTA did not have a profound effect on the adoption of new technologies in Mexico. However, a more recent evaluation of this integration process reveals important gains for cities and areas taking advantage of North American value chains (Parilla and Berube, 2013).

3. CONCEPTUAL FRAMEWORK, MAIN HYPOTHESIS, AND VARIABLE DEFINITIONS

Our conceptual framework rests on the specification of an idea production function (Griliches, 1979). We feel that focusing on the determinants of ideas is a better way of understanding how trade liberalization impacts innovation than using a standard production function where the focus of the analysis is on productivity.[5] Our proxy for ideas generation will be the number of patents filed by country residents in a particular year. Although patents have several shortcomings when it comes to assessing innovation,[6] measurements are relatively harmonized across countries and normally cover a reasonably long time period. No other innovation indicator has these two advantages. We follow Ang and Madsen (2013) and augment a standard closed-economy ideas production function to consider the effects of human capital, knowledge spillovers, and trade liberalization variables, as follows:

$$\dot{A} = \alpha X^{\sigma} Q^{\delta} A^{\varphi} e^{(\theta . H)} (A^{\omega})^{\varphi - \beta} e^{\delta Lib} \quad (1)$$

where $\dot{A}$ is new ideas, α is a research productivity parameter, X is R&D effort, Q is the size of the economy capturing the presence of scale effects, A is the domestic stock of ideas of knowledge, H is human capital, A^{w} is the relevant knowledge frontier for each country, and *Lib* is a variable capturing the extent of trade reforms and liberalization. In terms of the parameters, we expect that $\alpha > 0$, 1>σ>0 if there are positive but decreasing returns to R&D; 1>δ≥0 if there are positive but decreasing returns to scale due for example to product proliferation as the economy expands;[7] $\theta > 0$ if there are positive effects from human capital beyond the effects of the human capital already employed in the R&D sector, in other words, we allow that people not engaged in R&D activity may also contribute to idea production; while $(\varphi - \beta)$ captures the effects of the knowledge frontier, which are not necessarily always positive for each individual country. On the one hand, the larger the world's stock, the more opportunities there are for innovators in individual countries to expand on the ideas that are already developed elsewhere—an effect that is captured by the φ term. On the other hand, international knowledge raises the bar which defines which ideas are new to world—an effect that is captured by the β (Porter and Stern, 2000). In this basic model, trade liberalization affects the generation of ideas through an increase in research productivity, in other words, through a better use of the resources available for innovation, which can be associated with an increase in competition pressures, a reduction in X-inefficiency by firm managers, or a reallocation of economic resources toward sectors with higher research productivity.

Taking logs of equation (1) yields the following empirical specification:

$$ln\dot{A}_{it} = \alpha_i + \alpha_1 lnX_{it-1} + \alpha_2 lnQ_{it-1} + \alpha_3 lnA_{it-1} + \alpha_4 H_{it-1} + \alpha_5 lnA^{w}_{it-1} + \alpha_6 Lib_{it-1} + \varepsilon_{it} (2)$$

The main variables are defined as follows. $\dot{A}$ is measured as the number of patents applied for by domestic residents.[8] With regard to the independent variables, *X* is measured by real R&D expenditures; *Q* is measured by real GDP; *A* is measured as the stock of R&D accumulated by each country; *H* is measured as the average number of years of schooling among the working-age population adjusted by the estimated return to schooling for each country; and A^{w} is the relevant knowledge frontier for each country, which we measured as the sum

[5] Productivity is not a well-behaved variable for assessing innovation. Griliches (1979) has demonstrated that productivity accounts are strongly biased and cannot be properly measured in many sectors of the economy. Aghion and Howitt (1998) show formally that productivity growth rates are significantly underestimated because quality improvements are hard to include in national accounts. Furthermore, productivity is influenced by factors that may be unrelated to idea production, such as factor utilization, efficiency of production, and resource reallocation, which are also very difficult to control for.

[6] Patents are more an indicator of invention than of innovation because very few patents have significant economic value and many significant innovations are never patented. Furthermore, the effectiveness of patents as a mechanism to protect innovation depends on economic sector, so a country's production structure will also affect its propensity to patent.

[7] To guarantee sustained growth in knowledge, R&D has to increase over time in order to counteract the increasing range and complexity of products, which lower the productivity effects of R&D activity.

[8] Given the limitations of patents we also run the same model using the index of economic complexity as a dependent variable. The economic complexity index is a measure of the knowledge in a society as expressed in the products it makes. The economic complexity of a country is calculated based on the diversity of exports a country produces and their ubiquity, or the number of countries able to produce them (and those countries' complexity) (http://atlas.cid.harvard.edu/downloads).

of A for all the other countries in the sample (excluding the country under consideration), weighted by the distance of each country from the knowledge frontier: $(A^{MAX} - A)/A$. In other words, the relevant knowledge frontier is a country-specific variable. With regard to the knowledge frontier, it is not enough for a country to be small—the country also needs to be far behind that frontier in order for this be relevant to it. In other words, countries that are near the frontier should not expect to receive too many knowledge spillovers from the international knowledge frontier. Equation (2) includes a country fixed effect to capture omitted time-constant variables so the results can be interpreted directly as in a difference-in-difference context. Additionally, we included all the explanatory variables with a lag in order to at least partially control for endogeneity concerns. All the regressions include a set of year and country dummies.

All the data is measured from 1965 to 2014 on a yearly basis. Data from patents is extracted from the World Bank World Development Indicators. R&D data comes from UNESCO and the World Bank, from which we downloaded information about R&D investment as a proportion of the GDP. Data from GDP comes from the PWT9.0 from the Groningen Growth and Development Center (CGDC) covering the period 1960–2014. All countries in the dataset have been classified into nine regions following the World Bank classification.

With regard to the main trade liberalization variables, we use trade liberalization dummies, closely following the methodology of Wacziarg and Welch (2008). These authors look at the impact of trade liberalization on growth using the years of liberalization identified according to the criteria defined by Sachs and Warner (1995). According to this a country is considered closed in any given year when at least one of the following conditions is met: (i) average tariffs are higher than 40%, (ii) nontariff barriers cover over 40% of imports, (iii) the economic system is socialist, (iv) the black market premium is higher than 20%, or (v) many of its exports are controlled by a state monopoly. It should be noted that this indicator of openness to international trade captures not only trade-related policies but also other economic reforms accompanying trade liberalization. For this reason, following Giavazzi and Tabellini (2005) and Billmeier and Nannicini (2013), this indicator should be interpreted as an event of comprehensive promarket reforms, including trade liberalization. Given this limitation, we also test the robustness of our results using a more direct import tariff variable, which is more precise as a proxy of trade liberalization but is available for a shorter time period (see the appendix for these results).

4. EMPIRICAL RESULTS: AN IDEAS PRODUCTION FUNCTION MODEL AUGMENTED BY TRADE LIBERALIZATION

Table 1 presents the main descriptive statistics by region using the World Bank classification. The average country in the sample files 4,195 patents per year, although there is a large variation across regions. The largest patenting region is East Asia and the Pacific, which files almost 30,000 patents, although this figure is strongly dominated by the performance of China and, to some extent, South Korea. Two other major patenting regions are Western Europe (about 4,000 patents) and North America (around 2,917 patents). Latin America shows very little patenting activity, with an average of about 300 patents per country per year. In terms of the explanatory variables, the most R&D-intensive region is North America, followed by Western Europe and East Asia. Latin America's performance in this area is also very poor, with the typical country spending about five times less on R&D than the most R&D-intensive region. North America is also the largest region in terms of domestic knowledge stock, followed by Western Europe and East Asia. Regarding the relevance of the international knowledge stock, this variable is lowest for North America, Western Europe, and East Asia, capturing the fact that these are regions are closer to the knowledge frontier. On the other hand, this variable is very relevant for the regions that are lagging most: Latin America, the Caribbean, and Sub-Saharan Africa. In terms of human capital, North America, Western Europe, and East Asia are again the three most intensive regions, while Latin America is in the middle of the ranking. In terms of trade liberalization, 48% of country-year observations are liberalized, and Latin America is close to that average, although its degree of liberalization is significantly lower than North America, Western Europe, and East Asia.

TABLE 1. MAIN DESCRIPTIVE STATISTICS (MEANS), 1962–2014

World Bank Region	Pat	lnX	LnQ	lnA	lnA(w)	H	Lib
Caribbean	4	0.43	9.13	1.01	34.66	2.14	0.46
Sub-Saharan Africa	59	0.76	9.29	1.4	34.24	1.43	0.26
Easter Europe and Central Asia	1744	3.95	11.49	5.2	29.26	2.75	0.37
Middle East and North Africa	409	3.46	11.16	5.18	27.94	1.76	0.18
East Asia and Pacific	29707	5.73	12.36	7.54	24.34	2.33	0.72
South Asia	565	3.87	11.8	5.46	27.82	1.59	0.31
Western Europe	4261	6.18	11.83	7.98	24.17	2.79	0.92
North America	2917	8.62	13.47	10.91	20.05	3.21	1.00
Latin America	295	3.38	10.83	5.22	27.59	2.00	0.48
Total	4195	3.37	10.8	4.73	28.99	2.05	0.48

Source: PWT9.0 (CGDC), World Developing Indicators, UNESCO.

Table 2 summarizes the results for the main model for the whole world. All the regressions control for year and country fixed effects and all the explanatory variables are included with a lag. Column 1 shows the relationship between patents and the trade liberalization dummy. Column 2 controls also for domestic R&D investment, the size of the economy, and the domestic knowledge stock. Column 3 also includes human capital, while column 4 controls for the international knowledge stock. Column 5 interacts the trade liberalization dummy with R&D investment, in column 6 the interaction is between trade liberalization and the domestic knowledge stock, while in columns 7 and 8 the interactions are between trade liberalization and human capital and the international knowledge frontier, respectively. The aim of including these interactions is to explore how the impact of trade is affected by certain characteristics of domestic innovation systems.

TABLE 2. PATENTS, TRADE LIBERALIZATION AND INNOVATION EFFORTS 1962–2014 (DEPENDENT VARIABLE IS IN LN)

	Patents I	Patents II	Patents III	Patents IV	Patents V	Patents VI	Patents VII	Patents VIII
Lib	0.062	0.046	0.085	0.173	0.266	0.367	-1.598	-0.846
	(0.21)	(0.18)	(0.33)	(0.69)	(0.95)	(1.20)	(2.15)**	(0.86)
LlnX		0.170	0.184	0.167	0.186	0.163	0.152	0.159
		(2.20)**	(2.34)**	(2.17)**	(1.76)*	(2.25)**	(1.90)*	(2.23)**
LlnQ		0.412	0.256	0.198	0.194	0.185	0.272	0.184
		(1.91)*	(1.21)	(1.01)	(1.01)	(0.97)	(1.45)	(0.96)
LlnA		0.087	0.063	0.427	0.451	0.501	0.348	0.472
		(1.70)*	(1.13)	(3.11)***	(3.06)***	(3.14)***	(2.44)**	(3.41)***
H			1.151	0.829	0.865	0.903	-0.088	0.881
			(2.14)**	(1.54)	(1.59)	(1.65)	(0.14)	(1.62)
LlnA(w)				0.193	0.206	0.217	0.151	0.197
				(3.41)***	(3.15)***	(3.35)***	(2.46)**	(3.48)***
LlnX*Lib					-0.037			
					(0.43)			
LnA*Lib						-0.049		
						(0.80)		
H*lib							0.913	
							(2.09)**	
LlnA(w)*Lib								0.034
								(1.14)
R^2	0.21	0.31	0.31	0.33	0.33	0.33	0.35	0.33
Country Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	6,070	6,070	6,070	6,070	6,070	6,070	6,070	6,070

Robust t statistics in parentheses. *significant at 10%, ** significant at 5%;*** significant at 1%.

The results suggest that trade liberalization is not an important determinant of the idea production function. According to the results in table 2, the unconditional impact of trade liberalization on patenting activity is 6%, although the result is not significantly different from zero.[9] The result remains nonsignificant across the different columns. On the other hand, innovation system domestic variables are very relevant for the ideas production function. Indeed, across the different estimates, a 1% increase in R&D leads to about a 0.15% increase in patenting, a result that is also stable across the different columns in the table. Size is another determinant of patenting, although the result is only significant in column II, with an increase of 1% in GDP leading to growth of about 0.41% in patenting. The domestic knowledge frontier and human capital are also positive and significant determinants of patenting. Overall, the results from column IV suggest that R&D, size, human capital, and the domestic knowledge stock are key determinants of patenting activity but with decreasing returns on all these variables, a result that is generally consistent with semi-endogenous growth

[9] The dependent variable in ln(patents)

models. Regarding globalization variables, we find that access to the international knowledge frontier has a positive and significant effect on patenting. Indeed, according to the results in column IV, the international knowledge stock variable has a positive coefficient which is half the value of the estimate for the domestic knowledge frontier. Regarding the interactions, we found that trade liberation decreases the importance of domestic R&D and the domestic knowledge stock for patenting (columns V and VI), but neither of these results is significantly different from zero. On the other hand, liberalization increases the importance of human capital (column VII) and the international knowledge frontier (column VIII), although only the human capital coefficient interaction is significantly different from zero. This result is interesting because it suggests that the effects of trade liberalization depend on a country's human capital endowment. In fact, based on the results of the estimates, the threshold of human capital beyond which the effects of liberalization are positive is around 1.750 (1.598/0.913). Based on the results of table 1, this is the level of the Middle East and North Africa, while LAC is just above that threshold. Another way to see this is to explore what would happen to the impacts of economic liberalization if human capital in LAC (2.00) would increase to the value of the USA (3.24), if this were the case, the coefficient of the liberalization dummy would jump from 0.23 to 1.33. In other words, to some extent, more open economies become less reliant on domestic knowledge efforts in order to innovate, and they become more reliant on the international knowledge stock and human capital necessary to adapt and use foreign knowledge.[10,11]

In summary, trade liberalization alone does not increase the efficiency of a domestic innovation system, idea generation remains determined by domestic efforts such as R&D investments, the domestic knowledge stock, and the adoption of knowledge from the international knowledge frontier. We do find, however, some weak evidence that the impact of trade liberalization on innovation seems to be positive but is conditional on investments in human capital, which need to be above a certain threshold. If trade liberalization does not play an important role in domestic knowledge generation, what policies could countries that are lagging behind put in place to take advantage of the opportunities emerging from the knowledge frontier due to trade liberalization?

5. POLICY DISCUSSION

The results described above suggest that trade liberalization per se is not enough to increase country-level innovation, and hence some sort of explicit innovation policies might be needed to take advantage of the opportunities offered by accessing the international global knowledge frontier. The focus of this section is not on the general measures that should be put in place at both the policy and institutional levels to improve the performance of Latin American innovation systems, as these sorts of recommendations are covered elsewhere in other reports (see Crespi et.al, 2014, for an overview). The focus in this section is on those market failures and associated innovation policy measures that need to be considered in order to take advantage of the potential for knowledge transfer generated by being in contact with the global knowledge frontier.

Economic liberalization might open the channels through which trade and/or foreign direct investment connect with the global knowledge frontier, however, the actual content of knowledge that can flow through those channels depends strongly on tackling several ailments that can severely hinder the results of the interaction between the country and international global providers. The knowledge frontier is complex and populated by a large set of technologies, each one with different degrees of accessibility and maturity. Searching for the one that is the best match for a given domestic technological need is no small task. In other

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[10] In appendix table A.1, we estimate the same model but using tariffs as a treatment variable. The results are qualitatively similar, although estimated over a shorter time period. For this we used a new tariff database which is a joint CESIfo Group-World Bank effort following the methodology of Felbermayr, Teti, and Yalcin (2018).

[11] In appendix table A.2, we estimate the same model but using the index of economic complexity as the main dependent variable. The results also hold, with the only difference that in this case the interaction between liberalization and R&D is the one that becomes statistically significant, suggesting that the impact of liberalization on economic complexity could become positive if countries develop sufficient R&D efforts.

words, asymmetric information and cost considerations are key aspects that might hinder technology transfer from the global knowledge frontier.

In dense innovation systems that are closer to the frontier, private-sector technology brokers are normally in place in order to connect international technology supply with demand. However, in countries that are far from the frontier, a "thin markets" problem might emerge: for technology brokers, the profits to be expected from commercializing a given technology in an innovation system that is far from the frontier might not cover their costs. In this scenario, firms will have to rely more on in-house capabilities to search for and explore the knowledge frontier, and these capabilities might be available for just a handful of firms. This results in a massive information problem that leads to a less-than-optimal level of international technology transfer.

However, asymmetric information between knowledge supply and demand is just part of the problem. The adoption of technology is something more complex than the mere acquisition of blueprints (or machines). Two important characteristics of new technologies are their tacitness and their circumstantial sensitivity. Technologies are tacit to the extent that their configuration is not fully embodied in a set of artifacts—machines, manuals, or blueprints for example. Consequently, the tacit components of a technology might be employed in quite different ways across producers using apparently identical production techniques. In addition to this, there is circumstantial sensitivity, which refers to the fact that the performance of a technique might be sensitive to the context in which it is used. Key complementary inputs of a given technology vary greatly across different locations (e.g. infrastructure, quality of land, water and power supplies, availability of subcontractors, etc.). Another important determinant is the institutional context in which the technology is being implemented, such as environmental regulations or the relationship between workers and managers. All these factors can also affect the performance of a given technology.

Moreover, although both tacitness and circumstantial sensitivity are important determinants of technology adoption decisions everywhere, their importance is expected to be even more pertinent when analyzing technological transfer from the frontier to developing countries. There are two consequences to all of this. First, whenever technology is characterized by tacitness and circumstantial sensitivity, learning will be involved, limiting the value of international spillovers and raising the role of local investments in education and human capital as complementary sources of innovation.

In order to overcome the tacitness and circumstantial sensitivity of a technology developed and imported from abroad, there must be a local investment in learning. There are two different sources of learning that are worth defining. On the one hand, producers might engage in learning-by-doing, experimenting with the new technology to reveal its tacit elements or determine the sensitivity of the technology to local conditions. Alternatively, producers might learn from others—that is, from other producers who are engaged in learning-by-doing. The two types of learning have very different implications for innovation policy. When producers learn from their own experimentation, they undertake an investment that yields uncertain returns. When producers learn from one another, not only is there a risky investment, but this investment generates information spillovers. If these sorts of information spillovers produce externalities,[12] then this provides a role for government to establish a mechanism for rewarding experimenters for the positive externalities generated by their activities. Taken together, these two types of learning form the process of "social learning," in which knowledge generated through experimentation by a plant increases that plant's future profits and generates an information externality which benefits other plants. In the remainder of this section, we discuss several

In appendix table A.1, we estimate the same model but using tariffs as the treatment variable. The results are the same, although they estimated over a shorter time period. For this we used a new tariff database which is a joint CESIfo Group-World Bank effort following the methodology of Felbermayr, Teti, and Yalcin (2018).

[12] In appendix table A.2, we estimate the same model but using the index of economic complexity as the main dependent variable. The results also hold, with the only difference that in this case it is the interaction between liberalization and R&D that is statistically significant.

policy experiments that have been put forward to deal with both asymmetric information and learning externality problems.

A first set of innovation policy interventions that mostly tackle the problem of asymmetric information and the lack of knowledge brokers for technology transfer are technology missions. These have been used by both developed and developing countries' innovation agencies to help domestic laggard firms explore the knowledge frontier. They do so by providing small subsidies to a group of firms in the same or related sector to enable them to attend international conferences, exhibitions, and demonstration labs where technology developers (both private and public) show and spread the latest advances in terms of innovation in a particular field. Despite being widely used in the region and having existed in the policy mix for a long time, very little is known about whether these programs are working as expected or not.

On exception is Innova, the Chilean innovation agency, which evaluated their technology mission's program some time ago. In a nutshell, the program subsidizes managing companies or brokers—mostly, although not always, related to business associations or universities—to coordinate a technology mission for a group of participating firms. Although the evaluation does not properly solve the attribution problem, some results are interesting. A large proportion of the participants considered that the places visited were pertinent, however, they also pointed out that the agenda was too rigid and supplied driven by the "managing company" with little room for flexibility for considering options or alternatives put forward by the participating firms. Despite this, most of the participating firms considered that the learning and knowledge acquired during the mission was satisfactory. In terms of results, most firms report having introduced production process innovations after the mission but only a few managed to introduce product innovations, while an important share of the participants reported organizational and commercialization innovations.

One interesting finding was that after the mission, almost 50% of the participants did not receive any kind of contact from the innovation agency to explore follow-up activities, while of the half that was contacted, 80% of the cases were to offer the firms a new technology mission. In other words, it seems that the operation of the agency lacked a more comprehensive approach to supporting improvements in the learning processes triggered by the missions. On the other hand, a more positive result is that about 40% of the firms reported having developed joint projects—mostly commercial rather than technological—with other participating firms after the mission. In general, the program was well evaluated not only in terms of allowing access to new technological knowledge but also in terms of building social capital among the participating firms, which could lead to more sophisticated projects later. However, despite this, little follow-up was done by the innovation agency to build upon these processes. Another area of improvement was the need to better align the incentives of the managing companies by rewarding them at least partially in terms of the results obtained by the participating firms (Innovación y Gestion Limitada, 2009).

Technology missions seek to address the asymmetric information problem that harms international knowledge transfers. However, in a world of tactic knowledge, missions might not be enough, as active engagement between domestic and international partners might be needed for successful technology transfer. In order to deal with this issue, most innovation agencies in developed countries have established international joint innovation programs with similar agencies from abroad. These programs encourage the formation of joint innovation projects between innovating firms from different countries to complement innovation capabilities and create more successful knowledge transfers.

From a social point of view, cooperative R&D is generally preferred to noncooperative R&D because it avoids wasteful duplication of scarce R&D resources. R&D cooperation may also be preferred by private firms (as well as socially) since it internalizes spillovers among them. Although these features of collaboration apply regardless of where the collaborating partners are located, one important feature of international collaboration is that it enlarges the set of potential partners, allowing for a better choice of partners and consequently for enhanced synergy effects. Perhaps one of the cases in which most intensive use has been made of these types of collaborative schemes is Israel's National Innovation Authority (formerly known as the Office of the Chief Scientist, OCS). Israel's innovation agency is the government organization responsible for executing policy related to supporting industrial R&D. It manages an annual budget of US$540 million for nearly 50 programs. Although the position of the Chief Scientist was formally established in 1968, it was not until 1974 that the organization became an active agency. From the beginning, the agency has had a strong focus on external markets, supporting any sort of R&D that can make Israeli firms more competitive at the global level.

Consequently, one of its first innovation instruments was the establishment of a bi-national Israeli–American cooperative industrial R&D fund (which started operating as the BIRD Foundation in 1976) (Nesta, 2016). Nowadays the agency manages joint R&D funds with the UK (BRITECH), Canada (CIIRDF), Singapore (SIIRD), South Korea (KORIL), and Australia (VISTECH). It also manages multinational collaborative funds with the European Union (ISERD and Eureka). In 2011, an impact evaluation was carried out regarding the impacts of participating in the Eureka program with the EU. Using a matching difference-in-difference quasi-experimental methodology, the results suggest that participation in Eureka increased postparticipation sales and employment by 28%, with somewhat larger effects for larger firms. At the aggregate level, this means that additional annual sales and employment due to firm participation in Eureka projects that started in 1996–2003 and finished by 2005 amount to almost €4 billion and 26,300 employees (Gayer, Lach, and Wasserteil, 2011).

Very few LAC innovation agencies have put these sorts of collaborative innovation agreements in place and there is an explanation for this. Its implementation requires the building up of a critical mass of potentially innovative domestic firms but also institutional capabilities to help domestic firms to search and identify for the most suitable collaborative partner abroad. To achieve this, some developed countries' innovation agencies have set up international offices abroad in target countries where they have previously identified technological capabilities that could complement domestic ones. These institutional capabilities are still very underdeveloped in the region.

A third channel through which it is possible to improve access to the global stock of knowledge is by exploiting the opportunities generated by technology licensing. The potential benefits of licensing for a licensee are multiple: (a) it provides the use of proven technology along with its associated know-how, permitting the licensee to move rapidly toward the best-practice frontier; (b) it saves time and costs on product development; (c) it establishes the possibility of a long-term alliance with a known and reputable producer; and (d) it avoids the possibility of long, costly legal disputes. However, these benefits are not automatic and the space for public policy development in this realm is large. Licensees are often not sure of what they are buying. This problem of asymmetric information can make the bargaining and the negotiation of licenses difficult and could impede such a transaction. A risk for licensees is that it could induce technology dependency by slowing rather than speeding up their productivity growth due to a lock-in phenomenon. Moreover, as suggested by the evidence in developed countries and successful catching-up economies, licensing complements the firm's own innovation efforts rather than substituting them, for the value of licenses is a function both of firm's "scanning" capacity as well as its "absorptive" capacity (Cassiman and Veugelers, 2000).

Licensing has increased over time in OECD countries *pari passu* with increased globalization and the new rules governing international trade. Indeed, while in 1981 the typical OECD country spent 0.19% of GDP on licensing, this figure grew by up to 2.35% in 2015 (OECD, MSTI, 2015). In LAC countries, the average spending on licensing grew from a mere 0.08% of GDP in 1981 to 0.22% of GDP in 2015. As a benchmark, during the same period the average spending on licensing in East Asia and Pacific countries grew from 0.01%

of the GDP to 0.38% of the GDP. In the case of South Korea, the same indicator passed from 0.13% of GDP in 1981 to 0.73% in 2015 (WB, 2016).

Given that licensing seems to be critically important for countries that are in the initial stages of the catching-up process, it seems that LAC is also lagging behind regarding this indicator. However, before proceeding, it is worth asking whether licensing does have an impact on firm performance. Álvarez, Crespi, and Ramos (2002) explicitly explore this question for a representative panel of Chilean manufacturing firms. Their descriptive statistics show that only 5% of Chilean manufacturing firms acquired licenses during their research period. They also found that licensing is a very sector-specific phenomenon, in that licensing rates are highest in chemical industries and much lower in consumer goods products. In order to explain the impacts of licensing on firm performance, the authors correlate the ratio of licensing to value-added at the firm level in an initial year with the rate of growth of total factor productivity over the subsequent years. They found that initial licensing had a strong impact over total factor productivity growth for the following six years, suggesting a licensing private return rate of around 30%. Interestingly, the authors also explore the extent to which there are licensing spillovers, which means that if nonlicensing firms benefit from the licenses purchased by licensing firms, they found that no spillover effects are in operation.

If private returns are so high, why has there been underinvestment in licenses in most of Latin America? The findings of Álvarez, Crespi, and Ramos (2002) ruled out one potential explanation: the imperfect appropriability of technical knowledge leading to sector spillovers. This left them with two other explanations. First, the market for licensing is quite imperfect, for the appropriate matching of licensors and licensees is harmed by insufficient information and high transaction costs. Second, Latin American firms have major deficiencies when it comes to identifying the best-practice technology most suitable to their needs and adapting it to local conditions.

The policy implications of this are clear. Licensing can be an important mechanism for speeding up catch up if it is exploited intelligently. This means recognizing the potential benefits it offers (in other words, encouraging, rather than restricting, its use) and helping reduce the high transaction costs which characterize this market, which are expected to be even higher for LAC firms, given that they are geographically distant from industrial knowledge centers. Government cofinancing of technology search missions by entrepreneurs can be a step in this direction, as mentioned above, by improving the scope of technology extension services to help domestic firms to adapt existent technologies (IDB, 2014). It is also important to increase the scope of domestic intellectual property offices for carrying out technology vigilance actions by screening those technologies, either those that are protected by patents or those that fall in the public domain and might be of relevance for key strategic sectors of the economy.[13,14]

Given that most tacit knowledge is embodied in the human capital involved during its development, it is not surprising that strategies of *brain circulation* are another complementary way of promoting knowledge transfer from abroad. Nowadays, among their innovation policy tools, most Latin American countries have programs targeting the accumulation of human capital abroad either through the financing of formal postgraduate studies or through short-term stays to learn specific techniques or participate in specific research projects. Some of these programs have a relatively narrow scope, targeting specific areas of vacancies in terms of knowledge or lack of human capital, while other programs are massive, spreading across a wide array of fields and disciplines.

Unfortunately, despite the large amount of financial resources spent on these programs, very little is known in terms of their actual impacts. Two recent exceptions are the postgraduate scholarship programs run in

[13] See, for example, the INAPI Proyecta application by the Chilean patent office http://www.inapiproyecta.cl/605/w3-channel.html.

[14] Another interesting case is the Industrial Technology Research Institute (ITRI) from Taiwan, which made intensive use of licensing and international collaboration regarding semiconductor research, which allowed them to incubate and spin off companies such as the United Microelectronics Corporation (UMC) and the Taiwan Semiconductors Manufacturing Company (TSMC), making Taiwan a global player in the semiconductor industry (Nesta, 2016).

Argentina and Colombia. Castro, Estupinan, Gordillo, Martinez, and Medina (2014) carried out an impact evaluation of Colciencias' PhD program, which provides financing for PhD-level studies both in Colombia and abroad. They use propensity score matching to solve the attribution problem, where the control group is formed by individuals that applied to the program and were accepted but did not make use of the financing.

In general, the results find that individuals who participated in the programs show a 38% increase in their after-graduation incomes, however, this result is explained entirely by those participants that received scholarships to study abroad, as the impact in the case of national scholarships is null. Participants to the program also showed higher research productivity than nonparticipants, while participants who studied abroad showed research productivity—in terms of published research—which is 40% higher than in the case of those who studied in national programs. The evaluation also assessed the extent to which the program had impacts at the firm level (in those firms that hired graduates in comparison with a group of control firms). In this case, the evaluation did not find any significant impacts at the firm level, mostly due to a mismatch between the soft skills acquired during the program—which is oriented more toward academic skills than companies' needs—but also due to the lack of absorptive capacities on the part of firms for taking advantage of the knowledge brought by the graduate.

Milesi and Aggio (2018) carried out an impact evaluation of Argentina's national postgraduate scholarship program (BEC.AR), which finances master-level studies abroad. The study compares the performance of graduate students that attended programs in the USA, France, Italy, and Spain with a control group of nonselected applicants. Using a difference-in-difference approach, the evaluation finds that the beneficiaries obtained a 30% increase in their wages in comparison with the control group. In academic terms, the evaluation also finds that the graduates make a significant contribution to human capital formation after they return to the country. Unlike the previous case, most of the graduates from this program ended up working in the private sector, which is consistent with the fact that during the design of the program, a strong emphasis was placed on identifying companies' areas of need for carrying out business-sector innovation.

Another trend in the region that is gaining momentum among policymakers is regarding policies to attract human capital from abroad. Indeed, as the experience of successful economies suggests, attracting human capital from abroad might be an important channel for building capacity and transferring knowledge during the early phases of the catching-up process (the cases of South Korea and China are emblematic examples of these policies).[15]

More specifically, there is a growing concern in LAC around implementing policies for attracting human capital from abroad with a focus on one attribute: entrepreneurial abilities. There is plenty of case-study-based evidence that suggests that immigrant entrepreneurs played a significant role in developing new sectors in several countries in the region—for example, the roles that Italian immigrants played in establishing Argentina's metalworking industry or that German immigrants played in developing the dairy industry in Chile and the textile and shoemaking industries in Brazil. It should therefore not be surprising that there has been a rekindling of the interest in fostering entrepreneurially oriented immigration. What is new in this case is the

[15] Toward the end of the 1960s, the South Korean government established the Korean Institute of Science and Technology (KAIST) based on the US MIT model. The aim of the institution was to supply the cohorts of engineers that would be needed during the 1970s, when industrial policies peaked. Most of the first teachers at KAIST were researchers brought in from abroad, mostly from the US, many of whom came from the Korean diaspora. In order to allow KAIST enough flexibility to make changes in training programs and to make job offers attractive enough for foreign researchers, the new university was given a special status and attached to the newly created Ministry of Science and Technology (MOST) rather than the Ministry of Education. The South Korean example also makes clear that governments should stay open to and in contact with their migrant communities. Policymakers should think of their diasporas as potential sources of know-how and capital that they can mobilize, perhaps more easily, than investments from other communities. Programs designed for active collaborations with diasporas that help governments learn about the level of development, engagement interests, professional interests, and the needs of the diaspora, and which actively learn from the diasporas, seem more sensible policies for diaspora engagement to start with (Hausman and Nedelkoska, 2018).

strong focus on using immigration to bring in specific and innovation-oriented entrepreneurial skills to strengthen not only the critical mass of domestic ecosystems but also the quality of these.

The first of the new cohort of programs aimed at attracting entrepreneurs from abroad is Start-Up Chile. Created in 2010, the program offers participants an equity-free cash infusion, coworking office space, and the possibility of being selected into an educational subprogram. This subprogram provides access to distinguished international guests and encourages peer networking, involves greater supervision, and provides entrepreneurial know-how. Participants in the program are selected from many countries from abroad by a specialized USA-based accelerator that does the screening process.

On top of the basic support and training subprogram, Start-Up Chile offers participants fast-track immigration status and support for opening a bank account in the country. Gonzalez-Uribe and Leatherbee (2017) take advantage of the features of the design of the program to evaluate its impacts. Using a fuzzy regression discontinuity approach, they first evaluate the impacts of basic entrepreneurial services (i.e. seed capital and coworking spaces) on start-up performance. Then, using the same approach, they assess the value-added effect of the entrepreneurial training program (combined with the basic services). They find evidence that training bundled with basic services leads to significantly higher venture fundraising, valuation, and scaling within the first four and a half years after participation. By contrast, they find no evidence that the basic entrepreneurial services of cash and coworking had a significant effect. Finally, and perhaps more importantly, they find evidence suggesting positive spillovers on local business development.

More specifically, the evaluation compared business creation rates before and after the program across industries related and unrelated to the program and in municipalities close to and far from Start-Up Chile's headquarters. The idea is that if the program had an impact on local entrepreneurship rates, it would most likely affect registrations in industries that are directly related to Start-Up Chile and in municipalities close to the program (where most of training and networking activities took place). The estimates show significant and positive effects on business registrations in industries and municipalities linked to the program.

The results suggest that bringing in entrepreneurs from abroad might be a reasonable policy for building up local innovation systems provided that an integrated approach is followed, wherein the provision of basic entrepreneurial services is combined with intensive entrepreneurial training. Given that providing entrepreneurial training requires some level of previous development of the domestic ecosystem, it seems that attracting entrepreneurs from abroad is more of a vehicle for dynamizing a domestic ecosystem with some degree of previous development than a tool for jump-starting an ecosystem from zero.

The implementation of the policy measures described above requires innovation agencies with institutional capacities to search for and interact with the global frontier. Developing these capacities takes time and requires financial resources for these specific activities. Many innovation agencies from developed countries suggest that setting up offices that could act as technological antennas abroad is a reasonable approach. However, given the limitations of resources and, in particular, personnel, this solution might be unfeasible for innovation agencies from LAC. In this context, a more reasonable approach would be to coordinate activities with export and investment promotion agencies abroad. Doing so might reduce costs but also could prepare the field for a more comprehensive supply of support programs for export-oriented innovative firms. Indeed, as previous research suggests, there are complementarities between innovation and export promotion programs that could be exploited better in a scenario of institutional coordination among the implementing agencies (IDB, 2014). This coordination could be achieved through different mechanisms with different degrees of complexity, such as the simple rotation of personnel, the organization of joint technological and commercial missions, common training programs for their officers, and the complete integration of both agencies under the same institutional umbrella (such is the case of Business Finland, which since 2018 has brought together both TEKES—Finland's innovation agency—and FINPRO—Finland's export promotion agency).

6. CONCLUSIONS

Trade liberalization alone does not increase the efficiency of a domestic innovation system. Idea generation remains determined by domestic efforts such as R&D investments, the domestic knowledge stock and the adoption of knowledge from the international knowledge frontier. We do find, however, some weak evidence that the impact of openness is heterogeneous and conditional on countries' absorptive capacities. Without the support of investment in human capital, openness alone is unlikely to do the job. What complementary policies could countries that are lagging behind put in place to take advantage of the opportunities emerging from the knowledge frontier due to trade liberalization?

The results described above suggest that some sort of explicit innovation policies might be needed in order to take advantage of the opportunities offered by accessing the international global knowledge frontier. Rather than focusing on the overall innovation policy measures that countries should put in place in order to improve innovations, this paper focuses on market failures and associated innovation policy measures that might be needed to take advantage of the potential for knowledge transfer generated by being in contact with the global knowledge frontier.

Four different policy measures are analyzed: organizing technology missions, supporting international collaboration aimed at innovation, encouraging the use of technology licensing, and taking advantage of brain circulation. Our assessment suggests that each one of these policy measures might be effective for encouraging international knowledge transfer, however, we also found that as a stand-alone program, each one might not be enough on its own. These programs have a greater impact when they are coordinated with other interventions that complement them and when the implementation agency has built sufficient institutional capacities to be able to use them with a strategic focus (e.g. targeting specific technologies or skills or specific knowledge suppliers that are better aligned with the areas of vacancies that need to be filled in local innovation systems). These institutional capabilities are still very underdeveloped in the region, but there are major opportunities for international regional collaboration.

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APPENDIX

TABLE A.1. PATENTS, TARIFFS, AND INNOVATION EFFORTS (1988–2014)

	lnpat I	lnpat II	lnpat III	lnpat IV	lnpat V	lnpat VI	lnpat VII	lnpat VIII	lnpat IX
ln(1+tariff)	-0.056	-0.042	-0.039	-0.055	0.076	0.079	-0.068	-0.362	-1.480
	(1.07)	(0.79)	(0.75)	(1.07)	(0.66)	(0.63)	(0.21)	(1.92)*	(1.28)
LlnX		0.034	0.033	0.030	0.078	0.029	0.030	0.029	0.109
		(0.75)	(0.7)	(0.66)	(1.38)	(0.64)	(0.66)	(0.64)	(0.70)
LlnQ		0.280	0.242	0.243	0.236	0.234	0.243	0.237	0.254
		(1.37)	(1.09)	(1.12)	(1.12)	(1.12)	(1.13)	(1.13)	(1.21)
LlnA		-0.032	-0.033	0.125	0.123	0.161	0.125	0.128	-0.019
		(0.94)	(0.94)	(1.86)*	(1.87)*	(2.20)**	(1.85)*	(1.94)*	(0.13)
H			0.711	0.557	0.532	0.536	0.544	0.523	0.360
			(1.25)	(0.98)	(0.94)	(0.95)	(0.85)	(0.92)	(0.52)
LlnA(w)				0.078	0.079	0.079	0.078	0.050	-0.015
				(2.55)**	(2.62)***	(2.64)***	(2.53)**	(1.55)	(0.19)
LlnX*ln(1+tariff)					-0.019				-0.031
					(1.38)				(0.51)
LnA*ln(1+tariff)						-0.015			0.060
						(1.31)			(0.97)
H*ln(1+tariff)							0.004		0.048
							(0.04)		(0.39)
LlnA(w)*ln(1+tariff)								0.013	0.039
								(1.56)	(1.24)
R^2	0.05	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.09
Country Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	3,123	3,123	3,123	3,123	3,123	3,123	3,123	3,123	3,123

Robust t statistics in parentheses. *Significant at 10%, ** significant at 5%; *** significant at 1%.

TABLE A.2. ECONOMIC COMPLEXITY, LIBERALIZATION, AND INNOVATION EFFORTS (1968–2014)

	lnECO I	lnECO II	lnECO III	lnECO IV	lnECO V	lnECO VI	lnECO VII	lnECO VIII	lnECO IX
Lib	-0.005	-0.003	-0.001	0.004	-0.005	-0.006	-0.017	0.024	-0.138
	(0.43)	(0.31)	(0.08)	(0.40)	(0.42)	(0.45)	(0.56)	(0.78)	(1.32)
LlnX		0.007	0.008	0.007	0.005	0.007	0.007	0.007	0.004
		(2.43)**	(2.65)***	(2.31)**	(1.64)	(2.37)**	(2.28)**	(2.33)**	(0.93)
LlnQ		0.014	0.006	0.002	0.002	0.003	0.003	0.002	0.002
		(1.16)	(0.58)	(0.19)	(0.23)	(0.25)	(0.27)	(0.22)	(0.19)
LlnA		-0.003	-0.004	0.015	0.013	0.012	0.014	0.014	0.010
		(0.96)	(1.34)	(2.45)**	(2.13)**	(1.82)*	(2.37)**	(2.27)**	(1.31)
H			0.058	0.039	0.035	0.035	0.028	0.038	0.036
			(1.73)*	(1.17)	(1.05)	(1.04)	(0.77)	(1.12)	(0.97)
LlnA(w)				0.010	0.009	0.009	0.010	0.010	0.007
				(3.95)***	(3.68)***	(3.60)***	(3.91)***	(3.97)***	(2.24)**
LlnX*Lib					0.004				0.004
					(1.72)*				(0.83)
LnA*Lib						0.002			0.005
						(1.51)			(0.83)
H*lib							0.011		-0.002
							(0.74)		(0.13)
LlnA(w)*Lib								-0.001	0.004
								(0.65)	(1.31)
R^2	0.02	0.03	0.04	0.06	0.06	0.06	0.06	0.06	0.06
Country Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	5,873	5,873	5,873	5,873	5,873	5,873	5,873	5,873	5,873

Robust t statistics in parentheses. *Significant at 10%, ** significant at 5%; *** significant at 1%.