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Trade, Global Value Chains and Upgrading: What, When and How?

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Abstract This paper explains how successful innovation systems interact with trade and global value chains (GVC) participation to foster learning and technological upgrading. It conducts an empirical investigation of 74 developing countries for 3 years, 2000, 2005 and 2010, to show that, while some countries manage to trade and export across a large number of technological export categories, many remain embedded in the export of low technology goods with little movement technologically. The analysis looks at why this is the case and what factors account for how firms are able to leverage trade to learn and upgrade in some instances, but not all. The results show that the ability to technologically diversify across export categories is linked to stronger innovation systems, as measured by national capability indicators, such as public R&D investments, scientific publications, intellectual property payments and patents by residents. The results also confirm the rise of several outperforming countries, the emerging economies. We conclude that, in successful, outperforming countries, firms rely on several attributes of the innovation system to leverage knowledge flows within and outside of GVCs to build export capacity and diversify horizontally into new GVCs.

Cet article explique comment les systèmes d'innovation efficaces interagissent avec les activités liées au commerce et à la chaîne de valeur mondiale (CVM) pour favoriser l'apprentissage et la modernisation technologique. Il décrit une enquête empirique sur 74 pays en développement sur trois années, 2000, 2005 et 2010, pour montrer que, si certains pays parviennent à commercer et à exporter un large spectre de technologies, beaucoup restent cantonnés à l'exportation de produits de basse technologie et avec peu de changements technologiques. L'article analyse les raisons derrière cela et les facteurs qui expliquent pourquoi, dans certains cas mais pas tous, les entreprises sont en mesure de tirer parti du commerce pour apprendre et se mettre à niveau sur le plan technologique. Les résultats montrent que la capacité à diversifier les catégories de produits technologiques voués à l'exportation est liée à des systèmes d'innovation plus forts, comme mesurés par les indicateurs nationaux de capacité tels que les investissements R&D publics, les publications scientifiques, les paiements et brevets de propriété intellectuelle déposés par les résidents. Les résultats confirment également l'essor de plusieurs pays surperformants que sont les économies émergentes. Nous concluons que dans les pays qui réussissent et qui sont surperformants, les entreprises s'appuient sur plusieurs attributs du système d'innovation pour tirer parti des flux de connaissances à l'intérieur et à l'extérieur des CVM pour renforcer la capacité d'exportation et se diversifier horizontalement dans de nouvelles CVM.

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Introduction

Global value chains (GVCs) have become the central mechanism for trade and investment in the world economy today. According to recent estimates, production today is unprecedentedly fragmented and conducted within GVCs, which accounted for 85% of total global trade in 2016 (UNCTADStat 2017).[1] This re-organization of production through GVCs transforms international trade dynamics from operating predominantly at the level of countries to operating between firms, where each firm adds value in a sequential fashion or trades in intermediate products that serve as inputs into final products elsewhere (Flento and Ponte, 2017; Ponte and Sturgeon, 2014). A new actor – the lead firm – upends the production process as we know it in the traditional sense, creating new forms of interfirm relationships along the chain, thus also determining access to international markets, access to technologies and capabilities building (Gereffi, 1999; Pietrobelli, 2008; Pietrobelli and Rabelloti, 2011).

These changes carry profound implications for all countries in general, and developing countries in particular, given the central role of technological change in structural transformation, catch-up and economic development (Johnson and Noguera, 2012; Suder *et al*, 2015). Although the literature on GVCs has focused on many aspects of this dynamic, including looking at how the fragmentation of production impacts upon industrial organization and employment, the research has predominantly emphasized these results for developed countries (Foster-McGregor *et al*, 2015). Studies have tended to assume that lead firms generally have positive impacts on other firms that participate in GVCs in terms of enabling them to upgrade and supply products and services to global markets (Gereffi, 1999; Sturgeon *et al*, 2008).[2]

Extending the analogy further, more recent GVC analyses have argued that value chains could present a rare option for local firms and suppliers not only to access new markets but also to access new technologies (Pietrobelli, 2008), identifying different kinds of possibilities for learning (Pietrobelli and Rabelloti, 2011). It has been proposed that GVCs may provide an ideal opportunity for smaller firms in developing countries to specialize in niche product categories, instead of struggling to build capabilities to master entire production systems (Baldwin, 2012).

Although many of these outcomes can be substantiated by evidence, the full range of effects that GVCs can have on countries at different levels of development are yet to be understood. Until now, most work on GVCs in developing countries has taken the form of case studies of firms in different sectors, and the inferences differ, based on the value chain and country in question.[3] However, many of the studies converge on one point, namely, the important role played by national innovation systems in enabling learning not only at the firm level but also at the sector or industry level. For example, studies of GVCs in East Asian countries have found that local firms are able to leverage learning from GVC participation to extract sector- and economy-wide effects (Estevadeordal *et al*, 2013; Feenstra and Hamilton, 2006; Lee, 2013), but the studies found that the learning effects were made possible mainly because of supportive in-country institutions and cohesive policy frameworks to promote innovation and capabilities building. Other case studies of GVCs that have looked at difficulties for upgrading often conclude the inverse: that reasons underlying why local firms benefit, or fail to benefit, from GVCs are more systemic (see, for example, Baffes, 2006; Gereffi, 1999; Gibbon and Ponte, 2005; Ponte, 2002).

The underlying systemic factors that allow/hinder firms from building capabilities have been studied extensively in evolutionary economics, and, more recently, using the innovation systems approach. Innovation studies have sought to analyze why firms fail to learn, even when exposed to knowledge-based opportunities within or outside the economy, highlighting a range of systemic factors that dictate how firms perform and make use of knowledge from internal and external sources for adaptation, use and innovation. These systemic features of an innovation system derive from strong and supportive institutions (or the lack thereof), which foster inquisitiveness and exploration, learning linkages and capabilities formation at the collective level. By extension, they also dictate how able firms are to absorb technologies and tacit know-how in their day-to-day transactions (Cohen and Levinthal, 1990). Thus, institutions build social capabilities (Gerschenkron, 1962) through the provision of a system of education and the availability of trained labour, as well as technological capabilities (Ernst and Kim, 2002) by providing for public research and development (R&D) institutes, universities and university centres of excellence, among other things (Amsden and Chu, 2003; Ernst and Kim, 2002). Many scholars have also emphasized the linkage building aspects of such institutions, which depend on policy support that promotes institutional cohesion and collaboration, further supporting the emergence of capabilities (Fagerberg and Srholec, 2009a, b).

Viewing these insights from GVC studies and innovation studies as part of a broad, and more traditional, discourse on economic development, the question is: How can trade – and opportunities generated through trade, such as GVCs – promote structural change and sustained economic growth in developing countries? The answer to this question is not easy and calls for an assessment of learning and capabilities building at a more aggregate (macro) level in countries. Recent empirical and theoretical advances from that perspective suggest that what countries export matters (Haussmann *et al*, 2007; UNCTAD, 2016). However, the export basket of a country is dictated by the presence of support structures that foster the capabilities of local firms to innovate and create complex technological products of the kind that generate manufacturing value added (Balland and Rigby, 2007; Hidalgo *et al*, 2007).

This article combines the central tenets of all these three approaches to understand how GVCs and national innovation systems interact to shape the ability of firms to create manufacturing value added and export capacity across complex technological categories.[4] We build our argument thus: local technological capabilities are instrumental to the way in which manufacturing value added is generated across sectors in developing countries. These are determined by systemic factors which shape technological capabilities building within innovation systems, such as the capacity of the public research institutes to support industry (as evidenced by public expenditure on R&D), the scientific capacity of institutions to engage in industrial and academic research (as evidenced by scientific and journal publications) and the ability of local firms to engage in R&D and innovation (as evidenced by patents granted to residents or by licensing activities of local firms), among other things. These capability indicators show the strength of the innovation system in which the firms operate (Fagerberg and Srholec, 2008; Oyelaran-Oyeyinka and Gehl Sampath, 2007). When national innovation institutions are strong, the firms are ready and able to absorb technological know-how, assimilate learning processes through interactions, technologically upgrade and add value domestically in all sectors (particularly in manufacturing), which supports structural change. Case studies of successfully industrializing countries exemplify this. In South Korea, for example, in sectors where local firms were able to leverage and benefit from GVCs and facilitate export-led growth, local institutions played a fundamental role. They not only dictated how firms integrate into and benefited from GVCs but they also helped firms channel these learning benefits to create broader sectoral and industrial spillovers or to move into other kinds of production frontiers when GVCs were not entirely conducive (Hobday, 1995; Lee *et al*, 2017).

In our analysis, we use trade data (trade in manufactured goods classified into technological export categories using the Lall, 2000 classification)[5] to investigate how the innovation systems of developing countries (as measured by capability indicators) dictate their ability to add value across manufacturing sectors. This approach is somewhat different from the traditional GVC approaches, which use input–output (IO) databases such as the Eora Multi-Region Input–Output (MRIO) for 189 countries; the OECD-WTO Trade in Value Added (TIVA) with information on 63 economies from 1995 onwards, or the World Input–Output Database (WIOD), which covers 43 countries starting from 2000. We acknowledge that trade in intermediate products is not the same as GVC participation; however, we use this approach to understand (1) the interaction between the development of technological capabilities and export capacity in sectors of different technological complexity (see among others, Lall, 1992, 2004) and (2) the ability of countries to benefit from integration into trade more broadly, including GVCs, than what is being explored in GVC studies. A thorough consideration of issues from a trade and technology perspective, we argue, can provide an alternate assessment of the circumstances under which the beneficial effects of GVCs for learning and technological upgrading can materialize.

The analytical focus is on the manufacturing sector and the dependent variable is manufacturing value added (MVA). The empirical analysis looks at how the national capabilities indicators that determine the strength of the national innovation system explain the existence (or absence) of MVA in different technological sectors in developing countries. "Understanding GVCs and Upgrading in the Broader Context of Economic Development" section of this article describes the relationship between GVCs, technological capabilities and economic development, homing in on the key variables relevant to this investigation. In our empirical analysis in "Empirical Analysis" section, we construct a dataset of 78 developing countries for all these variables. However, data inconsistencies for these countries prevented the creation of a balanced panel over time. In order to prevent any adverse impacts on the results, we ran the regressions for 3 years as snapshots, namely, 2000, 2005 and 2010, in order to draw conclusions about how and which national capabilities indicators condition the technological export categories that countries sustain over time. Our findings suggest a synergistic relationship between GVCs and the presence of local technological capabilities. "Results and Discussion" section discusses the results and "Concluding Remarks" section presents the broader implications of our findings.

Understanding GVCs and Upgrading in the Broader Context of Economic Development

Economic development results from structural change in an economy that shifts labor from low productivity activities (such as traditional agriculture) to higher productivity activities (Ros, 2000). This indispensable process, however, is not as simple as it sounds. 'Successful' structural change involves not only diversifying activities but also adopting and adapting existing technologies and climbing the technology ladder by continuously upgrading production structures in key sectors of manufacturing (Amsden, 2001; Gerschenkron, 1962).

In classical economic literature, manufacturing is considered crucial to building capabilities because it promotes cumulative causation that reinforces and increases the pace of economic growth (Hirschman, 1958; Myrdal, 1957).[6] However, some manufacturing sub-sectors are better suited than others to build and sustain the technological capabilities of the kind required to promote diversified production structures than others (Kaldor, 1981; Lall, 1992; Pavitt, 1986; Prebish, 1950). Particularly, when learning takes place in manufacturing sub-sectors that call for design and engineering activities – which is mostly in those sectors that are classified as medium-technology sectors – it forms the basis of a more virtuous cycle of technological change, prompting synergies and spillovers in a broader spectrum of manufacturing activities in the local economy (Hobday, 1998; Nelson, 1993). The learning accumulated in these sectors can be used to improve and technologically upgrade existing production capacity in low-technology domains, while serving as building blocks to move into more high-technology product categories. Clearly, for developing countries seeking to promote knowledge accumulation, generating learning in such sub-sectors that create the base for sectoral diversification is highly relevant. Over time, steeper learning curves in such sectors, along with rapidly falling costs and growing market shares, lead to economic catch-up (Cimoli *et al*, 2006).[7]

The task of achieving such synergies in manufacturing sub-sectors in developing countries in light of expanding trade and GVCs is not easy, and at least two important issues arise. First, as Felipe (2010) proposes, there is a 'proximity' in trading relationships, where countries with similar capabilities, technologies and infrastructure are likely to manufacture similar products, thus increasing the possibility that they crowd each other out. Second, exports facilitate technological diversification depending on current specialization patterns of countries: When a country is specialized in sectors that have synergies for learning and technological upgrading, it finds it easier to enter new sectors and industries by trading up (Haussmann and Klinger, 2006).

GVCs and Upgrading

The GVCs approach offers many insights into how countries can target opportunities in specific sub-sectors to learn and upgrade. There is a wealth of evidence showing that, when firms in developing countries integrate into existing trading patterns, they have ample leeway to move horizontally into other sectors (that demand a similar level of technological intensity), vertically into technological intensive sectors, or stay put in the same sector (Cirera and Maloney, 2017; Taglioni and Winkler, 2016). The approach also considers the notion of upgrading at length, but mainly in the context of the 'governance' of chains, which refers to the kinds of relationships that develop in the value chain and the power relationships they entail. As studies highlight, governance of value chains is the critical aspect that affects market access, determines the fast track acquisition of production capabilities, dictates the distribution of gains, and often also suggests various policy entry points to change GVC-related outcomes (Humphrey and Schmitz, 2002). In general, five key forms of GVC governance have been identified – market, modular, captive, relational and hierarchical (see Gereffi *et al*, 2005) and a wide number of other studies expand on these modes (see, for example, Ponte and Sturgeon, 2014).

Humphrey and Schmitz (2000, pp. 3–4) provide the most basic template for classifying upgrading within GVCs: process upgrading, product upgrading and functional upgrading. While process upgrading involves minor changes, product upgrading (changing the production of new products) and functional upgrading (adding new functions within the GVC) require greater capabilities on the part of local firms (Bazan and Navas-Aleman, 2004). A fourth form of upgrading – interchain upgrading (introduced more recently in the approach) – offers the possibility of a firm upgrading its products to move into an associated value chain (Pietrobelli and Rabelloti, 2011).

Strictly speaking, these forms of upgrading cannot be mapped on a one-to-one basis to the processes underlying technological change and do not necessarily conform to the notion of technological upgrading. However, GVC studies provide evidence of successful cases that show how GVCs open up several avenues for technology transfer. In these cases, GVCs enable local firms to enter into certain production networks that open them up to new business practices, management methods and organizational skills, in addition to promoting day-to-day technological change within firms (Gereffi and Fernandez-Stark, 2010a, b; Hernandez *et al*, 2014).

More recently, there have been efforts to link the discussion on governance modes to that on upgrading in the GVC literature. Pietrobelli and Rabelloti (2011), for example, link the different forms of governance with differential upgrading prospects for developing countries, arguing that modular and relational GVC governance forms may open up wider opportunities for technological upgrading when compared to captive or hierarchical GVCs that are widely found in the commodities or low-technology sectors.

However, while these insights might help explain some aspects of what happens when firms are inserted into particular value chains depending on the sector in question, not all insertions into GVCs carry positive outcomes for learning and technological upgrading, for a variety of reasons (Morrison *et al*, 2008). Furthermore, intangible knowledge protected through intellectual property rights is increasingly becoming an invaluable asset in value chain governance, helping lead firms to maintain advantages and gain larger shares of the revenue on a consistent basis (WIPO, 2017). Therefore, it seems plausible that, while some local firms manage to upgrade, others will lag behind and even face marginalization and exclusion within existing GVCs (see Gibbon and Ponte, 2005, p. 138).

All these reasons suggest that a narrow view of GVCs is not enough to tell the entire story. In fact, the difficulty in explaining many of these outcomes in a clear way has led many scholars to question the traditional, rather 'linear', paradigm of GVCs, arguing that many such processes are actually non-linear in nature (Horner and Nadvi, 2018). This is particularly true when viewed from the perspective of developing countries, where there is a need for a more structured discussion on how learning through GVCs can be promoted on a routine, systematic basis, rather than leaving it to the mercy of market outcomes.

The Relevance of a Technology Capabilities Perspective

How firms expand, learn, technologically upgrade and prosper within GVCs is not just a matter of the GVC itself. Rather, learning occurs as a result of the dynamic interactions between the firm and the value chain on the one hand and the firm and its innovation system on the other. The innovation system is instrumental in creating technological capabilities that shape the ability of actors to master and use existing technologies to carry out routine tasks, and to create new products and processes. These capabilities are what dictate learning and allow actors to innovate. Therefore, although the firm is the locus of innovation, it relies on social capabilities which are created by the system of education (especially at the tertiary level) and supportive policy regimes, and on technological capabilities, which are determined by sustained public R&D, the scientific capacity of institutions and the innovation potential of the economy.

As a result, although a firm's performance is ultimately linked to its own technological efforts, it is shaped by the technological capabilities available within the innovation system in general. Technology and innovation studies have created several useful taxonomies for technological capabilities that look at firm-level capabilities (Bell and Pavitt, 1993, 1995; Lall, 1992, 2001; Pavitt, 1984). There has been a parallel effort to create capability indicators that can measure institutional strengths of national innovation systems (Fagerberg and Srholec, 2008, 2009a, b; Kim, 1997).

In our analysis, we use Kim's (1997) notion of technological capabilities which account for a successful and supportive national innovation system, namely, the quality of a country's science base (as measured by publications), R&D investments (as measured by public expenditure on R&D) and patents and trademarks (as measured by intellectual property payments or by patents granted to residents). These capabilities foster collaborative learning in the innovation system, enable firm-level technological change and upgrading and support the diversification of production structures by facilitating continuous product or process improvements that generate MVA.

Hence, the evolution of a country's exports – whether through trade or GVC participation – will equally depend on the local support given to firms to develop their technological capabilities, as it does on international technological progress, competition or collaboration with foreign firms (Lall, 2000). If over time there is a 'deepening' of national technological capabilities, then we should be able to see two kinds of outcomes: Firms will upgrade technologically within existing activities (producing better quality products), and firms will move to new sectors or technologies with more complex activities (Lall, 2000, p. 5). In this process, if national capability indicators support the assimilation of "increasingly complex technologies that are mastered to international levels of efficiency", this helps create intra- and inter-sectoral externalities (Cassen and Lall, 1996, p. 331) within economies.

Empirical Analysis

The Data

The dataset used in this article relies on three different databases: the United Nations Statistical Division (UNSD) National Accounts Main Aggregates Database, the United Nations Conference on Trade and Development (UNCTADStat) and the World Development Indicators (WDI) Database.

The UNSD database was used to compute the dependent variable, total MVA. Trade in manufacturing exports and imports according to technological intensity were derived from UNCTADStat based on the Lall classification (Lall, 2000).[8] The capability variables used in the analysis come from the WDI database of the World Bank (see Table 1).

The analysis considers developing countries (including least developed countries, hereafter LDCs)[9] and contains information for the years 2000, 2005 and 2010 in constant USD.

Model Specification

As it is not possible to construct a balanced panel that contains the same variables for all developing countries for the entire time period, we constructed a dataset for 78 countries for 3 years, 2000, 2005 and 2010. We ran four regressions per year t, namely, (1) a regression including all developing countries after controlling for outliers ($n = 74$); (2) a robust regression ($n = 73$); (3) a regression excluding outperforming developing countries from the sample ($n = 65$); and (4) a robust regression excluding outperforming developing countries. The same procedure was used for year t_{+5} and year t_{+10}.

The model follows the form:

$$Y_{\mathrm{it}} = b_{0\mathrm{t}} + b_{1\mathrm{t}}X_{1\mathrm{it}} + b_{2\mathrm{t}}X_{2\mathrm{it}} + b_{3\mathrm{t}}X_{3\mathrm{it}} + U_{\mathrm{it}} \quad (1)$$

where Yit represents the observed value of MVA for country i in year t in constant USD (base year 2005), $X_{1\mathrm{it}}$ denotes manufacturing export variables with different levels of technological

Table 1: Definitions and sources of variables

Variable	*Data source*	*Definition*	*Explanation*	*Scaling*	*Expected relationship with MVA*
mva_gdp	Prepared with information from UNSD	Manufacturing value added (MVA)/GDP	This variable denotes the net output of country *i* after adding up all outputs and subtracting the intermediate inputs invested in production in constant USD (base year 2005). This variable was divided by GDP to control for country-size effects	Presented in thousands of USD. Divided by GDP	
xl1_gdp	UNCTADStats	Exports of low-technology manufactures: textile, garments and footwear (L1)/GDP	These manufactures call for relatively simple skills and capital equipment. Labour costs (wages) are the major element in their competitiveness	Presented in thousands of USD. Divided by GDP	(+)
xl2_gdp	UNCTADStats	Exports of low-technology manufactures: other products (L2)/GDP		Presented in thousands of USD. Divided by GDP	(+)
xm1_gdp	UNCTADStats	Exports of medium technology manufactures: automotive (M1)/GDP	These manufactures are the core of industrial activity in mature economies and call for capital intensity and economies of scale, along with mature technological skills that can be applied to short to medium-term product and process technologies. They imply moderately high levels of R&D, advanced skills and lengthy learning periods, as well as strong backward and forward linkages, including learning linkages	Presented in thousands of USD. Divided by GDP	(+)
xm2_gdp	UNCTADStats	Exports of medium technology manufactures: process (M2)/GDP		Presented in thousands of USD. Divided by GDP	(+)
xm3_gdp	UNCTADStats	Exports of medium technology manufactures: engineering (M3)/GDP		Presented in thousands of USD. Divided by GDP	(+)
xh2_gdp	UNCTADStats	Exports of high technology manufactures: other (H2)/GDP	These manufactures are mostly at the frontier of the field, impute high levels of R&D investment, with an emphasis on design, and new product and process capabilities. Engaging in this type of manufacturing requires sophisticated technology infrastructure, high levels of specialised technical skills, and advanced R&D capabilities with the ability to compete globally	Presented in thousands of USD. Divided by GDP	(+)

Table 1: *continued*

Variable	*Data source*	*Definition*	*Explanation*	*Scaling*	*Expected relationship with MVA*
mlow_gdp	UNCTATStats	Imports of low-technology manufactures (L1+L2)/GDP	These manufactures call for relatively simple skills and capital equipment. Labor costs (wages) are the major element in their competitiveness	Presented in thousands of USD. Divided by GDP	(−)
mm1_gdp	UNCTATStats	Imports of medium technology manufactures: automotive (M1)/GDP	These manufactures are the core of industrial activity in mature economies and call for capital intensity and economies of scale, along with mature technological skills that can be applied to short to medium-term product and process technologies. They imply moderately high levels of R&D, advanced skills and lengthy learning periods, as well as strong backward and forward linkages, including learning linkages	Presented in thousands of USD. Divided by GDP	(−)
mm2_gdp	UNCTATStats	Imports of medium technology manufactures: process (M2)/GDP		Presented in thousands of USD. Divided by GDP	(−)
mm3_gdp	UNCTATStats	Imports of medium technology manufactures: engineering (M3)/GDP		Presented in thousands of USD. Divided by GDP	(−)
mh2_gdp	UNCTATStats	Imports of high technology manufactures: other (H2)/GDP	These manufactures are mostly at the frontier of the field and impute high levels of R&D investment, with an emphasis on design, and new product and process capabilities. Engaging in this type of manufacturing requires sophisticated technology infrastructure, high levels of specialized technical skills, and advanced R&D capabilities with the ability to compete globally	Presented in thousands of USD. Divided by GDP	(−)
IPP_gdp	WDI	Intellectual property payments/GDP	Denotes charges for the use of intellectual property payments and receipts between residents and nonresidents for the authorized use of proprietary rights (such as patents, trademarks, copyrights, industrial processes and designs including trade secrets, and franchises) and for the use, through licensing agreements, of produced originals or prototypes (such as copyrights on books and manuscripts, computer software, cinematographic works, and sound recordings) and related rights (such as for live performances and television, cable, or satellite broadcasts)	Presented in thousands of USD. Divided by GDP	(+)

Table 1: *continued*

Variable	*Data source*	*Definition*	*Explanation*	*Scaling*	*Expected relationship with MVA*
RDexp	WDI	R&D expenditure	This variable denotes gross domestic expenditures on research and development (R&D), expressed as a percentage of GDP. The variable includes both capital and current expenditures in four main sectors: business enterprises, government, higher education and private non-profit. R&D covers basic research, applied research, and experimental development	% of GDP	(+)
lpatent	WDI	Patents by residents (log)	This variable denotes the number of patents granted to residents, implying domestic inventions and R&D capacity	Log (number of patents)	(+)
l_journal	WDI	Scientific publications (log)	This variable denotes the number of scientific and engineering articles published in all scientific fields	Log (number of publications)	(+)

intensity for country i in year t in USD, X_{2it} is the value of manufacturing import variables with different levels of technological intensity for country i in year t in USD, X_{3it} is the value of capabilities indicators with different levels of technology for country i in year t, U_{it} is a random error term. Lastly, b_{1it}–b_{3it} are the coefficients for year t capturing the influence of the different explanatory variables on the endogenous one, while b_{0t} is the intercept of the model in year t.

MVA, the dependent variable, was measured as the net output of country i after adding up all outputs and subtracting the intermediate inputs invested into production in constant USD (base year 2005). This variable was divided by GDP to control for country-size effects (see Table 1).

The explanatory variables consist of trade in manufactured goods classified into technological export/import categories using the Lall classification (Lall, 2000) and four capabilities indicators: patents of residents, scientific and technological publications, R&D expenditure and intellectual property payments. Each trade variable related to manufacturing exports and imports with different levels of technological intensity was divided by real gross domestic product (GDP) to control for country-size effects. This method was chosen instead of including real GDP as a variable in the regression because it allowed us to factor the level of development of each country into the sample more effectively. Capabilities variables, represented by the number of journal publications and number of patents by residents are presented in their logarithmic form to reduce skewness and improve normality, and R&D expenditure is presented as a percentage of GDP. As suggested in Table 1, we expect a positive relationship between exports of manufactures with different levels of technological complexity and MVA. The same positive relationship is expected between our dependent variable and our capabilities indicators.

Identification of Outliers

Several data points were located far outside the mean of the group. To identify these data points, which are observations with large residuals that affect the dependent variable value in an unusual form, we first calculated the leverage by standardizing the predictor variable to a mean equal to zero and a standard deviation equal to one. Given that the influence of an observation is dependent on how much the predicted scores for other observations would differ if the observation in question was not included, we used a Cook's D to calculate this influence, as those points with the largest influence produce the largest change in the equation of the regression line (Altman and Krzywinski, 2016; Cook, 1979). In particular, to identify potential outperformers, we applied the following expression for country i in each of the considered regressions:

$$Di \geq 4/n - (k + 1) \qquad (2)$$

where n is the number of countries and k the number of regressors.

After repeating this exercise for all 3 years and analyzing the outliers, we found four atypical observations that we did not include in the simple regressions for the years 2000, 2005 and 2010, thus limiting our sample to 74 observations.[10] In the robust regressions, we found an additional atypical observation, making our sample size 73 for all 3 years.[11] When comparing regressions with and without these outliers, we found no major changes in the results. Due to the reduced sample size, no causality test was performed in the analysis; therefore, any interpretation of the results should carefully consider causality running on both sides. Moreover, the reduced sample size could also account for the low statistical power of the

Table 2: Descriptive statistics

Variable (1)	*2000*		*2005*		*2010*	
	N = 74		*N = 74*		*N = 74*	
	Mean (2)	*SD (3)*	*Mean (4)*	*SD (5)*	*Mean (6)*	*SD (7)*
MVA/GDP	.1322371	.0688815	.1313698	.0650013	.1266121	.0688023
Exports L1/GDP	.0312834	.0551084	.0378707	.0759776	.0357826	.0743334
Exports L2/GDP	.0068714	.0100918	.010784	.0146729	.0148518	.0222871
Exports M1/GDP	.0025915	.0055102	.0046832	.0087728	.0055956	.0119214
Exports M2/GDP	.0067131	.0111327	.0110194	.0169492	.0160647	.0229711
Exports M3/GDP	.0088098	.0225216	.0157185	.0333808	.0206325	.0362037
Exports H2/GDP	.0025162	.004944	.00435	.0092982	.0073989	.0170865
Imports low (L1+L2)/GDP	.0000408	.0000363	.0000607	.0000821	.0000703	.0000511
Imports M1/GDP	.0149548	.009271	.0211998	.0130247	.0308604	.0187483
Imports M2/GDP	.0216001	.0146233	.0321925	.0186114	.0430439	.0249666
Imports M3/GDP	.0318576	.028578	.0471358	.0392081	.068456	.0521327
Imports H2/GDP	.010378	.008191	.0143143	.0104203	.0203118	.0123038
R&D expenditure	.1557838	.3746251	.1864459	.4547339	.2852973	.5470414
Intellectual property payments/GDP	0.000159	0.0059526	0.00222	0.008684	0.002818	0.01115
Log (patents by residents)	2.293017	2.560484	2.071706	2.458708	2.046723	2.480665
Log (publications)	4.215921	2.304805	4.449467	2.365016	4.623013	2.351605

regression, as well as the low statistical significance of some variables, with this being a potential limitation of our analysis.

Descriptive Statistics, Correlations and Multicollinearity

Table 2 presents descriptive statistics (i.e., the number of observations, mean and standard deviation) for the dependent and explanatory variables used in the study for the years 2000, 2005 and 2010. The observations used in the regression in their transformed state correspond with the number of observations presented in this table. Columns (2) and (3) of Table 2 present the statistics for all developing countries for the year 2000. Columns (4) and (5) refer to the year 2005 and columns (6) and (7) to the year 2010. The standard deviation for all variables does not show a large spread of the data with respect to the mean (i.e., less than 3 times the mean). Columns (2), (4) and (6) show that the mean MVA for all developing countries decreased slightly in 2010 when compared to the year 2000. However, the means of all explanatory variables increased in this period, with the exception of patents. The data indicate that, in 2010, there was a slight decrease in the number of patents by residents when compared to the year 2000.

The signs of the Pearson correlation coefficients, *r*, with respect to our dependent variable (MVA) were positive, indicating a positive correlation between these variables and MVA, except for M1 imports, intellectual property payments (IPP) and R&D expenditure, which had negative correlations. This indicates that higher values of M1 imports, IPP and R&D expenditure are associated with lower levels of MVA. Higher values among the rest of the variables are associated with greater levels of MVA. This holds for all years under consideration, 2000, 2005 and 2010.

We found a large correlation[12] between the dependent variable and exports of L2 and M3, and the number of publications in years 2000 and 2010. Additionally, a large correlation was found between exports of M2 and MVA in 2010. A moderate correlation[13] was also observed

Table 3: Outperforming developing countries

Code	*2000*	*2005*	*2010*
CHN	China	China	China
KOR	S. Korea	S. Korea	S. Korea
IND	India	India	India
BRA	Brazil	Brazil	Brazil
SGP	Singapore	Singapore	Singapore
TUR	Turkey	Turkey	Turkey
MEX	Mexico		
MYS	Malaysia	Malaysia	Malaysia
HKG	Hong Kong	Hong Kong	Hong Kong
ZAF			South Africa
THA	Thailand	Thailand	Thailand

Coded according to the ISO-alpha3 code of the United Nations Terminology Database (UNTERM).

between the dependent variable and exports of M2 and patents by residents in all years. The rest of the variables showed a smaller level of correlation[14] with MVA in all years.

Expecting relationships between the variables used in the regression, we ran multicollinearity tests with all the variables in our sample before proceeding with the analysis. Our results indicate high levels of multicollinearity among certain variables that would affect the results of the regression if included. This is the case in particular with imports and exports of high-technology manufactures: electronic and electrical (H1). This variable is highly correlated to imports and exports of medium-technology manufactures, particularly those related to engineering (M3). Therefore, we excluded H1 for both imports and exports from the analysis.

Results and Discussion

This section shows the results of estimating Eq. (1) for the three years considered 2000, 2005 and 2010 as explained in the previous section. Despite having eliminated outliers from our analysis, we found some countries consistently outperforming in the sample. Considering it important to check how the conclusions of our analysis are affected by the outperforming developing countries, we identified the outperformers in our sample (Table 3), a list that fits neatly with the discussions on emerging economies in the current academic and policy thinking. Graphic analysis that plots the performance of these countries across different export categories (not reported here but available from the authors on request) shows that these countries have managed to sustain export levels and maintain MVA in several technology export categories in a sustained way. For this reason, the analysis was performed for all the developing countries in our sample, including and also excluding the outperformers. Table 4 presents the results of the regressions performed for both samples.[15] Columns (1), (3) and (5) correspond to a simple regression for the years 2000, 2005 and 2010, respectively. Columns (2), (4) and (6) present the robust regression for these years. The regressions excluding the group of outperforming developing countries (as identified in Table 3) are presented in columns (7) to (12) for 2000, 2005 and 2010.

The results show that exports of low-technology manufactures (L1), that is, exports of textiles, garments and footwear, is the only category of exports positively and significantly associated with MVA in 2000, 2005 and 2010 for all developing countries. This holds true both with and without the outperforming developing countries. A graphic analysis of this

Table 4: Empirical results

Explanatory variables	*Independent variable: manufacturing value added/GDP*					
	2000					
	(1) Simple regression Coefficient (SE) N = 74	*(2) Robust regression Coefficient (SE) N = 73*	*(3) Simple regression Coefficient (SE) N = 74*	*(4) Robust regression Coefficient (SE) N = 73*	*(5) Simple regression Coefficient (SE) N = 74*	*(6) Robust regression Coefficient (SE) N = 73*
Exports of low-technology manufactures: textile, garment and footwear (L1)/GDP	**0.3283***** **(0.1955)**	**0.4333***** **(0.1741)**	**0.306***** **(0.119)**	**0.317***** **(0.130)**	**0.346***** **(0.132)**	**0.342***** **(0.139)**
Exports of low-technology manufactures: other products (L2)/ GDP	**7.5780*** **(1.8301)**	**4.2471***** **(1.6794)**	**2.138**** **(0.7653)**	**2.030***** **(0.843)**	0.430 (0.456)	0.407 (0.473)
Exports of medium technology manufactures: automotive (M1)/GDP	**− 2.4719***** **(1.3233)**	−0.6697 (1.1639)	1.003 (0.774)	0.579 (0.869)	**1.160***** **(0.594)**	0.470 (0.720)
Exports of medium technology manufactures: process (M2)/GDP	**−3.2717**** **(1.0551)**	**−2.0300***** **(0.9424)**	−0.509 (0.541)	−0.351 (0.596)	−0.425 (0.398)	−0.332 (0.416)
Exports of medium technology manufactures: engineering (M3)/GDP	−0.0163 ().8249)	0.6911 (0.7418)	0.458 (0.460)	0.446 (0.502)	**1.009***** **(0.423)**	**1.169***** **(0.444)**
Exports of high technology manufactures: other (H2)/GDP	−1.4978 (2.2898)	0.0534 (2.0436)	−0.172 (0.865)	−0.016 (0.954)	0.059 (0.467)	0.166 (0.492)
Imports of low-technology manufactures (L1+L2)/GDP	−42.1967 (381.4891)	−286.34 (337.97)	−1.325 (112.42)	−15.04 (123.05)	−322.8 (297.11)	−291.8 (309.6)
Imports of medium technology manufactures: automotive (M1)/GDP	−0.0378 ().8877)	−0.2578 (0.7812)	−0.380 (0.507)	−0.336 (0.553)	0.325 (0.408)	0.408 (0.424)
Imports of medium technology manufactures: process (M2)/GDP	−0.4321 (0.8167)	0.1325 (0.7186)	−0.076 (0.487)	−0.061 (0.531)	0.579 (0.440)	0.524 (0.457)
Imports of medium technology manufactures: engineering (M3)/GDP	−0.5424 (0.3988)	**−0.7085***** **(0.3646)**	**−0.542***** **(0.252)**	**−0.587***** **(0.275)**	**−0.616**** **(0.190)**	**−0.679**** **(0.200)**
Imports of high technology manufactures: other (H2)/GDP	0.4050 (1.2590)	1.2577 (1.1181)	1.114 (0.908)	1.090 (0.989)	0.405 (0.697)	0.247 (0.725)
Intellectual property payments/GDP	0.7013 (1.9767)	**8.4719***** **(3.5084)**	−0.234 (1.079)	3.160 (2.477)	−0.205 (0.743)	3.422 (2.200)

Table 4: *continued*

Independent variable: manufacturing value added/GDP						
Explanatory variables	*2000*					
	(1) Simple regression Coefficient (SE) N = 74	*(2) Robust regression Coefficient (SE) N = 73*	*(3) Simple regression Coefficient (SE) N = 74*	*(4) Robust regression Coefficient (SE) N = 73*	*(5) Simple regression Coefficient (SE) N = 74*	*(6) Robust regression Coefficient (SE) N = 73*
R&D expenditure	0.0351	0.0076	−0.009	−0.002	0.010	0.007
	(0.0229)	(0.0202)	(0.017)	(0.019)	(0.014)	(0.015)
Patents of residents (log)	0.0029	0.0034	0.002	0.002	**0.004*** **	**0.004*** **
	(0.0025)	(0.0022)	(0.002)	(0.002)	**(0.002)**	**(0.002)**
Number of scientific publications (log)	**0.0085*** **	0.0034	**0.006*** **	0.005	0.002	0.002
	(0.0035)	(0.0022)	**0.003**	(0.003)	(0.004)	(0.004)
Constant	**0.0776***	**0.0832***	**0.077***	**0.078***	**0.084***	**0.084***
	(0.0191)	**(0.0168)**	**(0.018)**	**(0.019)**	**(0.020)**	**(0.212)**
	R2 = 0.6833		R2 = 0.7284		R2 = 0.7283	

Independent variable: manufacturing value added /GDP						
Explanatory variables	*2000 (without outperformers)*		*2005 (without outperformers)*		*2010 (without outperformers)*	
	(7) Simple regression Coefficient (SE) N = 65	*(8) Robust regression Coefficient (SE) N = 65*	*(9) Simple regression Coefficient (SE) N = 66*	*(10) Robust regression Coefficient (SE) N = 65*	*(11) Simple regression Coefficient (SE) N = 65*	*(12) Robust regression Coefficient (SE) N = 64*
Exports of low-technology manufactures: textile, garment and footwear (L1)/GDP	**0.4363**** **(0.1594)**	**0.4236*** ** **(0.1778)**	**0.336**** **(0.123)**	**0.320*** ** **(0.131)**	**0.309*** ** **(0.136)**	**0.427*** ** **(0.137)**
Exports of low-technology manufactures: other products (L2)/GDP	**4.9201*** ** **(1.8561)**	**4.9240*** ** **(2.0702)**	**1.592*** ** **(0.931)**	1.035 (1.011)	0.075 (0.475)	0.169 (0.455)
Exports of medium technology manufactures: automotive (M1)/GDP	−2.7060 (2.0073)	−2.3033 (2.2388)	0.767 (1.147)	0.513 (1.224)	**2.723*** ** **(1.420)**	0.781 1.493

Table 4: *continued*

Explanatory variables	*Independent variable: manufacturing value added /GDP*					
	2000 (without outperformers)		*2005 (without outperformers)*		*2010 (without outperformers)*	
	(7) Simple regression Coefficient (SE) N = 65	*(8) Robust regression Coefficient (SE) N = 65*	*(9) Simple regression Coefficient (SE) N = 66*	*(10) Robust regression Coefficient (SE) N = 65*	*(11) Simple regression Coefficient (SE) N = 65*	*(12) Robust regression Coefficient (SE) N = 64*
Exports of medium technology manufactures: process (M2)/GDP	**−1.6632***** **(0.9300)**	−1.7206 (1.0373)	−0.393 (0.602)	−0.005 (0.652)	−0.065 (0.422)	0.240 (0.411)
Exports of medium technology manufactures: engineering (M3)/GDP	**1.9196***** **(0.9724)**	**1.8913***** **(1.0846)**	0.422 (0.526)	0.275 (0.565)	0.765 (0.490)	0.627 (0.473)
Exports of high technology manufactures: other (H2)/GDP	−0.6066 (2.0624)	−0.6278 (2.300)	−0.049 (0.909)	−0.242 (0.971)	0.031 (0.475)	−0.016 (0.454)
Imports of low-technology manufactures (L1+L2)/GDP	−371.44 (314.94)	−348.21 (351.27)	−20.24 (116.63)	−79.35 (126.14)	−269.4 (296.7)	−607.32*** (309.65)
Imports of medium technology manufactures: automotive (M1)/GDP	0.0184 (0.7558)	−0.0204 (0.8430)	−0.219 (0.5381)	0.063 (0.581)	0.017 (0.428)	0.281 (0.413)
Imports of medium technology manufactures: process (M2)/GDP	0.0989 (0.6824)	0.0670 (0.7611)	−0.0804 (0.527)	0.271 (0.575)	0.678 (0.454)	0.9290*** (0.444)
Imports of medium technology manufactures: engineering (M3)/GDP	**−0.9979***** **(0.3700)**	**−1.014***** **(0.412)**	**−0.513***** **(0.280)**	−0.458 (0.300)	**−0.541***** **(0.205)**	**−0.441***** **(0.199)**
Imports of high technology manufactures: other (H2)/GDP	0.7599 (1.0461)	0.8778 (1.1667)	0.923 (0.939)	0.223 (1.026)	0.315 (0.697)	0.396 (0.668)
Intellectual Property Payments/GDP	**9.6423**** **(3.3850)**	**9.782***** **(3.775)**	3.073 (2.542)	**20.145**** **(6.973)**	2.803 (2.284)	**18.241**** **(5.375)**
R&D expenditure	0.06926 0.0519	0.074 (0.057)	−0.0324 (0.0352)	−0.055 (0.038)	0.004 (0.026)	0.022 (0.025)

Table 4: *continued*

Independent variable: manufacturing value added /GDP						
Explanatory variables	*2000 (without outperformers)*		*2005 (without outperformers)*		*2010 (without outperformers)*	
	(7) Simple regression Coefficient (SE) N = 65	*(8) Robust regression Coefficient (SE) N = 65*	*(9) Simple regression Coefficient (SE) N = 66*	*(10) Robust regression Coefficient (SE) N = 65*	*(11) Simple regression Coefficient (SE) N = 65*	*(12) Robust regression Coefficient (SE) N = 64*
Patents of residents (log)	0.0027	0.003	0.003	0.003	**0.005*****	**0.003**
	(0.0020)	(0.002)	(0.002)	(0.002)	**(0.002)**	**(0.002)**
Number of scientific publications (log)	0.0025	0.001	**0.007*****	0.004	0.0001	−0.005
	(0.0033)	(0.003)	**(0.003)**	(0.004)	(0.004)	(0.004)
Constant	**0.0945***	**0.095***	**0.074***	**0.074***	**0.088***	**0.093***
	(0.0162)	**(0.018)**	**(0.018)**	**(0.200)**	**(0.020)**	**(0.020)**
	R2 = 0.6456		R2 = 0.5775		R2 = 0.5853	

*Significant at 1%, **significant at 5%, ***significant at 10%.

relationship (not reported here) shows that China is the only country that increased its volume of exports of low-technology manufactures while maintaining almost the same level (with a slight decrease) of MVA in both years. In 2000 and 2005, exports of manufactured goods in the low technology category of other products including office equipment and stationery (L2) were positively and significantly associated with MVA, both with and without the outperforming developing countries. However, the relationship between these two variables although positive, was not significant for all countries in 2010 both with and without the outperformers.

The results also show that, in the year 2000, there was a negative relationship between MVA and exports of manufactured goods in the medium-technology automotive category (M1), both with and without the outperforming developing countries. This relationship, however, became positive and significant (at 10%) in 2010 for all developing countries in the sample, both with and without the outperforming countries, indicating that countries exporting manufactured goods in the automobile sector exhibited a greater level of MVA in 2010 than in 2000. This result suggests that learning and technological upgrading took effect not only for the group of identified outperformers but also for the mean of all developing countries analyzed in our sample. The evolution in the assembling operations characterizing the automobile industry in many developing countries is critical in explaining this change, as analyzed by a number of innovation and industrial organization studies of the automobile sector in recent years. These studies note that inbound firms have undergone generational changes to assembly operations of a kind involving more local research and development (Doner *et al*, 2014; Vallejo, 2010).

There is a negative and significant relationship between MVA and exports of manufactured goods in the medium-technology category of process technologies (M2) in 2000, both with and without outperformers. In 2005 and 2010, this relationship remained negative but not significant, once again both with and without the outperformers. This indicates that a critical technological sector – M2 – which could serve as the backbone of diversified production structures may not be developed/supported sufficiently enough to facilitate MVA. The continuation of the trend in 2010 lends support to the conclusion that national capability indicators are not strong enough to support this kind of learning in many countries in our sample.

Exports of manufactured goods in the medium-technology category of M3 (i.e., engineering technologies) of a broad spectrum that are critical for diversification was associated positively in 2000 for all developing countries, excluding the outperformers, and in 2010 for all developing countries in the sample, but only when outperformers were included. This suggests that, compared to 2000, developing countries in general seem to have lost ground in MVA exports of engineering technologies (M3) to the outperformers, who emerged by 2010 as leading the sector in generating MVA. The growth of this sector, which is critical for diversified production structures (in addition to M2), seems to explain the rising competitiveness of the outperforming countries between 2000 and 2010.

With respect to imports, none were significantly associated with MVA for all countries in 2000, 2005 and 2010 except for the imports of medium-technology engineering products (M3), which show a negative relationship with MVA in 2010 for all countries in our sample. This indicates that developing countries importing this type of products demonstrated lower MVA at a significant level over time, suggesting that it might be both the result of, and leading to, lower learning and capabilities formation in their economies. These results are supported by other studies that suggest that, as countries acquire more and more ready products, particularly those products demanding substantial engineering skills, they do not present significant learning and technological upgrading possibilities and also eliminate several local firms actively engaged in producing such products, thereby deskilling (UNCTAD, 2013, 2016; UNECA, 2014).

We assessed the role of the national capability indicators in the performance of countries in our sample. Our analysis shows that there was no significant relationship between R&D expenditure (which signifies the capacity of public sector R&D) and the capacity to generate MVA in all technology categories in all countries in our sample. The number of scientific publications (which serves as an indicator of scientific capacity) was positively associated with MVA in 2000 for all developing countries with and without outperformers, and in 2005 for all developing countries without outperformers, but by 2010 it was not significant for MVA, also indicating a gradual weakening of innovation system support structures of this kind.

The two variables that were more closely related to firm-level efforts were significantly associated with MVA, indicative of a situation that is common in many developing countries where firm-level performance is not always supported and bolstered strongly by local institutions. This reinforces the argument that more support from the national innovation system to the firms could help strengthen their performance further. The IP payments variable (which denotes the ability of local firms to license existing IPRs from foreign firms) was positively and significantly associated with MVA in all developing countries excluding outperformers in all years. This, however, also shows that there is extensive reliance on foreign proprietary technologies. The variable patents by residents had a significant and positive relationship with value added in manufacturing in 2010 for all countries with and without outperformers, signalling the importance of local firm-level R&D in generating MVA in all countries in the sample.

Concluding Remarks

This article has combined the central tenets of the GVC approach, the innovation systems approach and the traditional discourse on economic development to analyze how technological capabilities as shaped by national innovation systems impact the ability of countries to trade – and by extension participate in GVCs – in ways that facilitate learning, technological upgrading and the generation of MVA. We have analyzed the situation from the perspective of trade with a view to complement existing GVC approaches. Our empirical results indicate that developing countries in our sample are not generating MVA across technological export categories other than category L1 (low technology) and M1 (automobiles). The analysis also identified several outperforming developing countries (coinciding neatly with the emerging economies), which account for most of the MVA in L1 and M1 categories and also exhibit technological diversification into the M3 category (design engineering products) by 2010.

We note two caveats. First, we were not able to use panel data for the entire period, which will be an avenue for future exploration. Second, the findings should be interpreted cautiously given that the sample consisted of 74 (and 65 when excluding outperformers) developing countries. Nevertheless, the analysis leads us to the following general conclusions that deserve further research. First, while countries are integrated into trade and GVCs based on their static comparative advantages, in the countries under consideration there has been a change in capacity to generate manufacturing value added, moving away from those sectors that are seen as critical for capabilities building (M2, which signifies exports in process technologies and M3, which signifies exports in design and engineering products) in the literature on learning and industrial catch-up. While M3 exports shifted from developing countries as a whole to the outperformer countries alone by 2010, there has been a general shift away from MVA in the M2 category for all countries in the sample, including the outperformers.

Second, we find a weakening relationship between capabilities indicators of the innovation systems (both public-sector R&D, as captured by public R&D expenditure, and scientific skills and capacity, as captured by scientific publications) and the capacity to generate MVA in exports in all countries over time. This suggests that national innovation systems need to be further strengthened and aligned more closely with firm-level needs in developing countries in order to better support them to trade and participate in GVCs in a beneficial manner. Patents by residents are positively and significantly associated with MVA in all countries with and without outperformers, showing the relevance of firm-level R&D efforts in the diversification process. In all developing countries in the sample, there is a positive and statistically significant relationship between IPR payments (which denotes the ability of local firms to license existing IPRs from foreign firms) and MVA, once again showing the technological dependence of the countries on proprietary technologies.

Third, our analysis corresponds accurately with the rise of the emerging economies globally: there is a significant overlap between the countries that are outperformers in our sample and those denoted as emerging economies in the wider literature (UNCTAD, 2012). Finally, our analysis points to the critical role of national capabilities in accounting for how countries benefit from trade and by extension, participation in GVCs. The gradual delinking of export value added from learning is predominantly linked to weak national innovation systems linkages in developing countries and a very worrisome trend. Coupled with the fact that institutional responses have been slow to enable firms to deal with export pressures in certain sectors, and that weak public support for innovation persists (exacerbated by the financial crises of 2007–2008), we conclude that technological upgrading in and through trade and GVCs can be understood and promoted only when considered in conjunction with national capabilities indicators. More work in this direction is required to study how countries can effectively address these issues.

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Notes

1. In light of the recent slowdown in trade, the share of GVCs in total trade has gone down, but it was still around 60% in 2017; see Rabelloti *et al* (2018).
2. For a critique of this, see Morrison *et al* (2008).
3. Some key GVCs that have been explored previously have included: coffee in Colombia, Uganda and Ethiopia; horticulture/cut flower sectors in Kenya, Tanzania and Ethiopia; garments in Bangladesh and Cambodia; and the electronics industry in East Asia. See, for example, Baffes (2006), Gereffi (1999), Gibbon and Ponte (2005) and Ponte (2002).
4. The services sector is becoming increasing important in developing countries and accounting for a large share of activity in the emerging economies. However, due to the difficulties of disaggregating services trade data into technological categories, this article does not include the services sector.

5. https://unstats.un.org/unsd/tradekb/Knowledgebase/50658/Technological-classification-of-exports-by-SITC.
6. The underlying process of 'cumulative causation' occurs when industrial expansion creates employment, incomes and demand on the one hand and leads to increased productivity on the other.
7. See also: studies on the cases of China's electronics and telecommunications equipment (Rodrik, 2003); South Korea's semiconductor and automobile sectors (Mathews and Cho, 2000); and Taiwanese computers and telecommunications (Amsden, 1989).
8. https://unstats.un.org/unsd/tradekb/Knowledgebase/50658/Technological-classification-of-exports-by-SITC.
9. http://unctadstat.unctad.org/EN/Classifications/DimCountries_DevelopmentStatus_Hierarchy.pdf.
10. The four countries are Belize, Bhutan, Chad and Mongolia.
11. The additional country that was excluded for the robust regressions is Guyana.
12. $| r | > 0.5$.
13. $0.3 < | r | < 0.5$.
14. $0.1 < ||r| < 0.3$.
15. The estimates of the regression coefficient follow a level-level regression specification, where the βs are the marginal effect (i.e., if we change 'x' by 1 then, we would expect 'y' to change by β_t), except in the case of journal publications and patents by residents. In those cases, the coefficients of the regression follow a level-log specification, where the βs represent the growth rate (i.e., if we change 'x' by 1%, we would expect 'y' to change by $\beta_t/100$).

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