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The Role of Productive and Technological Capabilities on Export Dynamics in Developing Countries*

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ABSTRACT

Productive and technological capabilities matter. The more conventional strands of the literature have emphasized them as major engines of export, growth and development. But how they matter is less clear, and many open questions remain on how capabilities influence export dynamics at microeconomic level. This paper empirically investigates their role on export dynamics in 40 developing countries between 2002 and 2012. In doing so, the paper exploits a country-sector-year database containing exporter-level statistical information. The empirical analysis shows that, within sectors, countries with higher productive capacities have more exporters, and the exporters are larger and charge higher prices for their products, even after controlling for level of development, size of the economy, commodity-dependency and other variables. The results also confirm a positive relationship between technological capabilities and diversification: within sectors, exporters in countries with stronger capabilities tend to export a higher number of products and to more destination markets. Finally, technological capabilities play a specific role in high-technology sectors, such as electronics, electrical machinery and equipment and pharmaceuticals. In these sectors, exporters from countries with higher R&D investments are more diversified in terms of destination markets. Thus, the paper shows that, even comparing exporters' behaviour only among developing countries, stronger productive and technological capabilities are significantly related to the "extensive" and "intensive" margin of exports, diversification across products and destinations, and product quality; all crucial aspects of developing countries' insertion in global markets. Overall, the paper underscores the role of capabilities not only on developing countries' macroeconomic resilience to trade shocks, but also on their medium-term development prospects.

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Sustainable Development Goals: 9.5, 8.2, 9B, 17.11

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I Introduction

Productive capacities and technological capabilities have been emphasized in several strains of economic literature as major engines of export, growth and development. The early contributions on development theory highlighted the transformation of the productive structure –from agriculture and extractive industries to more sophisticated and knowledge-based industries- as a critical factor in shaping the international specialization patterns (Hirschman, 1958; Singer, 1950; Prebisch, 1950). This would entail a process of accumulation of knowledge within the economy (Cimoli *et al*., 2009). Schumpeterian ideas also emphasized the importance of research and development (R&D) investments and innovation activities in shaping market dynamics, particularly through the process of creative destruction (Schumpeter, 1942).

Later, modern growth theories underscored the role of human capital, R&D investments and, more broadly, knowledge, as a major driver of economic growth (Romer, 1990; Aghion and Howitt, 1998). Finally, contributions on technology and trade theory underscored that technological asymmetries were major determinants of trade flows and specialization patterns in foreign markets, influencing on economic performance in the short and medium-term. The key idea was that trade patterns between countries would persist as along as differences in technological capabilities to absorb, generate and use knowledge remain in place (Posner, 1961; Dosi *et al*., 1990).

From an aggregate perspective, previous studies have shed light on the existing asymmetries regarding technological, export and growth indicators between countries. For example, Cimoli *et al*. (2005) discuss the position and evolution of Latin American countries on different indicators regarding structural change, international trade and productivity growth *vis a vis* the United States, Scandinavian countries and the Republic of Korea. The main results are that the performance of Latin American economies was relatively weak, with the region lagging with respect to several indexes of technological efforts, capabilities accumulation and productivity growth.

From an individual country perspective, many studies have shown the connection between capabilities and exports. For example, Ernst *et al.* (1998) examines technological capabilities and export success in the electronics and textile industries in several East Asian countries (Republic of Korea, Taiwan Province of China, Thailand, Indonesia, and Viet Nam). It clearly shows that learning, innovation and capabilities accumulation, including product design, production processes, management routines, marketing and the organization of production, are critical to export growth and for expanding developing countries' market share. Also, there is ample evidence showing that exporters are more productive than non-exporters, and that exporter productivity premia tend to increase with the share of exports in total sales (World Bank, 2007). Also, there is compelling evidence in favour of self-selection of more productive firms into export markets, but scarce evidence for the learning-by-exporting hypothesis. Furthermore, recent research has also emphasized that firms take the choice of entering or expanding their operations in foreign markets together with decisions on investment, technology adoption, product-mix, R&D and innovation.[1] For example, Aw *et al*. (2011) show that productivity growth for electronic producers in Taiwan evolves endogenously to firm's decisions to export and invest in R&D. Also, the results show that a firm's export and R&D decisions affect each other and that both decisions affect productivity growth.

1 Recent advances in the literature on international trade also offer interesting insights to understand the relationship between the weaknesses in global trade and the deceleration in productivity growth in recent years. It shows how trade, investment and technology decisions at firm level interact with each other and affects aggregate productivity growth (Vergara, 2017).

Despite these long-standing theoretical and empirical contributions, there are many open questions on how productive and technological capabilities influence export performance and dynamics, even more so across developing countries. This paper attempts to shed light on the role of productive and technological capabilities on export dynamics at the microeconomic level using a large sample of developing countries. For example, the average steel exporter in Turkey is 1.5 times larger than the average steel exporter in Mexico, and the initial level of exports of a new steel exporter in Turkey is about 1.6 times larger than in Mexico. Meanwhile, Bangladesh exporters of apparel and clothing accessories export to more than 4 destinations on average, while in Pakistan to only 2 destinations. The average Mexican exporter of electrical machinery and equipment exports on average more than 6 different products (at 6-digit of the HS 2002 classification), while Thailand exporters only 4 products. Obviously, these differences are related to the size of the country, level of development, market structure, trade policy and comparative advantages. But what about productive and technological capacities? And across which export margin?

Against this backdrop, this paper tackles the following questions: Do countries with stronger productive capacities have more and larger exporters, and do these exporters charge higher unit prices for their products? Do new exporters in foreign markets display a higher initial level of exports in countries with more productive capacities? Are exporters from countries with higher technological capabilities more diversified in terms of products and destinations? Thus, the goal is to uncover what are the links between capabilities and exporter dynamics in foreign markets. In particular, the paper attempts to connect the issue of capabilities with the extensive and intensive margin of exports (number and size of exporters), diversification across products and destinations, and product quality, all of which have been emphasized as crucial aspects of international competitiveness. In doing this, the empirical strategy controls for other country dimensions that can also be relevant, such as the size of the economy, level of development, trade openness, size of manufacturing sector and commodity dependency.

This paper uses data from the World Bank's *Exporter Dynamics Database*, which compiles statistical information from national sources exporter-level customs data, covering the universe of annual export transactions (Fernandes *et al*., 2016).[2] The database contains exporter-level information for 40 developing countries between 2002 and 2012 aggregated at sectoral level. A key issue is that there is no obvious approach to measure productive and technological capabilities. The concept of capabilities is closely connected to the accumulation of explicit and tacit knowledge, and to how different chunks of knowledge are mixed, combined and used to generate new productive and technological capacities. Thus, the issue of capabilities is multidimensional, encompassing economic, technological and institutional aspects.

The paper uses two proxies of capabilities, one for productive capacities, one for technological capabilities. To measure productive capacities, the empirical approach uses the *Economic Complexity Index* (ECI) (Hausmann *et al*., 2011). The ECI measures the multiplicity of productive knowledge in an economy by combining information on the diversity of a country's exports (based on the number of its export products) and the ubiquity of its products (based on the number of countries that export a particular product). Thus, the ECI builds upon productive diversification[3] and capabilities. As discussed by Mealy *et al*. (2018) and Kemp-Benedict (2014), the ECI is orthogonal to diversity, and it captures information on what type of products and capabilities

2 Fernandes *et al*. (2016) initially presented the *Exporter Dynamics Database*. They analyze how export behaviour is linked to country size and level of development. Interestingly, the paper shows that larger and more developed countries have more and larger exporters, and a greater share of exports controlled by the top 5% of exporters. This database opens a variety of research possibilities to improve the understanding of export dynamics at disaggregated levels.

3 There is ample evidence on the relationship between diversification and economic growth, especially for less developed countries (Cherif, *et al*., 2018; Al-Marhubi, 2000; Herzer and Nowak-Lehnmann, 2006).

countries are competitive in. Furthermore, the ECI provides a rank ordering of countries in terms of how similar their exports and capabilities are to each other and this ordering helps to explain variations in GDP per capita and future growth (Hidalgo and Hausmann, 2009). This suggest that some type of exports, and thus some type of capabilities, are more relevant to development, a crucial argument of the early development theories[4].

Meanwhile, to measure technological capabilities, the empirical approach uses R&D investments as a proxy[5]. The R&D investments reflect the technological efforts that countries put in place to foster knowledge creation and technological progress. In fact, firm's R&D activities encourage product and process innovations and enhance the absorptive capacity to assimilate external knowledge (Griliches, 1979; Cohen and Levinthal, 1990; Griffith *et al*., 2003). In addition, R&D activities can also convey intangible benefits to overcome barriers to exporting (Harris and Li, 2009; Tecce and Pisano, 1998), and they are also a crucial feature of *National Innovation Systems*[6]. In comparison to developed countries, national innovation systems in developing economies are generally characterized by low level of R&D, high participation of public R&D in total R&D expenditures, innovation activities concentrated in natural-resources and low-tech activities, low level of human capital and workforce capabilities and lack of interactions among economic agents (Arocena and Sutz, 2005).

The empirical hypotheses are that the ECI and R&D investments are positively correlated with different export dimensions. Intuitively, a higher level of sophistication and a wider variety of productive knowledge embedded in the productive structure should be reflected in the international competitiveness. Thus, a higher ECI could imply a larger number of exporters and higher levels of exports per exporter. Also, the productive knowledge could be reflected in the quality of products, thus a positive correlation with unit prices is also tested[7]. Similarly, the level of R&D is expected to be positively connected with diversification across products and destinations markets, particularly given the vital role it plays on product and process innovations (Mairesse and Mohen, 2010).

The contribution of this paper is threefold. *First*, it presents a comprehensive analysis within developing countries on the role of productive and technological capabilities on export dynamics. While the relevance of technological and innovation capabilities on firms' export indicators has been documented, comprehensive cross-country comparisons are scarce. *Second*, the paper uncovers explicit links on how productive and technological capabilities relates to export dynamics. *Third*, the links between capabilities and exports dynamics

4 For example, Hirschman (1958) and Singer (1950) emphasized that development implied factor reallocations from low-productivity sectors to high productivity sectors. See Hausmann et al. (2007) for a formal empirical validation of the argument. In developing countries, Lall (2000) shows that technologically sophisticated products are more strongly associated with export and income growth.

5 Measuring technological capabilities is a difficult task. On one hand, technological capabilities encompass multifaceted aspects, including the composition of the productive structure, R&D investments, patents, labour skills, among others. On the other, R&D investments is not the only way to acquire new technologies in developing countries, which can materialize through capital goods, technology licenses and foreign direct investment.

6 The concept of *National Innovation Systems* (NIS) emerged to explain the differences in innovative performances of developed countries. The underlying idea was that innovation differences depended on "*institutional differences in the mode of importing, improving, developing and diffusing new technologies, products and processes*" and on the level of interactions of different agents and institutions within the society (Freeman, 1995). The NIS approach then became a useful framework to address the complexity of innovation activities as a "systemic process" in developing countries.

7 Using unit prices as a proxy of product quality at sectoral level is a strong simplification. Price dispersions exist due to quality differences and several other reasons, including demand shocks, market power, production costs, among others. However, using unit prices across sectors for a comprehensive set of countries and for a relatively extended period seems to be a plausible approach to reduce its problems as a proxy for product quality. For example, Schott (2004) shows that countries more abundant in physical and human capital export to the United States at higher unit prices, even within narrow categories.

underline their role not only on developing countries' resilience to trade shocks, but also on their medium-term development prospects. Obviously, the paper also displays several limitations. Most importantly, the empirical analysis and the nature of the data prevents any inference on *causality* between capabilities and export dynamics. The paper is organised as follows. Section 2 describes the data and some basic statistics, providing an aggregate picture for the empirical analysis. Then, section 3 presents the empirical approach, while Section 4 discusses the main results. Finally, section 5 concludes.

II Data and basic statistics

The statistical information regarding export dynamics comes from the *Exporter Dynamics Database*[8]. This database compiles export information from national sources exporter-level customs data, covering the universe of annual exporter transactions. The database contains information for 40 developing countries between 2002 and 2012. Thus, it is a country-sector-year database, unevenly distributed across developing countries (see Annex A1). In particular, it comprises aggregated information at sectoral level (2-digit of the Harmonized System 2002 Classification)[9] for the number of exporters (total and per product), average value of exports per exporter and per entrant (new exporter in year *t*), average unit prices per exporter, average number of products per exporter; and the average number of destinations per exporter, among other variables.

As discussed, productive capacities are proxied by the *Economic Complexity Index* (ECI), from the MIT's *Observatory of Economic Complexity*[10]. The ECI measures the sophistication of a country's productive structure by combining information on the *diversity* of country exporting activity and the *ubiquity* of its products. These dimensions are based on the number of products that a country exports and the number of countries that export a specific product, respectively. The intuition is that more sophisticated economies tend to be more diversified, and they are able to export products that, on average, have low ubiquity. Thus, it encompasses information on the diversification and on what type of capabilities countries are competitive. Meanwhile, technological capabilities are proxied by R&D investments over GDP, data that comes from the *World Development Indicators* of the World Bank[11]. The R&D investments reflect technological efforts. R&D investments is a variable commonly used to measure country's technological effort to generate, absorb and use knowledge, and it constitutes a crucial input for introducing products and process innovations.

Figure 1 displays a simple correlation plot of the ECI and R&D across developing countries[12], with a significant country variation across both dimensions. The ECI ranges from -2.2 to 0.98, with an average of -0.39 and a standard deviation of 0.70[13]. Meanwhile, R&D investments range from 0 to above 2.0 per cent over GDP, with an average of 0.45 and a standard deviation of 0.36[14]. As expected, there is a relatively strong and positive correlation between ECI and R&D activities, and countries with more productive knowledge tend to

8 For details about the database, see http://www.worldbank.org/en/research/brief/exporter-dynamics-database.

9 https://unstats.un.org/unsd/tradekb/Knowledgebase/50043/HS-2002-Classification-by-Section

10 See Annex A2 for details about the calculation of the *Economic Complexity Index* (https://atlas.media.mit.edu/en/.)

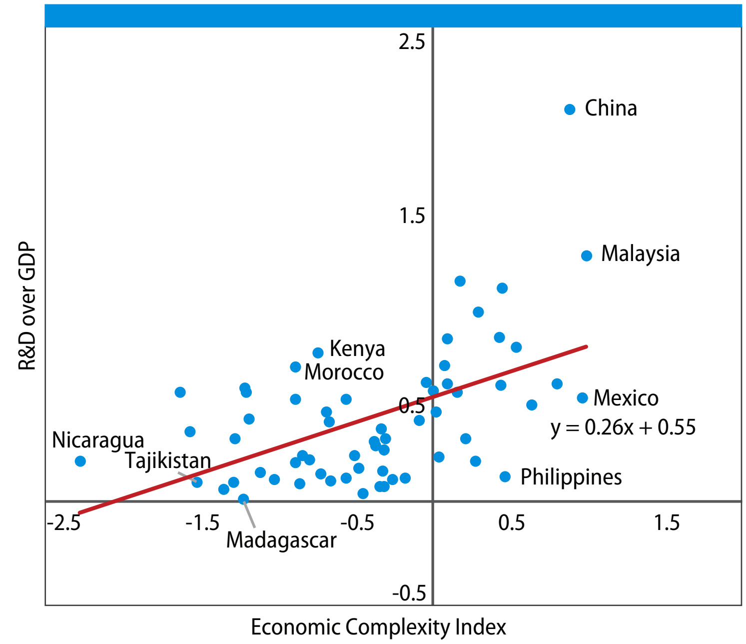
11 https://data.worldbank.org/products/wdi.

12 This description covers all developing countries with available information for ECI and R&D investments, not only the 40 developing countries included in the sample estimation. China, for example, is not included in the *Exporters Dynamics Database*. Thus, China is included only in the descriptive statistics (Figure 1 and 2), but not in the econometric estimations (see Annex A.1).

13 For developed countries, the ECI ranges between -0.27 and 2.42, with an average of 1.11 and a standard deviation of 0.60.

14 Annex A3 displays the histograms of ECI and R&D investments based on the sample estimation data.

Figure 1
Economic complexity and R&D investments, 2015



Source: Author's own elaboration based on data from the WDI and MIT Observatory on Economic Complexity.

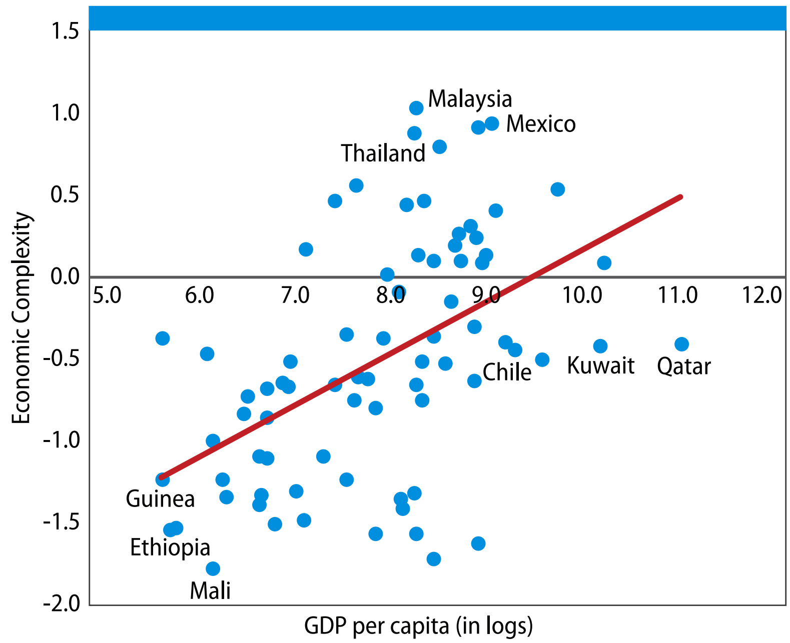
exhibit higher technological efforts. China and Malaysia are among those with the highest combinations on productive and technological capabilities, while countries such as Nicaragua and Tajikistan exhibit a relatively deficient performance.

The different combinations along these indicators for specific countries also underscore that the ECI and R&D investments reflect distinct aspects of capabilities. For example, Mexico displays a relatively high ECI as its export structure is diversified, with a relatively large share of medium-high and high-technology products.[15] However, technological efforts in the Mexican economy is limited, with relatively low levels of R&D investments, only 0.55% of GDP. This illustrates several weaknesses in its national innovation system, including a low participation of the private sector on R&D activities, lack of interactions and cooperation between private sector and universities, and relatively low level of human capital (Casanova, 2015). By contrast, Kenya exhibit a relatively low level of ECI, with an export structure highly concentrated in a few agricultural products and textiles. However, Kenya has visibly strengthened its efforts to increase R&D investments, to about 0.8% of GDP, particularly by designing comprehensive innovation policy frameworks (Ndemo, 2015).

Figures 2 and 3 display simple correlation plots of ECI and R&D investments with the level of development across developing countries, using GDP per capita as a proxy. As expected, both variables are positively correlated with GDP per capita. The correlation is higher for the ECI (0.49), yet, some countries such as Kuwait and Qatar and some Latin American economies exhibit a low level of productive capacities, despite a relatively high level of GDP per capita. The correlation between R&D and level of development across developing countries is lower, only 0.26. This shows that, while relatively poor countries tend to invest little

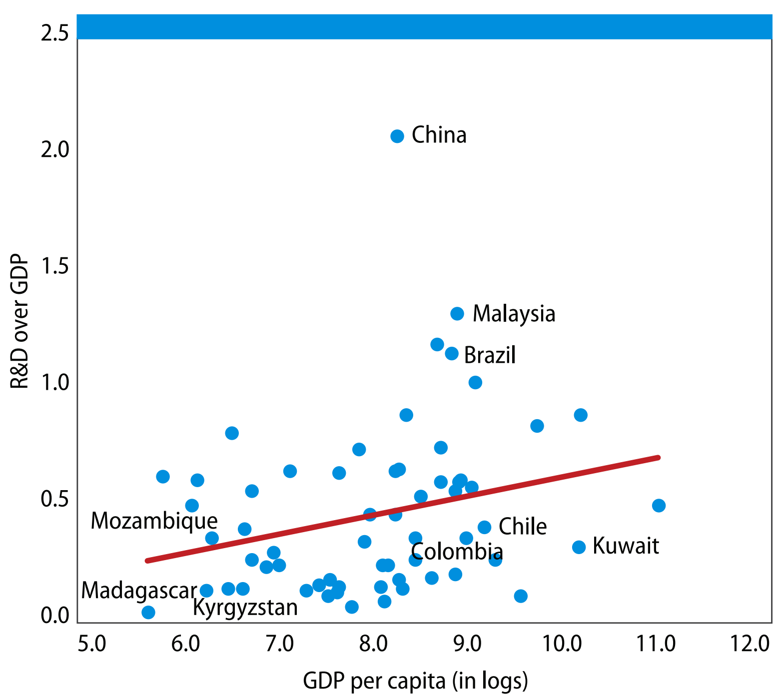
15 In Mexico, export products such as automobiles, vehicle parts, trucks, computers and other machinery and equipment products account for more than 60% of total merchandise exports.

Figure 2
Economic complexity index and GDP per capita, 2015



Source: Author's own elaboration based on data from World Development Indicators, World Bank, and the MIT's Observatory of Economic Complexity https://atlas.media.mit.edu/en/

Figure 3
R&D investments and GDP per capita, 2015



Source: Author's own elaboration based on data from World Development Indicators, World Bank. R&D data is for 2015 or latest available information.

in R&D as a norm, there are also a variety of country specific circumstances[16]. For example, countries such as Chile, Colombia and some Arab States of the Persian Gulf display a relatively high GDP per capita, but underperform regarding R&D investments.

III Empirical approach

This section describes the empirical strategy to analyse the role of productive and technological capabilities on the different export dynamics dimensions. The approach closely follows the one taken by Fernandes *et al.* (2016). To analyse the role of productive capacities on different export dimensions, I specify the following equation:

$$Export\ dimensions_{ijt} = \alpha_i + \delta_t + \theta ECI_{jt} + \beta X_{jt} + \varepsilon_{ijt} \qquad (1)$$

where *i*, *j*, and *t* represent sectors, countries and years, respectively. There are several dependent variables: i) *Number of exporters* (log of the total number of exporters), ii) *Number of exporters per product* (log of the average number of exporters per product - products defined at 6-digit of the HS 2002 classification); iii) *Exports per exporter* (log of the average exports per exporter); iv) *Exports per entrant* (log of the average exports per entrant, which is a new exporter in year t), and v) *Unit prices* (log of the average export value over quantity). The variable *ECI* corresponds to the Economic Complexity Index and the vector X encompasses several control variables: GDP is the log of GDP in constant US dollars; *GDP per capita* is the log of GDP per capita in constant US dollars; *Trade over GDP* is total merchandise exports and imports over GDP; *Manufacturing sector* correspond to the share of the manufacturing sector in the economy; and *Commodity-Dependent* is a dummy variable that takes the value 1 if the country is a commodity dependent economy[17]. Finally, αi and δt correspond to sectoral and year effects. The equation (1) is estimated by Ordinary Least Squares (OLS), using robust standard errors adjusted by "clustering" at country level.

Similarly, the equation to investigate the role of technological capabilities –using as proxy R&D investments- on diversification across products and destinations is the following:

$$Diversification\ dimension_{ijt} = \alpha_i + \delta_t + \theta R\&D_{jt} + \gamma R\&D_{jt} * HighTech_{ijt} + \beta X_{jt} + \varepsilon_{ijt} \qquad (2)$$

where *i, j,* and *t* represent sectors, countries and years, respectively. The dependent variables are i) *Products per exporter* (log of the average number of products per exporter – products defined at 6-digit of the HS 2002 classification); and ii) *Destination per exporter* (log of the average number of destination countries per exporter). *R&D* corresponds to aggregate R&D investments over GDP. Similarly, *GDP*, *GDP per capita*, *Manufacturing sector* and *Commodity-Dependent* are control variables. This approach includes a multiplicative variable of *R&D* and *HighTech,* which is a dummy variable that takes the value 1 if the sector is R&D intensive[18].

16 There is large literature that attempt to explain why poor countries invest too little on R&D. Cirera and Maloney (2017) argue that the main reason is the scarcity of complementary factors to innovation, including physical and human capital, credit markets and managerial quality, among others.

17 There are 22 commodity-dependent economies in the estimation sample: Cameroon, Chile, Colombia, Ecuador, Ethiopia, Gabon, Guatemala, Guinea, Kenya, Kuwait, Kyrgyzstan, Lao People's Dem. Rep., Madagascar, Malawi, Mali, Paraguay, Peru, Senegal, Uganda, Uruguay, Yemen and Zambia (UNCTAD, 2017).

18 High-technology sectors are defined following the definition of Medium and High technology manufacturing products (Lall, 2000). See Annex A4 for the list of high technology sectors ("sections" at the 2-digit HS classification).

Including this multiplicative variable allows us to test for a heterogeneous relation between R&D and export dynamics across different sectors. In fact, it has been widely discussed that technical progress does not occur evenly across sectors, and some sectors are more innovative and stimulate technological diffusion more than others (Pavitt, 1984). An illustration of this is that R&D investments do not distribute homogenously across sectors, and sectors such as electronics, machinery and pharmaceuticals concentrate the bulk of technological efforts. Again, equation (2) is estimated by Ordinary Least Squares (OLS), using robust standard errors adjusted by "clustering" at country level.

IV Regression results

Table 1 presents the estimation results regarding the number of exporters, total and per product. Columns (1) and (3) provide the baseline estimations, including only ECI and the level of GDP as explanatory variables, while column (2) and (4) include the whole set of control variables. All regressions include sectoral and year fixed effects. The coefficients associated to ECI are significant at 5% in the baseline regressions for the total number of exporters and for the number of exporters per product. Likewise, when including all the control variables in column (2) and (4), ECI remains significant, at 10%, in both cases. This suggest that within sectors, countries with stronger productive capacities have more exporters, total and per product. The regressions also show that the size of the economy is positively associated with the number of exporters, which confirms previous results obtained by Fernandes *et al.* (2016). Thus, productive capacities tend to be positively correlated with the extensive margin of exports across a relatively large sample of developing countries.

Table 2 displays the estimation results regarding the level of exports per exporter and the level of export per new entrant in foreign markets. Again, column (1) and 3) provides the baseline regressions, while columns (2) and (4) presents the regression with the full set of control variables. In the case of exports per exporter, the coefficient associated to ECI is positive and significant, at 10% in the baseline and at 10% with all the control variables. Among the other variables, the results show that the size of the economy, the relevance of the manufacturing sector and trade openness are positively correlated with the level of exports per exporter. In addition, commodity-dependent economies tend to have a higher level of exports per exporter, due to the importance of sectors based on natural resources. In facts, these sectors tend to be capital intensive and dominated by only a few but very large exporters. For the case of exports per entrant, the coefficients associated to ECI are positive and significant in the two regressions. Thus, within sectors, new exporters from countries with more productive capacities tend to have higher levels of exports, even when controlling for other relevant variables. Altogether, this suggests that there is clear-cut correlation between productive capacities and the intensive margin of exports across developing countries.

Interestingly, column (4) of Table 2 also shows that the level of development, proxied by GDP per capita, is negatively associated with the average level of export per entrant. Thus, it suggests that the initial levels of exports for new exporters is *larger* in countries with lower levels of development. While it might seem counterintuitive, this is consistent with the literature of trade costs and barriers to trade, which clearly underscore that trade costs decrease as per capita income increases (Arvis *et al.*, 2012). Thus, new exporters in poorer countries confronts much higher trade costs than a new exporter in a more developed and globally integrated economy. As a result, new exporters then need to start their exporting activity with a relatively larger volume of exports to confront higher trade costs.

Meanwhile, the regression results regarding unit prices per exporter are presented in Table 3. GDP per capita and the ECI are the only variables that display a significant correlation with unit prices. Thus, exporters from countries with higher levels of development and productive capacities tend to have higher average unit prices for their products, in the comparison across sectors. I interpret this result as a strong indication that, within sectors, productive capacities are positively correlated with product quality across developing countries. In fact, while unit price dispersions exist due to a multiplicity of factors –such as demand shocks, market power or others-, the significant role play by productive capacities for such a comprehensive sample of countries and for an extended period of time is a solid indication that the main driver for these unit prices differences (in levels) is product quality.

Finally, Table 4 displays the regression results for the role of R&D investments on exporter's diversification across products and destinations. Note that in these estimations the number of countries considered are lower, only 31, due to the lesser availability of R&D data for some countries. Column (1) presents the baseline regression when using products per exporter as a dependent variable. Then, columns (2) and (3) sequentially add the control variables and the multiplicative variable *R&D*High-Tech*. The estimated coefficients associated to R&D investments are stable and suggest a positive and significant correlation with the number of products per exporter. Thus, exporters in countries with higher level of R&D investments export a larger number of products, at 6-digit of the HS classification, to foreign markets. Meanwhile, the size of the economy, the trade openness and the size of the manufacturing sector are also positively correlated with product diversification, which are, a priori, intuitive results. Interestingly, the multiplicative variable R&D*High-tech is not significant, showing there are no heterogeneous effects for high-technology sectors.

Columns (4), (5) and (6) of Table 4 displays the regression for the number of destinations per exporter. When including all the control variables, the result shows that R&D investment is positively correlated with diversification across destinations, together with level of development, the size of manufacturing sector and the dummy for commodity-dependent economies. Thus, within sectors, exporters from countries with higher R&D tend to export their products to a larger number of destinations. Interestingly, the *variable R&D*HighTech* is positive and significant at 5%. This suggests that there is an additional correlation between R&D investments and the number of destinations per exporter in high-technology sectors. Thus, the higher the level of R&D, the larger the number of (average) destinations per exporter in high technology sectors. This result is consistent with a growing literature emphasizing the relationship between R&D activities and export diversification, with a causality that could run in both directions[19].

In order to analyse the sensitivity of the results, several robustness checks are implemented. A key aspect to consider is to what extent the empirical results regarding productive and technological capabilities could be driven by the estimation sample. In fact, the estimation sample is not balanced across countries, and some countries are observed in the database for longer periods of time. To address this issue, I follow a twofold strategy. First, the equations are estimated using a restricted sample with the same number of observations per country. Thus, the "additional" observations for some countries, in comparison to countries with fewer

19 For example, Baum (2015) examines the endogenous relationship between diversification and R&D activities in UK firms. The results suggest that geographical sales diversification induces UK firms to increase R&D expenditures. Also, the results imply that R&D expenditures cause higher export sales but do not cause export sales diversification. Meanwhile, Wagner (2017) investigates the links between innovation and R&D activities and diversification in manufacturing firms in Germany. The results confirm that more innovative firms outperform less innovative firms in the number of products and destinations.

Table 1

Productive capacities and the extensive margin of exports

	Number of exporters (1)	Number of exporters (2)	Number of exporters per product (3)	Number of exporters per product (4)
ECI	0.472	0.360	0.260	0.230
	(2.60)**	(1.70)*	(2.17)**	(1.73)*
GDP	0.690	0.646	0.468	0.490
	(8.28)***	(5.74)***	(7.36)***	(6.40)***
GDP per capita		0.041		-0.063
		(0.029)		(-0.77)
Trade over GDP		-0.001		0.001
		(-0.32)		(0.47)
Manufacturing Sector		0.027		0.013
		(1.49)		(1.27)
Commodity-Dependent		-0.246		-0.226
		(-1.20)		(-1.60)
Sectoral Dummies	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes
R-squared	0.69	0.71	0.60	0.62
Number of countries	40	39	40	39
Observations	28,921	27,931	27,634	26,707

Notes: *Number of exporters* is the log of the total number of exporters. *Exporters per product* is the log of the number of exporters per product, with products defined at 6-digit of the HS 2002 classification. GDP is the log of GDP in constant US dollars and *GDP per capita* is the log of GDP per capita in constant US dollars. *ECI* corresponds to the Economic Complexity Index. *Trade over GDP* is total merchandise exports and imports over GDP. *Manufacturing sector* correspond to the share of the manufacturing sector in the economy. *Commodity-Dependent* is a dummy variable that takes the value 1 if the country is a commodity dependent economy. OLS estimations at sector level (HS 2-digit codes). t statistics with robust standard errors adjusted by clustering at country level in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 2

Productive capacities and the intensive margin of exports

	Exports per exporter (1)	Exports per exporter (2)	Exports per entrant (3)	Exports per entrant (4)
ECI	0.497	0.294	0.251	0.310
	(1.88)*	(1.88)*	(1.74)*	(2.29)**
GDP	0.384	0.469	0.266	0.471
	(5.56)***	(5.36)***	(4.24)***	(5.90)***
GDP per capita		0.070		-0.258
		(0.79)		(-2.64)**
Trade over GDP		0.007		0.011
		(2.31)**		(3.66)**
Manufacturing Sector		0.045		0.003
		(2.49)**		(0.09)
Commodity-Dependent		0.547		0.223
		(3.58)**		(1.41)
Sectoral Dummies	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes
R-squared	0.40	0.42	0.32	0.33
Number of countries	40	39	39	38
Observations	27,634	26,707	24,195	23,435

Notes: : *Exports per exporter* is the log of the (mean) exports per exporter. *Exports per entrant* is the log of the (mean) exports per entrant. *GDP* is the log of GDP in constant US dollars and *GDP per capita* is the log of GDP per capita in constant US dollars. ECI corresponds to the Economic Complexity Index. *Trade over GDP* is total merchandise exports and imports over GDP. *Manufacturing sector* correspond to the share of the manufacturing sector in the economy. *Commodity-Dependent* is a dummy variable that takes the value 1 if the country is a commodity dependent economy. OLS estimations at sector level (HS 2-digit codes). t statistics with robust standard errors adjusted by clustering at country level in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 3
Productive capacities and unit prices

	Unit prices per exporter (1)	Unit prices per exporter (2)
ECI	0.519	0.275
	(4.15)***	(2.18)**
GDP	0.147	0.158
	(1.81)*	(1.57)
GDP per capita		0.209
		(2.87)**
Trade over GDP		0.002
		(0.90)
Manufacturing Sector		-0.005
		(-0.41)
Commodity-Dependent		0.099
		(0.64)
Sectoral Dummies	Yes	Yes
Year Dummies	Yes	Yes
R-squared	0.55	0.57
Number of countries	34	33
Observations	21,543	20,616

Notes: *Unit prices* is the log of the total export value over quantity. *ECI* corresponds to the Economic Complexity Index. *GDP* is the log of GDP in constant US dollars and *GDP per capita* is the log of GDP per capita in constant US dollars. *Trade over GDP* is total merchandise exports and imports over GDP. *Manufacturing sector* correspond to the share of the manufacturing sector in the economy. *Commodity-Dependent* is a dummy variable that takes the value 1 if the country is a commodity dependent economy. OLS estimations at sector level (HS 2-digit codes). t statistics with robust standard errors adjusted by clustering at country level in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 4
Technological capabilities and diversification

	Products per exporter (1)	Products per exporter (2)	Products per exporter (3)	Destinations per exporter (4)	Destinations per exporter (5)	Destinations per exporter (6)
R&D	0.182	0.192	0.188	0.148	0.317	0.291
	(2.05)**	(2.12)**	(2.09)**	(1.57)	(4.52)***	(4.14)***
GDP	0.016	0.020	0.020	0.043	-0.004	-0.004
	(2.22)**	(2.35)**	(2.35)**	(2.01)*	(0.22)	(0.23)
GDP per capita		0.015	0.155		0.0758	0.075
		(1.08)	(1.08)		(4.16)***	(4.17)***
Trade over GDP		0.001	0.001		-0.001	-0.001
		(2.39)**	(2.39)**		(1.55)	(1.56)
Manufacturing Sector		0.005	0.005		0.017	0.017
		(2.85)**	(2.85)**		(3.69)***	(3.69)***
Commodity-Dependent		0.032	0.032		0.154	0.153
		(1.14)	(1.14)		(3.83)***	(3.83)***
R&D * High-tech sector			0.030			0.205
			(1.20)			(2.95)**
Sectoral Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.60	0.61	0.61	0.26	0.32	0.32
Number of countries	31	31	31	31	31	31
Observations	13,107	12,674	12,674	13,107	12,674	12,674

Notes: *Products per exporter* is the log of the (mean) number of products per exporter. *Destination per exporter* is the log of the (mean) number of destination countries per exporter. *R&D* corresponds to aggregate R&D investments over GDP. *GDP* is the log of GDP in constant US dollars and *GDP per capita* is the log of GDP per capita in constant US dollars. *Manufacturing sector* correspond to the share of the manufacturing sector in the economy. *Commodity-Dependent* is a dummy variable that takes the value 1 if the country is a commodity dependent economy. *High-tech sector* is a dummy variable that takes the value 1 if the sector is R&D intensive. OLS estimations at sector level (HS 2-digit codes). t statistics with robust standard errors adjusted by clustering at country level in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

observations, are left out from the estimation sample. Second, the estimations are implemented on a second restricted sample, where countries have, at least, 500 observations. With this approach, countries with fewer observations are left out from the estimation sample, approximately 20% of the full sample. Finally, the equations are estimated by correcting for the issue that some sectors have zero exports –in fact, not all countries export in every sector. Correcting this issue expands the database by approximately 5%. Despite some variations, the robustness checks, particularly the results regarding productive and technological capabilities, confirm the main conclusions[20].

V Concluding Remarks

The accumulation of productive and technological capabilities is a major driver of economic growth, structural change and development. This paper examines their role on export dynamics at microeconomic level in a large sample of developing countries. The results indicate that productive capabilities, proxied by the Economic Complexity Index, are positively correlated with the intensive and the extensive margins of exports and product quality. The results also confirm that technological capabilities, proxied by R&D investments, are strongly linked to firms' diversification across products and destinations, especially in high-technology sectors. In short, within similar sectors, developing countries with higher productive and technological capabilities have more exporters; and the exporters are larger, more diversified and charge higher unit prices for their products.

These findings are important for several reasons. First, they explicitly and empirically underscore the relevance of asymmetries of productive and technological capabilities across developing countries, a crucial issue emphasized by the structuralist tradition. So far, most of the aggregate literature have compared technological capabilities between developing and developed countries. As expected, these studies demonstrate that capabilities are a major determinant of productivity, export and growth. This paper shows that capabilities matter even when comparing export dynamics only among developing countries. Second, the results illustrate how the accumulation of productive and technological capabilities play a role on developing countries' insertion in international markets through different channels. These results are consistent with the 'Kaldorian' view that the creation and the development of productive capacities for exporting activity are prior to the effect that "incentives", such as trade liberalization reforms, might have on exports.

Therefore, the paper underlines the role of capabilities not only on developing countries' macroeconomic resilience to trade shocks -a major risk in the current international environment-, but also on their medium-term development prospects. In fact, the accumulation of capabilities is reflected in product and market diversification, a key factor to navigate international trade shocks. In addition, productive and technological capabilities are mirrored in the extensive and intensive margin of trade and on product quality, which are relevant aspects of international competitiveness and on how countries adjust to changing demand patterns. Thus, these links emphasize different aspects of how the micro-macro interactions drive development trajectories under a different setup of capabilities. Finally, the paper implicitly suggest that productive and technological capabilities should also be a major dimension to understand and evaluate the consequences and dynamics from the changing global trade environment.

20 The Annex tables A5.1-A5.4. display the regressions for the robustness checks using a balanced number of observations across countries ("balance sample"). The other robustness checks are available upon request.

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Annex A1

Database – Distribution of observations across countries

Country	Frequency	Per cent	Cum.
Albania	834	3.00	3.00
Bangladesh	756	2.72	5.72
Botswana	939	3.38	9.10
Cambodia	569	2.05	11.15
Cameroon	893	3.21	14.36
Chile	950	3.42	17.78
Colombia	570	2.05	19.83
Costa Rica	934	3.36	23.19
Dominican Republic	925	3.33	26.52
Ecuador	931	3.35	29.87
El Salvador	665	2.39	32.26
Ethiopia	422	1.52	33.78
Gabon	80	0.29	34.07
Georgia	926	3.33	37.04
Guatemala	760	2.73	40.14
Guinea	280	1.01	41.14
Jordan	896	3.22	44.37
Kenya	665	2.39	46.76
Kuwait	188	0.68	47.44
Kyrgyzstan	654	2.35	49.79
Lao People's Dem. Rep.	377	1.36	51.15
Lebanon	475	1.71	52.86
Madagascar	559	2.01	54.87
Malawi	613	2.21	57.07
Mali	336	1.21	58.28
Mauritius	944	3.4	61.68
Mexico	950	3.42	65.10
Morocco	950	3.42	68.51
Nicaragua	912	3.28	71.80
Pakistan	760	2.73	74.53
Paraguay	473	1.70	76.23
Peru	950	3.42	79.65
Senegal	904	3.25	82.90
South Africa	948	3.41	86.32
Thailand	95	0.34	86.66
Turkey	950	3.42	90.08
Uganda	587	2.11	92.19
Uruguay	930	3.35	95.53
Yemen	397	1.43	96.96
Zambia	844	3.04	100.00

Source: Author's own elaboration based on Exporter Dynamics Database. http://www.worldbank.org/en/research/brief/exporter-dynamics-database.

Annex A2
Economic Complexity Index

The Economic Complexity Index (ECI) is s calculated from exports data that connect countries to products where they have Revealed Comparative Advantages (RCA). Defining Mcp as a matrix that is I if country c produces product p and 0 otherwise, then it is possible to measure diversity and ubiquity by summing over the rows or columns of the matrix.

$$Diversity = K_{c,0} = \sum_p M_{cp} \qquad (1)$$

$$Ubiquity = K_{p,0} = \sum_c M_{cp} \qquad (2)$$

Then, a matrix can be defined that connects countries that export similar products, weighted by the inverse of the ubiquity of a product to discount for common products, and normalized by the diversity of a country:

$$M^*_{cc'} = \frac{1}{K_{c,0}} \sum_p \frac{M_{cp} M_{c'p}}{K_{p,0}} \qquad (3)$$

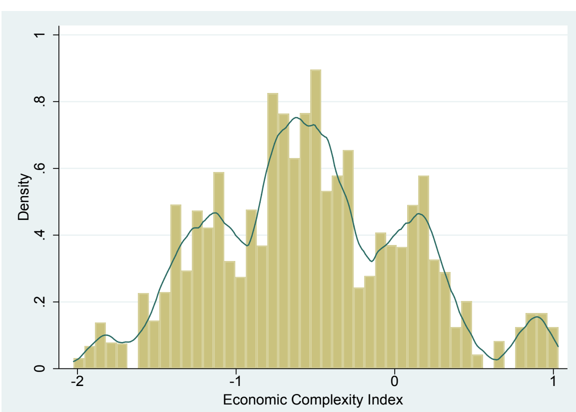
Finally, the ECI can be defined as:

$$ECI_c = \frac{K_c - \langle K \rangle}{std(K)} \qquad (4)$$

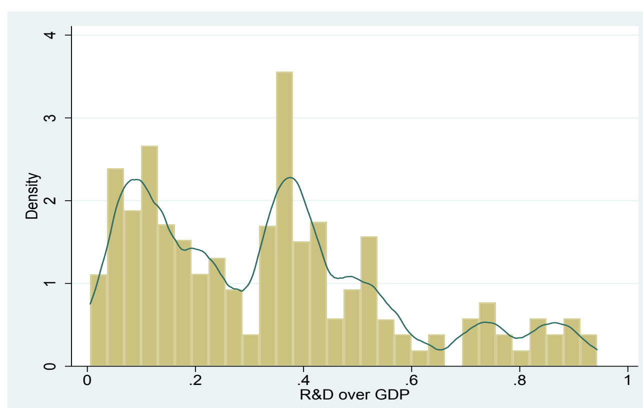
Where < > represents the average and K_c is the eigenvector of $M^*_{cc'}$ associated with the second eigenvalue (the vector associated with the largest eigenvalue is a vector of ones). For more details, see Hausmann *et al.* (2011).

Annex A3
Histograms – Sample data

Economic Complexity Index



R&D Investments



Source: Author's own elaboration based on data from MIT's Observatory of Economic Complexity https://atlas.media.mit.edu/en/ and World Development Indicators, The World Bank. https://data.worldbank.org/products/wdi.

Annex A4
High technology sectors at 2-digit HS 2002 Classification

Section	Description
30	Pharmaceutical products
37	Photographic or cinematographic goods.
84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof
85	Electrical machinery & equipment; sound recorders/reproducers, televisions, parts & accessories
86	Railway or tramway locomotives, mechanical and electro-mechanical traffic signalling equipment.
87	Vehicles other than railway or tramway rolling-stock, and parts and accessories thereof.
88	Aircraft, spacecraft, and parts thereof.
89	Ships, boats and floating structures.
90	Optical, precision, medical or surgical instruments and apparatus; parts & accessories
91	Clocks and watches and parts thereof.
92	Musical instruments; parts and accessories of such articles.
93	Arms and ammunition; parts and accessories thereof.

Source: Author's own elaboration using the 2-digit HS 2002 classification, based on Lall (2000).
https://unstats.un.org/unsd/tradekb/Knowledgebase/50043/HS-2002-Classification-by-Section

Annex A5.1
Productive capacities and the extensive margin of exports

Balanced sample

	Number of exporters (1)	Number of exporters per product (2)
ECI	0.478	0.285
	(2.12)**	(2.06)**
GDP	0.632	0.480
	(5.11)***	(5.61)***
GDP per capita	0.017	-0.078
	(0.12)	(-0.93)
Trade over GDP	-0.002	0.000
	(-0.42)	(0.28)
Manufacturing Sector	0.018	0.005
	(0.78)	(0.43)
Commodity-Dependent	-0.160	-0.184
	(-0.73)	(-1.26)
Sectoral Dummies	Yes	Yes
Year Dummies	Yes	Yes
R-squared	0.70	0.61
Number of countries	38	38
Observations	12,122	11,525

Notes: Number of exporters is the log of the number of exporters. Number of exporters per product is the log of the number of exporters per product. GDP is the log of GDP in constant US dollars and GDP per capita is the log of GDP per capita in constant US dollars. ECI corresponds to the Economic Complexity Index. Trade over GDP is total merchandise exports and imports over GDP. Manufacturing sector correspond to the share of the manufacturing sector in the economy. Commodity-Dependent is a dummy variable that takes the value 1 if the country is a commodity dependent economy. OLS estimations at sector level (HS 2-digit codes), using a balanced estimation sample. t statistics with robust standard errors adjusted by clustering at country level in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Annex A5.2

Productive capacities and the intensive margin of exports

Balanced sample

	Exports per exporter (1)	Exports per entrant (2)
ECI	0.228	0.271
	(1.56)	(1.78)*
GDP	0.482	0.481
	(5.44)***	(6.43)***
GDP per capita	0.060	-0.251
	(0.70)	(-2.64)**
Trade over GDP	0.008	0.012
	(2.81)**	(4.25)***
Manufacturing Sector	0.055	-0.004
	(3.09)**	(-0.21)
Commodity-Dependent	0.503	0.149
	(3.38)**	(1.02)
Sectoral Dummies	Yes	Yes
Year Dummies	Yes	Yes
R-squared	0.42	0.32
Number of countries	38	38
Observations	11,525	10,293

Notes: Exports per exporter is the log of the (mean) exports per exporter. Exports per entrant is the log of the (mean) exports per entrant. GDP is the log of GDP in constant US dollars and GDP per capita is the log of GDP per capita in constant US dollars. ECI corresponds to the Economic Complexity Index. Trade over GDP is total merchandise exports and imports over GDP. Manufacturing sector correspond to the share of the manufacturing sector in the economy. Commodity-Dependent is a dummy variable that takes the value 1 if the country is a commodity dependent economy. OLS estimations at sector level (HS 2-digit codes). t statistics with robust standard errors adjusted by clustering at country level in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Annex A5.3

Productive capacities and unit prices

Balanced sample

	Unit prices per exporter (1)
ECI	0.243
	(1.75)*
GDP	0.150
	(1.28)
GDP per capita	0.154
	(1.99)*
Trade over GDP	0.001
	(0.38)
Manufacturing Sector	0.006
	(0.38)
Commodity-Dependent	0.031
	(0.20)
Sectoral Dummies	Yes
Year Dummies	Yes
R-squared	0.56
Number of countries	30
Observations	8,679

Notes: Unit prices is the log of the total export value over quantity. ECI corresponds to the Economic Complexity Index. GDP is the log of GDP in constant US dollars and GDP per capita is the log of GDP per capita in constant US dollars. Trade over GDP is total merchandise exports and imports over GDP. Manufacturing sector correspond to the share of the manufacturing sector in the economy. Commodity-Dependent is a dummy variable that takes the value 1 if the country is a commodity dependent economy. OLS estimations at sector level (HS 2-digit codes). t statistics with robust standard errors adjusted by clustering at country level in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Annex A5.4

Technological capabilities and diversification

Balanced sample

	Products per exporter (1)	Destinations per exporter (2)
R&D	0.217	0.312
	(2.41)**	(3.88)**
GDP	0.023	-0.010
	(2.57)**	(-0.40)
GDP per capita	0.008	0.084
	(0.63)	(4.16)***
Trade over GDP	0.001	-0.001
	(2.36)**	(-1.35)
Manufacturing Sector	0.007	0.017
	(4.08)***	(3.73)**
Commodity-Dependent	0.041	0.148
	(1.57)	(3.12)*
R&D * High-tech sector	0.018	0.174
	(0.71)	(2.39)**
Sectoral Dummies	Yes	Yes
Year Dummies	Yes	Yes
R-squared	0.62	0.33
Number of countries	30	30
Observations	8,563	8,563

Notes: Products per exporter is the log of the (mean) number of products per exporter. Destination per exporter is the log of the (mean) number of destination countries per exporter. R&D corresponds to aggregate R&D investments over GDP. GDP is the log of GDP in constant US dollars and GDP per capita is the log of GDP per capita in constant US dollars. Manufacturing sector correspond to the share of the manufacturing sector in the economy. Commodity-Dependent is a dummy variable that takes the value 1 if the country is a commodity dependent economy. High-tech sector is a dummy variable that takes the value 1 if the sector is R&D intensive. OLS estimations at sector level (HS 2-digit codes). t statistics with robust standard errors adjusted by clustering at country level in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.