The role of productive and technological capabilities in export dynamics in developing countries[1]

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Abstract

Productive and technological capabilities are major engines of export. But how they affect export behaviour at the microeconomic level is less clear and many questions remain. This paper empirically investigates their role in export dynamics in 40 developing countries. The analysis shows that, within sectors, countries with greater productive capacities have more exporters, and the exporters are larger and charge higher prices for their products. 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. Lastly, technological capabilities also play a specific role in the diversification of products and market destinations of high-technology sectors. Thus, even comparing exporters' behaviour only among developing countries, productive and technological capabilities are found to be strongly related to the extensive and intensive margins of exports, and to diversification and product quality.

Keywords

Exports, export development, technological change, technological innovations, productivity, measurement, research and development, investments, developing countries

JEL classification

F14, O3

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I. Introduction

Productive capacities and technological capabilities have been emphasized in several areas 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 international specialization patterns (Hirschman, 1958; Singer, 1950; Prebisch, 1950). This appears to entail a process of accumulation of knowledge within the economy (Cimoli, Dosi and Stiglitz, 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, 1943).

Later, modern growth theories underscored the role of human capital, R&D investments and, more broadly, knowledge, as major drivers of economic growth (Romer, 1990; Aghion and Howitt, 1998). Lastly, contributions to technology and trade theory underscored that technological asymmetries were major determinants of trade flows and specialization patterns in foreign markets, influencing economic performance in the short and medium terms. The key idea was that trade patterns among countries would persist as long as differences in technological capabilities to absorb, generate and use knowledge remained in place (Posner, 1961; Dosi, Pavitt and Soete, 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 and others (2005) discuss the position and evolution of Latin American countries on different indicators regarding structural change, international trade and productivity growth vis-à-vis the United States, Scandinavian countries and the Republic of Korea. The analysis shows that the performance of Latin American economies was relatively weak, with the region lagging behind with respect to several indices of technological efforts, capability accumulation and productivity growth.

From an individual country perspective, many studies have shown the connection between capabilities and exports. For example, Ernst, Ganiatsos and Mytelka (1998) examine technological capabilities and export success in the electronics and textile industries in six East Asian countries (Indonesia, the Republic of Korea, Taiwan Province of China, Thailand, and Viet Nam). They clearly show that the accumulation of learning, innovation and capabilities —including product design, production processes, management routines, marketing and the organization of production— is critical to export growth and to expanding developing countries' market share. In addition, there is ample evidence 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). There is also compelling evidence of self-selection of more productive firms into export markets. Yet, recent research has also begun to emphasize the learning-by-exporting hypothesis in developing countries, where exporters are further away from the technological frontier (Brenton, Cadot and Pierola, 2012). Notably, recent research has also emphasized that firms choose to enter or expand their operations in foreign markets together with decisions on investment, technology adoption, product mix, R&D and innovation.[2] For example, Aw, Roberts and Yi Xu (2011) show that productivity growth for electronic producers in Taiwan Province of China evolves endogenously to firms' decisions to export and invest in R&D. The results also show that a firm's export and R&D decisions affect each other and that both decisions affect productivity growth.

[2] 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 the firm level interact with each other and affect aggregate productivity growth (Vergara, 2017).

Despite these long-standing theoretical and empirical contributions, many questions remain regarding how productive and technological capabilities influence export performance and dynamics, particularly across developing countries. This paper attempts to shed light on the role of productive and technological capabilities in export dynamics at the microeconomic level using a large sample of developing countries. For example, on average a steel exporter in Turkey is 1.5 times larger than a steel exporter in Mexico, and the initial level of exports of a new steel exporter in Turkey is around 1.6 times higher than in Mexico. Meanwhile, Bangladeshi exporters of apparel and clothing accessories export to more than four destinations on average, while Pakistani exporters export to only two. The average Mexican exporter of electrical machinery and equipment exports on average more than six different products (at the six-digit level of the Harmonized System (HS) 2002 classification), while Thai exporters export only four products. Obviously, these differences are related to the country's size, level of development, market structure, trade policy and comparative advantages. But what about national productive and technological capacities? And how do these affect the export margins?

Against this backdrop, this article 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 to foreign markets display a higher initial level of exports in countries with more productive capacities? Are exporters based in countries with higher technological capabilities more diversified in terms of products and destinations? Thus, the goal is to uncover the links between capabilities and exporter dynamics in foreign markets. In particular, by seeking to establish the connection between the issue of capabilities and the extensive and intensive margins of exports (number and size of exporters), the diversification of export products and market destinations, and product quality, all of which have been identified as crucial aspects of international competitiveness. To this end, the empirical strategy employed controls for other country dimensions that may also be relevant, such as the economy's size, level of development, trade openness, manufacturing sector size and commodity dependency.

This article uses data from the World Bank's Exporter Dynamics Database (Fernandes, Freund and Pierola, 2016), which compiles statistical information from national sources of exporter-level customs information, covering the universe of annual exporter transactions.[3] The database contains exporter-level information for 40 developing countries covering the period between 2002 and 2012, aggregated at the sectoral level. A key issue is that there is no obvious approach for measuring productive and technological capabilities. The concept of capabilities is closely connected to the accumulation of explicit and tacit knowledge, and to how different abilities 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 each for productive capacities and technological capabilities. To measure productive capacities, the empirical approach uses the Economic Complexity Index (ECI) (Hausmann and others, 2011), which measures the multiplicity of useful knowledge embedded in an economy by capturing information on the diversity of a country's exports (based on the number of products it exports) and on the ubiquity of its products (based on the number of countries that export a given product). Thus, ECI is built on the basis of productive diversification[4] and capabilities. As discussed by Mealy, Farmer and Teytelboym (2018) and Kemp-Benedict (2014), ECI is orthogonal to diversity, and captures information on the type of products and capabilities in which countries are competitive. Furthermore, it ranks countries according to how similar their exports and capabilities are

[3] Fernandes, Freund and Pierola (2016) presents the Exporter Dynamics Database. They analyse how export behaviour is linked to country size and stage of development. Interestingly, the results show that larger and more developed countries have more and larger exporters, and a greater share of exports controlled by the top 5% of firms. This database opens up a variety of research possibilities to improve understanding of export dynamics at disaggregated levels.

[4] There is ample evidence on the relationship between diversification and economic growth, especially for less developed countries (Cherif, Hasanov and Wanget, 2018; Al-Marhubi, 2000; Herzer and Nowak-Lehnmann, 2006).

to each other. This ranking helps to explain variations in per capita GDP and future growth (Hidalgo and Hausmann, 2009). This suggests that some types of exports, and thus some types of capabilities, are more relevant to development, a crucial argument of the early economic development theories.[5]

Meanwhile, to measure technological capabilities, the empirical approach uses R&D investments as a proxy,[6] as they reflect the technological efforts that countries make to foster knowledge creation and technological progress. In fact, firms' R&D investments encourage product and process innovations and enhance the absorptive capacity to assimilate external knowledge (Griliches, 1979; Cohen and Levinthal, 1990; Griffith, Redding and Van Reenen, 2003). In addition, R&D investments can bring intangible benefits to overcome barriers to exporting (Harris and Li, 2009; Teece and Pisano, 1998) and they are also a crucial feature of national innovation systems.[7] In comparison to developed countries, national innovation systems in developing economies are generally characterized by low levels of R&D, a large proportion of public sector spending in total R&D expenditure, innovation activities concentrated in natural resources and low-tech manufactured products, a low level of human capital and workforce capabilities, and a lack of interactions among economic agents (Arocena and Sutz, 2002).

The empirical hypotheses are that 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 a country's international competitiveness. Thus, a higher ECI score could indicate a larger number of exporters and higher levels of exports per exporter. Also, productive knowledge could be reflected in product quality, thus a positive correlation with unit prices is also tested.[8] Similarly, the level of R&D is expected to be positively connected with diversification across products and destination markets, particularly given the vital role it plays in product and process innovations (Mairesse and Mohnen, 2010).

The contribution of this work is threefold. Firstly, it presents a comprehensive analysis of the role of productive and technological capabilities in export dynamics in developing countries. While the relevance of technological and innovation capabilities for firms' export indicators has been documented, comprehensive cross-country comparisons are scarce. Second, the paper uncovers explicit links between productive and technological capabilities and export dynamics. Third, the links between capabilities and export dynamics highlight their role in developing countries' resilience to trade shocks. This is a crucial issue if, for example, the current reconfigurations of global and regional value chains in the wake of the global coronavirus disease (COVID-19) pandemic gain further traction. The article has several limitations: most importantly, the nature of the data precludes any inference regarding causality between capabilities and export dynamics. This article is organized as follows. The data and some basic statistics are described in section II, providing an aggregate picture for the empirical analysis. Then, the empirical approach is presented in section III, while the main results are discussed in section IV. Lastly, the conclusions are set out in section V.

[5] For example, Hirschman (1958) and Singer (1950) emphasize that development implies the reallocation of factors from low-productivity sectors to high productivity sectors. See Hausmann, Hwang and Rodrik (2007) for a formal empirical validation. In developing countries, Lall (2000) shows that high-tech products are more strongly associated with export and income growth.

[6] 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 and labour skills, among others. On the other, R&D investments are not the only way to acquire new technologies in developing countries, as these can be obtained through capital goods, technology licences and foreign direct investment (Lall, 1992; Smith, 2005).

[7] The national innovation system (NIS) concept 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, p. 20). The NIS approach then became a useful framework to address the complexity of innovation activities as a "systemic process" in developing countries.

[8] Using unit prices as a proxy of product quality at sectoral level is a simplification. Price dispersions exist owing to quality differences and for several other reasons, including demand shocks, market power and production costs. 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 their problems as a proxy for product quality. For example, Schott (2004) shows that countries that are more abundant in physical and human capital export to the United States at higher unit prices, even within narrow categories.

II. Data and basic statistics

The statistical information regarding export dynamics comes from the Exporter Dynamics Database (Fernandes, Freund and Pierola, 2016).[9] This database compiles export information from national sources of exporter-level customs data, covering the universe of annual exporter transactions for 40 developing countries between 2002 and 2012. Thus, it is a country-sector-year dataset, unevenly distributed across developing countries (see annex A1). In particular, it comprises aggregated information at the sectoral level (the two-digit level of the HS 2002 classification)[10] for the number of exporters (total and per product), the average value of exports per exporter and per entrant (new exporters 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, for productive capacities the proxy used is ECI,[11] from the Observatory of Economic Complexity developed at the MIT Media Lab of the Massachusetts Institute of Technology. ECI measures the sophistication of a country's productive structure by combining information on the diversity of its 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, ECI encompasses information on product diversification and on the capabilities in which countries are competitive. Technological capabilities are proxied by R&D investments over GDP, through data taken from the World Development Indicators of the World Bank.[12] This variable reflects technological efforts and is commonly used to measure the effort to generate, absorb and use knowledge. As such, these investments constitute a crucial input for introducing product and process innovations.

Figure 1 displays a simple correlation plot of ECI and R&D investments across developing countries,[13] showing significant country variation across both dimensions. The ECI values range from -2.2 to 0.98, with an average of -0.39 and a standard deviation of 0.70.[14] Meanwhile, R&D investments range from 0% to over 2.0% of GDP, with an average of 0.45% and a standard deviation of 0.36.[15] As expected, there is a relatively strong and positive correlation between ECI and R&D investments, and countries with more productive knowledge tend to exhibit greater technological efforts. China and Malaysia are among those with the highest combinations of productive and technological capabilities, while the performance of countries such as Nicaragua and Tajikistan is relatively poor.

The different combinations of these indicators for specific countries also underscore that ECI and R&D investments reflect different aspects of capabilities. For example, Mexico displays a relatively high ECI value, as its export structure is diversified, with a relatively large share of medium-high and high-technology products.[16] However, technological effort in the Mexican economy is limited, with relatively low levels of R&D investment, at only 0.55% of GDP. This illustrates several weaknesses in the country's national innovation system, including low participation by the private sector in R&D activities,

[9] For details on the database, see [online] http://www.worldbank.org/en/research/brief/exporter-dynamics-database.

[10] See [online] https://unstats.un.org/unsd/tradekb/Knowledgebase/50043/HS-2002-Classification-by-Section.

[11] See annex A2 for details concerning the calculation of the Economic Complexity Index. See also the Observatory of Economic Complexity [online] https://oec.world/.

[12] See [online] https://data.worldbank.org/products/wdi.

[13] 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 (figures 1 and 2), but not in the econometric estimations (see annex A.1).

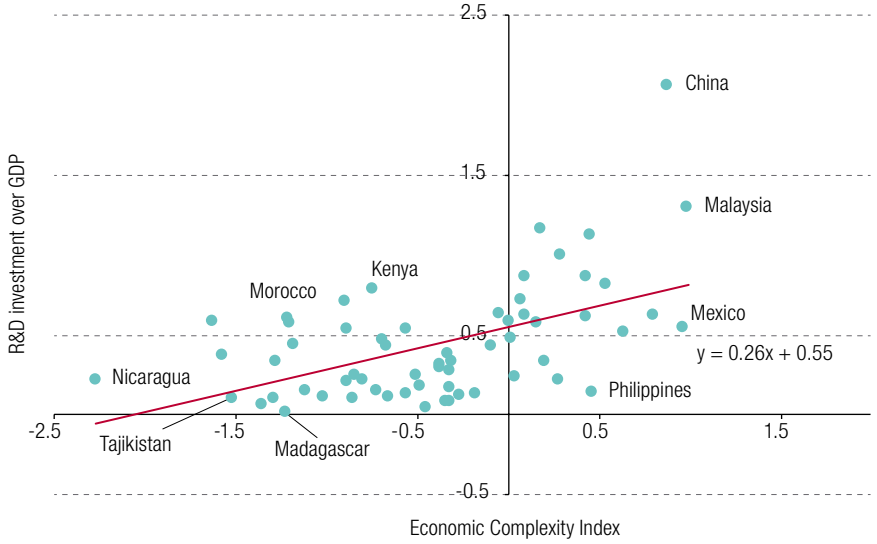
[14] For developed countries, ECI values range from -0.27 to 2.42, with an average of 1.11 and a standard deviation of 0.60.

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

[16] 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.

a lack of interaction and cooperation between the private sector and universities, and a relatively low level of human capital (Casanova and Rullán, 2015). By contrast, Kenya exhibits a relatively low ECI value, with an export structure that is highly concentrated in a few agricultural products and textiles. However, Kenya has strengthened its efforts to increase R&D investment, which stands at around 0.8% of GDP, in particular by designing comprehensive innovation policy frameworks (Ndemo, 2015).

Figure 1
Developing countries: ECI and R&D investment over GDP, 2015

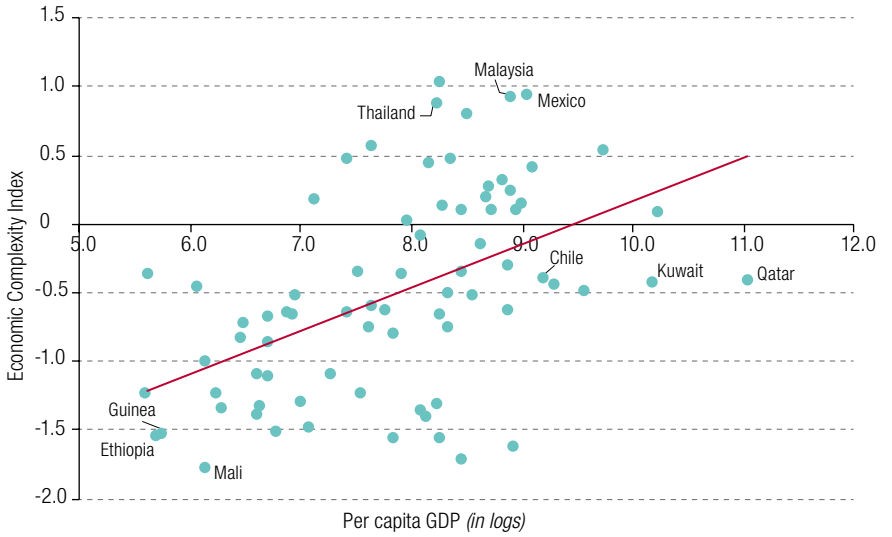


Source: Prepared by the author, on the basis of World Bank, "World Development Indicators", 2020 [online database] https://databank.worldbank.org/source/world-development-indicators, and A. Simoes and C. Hidalgo, "The Economic Complexity Observatory: an analytical tool for understanding the dynamics of economic development", 2011 [online database] https://oec.world/.

Figures 2 and 3 display the simple correlation plots of ECI and R&D investment with the level of development across developing countries, using per capita GDP as a proxy. As expected, both variables are positively correlated with per capita GDP. The correlation is higher for ECI (0.49), yet some countries —such as Kuwait, Qatar and some Latin American economies— exhibit low productive capacities, despite a relatively high per capita GDP (see figure 2). The correlation between R&D and level of development across developing countries is lower, at just 0.26. This shows that, while relatively poor countries generally invest little in R&D, there are also a variety of country-specific circumstances.[17] For example, countries such as Chile, Colombia and some Gulf States display relatively high per capita GDP, but underperform on R&D investment (see figure 3).

[17] There is an extensive body of literature attempting to explain why poor countries invest too little in R&D. Cirera and Maloney (2017) argue that the main reason is the scarcity of factors that are complementary to innovation, including physical and human capital, credit markets and managerial quality.

Figure 2
Developing countries: ECI and per capita GDP, 2015



Source: Prepared by the author, on the basis of World Bank, "World Development Indicators", 2020 [online database] https://databank.worldbank.org/source/world-development-indicators, and A. Simoes and C. Hidalgo, "The Economic Complexity Observatory: an analytical tool for understanding the dynamics of economic development", 2011 [online database] https://oec.world/.

Figure 3
Developing countries: R&D investment and per capita GDP, 2015[a]

Source: Prepared by the author, on the basis of World Bank, "World Development Indicators", 2020 [online database] https://databank.worldbank.org/source/world-development-indicators.

[a] R&D investment data are for 2015 or latest available year.

III. Empirical approach

This section describes the empirical strategy employed to analyse the role of productive and technological capabilities in the different dimensions of export dynamics. The approach closely follows Fernandes, Freund and Pierola (2016). To analyse the role of productive capacities on different export dimensions, the following equation is specified:

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

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) *Exports per exporter* (log of average exports per exporter); (iii) *Exports per entrant* (log of average exports per entrant, an "entrant" being a new exporter in year t); and (iv) *Unit prices* (log of average export value over quantity). The variable ECI is the Economic Complexity Index and the vector X encompasses several control variables: *GDP* is the log of GDP in constant United States dollars; *per capita GDP* is the log of per capita GDP in constant dollars; *Trade over GDP* is total merchandise exports and imports over GDP; *Manufacturing sector* is the share of the manufacturing sector in the economy; *Financial sector* is an index of financial development;[18] *Exchange rate* is an index that measures fluctuations in the real effective exchange rate; *Trade costs* is a proxy for transportation costs[19] and *Commodity-dependent* is a dummy variable that takes the value 1 if the country's economy is commodity-dependent.[20] Lastly, α_i and δ_t correspond to sectoral and year effects. Equation (1) is estimated by ordinary least squares (OLS), using robust standard errors adjusted by clustering at the country level.

Similarly, the equation to investigate the role of technological capabilities —using R&D investments as a proxy— in diversification across products and destinations is as follows:

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

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, with products defined at the six-digit level of the HS 2002 classification); and (ii) *Destination per exporter* (log of the average number of destination countries per exporter). *R&D* is aggregate R&D investments over GDP. The control variables *GDP*, *per capita GDP*, *Trade over GDP*, *Manufacturing sector*, *Financial sector, Exchange rate, Trade costs* and *Commodity-dependent* are also included in the regressions. 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.[21] Including this multiplicative variable allows us to test for a heterogeneous relation between R&D investments 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 are not distributed homogenously across sectors,

[18] This variable is an index that ranges from 0 to 1. For more details, see Sahay and others (2015).

[19] Trade costs measure the fees levied on a 20-foot container in United States dollars. All the fees associated with completing export and import procedures are taken into account, including the costs of documents, administrative fees for customs clearance and technical controls, customs broker fees, terminal handling charges and inland transport. See [online] https://wits.worldbank.org.

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

[21] 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 two-digit level of HS 2002).

and the bulk of technological efforts are concentrated in sectors such as electronics, machinery and pharmaceuticals. Again, equation (2) is estimated by OLS, using robust standard errors adjusted by clustering at the country level.

IV. Regression results

The estimation results of how productive capacities relate to the number of exporters are presented in table 1. Column (1) provides the baseline estimation, including only ECI and the level of GDP as explanatory variables, while column (2) includes the whole set of control variables. All regressions include sectoral and year fixed effects. The coefficient associated with ECI is significant at 5% in the baseline regression and at 10% when including all the control variables. This suggests that countries with stronger productive capacities have more exporters within sectors. Thus, productive capacities tend to be positively correlated with the extensive margin of exports across a relatively large sample of developing countries. The regressions also show that the size of the economy, as expected, is positively associated with the number of exporters, which confirms previous results obtained by Fernandes, Freund and Pierola (2016). Interestingly, there also seems to be a role for the development of the financial sector in promoting the extensive margin of exports across countries.

Table 1
Productive capacities and the extensive margin of exports

	Number of Exporters (1)	Number of Exporters (2)
ECI	0.472	0.414
	(2.60)**	(1.82)*
GDP	0.690	0.722
	(8.28)***	(6.61)***
Per capita GDP		-0.03
		(0.26)
Trade over GDP		-0.000
		(0.08)
Manufacturing sector		0.030
		(1.22)
Financial sector		1.176
		(3.07)**
Exchange rate		0.003
		(0.68)
Trade costs		0.107
		(0.47)
Commodity-dependent		0.065
		(0.26)
Sectoral dummies	Yes	Yes
Year dummies	Yes	Yes
R-squared	0.69	0.74
Number of countries	40	32
Observations	28 921	17 972

Source: Prepared by the author.

Notes: *Number of exporters* is the log of the total number of exporters. *ECI* is the Economic Complexity Index. *GDP* is the log of GDP in constant dollars and *Per capita GDP* is the log of per capita GDP in constant dollars. *Trade over GDP* is total merchandise exports and imports over GDP. *Manufacturing sector* is the share of the manufacturing sector in the economy. *Financial sector* is an index of financial development. *Exchange rate* is an index that measures fluctuation of the real effective exchange rate. *Trade costs* is the log of a variable that measures transportation costs. *Commodity-dependent* is a dummy variable that takes a value of 1 if the country's economy is commodity-dependent. OLS estimations were performed at the sector level (at the two-digit level of HS 2002). *t* statistics (shown in parentheses) with robust standard errors were adjusted by clustering at the country level. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 2 displays the estimation results regarding the intensive margin of exports, and particularly how ECI relates to the level of exports per exporter and per new entrant in foreign markets. Columns (1) and (3) provide the baseline regressions, while columns (2) and (4) present the regressions with the full set of control variables. Notably, in all regressions the coefficients associated with ECI are positive and significant, either at 10% or 5%. This shows that, within sectors, exporters and new exporters based in countries with greater productive capacities tend to be larger, even when controlling for other relevant variables. This points to a clear-cut correlation between productive capacities and the intensive margin of exports across developing countries. Among the other variables, the results show that economy size, trade openness and the relative size of the manufacturing sector are also positively correlated with the size of exporters.

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	0.262	0.251	0.217
	(1.88)*	(1.92)*	(1.74)*	(2.10)**
GDP	0.384	0.439	0.266	0.398
	(5.56)***	(5.06)***	(4.24)***	(6.58)***
Per capita GDP		0.126		-0.120
		(1.49)		(1.76)*
Trade over GDP		0.008		0.012
		(2.06)**		(4.56)***
Manufacturing sector		0.035		-0.003
		(1.87)*		(0.16)
Financial sector		-0.490		-1.153
		(1.85)*		(4.53)***
Exchange rate		0.002		-0.002
		(0.87)		(0.74)
Trade costs		-0.291		-0.04
		(0.87)		(0.47)
Commodity-dependent		0.412		-0.119
		(2.79)		(0.89)
Sectoral dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
R-squared	0.40	0.44	0.32	0.35
Number of countries	40	32	39	31
Observations	27 634	17 242	24 195	15 562

Source: Prepared by the author.
Notes: *Exports per exporter* is the log of (mean) exports per exporter. *Exports per entrant* is the log of (mean) exports per entrant. *ECI* is the Economic Complexity Index. *GDP* is the log of GDP in constant dollars and *Per capita GDP* is the log of per capita GDP in constant dollars. *Trade over GDP* is total merchandise exports and imports over GDP. *Manufacturing sector* is the share of the manufacturing sector in the economy. *Financial sector* is an index of financial development. *Exchange rate* is an index that measures fluctuation of the real effective exchange rate. *Trade costs* is the log of a variable that measures transportation costs. *Commodity-dependent* is a dummy variable that takes a value of 1 if the country has a commodity-dependent economy. OLS estimations were performed at the sector level (at the two-digit level of HS 2002). *t* statistics (shown in parentheses) with robust standard errors were adjusted by clustering at the country level. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Interestingly, the financial sector also seems to play a major role in the size of exporters. In the case of new exporters (entrants), in the comparison across countries the negative coefficient suggests that development of the financial sector allows smaller firms to become exporters. Column (4) of table 2 also shows that the level of development, measured by the proxy per capita GDP, is negatively associated with average export level per entrant. This indicates that initial export levels of new exporters

are higher in countries with lower levels of development. While this might seem counterintuitive, it is consistent with the literature on barriers to trade, which underscores that becoming an exporter is easier as countries develop. In fact, new exporters from poorer countries face higher export costs and have less public support than new exporters from more developed and globally integrated economies. As a result, new exporters from poorer countries need to start their activity in foreign markets with a relatively larger volume of exports.

The regression results regarding unit prices per exporter are presented in table 3. Again, ECI is significant in explaining differences in unit prices. Thus, in the comparison across sectors, exporters from countries with higher productive capacities tend to have higher average unit prices for their products. This is a strong indication that across developing countries productive capacities are positively correlated with product quality within sectors. In fact, while a multiplicity of factors determine unit price —such as demand shocks or market power— the role played by productive capacities in such a comprehensive sample of countries and over an extended period of time is a firm indication that the main driver of these unit price differences (in levels) is product quality. In addition, economy size, trade openness and financial sector development are all positively correlated with unit prices.

Table 3
Productive capacities and unit prices

	Unit prices per exporter (1)	Unit prices per exporter (2)
ECI	0.519	0.458
	(4.15)***	(3.85)**
GDP	0.147	0.219
	(1.81)*	(2.85)**
Per capita GDP		0.061
		(0.81)
Trade over GDP		0.004
		(1.87)*
Manufacturing sector		-0.022
		(1.22)
Financial sector		0.546
		(2.32)**
Exchange rate		0.002
		(0.85)
Trade costs		-0.404
		(1.90)*
Commodity-dependent		0.342
		(2.10)**
Sectoral dummies	Yes	Yes
Year dummies	Yes	Yes
R-squared	0.55	0.58
Number of countries	34	28
Observations	21 543	14 316

Source: Prepared by the author.

Notes: *Unit prices* is the log of total export value over quantity. *ECI* is the Economic Complexity Index. *GDP* is the log of GDP in constant dollars and *Per capita GDP* is the log of per capita GDP in constant dollars. *Trade over GDP* is total merchandise exports and imports over GDP. *Manufacturing sector* is the share of the manufacturing sector in the economy. *Financial sector* is an index of financial development. *Exchange rate* is an index that measures the fluctuation of the real effective exchange rate. *Trade costs* is the log of a variable that measures transportation costs. *Commodity-dependent* is a dummy variable that takes a value of 1 if the country has a commodity-dependent economy. OLS estimations were performed at the sector level (at the two-digit level of HS 2002). *t* statistics (in parentheses) with robust standard errors were adjusted by clustering at the country level. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Lastly, table 4 displays the regression results for the role of R&D investments in exporters' diversification across products and destinations. Fewer countries are considered in these estimations, owing to the more limited availability of R&D investment 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*, respectively. The coefficients associated with R&D investments are stable and suggest a positive and significant correlation with the number of products per exporter. Thus, exporters in countries with a higher level of R&D investment export a larger number of products to foreign markets, at the six-digit level of the HS 2002 classification. Meanwhile, economy size, manufacturing sector size and financial sector development are also positively associated with product diversification. These are, a priori, intuitive results. Interestingly, the multiplicative variable *R&D*High-tech* is not significant, showing there are no heterogeneous effects for R&D investments on product diversification in high-technology sectors.

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	0.118	0.116	0.148	0.315	0.294
	(2.05)**	(1.89)*	(1.88)**	(1.57)	(3.31)**	(3.13)**
GDP	0.016	0.031	0.031	0.043	-0.012	-0.012
	(2.22)**	(2.52)**	(2.52)**	(2.01)*	(0.50)	(0.50)
Per capita GDP		-0.003	-0.003		0.072	0.072
		(0.26)	(0.26)		(3.92)**	(3.92)**
Trade over GDP		0.000	0.000		-0.001	-0.001
		(1.23)	(1.23)		(1.66)	(1.66)
Manufacturing sector		0.005	0.004		0.015	0.015
		(1.82)*	(1.82)*		(3.28)**	(3.28)**
Financial sector		0.212	0.212		0.134	0.134
		(2.13)**	(2.13)**		(1.32)	(1.31)
Exchange rate		-0.000	-0.000		-0.000	-0.000
		(0.76)	(0.76)		(0.26)	(0.26)
Trade cost		-0.214	-0.214		-0.026	-0.026
		(1.66)*	(1.66)*		(0.73)	(0.72)
Commodity-dependent		0.066	0.066		0.163	0.163
		(2.24)**	(2.24)**		(2.59)**	(2.59)**
R&D * High-tech sector			0.011			0.170
			(0.54)			(2.28)**
Sectoral dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.60	0.65	0.65	0.26	0.33	0.33
Number of countries	31	25	25	31	25	25
Observations	13 107	8 597	8 597	13 107	8 597	8 597

Source: Prepared by the author.

Notes: *Products per exporter* and *Destinations per exporter* are the logs of the (mean) number of products and destinations per exporter, respectively. *R&D* is aggregate R&D investments over GDP. *GDP* is the log of GDP in constant dollars and *Per capita GDP* is the log of per capita GDP in constant dollars. *Trade over GDP* is total merchandise exports and imports over GDP. *Manufacturing sector* is the share of the manufacturing sector in the economy. *Financial sector* is an index of financial development. *Exchange rate* is an index that measures fluctuation of the real effective exchange rate. *Trade costs* is the log of a variable that measures transportation costs. *Commodity-dependent* is a dummy variable that takes a value of 1 if the country has a commodity-dependent economy. *High-tech sector* is a dummy variable that takes a value of 1 if the sector is R&D-intensive. OLS estimations were performed at the sector level (at the two-digit level of HS 2002). *t* statistics (in parentheses) with robust standard errors were adjusted by clustering at the country level. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Columns (4), (5) and (6) of table 4 display the regressions for the number of destinations per exporter. When including all the control variables, the results show that R&D investments are positively correlated with diversification across destinations. Thus, within sectors, exporters from countries with higher R&D investments tend to export their products to more destination markets. Interestingly, the variable *R&D*HighTech* is positive and significant at 5%. This shows that there is an additional correlation between R&D investment and the number of destinations per exporter in high-technology sectors. The higher the level of R&D investment, the higher the (average) number of destinations per exporter in high-technology sectors. This result is consistent with a growing empirical literature emphasizing the relationship between R&D activities and export diversification, with a causality that can run in both directions.[22]

To analyse the sensitivity of the results, several robustness checks were performed. A key aspect to consider is the extent to which the empirical results could be driven by the estimation sample. The estimation sample is not balanced across countries, and some countries are observed in the database for longer periods than others. To address this issue, a twofold strategy was adopted. First, the equations were 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 observations, are omitted from the sample. Second, the estimations were performed for a second restricted sample, of countries with at least 500 observations. With this approach, countries with fewer observations —around 20% of the full sample— were omitted from the estimations. Lastly, the equations were estimated by correcting for the fact that some sectors have zero exports; in other words, 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.[23]

V. Conclusions

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

These findings are important for several reasons. Firstly, they explicitly and empirically underscore the importance of asymmetries of productive and technological capabilities across developing countries, a crucial issue highlighted by the structuralist tradition. To date, most of the aggregate literature has compared technological capabilities between developing and developed countries. As is to be expected, these studies demonstrate that capabilities are a major determinant of productivity, exports and growth. This paper shows that capabilities matter even when comparing export dynamics only

[22] For example, Baum, Caglayan and Talavera (2015) examine the endogenous relationship between diversification and R&D activities in firms in the United Kingdom. The results suggest that geographical sales diversification induces British firms to increase R&D expenditures. They also suggest 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 terms of number of products and destinations.

[23] Tables A5.1 to A5.4 in annex A5 display the regressions for the robustness checks using a balanced number of observations across countries ("balanced sample"). Other robustness checks are available upon request.

among developing countries. Secondly, the results illustrate how the accumulation of productive and technological capabilities plays a role in developing countries' insertion in international markets through different channels. These results are consistent with the Kaldorian view that the productive capacities for export activity must first be built and developed , in order for "incentives" such as trade liberalization reform to have an effect on exports.

Therefore, this paper underlines the role of capabilities not only in the macroeconomic resilience of developing countries to trade shocks but also in their medium-term development prospects. Indeed, the accumulation of capabilities is reflected in product and market diversification, which are key factors when navigating international trade shocks. In addition, productive and technological capabilities are mirrored in the extensive and intensive margins of trade and in product quality, which are key aspects of international competitiveness and of how countries dynamically adjust to changing demand patterns. These links underscore the diverse ways that micro-macro interactions drive development trajectories under different capability setups. This suggests that, on the whole, productive and technological capabilities will also play a crucial role in how developing countries adjust to significant and permanent reconfigurations of global and regional value chains in the wake of the COVID-19 pandemic.

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Annex A1

Table A1.1
Distribution of observations across countries

Country	Frequency	Percent	Cumulative
Albania	834	3.00	3.00
Bangladesh	756	2.72	5.72
Botswana	939	3.38	9.1
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 Democratic Republic	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	100.0

Source: Prepared by the author, on the basis of World Bank, "Exporter Dynamics Database", 2016 [online] http://www.worldbank.org/en/research/brief/exporter-dynamics-database.

Annex A2

Economic Complexity Index

The Economic Complexity Index (ECI) is calculated from export data that connect countries to products where they have a revealed comparative advantage. Defining M_{cp} as a matrix that is 1 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.

$$Diversity = K_{c,0} = \sum_p M_{cp} \tag{1}$$

$$Ubiquity = K_{p,0} = \sum_c M_{cp} \tag{2}$$

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:

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

Lastly, ECI can be defined as:

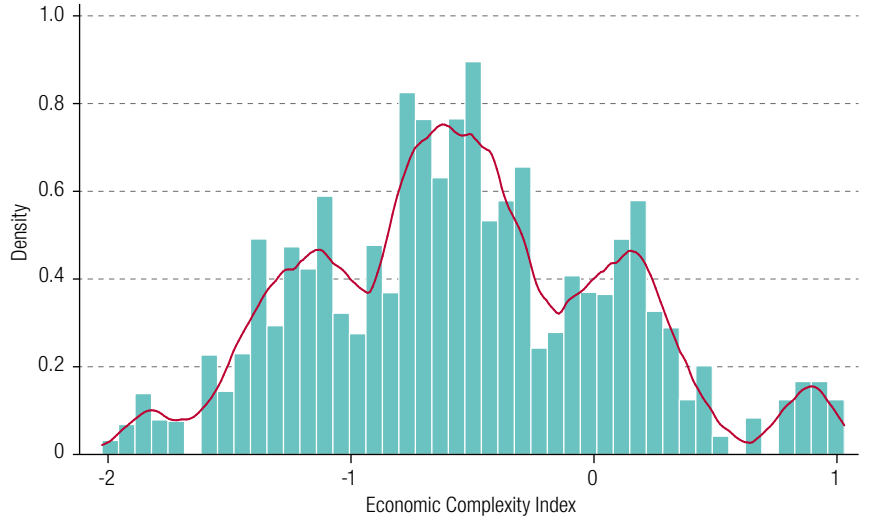
$$ECI_c = \frac{K_c - < K >}{std(K)} \tag{4}$$

Where $<K>$ 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 and others (2011).

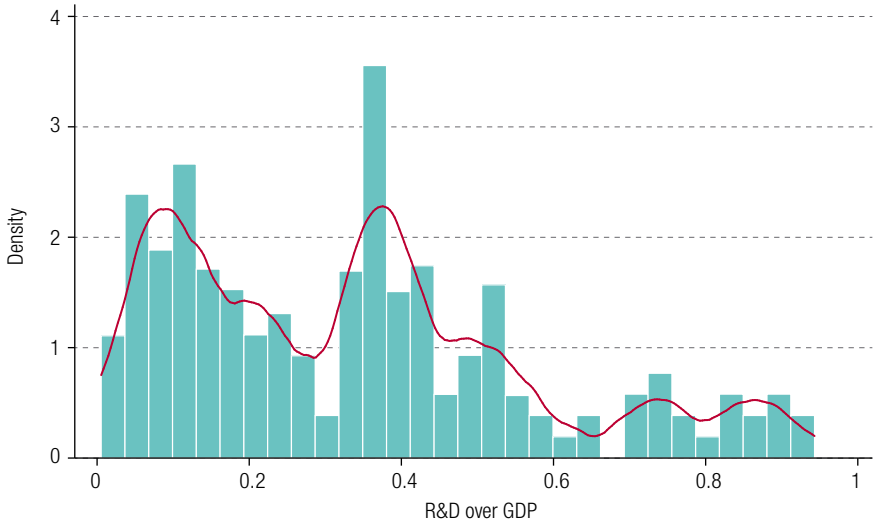
Annex A3

Figure A3.1

A. Economic Complexity Index histogram



B. R&D investments histogram



Source: Prepared by the author, on the basis of World Bank, "World Development Indicators", 2020 [online database] https://databank.worldbank.org/source/world-development-indicators, and A. Simoes and C. Hidalgo, "The Economic Complexity Observatory: an analytical tool for understanding the dynamics of economic development", 2011 [online database] https://oec.world/.

Annex A4

Table A4.1
High-technology sectors at two-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 and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.
86	Railway or tramway locomotives, rolling-stock and parts thereof; railway or tramway track fixtures and fittings and parts thereof; mechanical (including electro-mechanical) traffic signalling equipment of all kinds.
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, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; parts and accessories thereof.
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: Prepared by the author, on the basis of United Nations International Trade Statistics Database, "HS 2002 Classification by Section", 2016 [online] https://unstats.un.org/unsd/tradekb/Knowledgebase/50043/HS-2002-Classification-by-Section, and S. Lall, "The technological structure and performance of developing country manufactured exports, 1985-98", *Oxford Development Studies*, vol. 28, No. 3, 2000.

Annex A5

Table A5.1
Productive capacities and the extensive margin of exports
(Balanced sample)

	Number of Exporters
ECI	0.523
	(2.22)**
GDP	0.751
	(5.86)***
Per capita GDP	-0.073
	(0.49)
Trade over GDP	-0.000
	(0.13)
Manufacturing sector	0.016
	(0.57)
Financial sector	1.318
	(3.00)**
Exchange rate	0.005
	(0.69)
Trade costs	-0.052
	(0.20)
Commodity-dependent	0.240
	(0.89)
Sectoral dummies	Yes
Year dummies	Yes
R-squared	0.73
Number of countries	31
Observations	9 625

Source: Prepared by the author.

Notes: *Number of exporters* is the log of the number of exporters. *Exporters per product* is the log of the number of exporters per product. *GDP* is the log of GDP in constant United States dollars and *per capita GDP* is the log of per capita GDP in constant dollars. *ECI* is the Economic Complexity Index. *Trade over GDP* is total merchandise exports and imports over GDP. *Manufacturing sector* is the share of the manufacturing sector in the economy. *Financial sector* is an index of financial development. *Exchange rate* is an index that measures fluctuation of the real effective exchange rate. *Trade costs* is the log of a variable that measures transportation costs. *Commodity-dependent* is a dummy variable that takes the value 1 if the country has a commodity-dependent economy. OLS estimations were performed at the sector level (the two-digit level of HS 2002), using a balanced estimation sample. *t* statistics (in brackets) with robust standard errors were adjusted by clustering at the country level. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table A5.2
Productive capacities and the intensive margin of exports
(Balanced sample)

	Exports per exporter (1)	Exports per entrant (2)
ECI	0.257	0.154
	(1.86)*	(1.46)
GDP	0.441	0.411
	(4.66)***	(6.37)***
Per capita GDP	0.093	-0.099
	(1.08)	(1.48)
Trade over GDP	0.008	0.012
	(2.19)**	(4.77)***
Manufacturing sector	0.041	-0.010
	(1.93)*	(0.62)
Financial sector	-0.415	-1.107
	(1.46)	(4.18)***
Exchange rate	0.002	0.0006
	(0.47)	(0.14)
Trade costs	-0.250	-0.007
	(1.94)*	(0.06)
Commodity-dependent	0.686	-0.197
	(2.43)**	(1.28)
Sectoral dummies	Yes	Yes
Year dummies	Yes	Yes
R-squared	0.43	0.34
Number of countries	31	31
Observations	9 177	8 248

Source: Prepared by the author.

Notes: *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 United States dollars and *Per capita GDP* is the log of per capita GDP in constant dollars. *ECI* is the Economic Complexity Index. *Trade over GDP* is total merchandise exports and imports over GDP. *Manufacturing sector* is the share of the manufacturing sector in the economy. *Financial sector* is an index of financial development. *Exchange rate* is an index that measures fluctuation of the real effective exchange rate. *Trade costs* is the log of a variable that measures transportation costs. *Commodity-dependent* is a dummy variable that takes the value 1 if the country has a commodity-dependent economy. OLS estimations were performed at the sector level (at the two-digit level of HS 2002). *t* statistics (in brackets) with robust standard errors adjusted by clustering at the country level. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table A5.3
Productive capacities and unit prices
(Balanced sample)

	Unit prices per exporter
ECI	0.510
	(3.72)**
GDP	0.259
	(2.68)**
Per capita GDP	-0.035
	(0.41)
Trade over GDP	0.005
	(1.67)*
Manufacturing sector	-0.020
	(0.93)
Financial sector	0.739
	(3.37)*
Exchange rate	0.003
	(0.66)
Trade costs	-0.534
	(2.64)**
Commodity-dependent	0.432
	(2.62)**
Sectoral dummies	Yes
Year dummies	Yes
R-squared	0.58
Number of countries	25
Observations	7 336

Source: Prepared by the author.

Notes: *Unit prices* is the log of the total export value over quantity. *ECI* is the Economic Complexity Index. *GDP* is the log of GDP in constant United States dollars and *Per capita GDP* is the log of Per capita GDP in constant dollars. *Trade over GDP* is total merchandise exports and imports over GDP. *Manufacturing sector* is the share of the manufacturing sector in the economy. *Financial sector* is an index of financial development. *Exchange rate* is an index that measures fluctuation of the real effective exchange rate. *Trade costs* is the log of a variable that measures transportation costs. *Commodity-dependent* is a dummy variable that takes the value 1 if the country has a commodity-dependent economy. OLS estimations were performed at the sector level (at the two-digit level of HS 2002). *t* statistics (in brackets) with robust standard errors adjusted by clustering at the country level. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table A5.4
Technological capabilities and diversification

(Balanced sample)	Products per exporter (1)	Destinations per exporter (2)
R&D	0.190	0.354
	(2.25)**	(3.50)**
GDP	0.042	-0.023
	(3.12)**	(1.05)
Per capita GDP	-0.010	0.057
	(0.81)	(3.94)**
Trade over GDP	0.001	-0.001
	(1.71)*	(1.61)
Manufacturing sector	0.004	0.020
	(0.84)	(4.17)***
Financial sector	0.194	0.144
	(2.34)**	(1.28)
Exchange rate	-0.000	-0.000
	(0.13)	(0.58)
Trade costs	0.038	-0.026
	(1.50)	(0.69)
Commodity-dependent	0.103	0.150
	(2.30)**	(2.27)**
R&D * High-tech sector	0.009	0.112
	(0.30)	(1.81)*
Sectoral dummies	Yes	Yes
Year dummies	Yes	Yes
R-squared	0.64	0.33
Number of countries	22	22
Observations	4 550	4 550

Source: Prepared by the author.

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* is aggregate R&D investments over GDP. *GDP* is the log of GDP in constant United States dollars and *Per capita GDP* is the log of Per capita GDP in constant dollars. *Manufacturing sector* is the share of the manufacturing sector in the economy. *Financial sector* is an index of financial development. *Exchange rate* is an index that measures fluctuation of the real effective exchange rate. *Trade costs* is the log of a variable that measures transportation costs. *Commodity-dependent* is a dummy variable that takes the value 1 if the country has 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 were performed at the sector level (at the two-digit level of HS 2002). *t* statistics (in brackets) with robust standard errors adjusted by clustering at the country level. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.