WORKING PAPER NO: 629

Global Value Chain Participation and Intermediate Export Sophistication

Neha Vinod Betai
Academic Associate
Economics and Social Sciences Area
Indian Institute of Management Bangalore
Bannerghatta Road- 560076
neha.betai@iimb.ac.in

Rupa Chanda
RBI Chair Professor of Economics
Indian Institute of Management Bangalore
Bannerghatta Road, Bangalore – 560076
rupa@iimb.ac.in

Year of Publication- November 2020

Global Value Chain Participation and Intermediate Export Sophistication

Abstract

The reorganization of the production process in the past two to three decades has led to the emergence of Global Value Chains (GVCs) where the production chain is spread across different geographies. This has in turn led to increased foreign value-added content in each country's exports as well as increased trade in intermediate goods. Given the rise of GVCs as a key form of international trade and production, several studies in recent years have tried to analyse the benefits from GVC participation. In this paper, we focus on the impact of GVC participation on the sophistication of intermediate exports, i.e., the main channel through which countries participate in GVCs. Our analysis confirms the fact that GVC participation, both backward and forward, contributes positively to the sophistication of intermediate manufactured exports. However, the significance of the two channels varies depending on the income and human capital levels of a country. We find that backward participation has a positive, significant impact only for the high-income countries whereas forward participation is positive and significant for high-income as well as the low- and middle-income countries. Similarly, human capital and FDI, are significant only for the high-income economies, whereas distance from the technological frontier is an important factor determining sophistication for all sets of countries. Our analysis suggests that for countries to derive benefits from GVCs, there needs to be investment in innovation and human capital along with creating a conducive business environment and maintaining liberal trade and investment policies.

Key words: Global Value Chains (GVCs)**,** Export Sophistication, Intermediate Goods, Forward Participation, Backward Participation.

JEL Classification: F61, F68, L60

1. Introduction

Globalisation in recent years has not only meant an increase in movement of goods, services and people but has also resulted in reorganisation of production processes. The new Globalisation process is far different from the earlier Globalisation, which has been referred as the first unbundling while the newer Globalisation is called the second unbundling (Baldwin 2006). The first unbundling of trade was the result of the steam engine revolution which allowed for the separation between consumption and production. Earlier, the two were tied together geographically – people generally consumed what was locally produced. The reduction in transport costs due to the steam engine revolution allowed for production to be located far away from the consumption. Thus, there was an increase in the scale of production as firms took advantage of economies of scale and used cheap transportation to sell their goods all over the world as well as purchase cheaper inputs that helped further reduce costs of production. The first unbundling resulted in an interesting phenomenon. As transport costs fell, there was dispersion of production globally, but this dispersion also led to the formation of manufacturing clusters in some countries. These clusters came about to reduce coordination costs – large production processes tend to be complex and require coordination.

The 1980s saw advances in communication technology which resulted in the second unbundling. The information and communication technology (ICT) revolution eased the constraints on coordination by reducing its costs. This allowed for production to be dispersed globally giving rise to the existence of Global Value Chains (GVCs). GVCs essentially imply a breakdown of the production chain into specific tasks and production processes that are no longer bound geographically but rather spread all over the world. The location of these tasks and processes is chosen to exploit the relatively cheaper factors of production.

The internationalisation of production is evident from the rise in foreign value-added (FVA) content of exports. The FVA content of exports increased from 23 per cent in 1990 to a peak of 30 per cent in 2008. Post the Global Financial Crisis, there was some dip in the FVA content, but it has since recovered. In 2018, it was close to 29 per cent. This rise in FVA content is common to all countries.[1]For instance, Vrh (2018) finds a decline in the share of domestic value added (DVA) content (and hence an increase in FVA content) of exports (merchandise and as well as services exports) in the EU-15 and Central and Eastern European Countries. Banga (2013) similarly finds that between 1995 and 2010, FVA in gross exports has increased for a large proportion of developing as well as developed countries. The decline in DVA during the same period varied from 3 to over 21 percentage points. This rise in the

[1] The total value-added content of exports can be divided into two parts – Foreign Value Added content and Domestic Value-Added content. An increase in the share of one component implies a decline in the share of the other.

FVA content of exports implies that we can no longer find a product that has been manufactured from its inception to the end in the same factory, or even the same country.

This disintegration of production has changed the nature of bilateral trade relationships between countries. Increased fragmentation of production implies that trade between countries is no longer of the "cloth for wine" kind that was theorised by Ricardo. The new form of trade involves exchange not of finished products, but rather of intermediate goods and services. An intermediate good is a produced good which is used as an input in the production process. Unlike capital goods, which are a fixed asset (like land), intermediate goods are completely used up in the production process. A study by OECD finds that a large proportion of the trade among developed countries, 56 per cent for goods and 73 for services, is in intermediate inputs. Another study by UNCTAD finds that intermediate goods accounted for 55 per cent of world trade in 2011 and 58 per cent of developing countries exports. For the high-income economies, the automobile industry accounts for the largest share of intermediate exports, whereas for developing countries, the share varies according to the region. For instance, in East Asia, information and technology products dominate intermediate exports whereas textiles and apparel are the major exports for the countries in South and West Asia and North Africa (UNCTAD, 2011)

While the dominance of GVCs is a widely accepted fact, the impact of participation in GVCs is still under investigation. As per the World Development Report 2020, trade openness and GVC integration have been instrumental in improving economic performance, by promoting higher income growth and productivity gains while also increasing employment and reducing poverty. Raei, Ignatenka, and Mircheva (2019) find that GVC-related trade positively impacts per capita income, although the effects may depend on the income level and institutional factors. Örgün (2014) also finds that GVCs are instrumental in promoting income growth which further results in increased employment, as long as countries are not forced to keep their wages low to maintain competitiveness (as the latter may limit income growth and lower the standard of living)

While GVCs have wide and varied benefits as described above, the focus of this paper is to understand the improvement in productivity brought about through GVC participation. Several studies have documented in detail the productivity benefits of GVC integration as well as the channels through which productivity improvement takes place (Antras, 2020; Grossman and Rossi-Hansberg, 2008; Becker, Ekholm, and Muendler, 2013; Feenstra and Hanson, 1996; Criscuolo, Timmis and Johnstone, 2015). These channels range from knowledge diffusion as a result of outsourcing to learning from importing and exporting.

In this study, we further explore the productivity enhancing benefits of GVCs. More specifically, we examine how participation in GVC has itself let to upgrading and productivity improvement in

intermediate exports, i.e., the main channel through which the majority of countries (close to 100) have participated in GVCs between 1999 to 2018. However, we restrict our analysis to manufactured and chemical intermediate exports. Using the methodology developed by Hausmann, Hwang and Rodrik (2006), we first rank the intermediate goods based on their implied productivity levels and then weigh the intermediate export basket of countries using this measure of implied productivity. Our aim is to observe if participation in GVCs has a positive productivity relationship with the nature of a country's GVC participation, i.e., backward and forward participation. We find that benefits from participation, specifically different types of participation, depend on the income levels of the economies, as well as other factors such as FDI flows, market concentration, human capital and the distance from the technological frontier.

The rest of the paper is organised as follows. In Section 2, we briefly review the literature on the relationship between production, trade and GVCs. In Section 3, we examine recent trends in GVC participation and intermediate goods trade. Sections 4 and 5, respectively, discuss the methodology and present relevant descriptive statistics for the indices used. Section 6 provides the empirical analysis of the factors which influence the sophistication of intermediate export baskets. Section 7 discusses the results and key insights that emerge while Section 8 concludes the paper.

2. Review of Literature

Several reports and studies in recent years have tried to elucidate the productivity enhancing benefits of Global Value Chains. For instance, as per the World Development Report 2020, increased participation in GVCs has been instrumental in improving productivity, efficiency and fostering technology transfer. Although such claims are often contested and there is no conclusive proof to say that participation in value chains will help improve the productive capacity of an economy, there is ample evidence to show that different aspects of GVCs do benefit economies. These benefits arise from increased trade in inputs, technology transfer, hyper specialisation by firms, access to capital goods, and exposure to the technology frontier. The following sections highlight how different aspects of GVC participation can improve economic performance.

2.1. Scale effects, Specialisation, and demand effects

Increased productivity from any trade, including the kind of trade seen under GVCs, can stem from scale effects. The latter refers to specialisation in the production of a commodity as the size of the market increases. There has been evidence that the most productive firms in an economy are those which serve the highest number of markets (Andersson, Loof and Johansson, 2008; De Loecker, 2007; Van Biesebroeck, 2005). A study by Castellani (2002) finds that productivity growth in firms is related to export intensity, i.e., by firms that are substantially involved in export of goods. By trading with different countries, firms find a larger market for their products, which incentivises them to invest in

skills and technology, and promotes more division of labour, thereby improving productivity. The importance of a large market was also recognised by Gary Becker in his 1964 book, Human Capital, where he said,

> *"Specialization in an activity would be discouraged if the market were very limited; thus, the incentive to specialize and to invest in oneself would increase as the extent of the market increased. Workers would be more skilled the larger the market, not only because "practice makes perfect," which is so often stressed in discussions of the division of labour, but also because a larger market would induce a greater investment in skills"*

The fragmentation of production under GVCs, gives rise to very fine division of labour and thus, larger gains from specialisation (Antras, 2020). Grossman and Rossi-Hansberg (2008) show that an increase in "trade in tasks" results in productivity benefits for all domestic factors including those whose tasks can be easily off-shored. They find that as the ease of trade in specific tasks increases, firms can benefit by performing only those tasks in which they are most efficient, while offshoring the rest. The Global Value Chain Development Report 2019, too, argues that value chains have been instrumental in increasing demand for skilled workers by allowing for specialisation across sectors and within sectors. A study by UNCTAD (2015) finds that the current global LED market is concentrated in four regions, each region specialising in production and development of special parts. Europe-America specialise in general lighting, Japan in backlit display, Korea and Taiwan in LED-monitor backlight and LED-TV backlight, and finally China which focuses on red, yellow, and green lights, outdoor display and advertising screen fields.

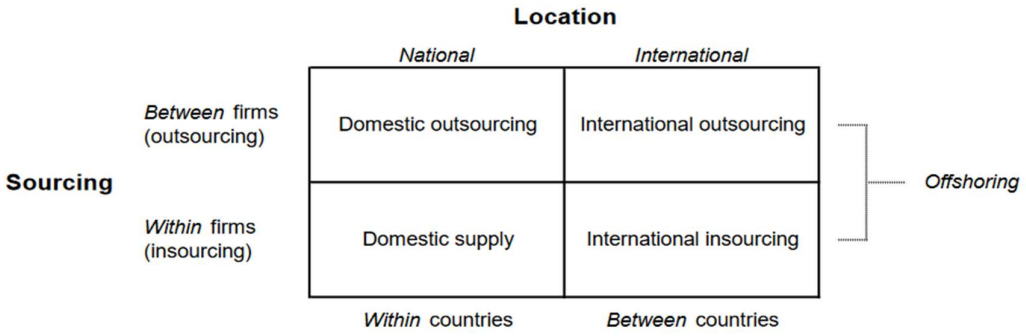
2.2. Knowledge diffusion

Knowledge diffusion from participation in GVCs can be direct or indirect. Explicit technology transfers take place when firms choose to transfer technology to their partners in other countries. This could be through FDI, offshoring, or through technology licensing. Indirect knowledge transfers can take place not only via FDI and offshoring, but also through knowledge embodied in imported inputs and capital goods.

2.3. FDI and outsourcing

Technology transfer through FDI, outsourcing and offshoring takes place when the investor firm or the larger firm has access to cutting edge technology and is willing to transfer it to its partners, subsidiaries, or suppliers in other countries. Although the terms outsourcing, and offshoring are used interchangeably, there are subtle distinctions between them (highlighted in Figure 1). The differences between the two terms come from the location of production and the ownership.

Figure 1: Matrix of Outsourcing, Insourcing and Offshoring



Source: Olsen, K. B. (2006). Productivity Impacts of Offshoring and Outsourcing. *OECD Science, Technology and Industry Working Papers*. doi:10.1787/685237388034

Outsourcing is when a firm sources its inputs from a different but related firm. Outsourcing can be done nationally or internationally. On the other hand, offshoring refers to the practice of shifting parts of production to a different location. Offshoring can be done within the firm or outside the firm. Within this matrix, the bottom right corner, within firm, international outsourcing captures vertical FDI.

Studies have found that spillovers that increase productivity take place when an MNC has backward linkages. In this case, the receivers of investment, experience upgradation as the lead firm willingly transfers technology to its suppliers (international outsourcing) or its partners (vertical FDI) (Alfaro, Kalemli-Ozcan, & Volosovych, 2014; Havranek and Irosva, 2011). FDI can also lead to transfer of soft skills such as management and organisational skills which can improve productivity in an enterprise (Arnold and Javorcik, 2009; Guadalupe, Kuzmina, and Thomas, 2012). There is also evidence for indirect technology transfer through FDI. One study shows a positive relationship between the level of foreign investment in a given city and firm productivity (Asia Pacific Trade and Investment Report, 2015), providing evidence for indirect, horizontal spillovers.

Moreover, the benefits from offshoring and outsourcing are not limited only to the receiving economies. The lead firms also gain from imports of cheap, better quality inputs while focusing on tasks, referred to as ‘core competences’ in which they are more efficient. A study by McKinsey Global institute (2005) found that firms in the US experienced significant cost savings from outsourcing some of their activities to India. These cost savings were then channelled into investments in the country. Similar findings were also reported by Grossman and Rossi-Hansberg (2005) in their model of offshoring.

2.4. R&D spill-overs

Indirect knowledge diffusion is also said to take place from those countries that tend to invest in R&D to other countries (Coe and Helpman, 1995, Coe, Helpman and Hoffmaister, 1997; Zhu and Jeon 2007; Helpman, 1997; Lumenga-Neso. Olarreaga, & Schiff, 2001). Coe and Helpman (1995) find that a country's total factor productivity depends on domestic and foreign R&D capital, where the diffusion of foreign R&D capital takes place through trade. In a subsequent paper, Coe et al (1997) find that a developing country can improve its productivity by importing intermediate and capital products which embody foreign knowledge, thereby gaining access to technology that would otherwise be difficult to obtain.

Although there is ample evidence for R&D knowledge spillovers, Keller (1998) shows evidence against international R&D spillovers. Funk (2001), on the other hand, finds that R&D spillovers do not take place through import of goods but rather through exports. On the other hand, Lee (2006) finds that spillovers through FDI are more robust and significant than spillovers through trade.

It is important to remember that knowledge diffusion and productivity improvement may depend on where you are relative to the technology frontier. Pahl and Timmer (2019) find that positive effects for the formal manufacturing sector from GVC participation are stronger when the gap with the global frontier is larger, as there is more knowledge to absorb. Rodrik (2012), too, finds evidence for catch up by lagging countries. On the other hand, Saia, Andrews and Albrizio(2015), Banh, Wingender and Gueye (2020) find that firms that are far from the frontier do not benefit as much from their participation in GVCs as they do not have the absorptive capacity.

2.5. Learning from exports, imports and GVCs

Productivity benefits need not always come from tangible sources. Learning as a result of exporting, importing, or being a part of GVCs can also induce productivity benefits. There is a vast literature that captures the learning and consequently productivity improvement that takes place as a result of exporting (also referred to as "Learning by Exporting") and importing (known as "Learning from Importing"). This learning is said to stem from formation of buyer-seller relationships through which there is increased knowledge about foreign markets, consumers, quality, exposure to better practices and technology (for instance, through higher quality inputs) as well as transfer of soft skills and technology (Baldwin and Gu, 2004; Guadalupe, Kuzmina, and Thomas, 2012). There is evidence that one need not even export to experience learning. Even the decision to begin exporting can induce learning as firms invest in new technology, causing productivity changes to occur (Alvarez and Lopez, 2005).

The extension of this applies to Global Value Chains. For instance, Montalbano et al, 2018 find that in Latin American and Caribbean countries, participation in GVCs offers potential for learning from exchanges and knowledge and technology flows, thereby increasing productivity. As per the UNESCAP report on Asia-Pacific Trade and Investment (2015), upgrading as a result of GVC participation can take place when producers from developing countries cater to international markets due to which they have producer goods for a large variety of consumers (not just domestic consumers) which requires them to emphasize quality and uniformity through international standards.

2.6. Trade in inputs

Studies have found that an increase in the variety of foreign inputs available can substantially increase productivity in an economy (Amiti and Konings, 2007; Topalova and Khandelwal, 2011; Halpern, Koren, and Szeidl, 2015). The availability of previously inaccessible inputs provides firms with additional opportunities for production, enabling them to either save on costs or upgrade the quality of their inputs (Criscuolo, Timmis, and Johnstone, 2015). Bas and Strauss-Kahn (2015) find that easing of restrictions on imports of inputs in China increased access to better quality inputs which helped in quality upgradation of their exports.

Another way in which input trade helps improve productivity is by increasing the competition in local markets (Topalova and Khandelwal, 2011; Pavcnik, 2002). Melitz and Ottaviano (2008) using a theoretical model show that trade liberalisation increases competition within a country which in turn raises aggregate productivity while lowering the probability of an individual firm's survival. However, this effect is felt disproportionately in the bigger countries. Pavcnik (2002) finds within plant productivity in Chilean manufacturers because of liberalised trade in the import competing sector. She attributes productivity improvements stemming from reshuffling of resources from less to more efficient producers.

Foreign inputs have other benefits as well. Goldberg et al (2010) find that tariff reduction on inputs increased access to new input varieties which resulted in many new products being introduced by the domestic firms. They are also influential in increasing exports (Kasahara and Lapham, 2013; Bas and Strauss Kahn, 2015).

It has been found that foreign inputs increase the skill level in an economy by promoting changes in the employment structure. Kasahara, Liang, and Rodrigue (2016) find that importing increases the relative demand for more educated workers in plants in Indonesia. This increased demand for skilled workers is seen within each occupation category. Similarly, Schady and Sanchez-Paramo (2003) find that trade intensity, especially import intensity, is significantly related to changes in the demand for skilled workers in five countries in Latin America. As per their study, the demand for skilled workers coincides

with a period when the import penetration, including that of capital goods, increased considerably in Latin America. Attanasio, Goldberg, and Pavcnik (2004), Meschi, Taymaz, and Vivrelli (2011), Araujo, Bogliacino and Vivarelli (2011), Pavcnik (2002) also find similar results in other countries. There is also evidence for positive association between offshoring and plant-level skill intensity (Becker at al, 2013; Feenstra and Hanson, 1996). Reijnders and Vries (2018) further find that technological change within GVCs increases the demand for non-routine (more skilled) jobs compared to the routine ones, with a strong effect of technological change that is biased against routine jobs.

Lastly, productivity improvements from trade in inputs also arises due to knowledge embodied in them. Capital goods that are imported can give rise to knowledge spillovers as workers who learn how to operate them can take their knowledge to other firms who will then acquire the same technology (Asia Pacific Trade and Investment Report, 2015). Innovations and productivity change due to imported inputs are also because imports of such inputs prompt reverse engineering and imitation in the importing countries (Beaulieu and Wan, 2016; Connolly, 2003).

According to the World Development Report 2020, the benefits from trade get magnified through participation in GVCs, which also includes the benefits from trade in inputs. Halpern, Koren, and Szeidl (2015) find that GVCs tend to provide access to competitively priced inputs as well as increased variety, which are important sources of productivity. Similarly, Tajoli and Felice (2018) show that involvement in GVCs, particularly by developing countries which import inputs from advanced economies, is positively related with a country's innovation

2.7. Problem of self-selection and endogeneity

The above discussion proves that there are productivity benefits from participating in trade, specifically GVCs. However, there is also a large literature that argues that productivity benefits from trade are due to a self-selection mechanism, i.e., only the most productive firms self-select into the export and import markets. For instance, Bernard and Jensen (1999), Agarwal and Barua (1994) find that it is the good firms that become exporters and future exporters already have excellent performance characteristics years before they begin exporting. It is argued that self-selection arises because of the existence of costs, such as transport costs or advertising expenses or other sunk costs, associated with exporting which only the more productive and profitable firms can bear (Bernard and Jensen, 1999 and 2004; Clerides, Lach and Tybout, 1998; Melitz, 2003; Delgado, Farinas, and Ruano, 2002). The same goes for import markets. Since only the most productive firms can bear the fixed cost of imports, it is only the most productive firms that import (Castellani, Serti and Tomasi, 2010; Muuls and Pisu, 2009; Vogel and Wagner, 2009). There is also evidence for self-selection into outsourcing and offshoring activities, i.e., firms that undertake these activities tend to be more productive before they enter the market (Fariñas,

López, and Martín- Marcos 2014; Fariñas and Martín-Marcos 2010; Kohler and Smolka 2014; Kohler and Smolka 2012; Tomiura 2007)

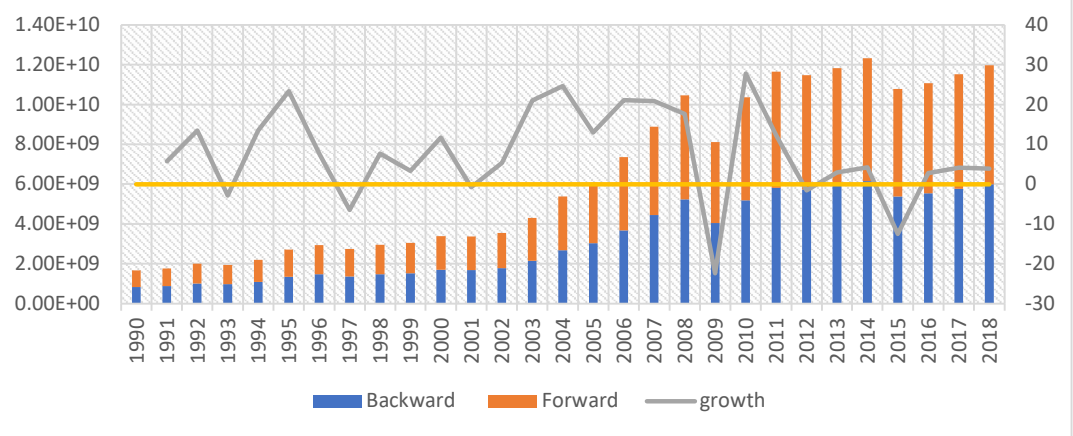
Moreover, learning from GVCs, and thus upgradation, is not automatic. There needs to be absorptive capacity and necessary investment for the flows to occur (Keller, 2004; Griffith et al, 2004; Sai, Andrews and Albrizio, 2015). Francis (2019) argues that "acquisitive, operative, adaptive and innovative capabilities" are necessary conditions required to bring out the positive spillovers as well as other dynamic gains from trade, GVCs, and FDI.

3. Trends and Recent Patterns

In Section 1, we discussed the changes in trade patterns that have taken place since the Information and Technology revolution and lowering of transport costs. These changes have contributed to a breakdown of production processes by reducing coordination and trade costs, thereby enabling the rise of GVCs. In this section, we review the trends to shed light on the changing nature of trade – specifically we look at evidence that shows increase in GVC participation, internationalisation of production, and increased reliance on foreign inputs.

Participation in GVCs is measured by adding up the Direct Domestic Value (DVX) added content of exports and FVA content of exports. The FVA content of exports is referred to as backward participation whereas DVX content represents forward participation. In Figure 2, we show the absolute GVC participation (and its composition) and its year-on-year growth. From the figure, we can observe a rise in GVC participation since 1990. The rate of growth of GVC participation has been positive in almost all years. However, a large dip in participation was seen in 2009 after which the growth of GVCs has also significantly slowed down.

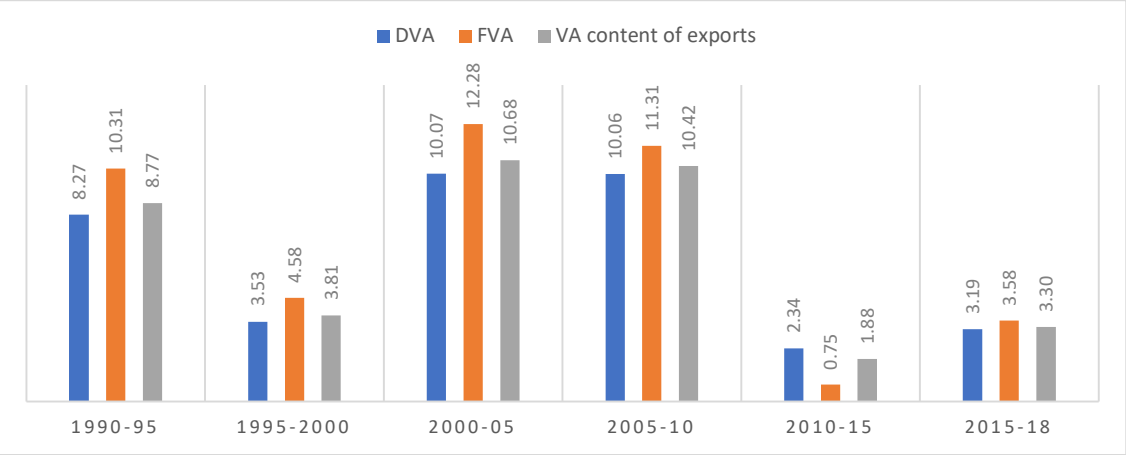
Figure 2: GVC participation and growth



Source: Authors' own calculations using UNCTAD-EORA Global Value Chains Database, https://worldmrio.com/unctadgvc/ (accessed August 10, 2020)

From the above figure, we see that backward participation has increased quite rapidly, indicating internalisation of production. In fact, backward participation has grown significantly faster than forward participation. This is reflected in Figure 3 which shows that in all periods, except the period immediately after the global financial crisis, FVA has grown faster than DVA and the total value-added content of exports. The rapid rise in FVA content of export was due to increased offshoring of production to emerging market economies, The opening up of countries such as China, India, Vietnam, and Bangladesh, made available to the world a large, cheap labour force that was previously inaccessible. Additionally, advances in communication technology and declining costs of offshoring meant that a larger number of firms could now take advantage of the cheap labour abroad. It was a combination of these factors that lead to the emergence of certain economies as the focal points of GVC-related activities. For instance, China was turned into the factory of the world while India became the world's back office (Gereffi and Sturgeon, 2013).

Figure 3: Growth of components of value-added (World)



Source: Authors' own calculations using UNCTAD-EORA Global Value Chains Database, https://worldmrio.com/unctadgvc/ (accessed August 10, 2020)

The rapid growth of FVA content compared to other value-added components of exports implies an increase in the share of FVA content. This is evident from Table 1. For all regions except Northern Africa, the share of FVA in 2018 was higher than in 1990. Although the share has increased in the last 30 years, there was a slight decline in the share for almost all regions around 2010.

Table 1: Share of FVA content of exports in total VA (%)

	1990	2000	2010	2018
Middle East	11.11	11.27	13.44	12.48
Central and Western Asia	19.62	26.5	26.95	26.10
Eastern Asia	19.33	19.10	24.07	21.64
Eastern Europe	18.31	28.94	30.00	29.37
Latin America and the Caribbean	14.30	22.27	19.29	20.48
Northern Africa	13.16	12.11	12.52	12.86
Northern America	12.66	16.8	18.1	17.67
Northern Southern and Western Europe	30.26	34.1	38.04	36.92
South-Eastern Asia and the Pacific	30.34	35.76	33.46	31.10
Southern Asia	8.3	9.23	12.46	12.48
Sub-Saharan Africa	12.13	14.05	13.74	14.04

Source: Authors' own calculations using UNCTAD-EORA Global Value Chains Database, https://worldmrio.com/unctadgvc/ (accessed August 10, 2020)

While a rise in FVA content is enough to signify the rising importance of foreign inputs in the production process, our earlier observations can be reiterated by looking at the growing importance of intermediate goods in the trade baskets of different regions.

Table 2: Share of intermediate exports in trade baskets

		1990	**2000**	**2010**	**2018**
Central and Western Asia	**Imports**	69.5	58.9	58.0	58.3
	Exports	43.9	61.6	64.8	61.8
East Asia	**Imports**	69.1	61.5	70.3	71.5
	Exports	43.1	48.4	48.5	52.1
South-East Asia and the Pacific	**Imports**	61.2	65.4	61.7	62.2
	Exports	67.1	62.8	68.4	62.3
South Asia	**Imports**	73.0	78.8	79.9	81.2
	Exports	53.8	62.0	59.1	47.4
Middle East	**Imports**	45.9	49.5	48.5	46.0
	Exports	92.4	88.2	86.2	66.4
North Africa	**Imports**		63.7	59.4	61.2
	Exports		65.8	80.7	55.7
Sub-Saharan Africa	**Imports**	51.2	53.1	50.2	49.7
	Exports	68.4	80.2	80.8	80.2
Eastern Europe	**Imports**		62.1	56.3	56.3
	Exports		67.7	60.9	57.5
Northern, Western, Southern Europe	**Imports**	54.1	52.4	53.7	53.6
	Exports	49.9	50.6	50.1	48.0
Latin America and the Caribbean	**Imports**	63.4	58.5	57.4	56.3
	Exports	71.7	57.7	63.8	60.0
North America	**Imports**	53.3	48.7	49.5	45.8
	Exports	68.2	60.0	59.9	59.4

Source: Authors' own calculation using the WITS dataset, https://wits.worldbank.org/ (accessed August 20, 2020)

As we can see from Table 2, intermediate goods constitute a majority share of the trade baskets of all regions. Moreover, we find that the shares have not been constant. For many regions, the share of these goods in their basket increased in the 1990s and 2000s but has come down in recent years. For instance, North and Latin America, as well as Middle East and North Africa saw the share of intermediates reduce in both, exports as well as imports. The decline in the shares of intermediate goods is consistent with the narrative that the growth of GVCs has slowed down in recent years. However, despite this slowdown, the large share of intermediates still shows that GVCs remain a dominant form of international trade and production.

Thus, in this section we have highlighted the fact that GVC participation and trade in intermediates have grown since the 1990s. Although there has been a decline in the last few years, trade in intermediate goods continues to occupy a large chunk of countries' exports baskets. Given the importance of GVCs and the role that intermediate goods play, our aim is to study the impact of participation in GVCs on intermediate exports sophistication. In the next section, we elaborate on the methodology as well as the data sources used for this purpose.

4. Data Sources and Methodology

To study the impact of GVC participation on productivity, we build on the methodology developed by Hausmann et al (2005). The authors of the paper construct an index to rank goods based on their implied productivity, which is then used to weigh the productivity level associated with a country's export basket.

The measure of implied productivity proposed, called PRODY, is a weighted average of the per capita incomes of all countries exporting the product, where the weights used are the relative comparative advantage of countries in the export of that commodity. The rationale for using RCA rather than shares is to ensure that the size of a country does not distort the ranking of goods. The higher the PRODY value of a commodity, the higher is its productivity surmised to be (Hausmann, Hwang, and Rodrik, 2006). This relation assumes that a good that is produced largely by rich countries would be more productive/sophisticated than a good that is predominantly produced by low income countries.

Using this productivity measure, the productivity or sophistication level associated with a country's export basket, called EXPY, is constructed. EXPY is a weighted average of the PRODYs where the weights are share of the product in a country's export basket. The formulae for the two indices and method of calculation are mentioned in Appendix A.

The sophistication index, EXPY, captures the implicit productivity of goods. When countries export a commodity, they reveal their productivity levels similar to the concept of revealed comparative

advantage. Thus, the measure does not directly determine the intrinsic features of a commodity (e.g., embedded technology, levels of R&D investment, etc.) but rather infers from the observed patterns of trade, the products which require greater levels of development to be exported (Jarreau and Poncent, 2012, Fortunato & Razo, 2014). Thus, EXPY is an implicit measure of the similarity of an export basket with that of the most developed countries. This method of measuring the sophistication of an export basket has gained traction not only because of the sound theoretical structure provided by the authors but also because of the careful empirical treatment.

In the present study, we use this methodology and apply it to trade in intermediate goods. The study, however, deviates from the Hausmann, Hwang, and Rodrik (2006) in two ways. First, although the formulae used to calculate the two indices remain the same, there is a slight change in the components. The modified PRODY formula ranks not all goods but only the intermediate goods. Second, EXPY measures only the sophistication of the intermediate export basket.

The distinction between intermediate goods and other goods is arrived at using Broad Economic Classification (BEC). BEC classifies all Standard International Trade Classification (SITC) goods under three broad components – Consumption goods, Intermediate goods, and Capital goods, which are further subdivided into 19 categories. This categorisation is then applied to Standard International Trade Classification (SITC) Revision 3 which itself groups products under 10 broad categories that are further subdivided. Hence, BEC assigns the SITC Rev 3 goods across 19 categories, of which 8 are intermediate goods.[2] BEC is generally applied to SITC goods at either the 4th or the 5th level of disaggregation. We stick to only the intermediate products from SITC groups 5 to 8. Group 5 consists of Chemicals, Groups 6 and 8 comprise of all manufactured goods whereas Group 7 is made up of machinery and transport equipment. Groups 0 to 4 are natural resource-based products (e.g., live animals, metals, minerals) and are excluded for the reason that easy access to natural resources by developed countries may be misinterpreted as those products having high productivity (e.g., exports of agriculture based intermediate goods by Canada will show up as highly productive thereby increasing the sophistication of low-income countries who may also export them).

Using the BEC classification has one major drawback – it is based on judgement by experts and hence has an element of subjectivity to it. For instance, there are several goods which are classified as both, intermediate goods as well as final consumption goods. For example, Yarn of jute is classified as an intermediate as well as a consumer good since it can be used by firms and households alike. It is difficult

[2] The eight categories are Food and Beverages, primary, mainly for industry; Food and Beverages, processed, mainly for industry; Industrial supplies n.e.s., primary; Industrial supplies n.e.s., processed; Fuels and Lubricants, Primary; Fuels and Lubricants, Processed (other than motor spirit); Parts and accessories of capital goods; Parts and accessories of transport equipment.

to estimate how much of Yarn of jute is used under each category. This difficulty can lead to an overestimation or underestimation of the intermediate export basket. Another problem of using the trade dataset is that exports are completely assigned to the exporting county. No account is made for the imported content of these exports. Despite these drawbacks, BEC is used as BEC classification and trade data allow us to have a finer level of disaggregation, which is not possible when using value added datasets such as TiVA, EORA and WIOD.

Second, Hausmann, Hwang, and Rodrik (2006) calculate EXPY separately for all years under consideration (1992-2003) by holding PRODY constant (PRODY was taken as an average of PRODYs for each good for three years – from 1999 to 2001). In this study, we do not hold the PRODY constant. Rather, we calculate the PRODY for all industries for each year from 1999 to 2018 and use the specific year PRODYs to arrive at the EXPY numbers for countries for the concerned year. The advantage of this change is that we do not just capture the change in the shares of each product in a country's export basket, but we also consider how the nature of products itself might change.

On the other hand, like the original paper, we restrict the number of countries to those which are constant across the 20 years under consideration. Thus, our sample set is 100 countries. The time-period has been restricted to the 20 years from 1999 to 2018 even though there is data available from 1988, as the number of countries available prior to 1999 reduces the sample size further.

Thus, our main variable is the sophistication of the intermediate export basket, or EXPY. We observe the changes in EXPY to see if since the beginning of the decade there has been an increase in the sophistication of the intermediate export basket of countries and to what extent sophistication may have been determined by participation in GVCs.

In the following section, we take a look at relevant descriptive statistics for the two indices before moving on to the empirical analysis.

5. Descriptive Statistics

As mentioned earlier, we apply BEC on SITC Rev.3. BEC classifies all SITC goods under three broad components – Consumption goods, Intermediate good and Capital goods. Ignoring the consumption goods and capital goods, we are left with approximately 1,450 products from groups 4 to 8. Appendix B, Table B1 shows the top 5 and bottom 5 ranked products in 3 years. A close look at the table shows that the bottom ranked products in all 3 years shown are mainly textiles. This reflects the high comparative advantage that low and middle-income, developing countries have in the textile industry. While the bottom ranked goods are largely homogenous, the top 5 show quite a bit of variety.

Although we find the overwhelming presence of processed metal products such as flat-rolled iron products, magnetic tapes, tin and alloy plates, as well as of electrical products such as phonograph records, electrical resistors and conductors, what is surprising is the existence of products such as Toys and wood based products in the top ranked products. This is because some high-income countries have very high RCA in them. For instance, Luxembourg's RCA in fibreboard of wood exceeds 100.

Table B2 shows the summary statistics for EXPY, excluding the 6 outlier countries. The six countries that consistently showed up as high-ranking outliers are Zambia, Barbados, Iceland, Luxembourg, Malta, and Gambia. These countries represent a combination of two very diverse groups – The first group consists of small but industrialised OECD countries of Luxembourg, and Iceland. On the other hand, the second set of countries are the very small, developing countries in Africa and Caribbean of Barbados, Malta, Zambia, and Gambia. The presence of smaller countries is because of their relatively narrow export baskets and concentration of high productivity goods. For instance, cathode values and tube form over half of Malta's export basket. Similarly, Zambia has a very high share of manufactured copper products such as refined copper, copper plates, and copper anodes for electrolytic refining. These products push up Zambia's EXPY values as these products are also produced in some high-income countries included in our analysis, such as Finland which has a relatively high share of copper plates in its export basket and Australia which has a relatively high share of refined copper. Similarly, for Gambia products of plywood constitute a large part of its export basket which also occupy a relatively significant share in the export baskets of New Zealand and Canada.[3] The exclusion of the six outlier countries reduces the sample size to 94 countries of which 41 are high income, 53 are middle and low income.

We find that on average, the EXPY values, i.e., sophistication of export baskets, have been increasing across all income groups. An interesting observation here is that in some years, the minimum EXPY values for middle- and low-income countries are higher than those of high-income countries. This is because of the presence of certain oil producing countries which are classified as high-income and whose exports of intermediate manufactures is low. Most countries in the sample have experienced an increase in EXPY values from 1999 to 2018. Only 22 out of the 94 countries show a decrease.[4] Of the countries that registered a decrease, 4 were high income whereas the rest were middle- and low-income countries.

Table B3 shows the top and bottom 5 countries based on EXPY for three years – 2000, 2005, and 2018. Here, an interesting observation can be made. The bottom ranked countries are quite similar to the top-

[3] Some of these products such as plywood, firewood, and refined copper do not exactly fall into the realm of high productivity goods. However, their prevalence in the export baskets of high-income countries pushes up their income content

[4] No outlier country shows a decline in its EXPY values

ranking outlier countries. They are small Caribbean and African nations (along with one oil producing country). While the outlier nations had a very high share of high PRODY industries, the export baskets of these countries are dominated by low PRODY goods. The top 5 nations, on the other hand, are a heterogenous group. Most of these top countries, for instance, Chile, Georgia, have a very large share of one or two high PRODY value goods in their basket. However, countries like Israel and Ireland, have a largely sophisticated overall basket.

Plotting EXPY against the income levels of countries (Appendix B, Figure B1), we find EXPY increases with income. We also see that some developing countries such as Chile, India, Ukraine, Israel perform very well compared to other countries with the same income levels. Figure 4 and B2 plots the average EXPY for individual countries as well as the mean EXPY for the twenty years under consideration. From the figures, we can see that it is generally the OECD countries that have performed better on average, along with countries like India and Chile. Israel and Iceland have been the best performers over the 20-year period whereas countries like Suriname, Sao Tome and Principe have been the worst performers.

Comparing our observations to Hausmann, Hwang, and Rodrik (2006) we find a few similarities as well as dissimilarities. First, they, too, found that small island and developing nations such as French Polynesia had very sophisticated export baskets due to dominance of a few high PRODY products. Additionally, industrialised nations such as Luxembourg and Iceland ranked highly even in their study. Their low-ranking countries also featured countries like Ethiopia and Burundi, which feature on our lists as well. However, by their analysis China was an over-achiever compared to other countries with same income group whereas Chile was an under-performing country. However, we find the converse to be true. This disparity creeps in because Hausmann, Hwang, and Rodrik (2006) calculated EXPY for all goods, final and intermediate, whereas we have restricted our export basket to only intermediate manufactures. It implies China has a basket that comprises of high PRODY final and primary goods whereas its intermediate goods are of lower sophistication, whereas Chile has a relatively sophisticated intermediate export basket but the income-value of its entire export basket is relatively lower.

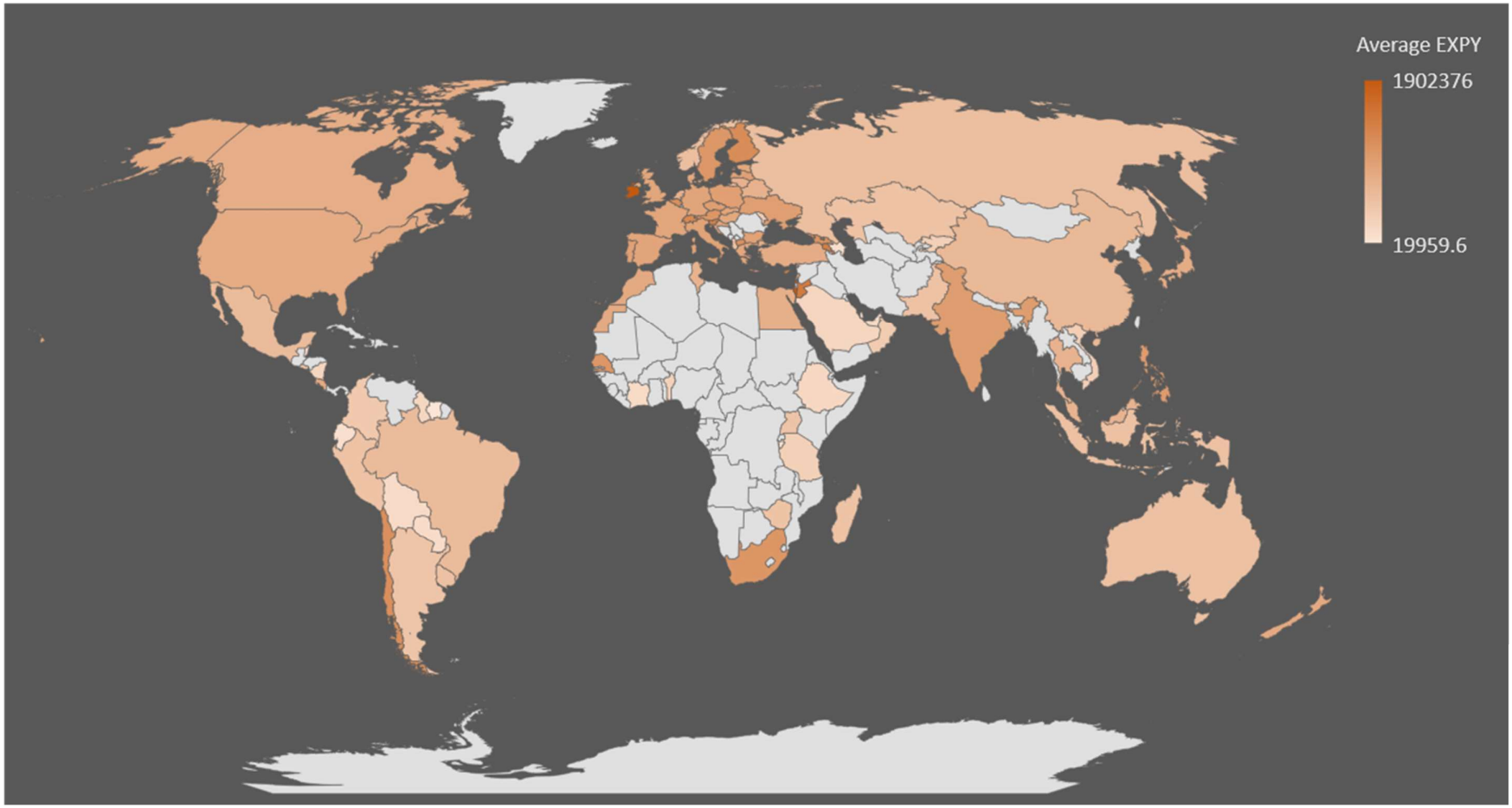
Next, we look at summary statistics of GVC participation indicators for our panel of countries (Table B4). There are three main participation indicators. The first is forward participation, defined as the DVX content of exports as a share of total VA. The second is backward participation, or the FVA content of exports as a share of total VA. The third indicator is total participation, which is a sum of forward and backward participation.[5] The trends here are similar to the trends we saw in Section 3 - mean

[5] Generally, participation indices are calculated as a share of gross exports. However, the size of the export basket can often distort the participation numbers (especially if the export baskets are too big or too small). To avoid this distortion, we use total value-added content of exports as the base.

participation in the GVCs (backward and forward) is higher in 2018 than it was in 2000. However, although there is an increase in participation, there was a slight fall around the global financial crisis. If we plot the indicators against the GDP per capita of the countries (Figure B3), we find that participation increases with income. The positive is more pronounced for backward participation, whereas for forward participation, the line is almost flat, i.e., although forward participation increases with GDP per capita, the absolute change in forward participation for a one per cent increase in GDP per capita is quite small or negligible. The relatively steep slope of backward participation on the other hand implies as countries develop, their reliance on intermediate imports increases.

In the next section, we try to determine the factors affecting the sophistication of intermediate exports. Our focus is on GVC participation and the extent to which integration in GVCs, whether forward or backward, can increase EXPY.

Figure 4: Average EXPY, 1999-2018



Source: Based on Authors' own calculations

6. Empirical Analysis and Discussion of Results

The brief review of literature in Section 2 gave us an overview of the channels through which GVC participation can increase productivity in the participating countries and firms. These channels can be divided into two groups – those that work through forward participation, and those that work through backward participation. Forward participation captures the "supply" side of GVCs and takes into account the DVA embodied in inputs exported for further processing. Forward participation in GVCs enhances productivity through scale effects, increase in specialisation, benefits from FDI inflows, especially if the parent company transfers soft skills as well as knowledge and production technology to its to its suppliers, as well as learning from exporting.

Backward participation, on the other hand, captures the "buyer" side of GVCs where countries import inputs for production of their exports. Backward participation channels that enhance productivity include access to embodied knowledge in foreign inputs, increased variety and availability of low cost, high quality inputs, changes in employment structure (increase the employment of skilled personnel), diffusion of technology and R&D, benefits from FDI and offshoring, especially if the parent company gains access to cost-effective inputs allowing it to focus on more skill-intensive tasks and learning from importing.

However, the extent of productivity benefits from either type of participation depends on several factors. First, it depends on an economy's location relative to the technology frontier. As highlighted earlier, there is debate whether a country that is far away from the frontier benefits more as there is more potential to absorb or one that is located closer to the frontier. Second, the benefits also depend on a country's absorptive capacity which is essentially determined by the quality of human capital.

Given the literature, we model EXPY as a function of the two types of participation, forward and backward, as well as the distance from frontier, and human capital. The distance from frontier is measured using the Economic Complexity Outlook Index (COI) from the growth lab at Harvard University.[6] Similarly, Human capital is measured using the Human Capital Index, the data for which was available from Penn World Tables.[7] We expect all these factors to, ceteris paribus, exert a positive effect on the sophistication of the intermediate export basket. However, distance from frontier can also exert a negative influence if being too close to the frontier hinders the additional productivity benefits that can be derived. As benefits from FDI are present under both backward and forward participation,

[6] COI measures the number of complex products near a country's current set of productive capabilities. A low value implies that only a few products are short distance away, making it difficult for the country to acquire the new know-how. Please refer to atlas.cid.harvard.edu for more details about the index and its calculation.
[7] The human capital index is based on the average years of schooling as well as an assumed rate of return to education estimated using the Mincer equation

we also include FDI (as a percentage of GDP) in our model. A positive sign for the FDI coefficient would imply that productivity benefits are derived from being a net lender, i.e., FDI outflows increase productivity. A negative sign would imply the opposite. The data for FDI (and GDP) was obtained from IMF's datasets. In addition to these main variables, we include three other variables. The first one is the Herfindahl-Hirschman (HH) Index of export market concentration which captures the size of the market for a country's exports.[8] We expect a negative impact of increased concentration on EXPY as a highly concentrated market would imply less division of labour and specialisation. The other two variables are policy related variables which capture the external policy (Trade Freedom) and internal policy (Fiscal Freedom) hurdles faced by businesses in an economy. As trade and fiscal freedoms increase, we expect EXPY to also increase. The data for HH index was taken from the WITS database while the Freedom Indices (fiscal and trade freedom) were taken from the Heritage Foundation's Index of Economic Freedom.[9] Our specification is similar to the one used by Kowalski et al (2015) wherein they measured the impact of sophistication of intermediate imports, backward participation, frontier distance, FDI inflows and several other variables such as the size of the economy on EXPY.

$$EXPY_{it} = \alpha + \beta_1 ForwardParticipation + \beta_2 BackwardParticipation + \beta_3 FrontierDistance + \beta_4 HumanCapital + \beta_5 FDI + \beta_6 HHindex + \beta_7 BTradeFreedom + \beta_8 FiscalFreedom + \beta_k CountryDummies + \varepsilon_{it}$$

We run the data for 79 countries[10] from 1999 to 2017[11] using the Least Squares Dummy Variables (LSDV) method for panel data. The advantage of using LSDV over fixed effects is that we can see the impact of country specific factors on EXPY. In order to counter any heteroscedasticity and autocorrelation in the data, the estimators were calculated using *Newey-West estimation*. Thus, the estimators obtained are robust.

[8] The HH index measures the dispersion of trade and ranges from 0 to 1. A country with few trade partners (high concentration) will have a value closer to 1, whereas a country with many trade partners will have an index value that is closer to 0.

[9] The Heritage Foundation and the Wall Street Journal measure Economic freedom using 12 quantitative and qualitative factors grouped into four categories. Each of the 12 factors (which includes Fiscal Freedom and Trade Freedom) are graded on a scale of 0-100

[10] Certain countries had to be dropped from analysis due to missing data

[11] The year 2018 was dropped from the analysis as data for certain variables such as Human capital was available only till 2017

Table 3: Variables and expected signs of the coefficients

Variable	Expected Coefficient	Reason
Forward Participation	Positive	Positive productivity impact due to scale effects, increase in specialisation, benefits from FDI inflows, learning from exporting.
Backward Participation	Positive	Positive productivity impact due increase in variety and availability of low cost, high quality inputs, changes in employment structure, diffusion of technology and R&D, benefits from FDI and offshoring, learning from exporting.
Frontier Distance	Positive	As a country gets closer to the frontier, it will have more absorptive capacity to derive productivity benefits
	Negative	A country that is too close to the frontier may not have enough information to absorb, reducing the additional productivity gains that can be derived
Human Capital	Positive	Human Capital increases the absorptive capacity of an economy, making it more likely that it will be able to the productivity benefits from participation
HH Index	Negative	Productivity benefits from specialisation require access to large markets. A highly concentrated export market would imply lower incentive to specialise and invest in division of labour
Trade Freedom	Positive	Trade freedom enables trade which has a positive impact on productivity
Fiscal Freedom	Positive	Fiscal freedom implies lower tax burden which results in more funds for investment

The regression output is shown in Appendix C, Table C1. The results of econometric analysis show that the coefficients of four of the five main variables are significant and positive. Backward participation is insignificant whereas Human capital has the strongest effect on EXPY, followed by distance from frontier. However, when we divide the panel into two groups based on income, we find that backward participation is positive and significant for the high-income countries but negative and insignificant for the middle- and low-income countries, whereas forward participation is significant for both groups of countries. We also find distance from frontier to be significant and positive, exerting the largest effect on the middle- and low-income countries. Human capital and FDI, on the other hand, are significant only for the high-income economies.

As expected, HH index is negative and significant for all sets of countries, with the largest effect for the high-income economies. Lastly, out of the two policy variables, trade freedom is significant for high as well as middle- and low-income economies, but fiscal freedom is only significant for the middle- and middle- and low-income economies.

In an extension to the model, we add lags of backward and forward participation. The regression output is shown in Table C2. We find that lags of backward participation are largely insignificant (except the second-period lag for high-income countries), whereas forward participation is significant but only for the middle- and low-income countries. The patterns of significance, and signs do not change for the other variables. FDI and HC still remain significant only for the high-income countries, fiscal freedom is significant for only middle- and low-income countries, whereas distance from frontier and HH is significant throughout.

7. Discussion of the Results

Backward participation, or an increase in foreign value-added content of exports, implies an increase in imports of intermediate goods. As was discussed earlier, imports of intermediate goods benefit an economy in various ways – from transfer of embodied knowledge to decreasing cost of production. In the case of developed countries, which tend to be close to the frontier and hubs of innovation, one can assume that benefits come from the latter half of the spectrum. This assumption is also validated by the positive and significant coefficient of FDI in our model which indicates that developed countries benefit from relocating parts of their production.

In recent years, we find that the share of intermediate imports from High-income countries, by both low- and high-income countries, has reduced. Appendix D, Figure D1 shows that since 1999, the share of intermediate imports of high-income from other high-income countries has reduced from a little over 70 per cent to 55 per cent in 2018. For middle- and low-income countries, the share fell to less than half over the same period.

By importing a larger share of intermediate goods from developing countries, high-income countries save on the cost of production which can be redirected towards investment. Grossman and Rossi-Hansberg (2008) refer to these as the productivity effects. Moreover, high-income countries not only save on the cost of production but can also benefit from redeploying their labour to more sophisticated tasks. However, the redeployment of labour requires that the workers, who performed tasks that are now carried abroad, have the capacity to move on to more specialised activities. The positive coefficient of the Human capital for high-income countries hints at this availability and importance of skill. Studies have provided evidence for change in the employment structure of the developed countries that takes place through offshoring of tasks. For instance, Reijnders and Vries (2018) find that relocation of tasks combined with technological change in GVCs contributed to a rise in the relative demand for non-routine work in advanced economies. On the other hand, in emerging economies, while technological change was still skill biased, relocation of tasks increased the relative demand for routine tasks.

Thus, the mechanisms which work in the favour of high-income countries do not seem to hold for the middle- and low-income countries for whom the coefficient of backward participation is insignificant and negative, while FDI and Human Capital, although positive, are insignificant. Evidence for the hypothesis that developing countries can improve their productivity by importing intermediate goods, thereby gaining access to embodied foreign knowledge, is missing from our results. This may be because of two reasons. First, as we can see in Figure D1, although the share of intermediate imports from high income countries has come down in recent years, it remains relatively high. To benefit from imports from high-income countries, there need to be in place mechanisms that facilitate the absorption of knowledge embodied in them. It is possible that lack of required human capital necessary for such absorption is acting as a hindrance to productivity enhancement. In our sample, the mean value of the HC index is 3.17 for the high-income countries whereas it is only 2.37 for the middle- and low-income countries. Figures D2 & D3, show us HC index values for some prominent developed and developing economies for the years 2000 and 2015, respectively. From the figures, we see that most of the prominent emerging economies lie far below the levels of the developed economies.

Second, many low-income countries tend to be on the low skill end of GVC participation. For instance, Kummritz and Quast (2016) show that developing countries are largely concentrated in downstream activities such as assembly activities. Downstream location essentially means that firms in developing countries rely more on direct transfer of knowledge from lead firms (i.e., from forward participation) rather than on imports.

Developing countries, thus, derive benefit from forward participation. Forward participation implies a larger export of intermediate goods. The benefits in this case range from increase in specialisation to direct transfer of technology by MNEs to learning from exporting. To integrate into the value chain as suppliers and to attract investment, the developing economies have to reduce barriers to trade and create a suitable business environment. Since the 1990s, developing countries have focussed on opening their economies by reducing tariff and non-tariff barriers. A 2011 report by UNCTAD notes that preferential trade policies with developed economies have been important determinants of the localisation of production process in the emerging economies. In the same light, Kowalski et al (2015) point out that trade and investment agreements in South East Asia, North America and Eastern Europe are linked to the proliferation of production networks in these regions. Several policies that encourage FDI, high local content levels, R&D and engineering investment in return for market investment that have been used by many countries such as China, India, and South Africa in order to influence outcomes in the process of GVC integration (Thun and Sturgeon, 2019).

In addition to trade policies, industrial, taxation and other economy-wide policies also play an important role. Gereffi and Sturgeon (2013) refer to these as “horizontal policies”. The latter include policies that

focus on education, infrastructure, health, and work force development. They enhance the quality of the workforce and serve to build national competitiveness and attract investors to a country. Tax incentives, and taxation structure are also included. This explains the positive and significant coefficient of fiscal freedom and trade freedom in emerging economies.

Since the 1990s, the flow of foreign direct investment to the developing countries has increased. The share of OECD economies in total FDI inflows has fallen from 85 per cent in the 1990s to close to 53 per cent in 2018. The share had even fallen below half around 2013-14 before rising a little. Although the share of FDI inflows to non-OECD countries has increased, the share of non-OECD countries in FDI outflows is still quite low and has hovered between 25 to 35 per cent in the last 10 years. The increase in FDI inflow to developing countries hints at possible transfer of technology to these economies. Policies such as local content requirements (often used by India and China), explicit requirements for technology transfer from foreign investors, use of joint establishment ventures in return for market access are some of the many techniques used by developing countries to take advantage of knowledge transfers through FDI. UNCTAD (2013) finds that benefits from FDI and technology transfer are real but not automatic. Policies that improve the links between international and local firms and establish an appropriate IPR framework are needed alongside the earlier mentioned policies to maximise the benefits from GVCs. There is also argument in the favour of vertical industrial policies (Francis, 2019; Gereffi and Sturgeon, 2013). Francis (2019) argues that in the absence of tariff protection in GVCs, industrial policies assume greater importance in enabling indigenous technology which are crucial in extracting the benefits from GVC participation and increased FDI and MNC presence.

Although we have discussed forward participation only for the middle- and low-income economies, the high-income economies too seem to be deriving benefits from it. As mentioned earlier, a large proportion of FDI flows are still dominated by the OECD economies, indicating that transfer of R&D and diffusion of knowledge takes place between high-income economies as well. This type of transfer has been documented by several studies (Coe and Helpman, 1995; Lichtenberg and van Pottelsberghe de la Potterie, 1998). In a recent paper, Coe, Helpman, and Hoffmaister (2009) show once again the existence of cointegration between total factor productivity, domestic and foreign R&D. They further find that factors such as ease of doing business, legal systems, IPR protection, quality of tertiary education are important factors determining the extent of benefit that can be derived from domestic and foreign R&D processes.

Next, we consider the impact of distance from the frontier on productivity and sophistication. A simple interpretation of results would suggest that as a country grows closer to the frontier, the higher is the sophistication of its basket. However, a look at the actual Complexity Outlook Index reveals that

countries with low values are not just economies which have narrow, less sophisticated export baskets. A country will also have a low rank if it is already too close to the frontier. Figure D4 shows the scatter plot of COI against GDPPC for 2000 and 2018, respectively. As can be seen from the figure, Germany, a technologically advanced country often considered to be the frontier, has the lowest COI value, and is accompanied by oil-producing countries such as Oman, Qatar, and Saudi Arabia at the bottom. This suggests that a simple prescription to increase production and exports of high-technology products will not be sufficient. Rather, the solution depends on a country's existing levels of technology. For countries such as Germany, the only way to increase productivity would be through innovation and invention of new products. However, countries such as Oman and Qatar can increase their productivity levels through either innovation or by introducing already existing, high sophistication products into their baskets.

Lastly, in the extension of the model with lags of backward and forward participation, it is clear that backward participation has only an immediate impact on intermediate export productivity while forward participation has a more longer-term impact. These findings make sense in the light of the above discussion. Backward participation, which largely involves imports of intermediate goods for further production, needs the presence of strong human capital to benefit but does not really require any other type of capacity building. On the other hand, forward participation requires the presence of laws, policies and IPR systems that can enable the participating countries to take advantage of participation. Receiving countries and firms also need time to absorb the direct and indirect technology transfer from FDI inflows. Thus, while backward participation has an immediate impact, forward participation can result in long term benefits.

8. Key insights

This paper tries to study the impact of participation in GVCs on the productivity of the intermediate export basket. Our aim is to see if participation in GVCs has a positive productivity relationship with the nature of this participation.

Our analysis reveals that growth in GVC participation has been very rapid since the 1990s, declining only after the global financial crisis. The impact of this increased participation on the sophistication of the intermediate export basket depends on the income levels of the economies. We find that while high-income countries benefit from both backward as well as forward participation, middle- and low-income countries derive their benefit only from forward participation. We attribute these differences to variations in the levels of human capital as well as the direction of FDI flows. We also find that as the distance from the frontier reduces, the productivity of the basket increases.

The findings have a number of policy implications for the way countries approach GVC integration and their external as well as internal policies. We focus our attention first on the developing countries. This set of countries benefits from forward participation. The latter is quite dependent on the activities of Multinational Corporations (MNCs) which are driven largely by profit motive. Hence, if countries wish to continue benefitting from forward participation, they will have to ensure that their economies remain attractive for such firms. This requires that attention be paid to industrial policies. Factors that improve ease of doing business, such as taxation, are of utmost importance here. Policies that enhance contact and communication between the MNCs and local firms as well as facilitate the transfer of technology, are important. Additionally, trade agreements have to be framed in order to encourage investment flows. This requires deep RTAs and not just ones that look at movement of goods. Moreover, horizontal policies that improve national competitiveness and absorption capacity cannot be ignored. This involves investment in health, infrastructure, labour force training and most importantly, education. These horizontal policies will not serve to improve the benefits that countries derive from forward participation but will also help in benefitting from backward participation. As we saw, imports from developed countries still form a large chunk of the import basket. Horizontal policies that improve the absorptive capacity of the developing economies will ensure that the countries can take advantage of the knowledge embodied in these imports and reduce reliance on direct technology transfers by MNCs. The latter also requires development of in-house innovation capacity, building of R&D centres and focus on STEM education.

Next, coming to the developed countries, we find that this set countries benefits from both backward as well as forward participation. However, the extent of benefit from backward participation is greater. The problem with backward participation is that although there is cost saving in production by importing inputs from other countries, there is likely to be labour displacement. Hence, these countries have to ensure that the displaced labour is being redeployed and absorbed in other economic activities and is not being left out of the workforce. An inability to do so will result in increased unemployment and discontent from GVC participation, followed by rising unrest in these economies. Thus, investment in skill development and human capital is just as important for the high-income countries as it is for the middle- and low-income economies. An additional challenge facing the high-income economies is that they are close to the technology frontiers. Hence, in order to increase their productivity, innovation is key. This requires huge investment in R&D as well as strong national innovation systems. Also, policies have to framed in a way that enable North-North transfer of technology. Ease of doing business, tertiary education and IPR regimes play an important role in this context.

Lastly, we have to consider some of the threats to GVC participation as well as the threats from participation in GVCs. As mentioned earlier, movement of production to developing countries means displacement of labour in the high-income economies, resulting in unemployment. The rise in

unemployment as well as increase in trade deficits (due to increased imports from certain developing countries) have generated a negative sentiment towards trade. Recent tariff wars and withdrawal from trade agreements endanger the progression of GVCs. Moreover, in recent years, advancement in automation technology has served to reduce the cost advantage of developing economies. For instance, introduction of Sewbots (short for sewing robots) threatens the jobs of low skill workers in countries such as Vietnam and Bangladesh. Further advances in automation technology may imply that MNCs would be less likely to shift their production centres to the low- and middle-income economies. Related to automation technology is the major threat to developing countries from GVC participation itself wherein such participation and increased flow of knowledge from developed to developing countries has meant that developing countries get access to the latest technology that may not be suited to their needs. Robbins (2003) puts forth the argument of "Skill Enhancing Trade". He argues that trade liberalisation has induced capital deepening in developing countries, thereby bringing about Skill Biased Technological Change. Acemoglu (1998) argues that through technology flows from North to South via trade, the skill biased technology that has been introduced in the North also diffuses to the South. This change as well the import of automation technology in developing countries with huge populations can result in rising unemployment, poverty and falling standards of living.

In summary, our findings confirm the fact that GVC participation contributes to the sophistication of intermediate manufactured exports. However, the significance of the channels varies depending on the income and human capital levels of a country, where it lies relative to the technology frontier, and its market characteristics. The main takeaway from this analysis is that countries must maintain open trade and FDI policies, invest in human capital and innovation, and create a conducive business environment if they are to leverage GVC participation and derive the associated benefits.

References

Acemoglu, D. (1998). Why Do New Technologies Complement Skills? Directed Technical Change and Wage Inequality. *The Quarterly Journal of Economics, 113*(4), 1055-1089. doi:10.1162/003355398555838

Agarwal, M., & Barua, A. (1994). Effects of entry in a model of oligopoly with international trade. *The Journal of International Trade & Economic Development, 3*(1), 1-13. doi:10.1080/09638199400000001

Alfaro, L., Kalemli-Ozcan, S. and Volosovych, V. (2014), Sovereigns, Upstream Capital Flows, And Global Imbalances. *Journal of the European Economic Association*, 12: 1240-1284. doi:10.1111/jeea.12106

Alvarez, R., & Lopez, R. A. (2005). Exporting and performance: Evidence from Chilean plants. *Canadian Journal of Economics/Revue Canadienne D'economique, 38*(4), 1384-1400. doi:10.1111/j.0008-4085.2005.00329.x

Amiti, M., & Konings, J. (2007). Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia. *American Economic Review, 97*(5), 1611-1638. doi:10.1257/aer.97.5.1611

Andersson, M., Lööf, H., & Johansson, S. (2008). Productivity and International Trade: Firm Level Evidence from a Small Open Economy. *Review of World Economics, 144*(4), 774-801. doi:10.1007/s10290-008-0169-5

Antràs, P. (2020). Conceptual Aspects of Global Value Chains. *The World Bank Economic Review, 34*(3), 551-574. doi:10.1093/wber/lhaa006

Araújo, B. C., Bogliacino, F., & Vivarelli, M. (2011). Technology, trade and skills in Brazil: Evidence from micro data. *CEPAL Review, 2011*(105), 157-171. doi:10.18356/0266379b-en

Arnold, J. M., & Javorcik, B. S. (2009). Gifted kids or pushy parents? Foreign direct investment and plant productivity in Indonesia. *Journal of International Economics, 79*(1), 42-53. doi:10.1016/j.jinteco.2009.05.004

Attanasio, O., Goldberg, P., & Pavcnik, N. (2004). Trade Reforms and Wage Inequiality in Colombia. *Journal of Development Economics,* 331-366. doi:10.3386/w9830

Baldwin, J. R., & Gu, W. (2004). Trade Liberalization: Export-Market Participation, Productivity Growth and Innovation. *SSRN Electronic Journal*. doi:10.2139/ssrn.1375644

Baldwin, R (2006). "Globalisation: The Great Unbundling(s)", *Economic Council of Finland* 20(3): 5-47.

Banga, R (2013): "Measuring Value in Global Value Chains", UNCTAD, Background Paper, RVC-8 https://unctad.org/en/PublicationsLibrary/ecidc2013misc1_bp8.pdf

Banh, H., Wingender, P., & Gueye, C. (2020). Global Value Chains and Productivity. *IMF Working Papers, 20*(117). doi:10.5089/9781513542300.001

Bas, M., & Strauss-Kahn, V. (2015). Input-trade liberalization, export prices and quality upgrading. *Journal of International Economics, 95*(2), 250-262. doi:10.1016/j.jinteco.2014.12.005

Beaulieu, E., & Shan Wan, S. (2016). "International Technology Diffusion via Goods Trade: Theory and Evidence from China," *Working Papers 2016-38,* Department of Economics, University of Calgary.

Becker, G. S. (1964). Investment in Human Capital: Rates of Return. In *Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education, First Edition* (pp. 37-66). NBER.

Becker, S. O., Ekholm, K., & Muendler, M. (2013). Offshoring and the onshore composition of tasks and skills. *Journal of International Economics, 90*(1), 91-106. doi:10.1016/j.jinteco.2012.10.005

Bernard, A. B., & Jensen, J. B. (1999). Exceptional exporter performance: Cause, effect, or both? *Journal of International Economics, 47*(1), 1-25. doi:10.1016/s0022-1996(98)00027-0

Bernard, A. B., & Jensen, J. B. (2004). Why Some Firms Export. *Review of Economics and Statistics, 86*(2), 561-569. doi:10.1162/003465304323031111

Casella, B., Bolwijn, R., Moran, D., & Kanemoto, K. (2019). UNCTAD insights: Improving the analysis of global value chains: The UNCTAD-Eora Database. *Transnational Corporations, 26*(3), 115-142. doi:10.18356/3aad0f6a-en

Castellani, D. (2002). Export behavior and productivity growth: Evidence from Italian manufacturing firms. *Weltwirtschaftliches Archiv, 138*(4), 605-628. doi:10.1007/bf02707654

Castellani, D., Serti, F., & Tomasi, C. (2010). Firms in International Trade: Importers' and Exporters' Heterogeneity in Italian Manufacturing Industry. *World Economy, 33*(3), 424-457. doi:10.1111/j.1467-9701.2010.01262.x

Clerides, S. K., Lach, S., & Tybout, J. R. (1998). Is Learning by Exporting Important? Micro-Dynamic Evidence from Colombia, Mexico, and Morocco. *The Quarterly Journal of Economics, 113*(3), 903-947. doi:10.1162/003355398555784

Coe, D., & Helpman, E. (1995). International R&D Spillovers. *European Economic Review*. doi:10.3386/w4444

Coe, D. T., Helpman, E., & Hoffmaister, A. W. (1997). North-South R & D Spillovers. *The Economic Journal, 107*(440), 134-149. doi:10.1111/1468-0297.00146

Coe, D. T., Helpman, E., & Hoffmaister, A. W. (2009). International R&D spillovers and institutions. Retrieved from https://www.sciencedirect.com/science/article/pii/S0014292109000348
Connolly, M. (2003). The dual nature of trade: Measuring its impact on imitation and growth. *Journal of Development Economics, 72*(1), 31-55. doi:10.1016/s0304-3878(03)00067-1

Criscuolo, C., Timmis, J., and Johnstone, N. (2016), "The Relationship between GVCs and Productivity", Background Paper to the 2016 Conference of the Global Forum on Productivity.

De Loecker, J. (2007). Do exports generate higher productivity? Evidence from Slovenia. *Journal of International Economics, 73*(1), 69-98. doi:10.1016/j.jinteco.2007.03.003

Delgado, M. A., Fariñas, J. C., & Ruano, S. (2002). Firm productivity and export markets: A non-parametric approach. *Journal of International Economics, 57*(2), 397-422. doi:10.1016/s0022-1996(01)00154-4

Farrell, D., Laboissière, M., Pascal, R., Rosenfeld, J., De Segundo, C., Stürze, S. (2005). *The Demand for Offshore Talent in Services* (Rep.). McKinsey Global Institute.

Fariñas, J. C., & Martín-Marcos, A. (2010). Foreign Sourcing and Productivity: Evidence at the Firm Level. *World Economy, 33*(3), 482-506. doi:10.1111/j.1467-9701.2010.01264.x

Fariñas, J. C., López, A., & Martín-Marcos, A. (2016). Sourcing strategies and productivity: Evidence for Spanish manufacturing firms. *BRQ Business Research Quarterly, 19*(2), 90-106. doi:10.1016/j.brq.2015.08.002

Feenstra, R., & Hanson, G. (1996). Globalization, Outsourcing, and Wage Inequality. *American Economic Review, 86*(2), 240-245. doi:10.3386/w5424

Feenstra, R. C., Robert, I. & Marcel, T.P. (2015). The Next Generation of the Penn World Table. *American Economic Review, 105(10),* 3150-3182, retrieved from: www.ggdc.net/pwt

Fortunato, P., & Razo, C. (2014). Export sophistication, growth and the middle-income trap. In *Transforming economies* (pp. 267-284). International Labour Organisation.

Francis, S. (2019). *Industrial policy challenges for India global value chains and free trade agreements*. London: Routledge.

Funk, M. (2001). Trade and International R&D Spillovers among OECD Countries. *Southern Economic Journal, 67*(3), 725. doi:10.2307/1061461

Gereffi, G., & Sturgeon, T. (2013). Global value chain-oriented industrial policy: The role of emerging economies. In *Global value chains in a changing world* (pp. 329-360). Geneva: WTO Publications

Global Value Chains, Technology Transfers and innovation. (2015). In *Asia-pacific trade and investment report 2015: Supporting participation with value chains.* (pp. 147-161).

Goldberg, P. K., Khandelwal, A. K., Pavcnik, N., & Topalova, P. (2010). Imported Intermediate Inputs and Domestic Product Growth: Evidence from India. *The Quarterly Journal of Economics, 125*(4), 1727-1767. doi:10.1162/qjec.2010.125.4.1727

Grossman, G. M., & Rossi-Hansberg, E. (2008). Trading Tasks: A Simple Theory of Offshoring. *American Economic Review, 98*(5), 1978-1997. doi:10.1257/aer.98.5.1978

Guadalupe, M., Kuzmina, O., & Thomas, C. (2010). Innovation and Foreign Ownership. doi:10.3386/w16573

Halpern, L., Koren, M., & Szeidl, A. (2015). Imported Inputs and Productivity. *American Economic Review, 105*(12), 3660-3703. doi:10.1257/aer.20150443

Hausmann, R., Hwang, J., & Rodrik, D. (2006). What you export matters. *Journal of Economic Growth, 12*(1), 1-25. doi:10.1007/s10887-006-9009-4

Havranek, T., & Irsova, Z. (2011). Estimating vertical spillovers from FDI: Why results vary and what the true effect is. *Journal of International Economics, 85*(2), 234-244. doi:https://doi.org/10.1016/j.jinteco.2011.07.004

Helpman, E. (1997). R&D and Productivity: The International Connection. *NBER Working Papers* 6101, National Bureau of Economic Research, Inc.

Heritage Foundation (Washington, D.C.), & Wall Street Journal (Firm). (1995). *The index of economic freedom*. Washington, D.C: Heritage Foundation.

Jarreau, J., & Poncet, S. (2012). Export sophistication and economic growth: Evidence from China. *Journal of Development Economics, 97*(2), 281-292. doi:10.1016/j.jdeveco.2011.04.001

Kasahara, H., & Lapham, B. (2013). Productivity and the decision to import and export: Theory and evidence. *Journal of International Economics, 89*(2), 297-316. doi:10.1016/j.jinteco.2012.08.005

Kasahara, H., Liang, Y., & Rodrigue, J. (2016). Does importing intermediates increase the demand for skilled workers? Plant-level evidence from Indonesia. *Journal of International Economics, 102*, 242-261. doi:10.1016/j.jinteco.2016.07.008

Keller, W. (1998). Are International R&D Spillovers Trade-Related? Analyzing Spillovers Among Randomly Matched Trade Partners. *European Economic Review, 42*(8), 1469-1481. doi:10.3386/w6065

Kohler, W. K., & Smolka, M. (2012). Global Sourcing: Evidence from Spanish Firm-Level Data. *World Scientific Studies in International Economics Quantitative Analysis of Newly Evolving Patterns of International Trade,* 139-193. doi:10.1142/9789814383486_0004

Kohler, W., & Smolka, M. (2014). Global sourcing and firm selection. *Economics Letters, 124*(3), 411-415. doi:10.1016/j.econlet.2014.06.031

Kowalski, P., Lopez-Gonzalez, J., Ragoussis, A., & Ugarte, C. (2015). Participation of Developing Countries in Global Value Chains: Implications for Trade and Trade-Related Policies. *OECD Trade Policy Papers*. doi:10.1787/5js33lfw0xxn-en

Kummritz, V., & Quast, B. (2017, February 25). Global value chains in developing economies. Retrieved from https://voxeu.org/article/global-value-chains-developing-economies

Lee, G. (2006). The effectiveness of international knowledge spillover channels [Abstract]. *European Economic Review, 50*(8), 2075-2088. doi:10.1016/j.euroecorev.2005.10.001

Lichtenberg, F. R., & Van Pottelsberghe De La Potterie, B. (1998). International R&D spillovers: A comment. *European Economic Review, 42*(8), 1483-1491. doi:10.1016/s0014-2921(97)00089-5

Lumenga-Neso, O., Olarreaga, M., & Schiff, M. (2001). On “Indirect” Trade-related R&D Spillovers. *European Economic Review*. 49. 1785-1798. 10.1016/j.euroecorev.2004.06.004.

Melitz, M. J. (2003). The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. *Econometrica, 71*(6), 1695-1725. doi:10.1111/1468-0262.00467

Melitz, M. J., & Ottaviano, G. (2008). Market Size, Trade, and Productivity. *Review of Economic Studies 75,* 295-316.

Meschi, E., Taymaz, E., & Vivarelli, M. (2011). Trade, technology and skills: Evidence from Turkish microdata. *Labour Economics, 18*. doi:10.1016/j.labeco.2011.07.001

Miroudot, S., R. Lanz and A. Ragoussis (2009), "Trade in Intermediate Goods and Services", *OECD Trade Policy Papers*, No. 93, OECD Publishing, Paris, https://doi.org/10.1787/5kmlcxtdlk8r-en.

Muûls, M., & Pisu, M. (2009). Imports and Exports at the Level of the Firm: Evidence from Belgium. *World Economy, 32*(5), 692-734. doi:10.1111/j.1467-9701.2009.01172.x

Olsen, K. B. (2006). Productivity Impacts of Offshoring and Outsourcing. *OECD Science, Technology and Industry Working Papers*. doi:10.1787/685237388034

Örgün, B. O. (2014). GVCs Participation as Development Strategy. *Procedia - Social and Behavioral Sciences, 150*, 1287-1296. doi:10.1016/j.sbspro.2014.09.145

Pahl, S., & Timmer, M. P. (2019). Patterns of vertical specialisation in trade: Long-run evidence for 91 countries. *Review of World Economics, 155*(3), 459-486. doi:10.1007/s10290-019-00352-3

Pavcnik, N. (2002). Trade Liberalization, Exit, and Productivity Improvements: Evidence from Chilean Plants. *The Review of Economic Studies, 69*(1), 245-276. doi:10.1111/1467-937x.00205

Raei, F., Ignatenko, A., & Mircheva, B. (2019). Global Value Chains. *IMF Working Papers, 19*(18), 1. doi:10.5089/9781484392928.001

Reenen, J. V., Redding, S., & Griffith, R. (2000). Mapping the two faces of R&D: Productivity growth in a panel of OECD industries. *Working Paper Series*. doi:10.1920/wp.ifs.2000.0002

Reijnders, L. S., & Vries, G. J. (2018). Technology, offshoring and the rise of non-routine jobs. *Journal of Development Economics, 135*, 412-432. doi:10.1016/j.jdeveco.2018.08.009

Robbins, D. J. (2003). *The impact of trade liberalization upon inequality in developing countries: A review of theory and evidence.* Bogotá: Pontificia Universidad Javeriana.

Rodrik, D. (2012). Unconditional Convergence in Manufacturing*. *The Quarterly Journal of Economics, 128*(1), 165-204. doi:10.1093/qje/qjs047

Saia, A., Andrews, D., & Albrizio, S. (2015). Productivity Spillovers from the Global Frontier and Public Policy. *OECD Economics Department Working Papers*. doi:10.1787/5js03hkvxhmr-en

Sánchez-Páramo, C., & Schady, N. (2003). Off and Running? Technology, Trade, and the Rising Demand for Skilled Workers in Latin America. *Policy Research Working Papers*. doi:10.1596/1813-9450-3015

Tajoli, L., & Felice, G. (2018). Global Value Chains Participation and Knowledge Spillovers in Developed and Developing Countries: An Empirical Investigation. *The European Journal of Development Research, 30*(3), 505-532. doi:10.1057/s41287-017-0127-y

Technological innovation, supply chain trade, and workers in a globalized world: Global value chains development report 2019. (2019). Washington, DC: World Trade Organization.

The Growth Lab at Harvard University. The Atlas of Economic Complexity. http://www.atlas.cid.harvard.edu.

Thun, E., & Sturgeon, T. (2019). When Global Technology Meets Local Standards. *Policy, Regulation and Innovation in Chinas Electricity and Telecom Industries,* 177-220. doi:10.1017/9781108645997.005

Tomiura, E. (2007). Foreign outsourcing, exporting, and FDI: A productivity comparison at the firm level. *Journal of International Economics, 72*(1), 113-127. doi:10.1016/j.jinteco.2006.11.003

Topalova, P., & Khandelwal, A. (2011). Trade Liberalization and Firm Productivity: The Case of India. *Review of Economics and Statistics, 93*(3), 995-1009. doi:10.1162/rest_a_00095

UNCTAD (2011). Global Value Chains: Preliminary evidence and policy issues.
UNCTAD (2011): *Integration of developing countries in global supply chains, including through adding value to their exports*. (2011, March 25). Retrieved https://unctad.org/system/files/official-document/cid16_en.pdf

UNCTAD (2013). *World Investment Report 2013- Global Value Chains: Investment and Trade for Development.* United Nations publication. New York and Geneva

UNCTAD (2015). *Tracing the Value Added in Global Value Chains: Product-Level Case Studies in China.* United Nations publication. Geneva.

Van Biesebroeck, J. (2005). Exporting raises productivity in sub-Saharan African manufacturing firms. *Journal of International Economics, 67*(2), 373-391. doi:10.1016/j.jinteco.2004.12.002

Vogel, A., & Wagner, J. (2009). Higher productivity in importing German manufacturing firms: Self-selection, learning from importing, or both? *Review of World Economics, 145*(4), 641-665. doi:10.1007/s10290-009-0031-4

World Developemt Report 2020: Trading for Development in the Age of Global Value Chains. (2019). doi:10.1596/978-1-4648-1457-0

Zhu, L., & Jeon, B. N. (2007). International R&D Spillovers: Trade, FDI, and Information Technology as Spillover Channels. *Review of International Economics, 15*(5), 955-976. doi:10.1111/j.1467-9396.2007.00691.x

Appendix A

Calculation of Indices

As discussed in Section 4, we use the methodology developed by Hausmann, Hwang, Rodrik (2006) to arrive at the income/productivity level associated with a country's export basket. The authors calculate two indices, PRODY and EXPY, for this purpose. PRODY, the measure of applied productivity/sophistication of a good is a weighted average of the per capita incomes of all countries exporting the product. The weights used are the relative comparative advantage of countries in the export of that commodity. The formula for PRODY is given below.

$$PRODY_k = \sum_j \frac{x_{jk}/X_j}{\sum_j (x_{jk}/X_j)} Y_j$$

Y_j is the GDP per capita (2010 USD) of country j, k is the product, x_{jk} is the export of manufacturing good k by country j and X_j is the overall manufacturing export basket of country j.

EXPY, the productivity or sophistication level associated with a country's export basket, is the weighted average of the PRODYs. Here, the weights are share of the product in a country's export basket.

$$EXPY_j = \sum_k \frac{x_{jk}}{X_j} PRODY_k$$

A country is said to have a highly sophisticated export basket (or intermediate export basket) if it exports (intermediate) goods with higher PRODY values, i.e., it exports (intermediate) goods that are largely exported by the higher income countries.

An example showing the calculation of the two indices is provided below. For this example, we assume that the world has 5 countries, A, B, C, D and E., and there are only 5 products U, V, W, X, V, and Z. Each country may or may not export each product. The country's GDPPC as well as its exports of each of the products to the world are shown in the tables below.

Table A1: GDPPC of the countries, Year 1

	Country A	Country B	Country C	Country D	Country E
GDPPC ($)	25,000	20,000	15,000	10,000	5,000

Table A2: Product-wise exports of the countries, Year 1

	Country A	Country B	Country C	Country D	Country E	World
V	70,000.00	32,000.00	60,000.00	10,000.00	22,000.00	1,94,000.00
W	21,000.00	45,000.00	12,000.00	32,000.00	61,000.00	1,71,000.00
X	9,000.00	2,100.00	6,000.00	23,000.00	17,000.00	57,100.00
Y	13,500.00	0	75,000.00	500.00	2,000.00	91,000.00
Z	12,000.00	65,000.00	38,000.00	66,450.00	22,000.00	2,03,450.00
Total	1,25,500.00	1,44,100.00	1,91,000.00	1,31,950.00	1,24,000.00	7,16,550.00

As can be seen from the first table, Country A's GDPPC is the highest whereas the Country E's GDPPC is the lowest. In Table A2, we see that Country C has the highest exports whereas country E has the lowest. The RCA of each country in each of the 5 goods is shown in Table A3.

Table A3: Relative Comparative Advantage

	Country A	Country B	Country C	Country D	Country E
V	2.06	0.82	1.16	0.28	0.66
W	0.70	1.31	0.26	1.02	2.06
X	0.90	0.18	0.39	2.19	1.72
Y	0.85	0.00	3.09	0.03	0.13
Z	0.34	1.59	0.70	1.77	0.62

To calculate PRODY for each good, we multiply the RCA of each country with the GDPPC of the country and add the products. An example is shown in the following equation and the PRODY values for the other goods are given in Table A4.

$$PRODY_V = 25000 * 2.06 + 20000 * 0.82 + 15000 * 1.16 + 10000 * 0.28 + 5000 * 0.66$$
$$= 91{,}388.14$$

Table A4: PRODY values ($) and Ranking of the goods

	V	W	X	Y	Z
PRODY	91,388.14	68,119.08	62,545.22	68,488.27	71,564.62
Rank	1	4	5	3	2

As is clear from Table A4, good V ranks the highest as Country A, which is the richest of all countries, has a relative comparative advantage in it. On the other hand, goods W and X, the goods in which Country E has a relative advantage, rank the lowest.

Table A5: Share of goods in the countries' export baskets

	Country A	Country B	Country C	Country D	Country E
V	0.56	0.22	0.31	0.08	0.18
W	0.17	0.31	0.06	0.24	0.49
X	0.07	0.01	0.03	0.17	0.14
Y	0.11	0.00	0.39	0.00	0.02
Z	0.10	0.45	0.20	0.50	0.18

We take the product of the shares of the good in a country's basket and the PRODY value for the respective good and sum of the products to arrive at the EXPY values for each country. The following equation calculates the index for country A and the EXPY values for all countries are given the following Table.

$$EXPY_A = 0.56 * 91388.14 + 0.17 * 68119.08 + 0.07 * 62545.22 + 0.11 * 68488.27 + 0.10 * 71564.62 = 81{,}067.29$$

Table A6: EXPY values ($) and ranking of the countries

	A	B	C	D	E
EXPY	81,067.29	74,759.37	76,084.11	70,647.56	72,100.57
Rank	1	3	2	5	4

The above Table shows that the ranking of countries based on the sophistication of their export baskets is not the same as the ranking based on GDPPC. The sophistication of export baskets depends on the share of high and low productivity goods. For instance, although country E has the lowest GDPPC, and a high share of low PRODY goods compared to country D, it has relatively high share of the high PRODY good V.

Appendix B

Table B1: Top and Bottom 5 products ranked based on PRODY

2000	2010	2018
Top 5		
Fibreboard of wood or other ligneous materials, of a density exceeding 0.35 g/cm3 but not exceeding 0.50 g/cm3	Magnetic tapes, recorded, of a width exceeding 4 mm but not exceeding 6.5 mm, for sound or image	Non-driving axles and parts thereof for tractors, motor cars and other motor vehicles, etc.
Iron and nonalloy steel flat-rolled products, plated or coated with aluminium, not under 600 mm wide	Phonograph records, recorded	Toys, n.e.s.
Iron and steel sheet piling, welded angles, shapes, and sections	Tin and tin alloy plates, sheets, and strip over .2 mm thick	Electric conductors, for a voltage not exceeding 80 volts, n.e.s.
Wire-wound electrical variable resistors (including rheostats and potentiometers)	Magnetic tapes for sound recording or similar recording of other phenomena, of a width exceeding 4 mm but not exceeding 6.5 mm	Parts of electrical apparatus for line telephony or line telegraphy (including apparatus for carrier-current line systems)
Cermets and articles thereof (including waste and scrap)	Magnetic tapes, recorded, of a width exceeding 6.5 mm, for sound or image	Plywood, n.e.s., veneered panels and similar laminated wood with at least one outer ply of non-coniferous wood
Bottom 5		
Tin and tin alloy tubes, pipes and tube or pipe fittings (e.g. couplings, elbows, and sleeves)	Woven pile fabrics of manmade fibres, uncut (other than narrow or special fabrics)	Woven fabrics of vegetable textile fibres, n.e.s.; woven fabrics of paper yarn
Calcium, strontium, and barium; rare earth metals, scandium, and yttrium, whether not intermixed or inter-alloyed	Artificial flowers, foliage or fruit and articles and parts thereof, of plastics	Viscose rayon yarn, n.e.s. (no sewing thread), single, not over 120 turns per meter if twisted, not packaged for retail sale
Silk yarn, spun from silk waste, not packaged for retail sale	Fireworks	Ammonium chloride
Camphor	Woven fabrics of vegetable textile fibres, n.e.s.; woven fabrics of paper yarn	Artificial flowers, foliage or fruit and articles and parts thereof, of plastics
Selenium, tellurium, phosphorus, arsenic and boron	Silk yarn, spun from silk waste, not packaged for retail sale	Television picture tubes, colour

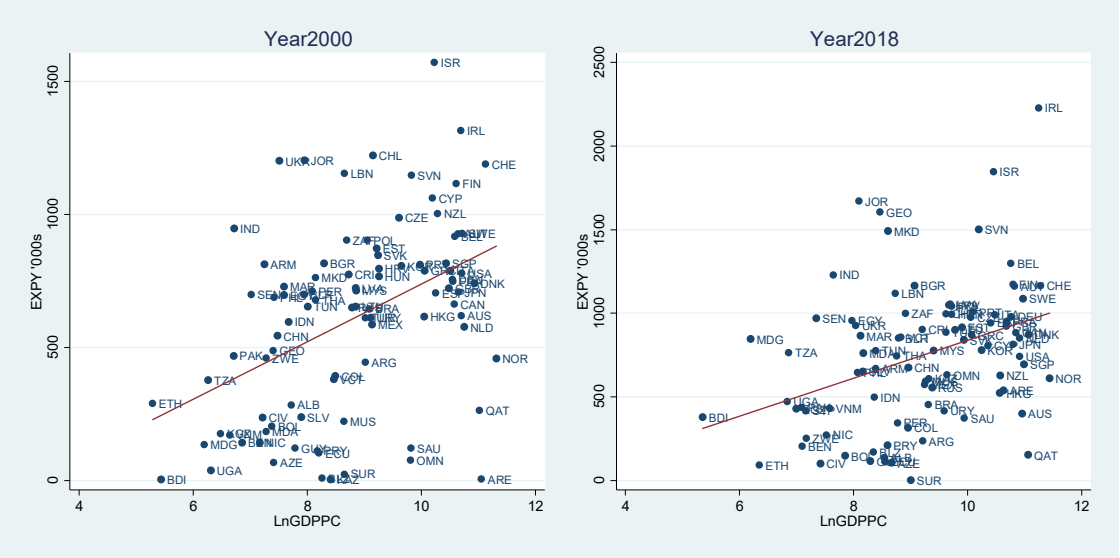
Table B2: EXPY – Summary Statistics, outliers excluded (constant 2010 $)

		Mean (in '000s)	Minimum (in '000s)	Maximum (in '000s)
High-Income	2000	783.55	5.71	1,571.85
	2010	931.87	0	2,207.30
	2018	917.18	153.03	2,227.75
Middle- and Low-Income	2000	460.43	2.98	1,203.65
	2010	573.17	18.95	2,070.5
	2018	612.38	3.06	1.670.14
Total	2000	601.37	2.98	1,571.85
	2010	729.63	0	2,207.30
	2018	745.32	3.06	2,227.75

Table B3: Top and bottom 5 countries ranked according to EXPY values

2000	2010	2018
Top 5		
Israel	Ireland	Ireland
Ireland	Jordan	Israel
Chile	Israel	Jordan
Jordan	Georgia	Georgia
Ukraine	Armenia	Slovenia
Bottom 5		
Burundi	United Arab Emirates	Suriname
Kazakhstan	Suriname	Ethiopia
United Arab Emirates	Sao Tome and Principe	Cote d'Ivoire
Belize	Belize	Azerbaijan
Sao Tome and Principe	Burundi	Ecuador

Figure B1: EXPY ('000s) against Log of GDP per capita



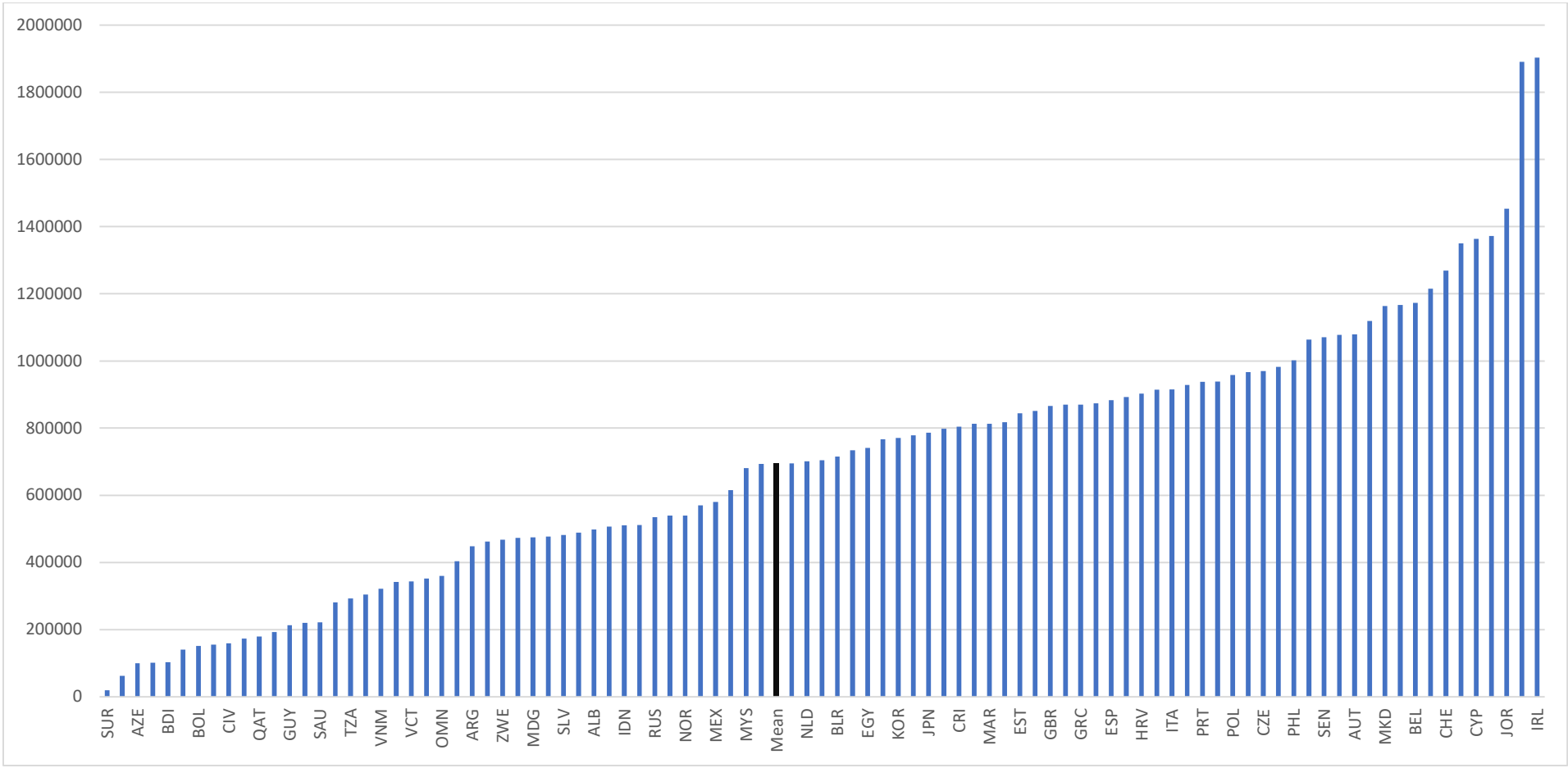
Source: Authors' own calculations. The data for GDP per capita was obtained from World Bank Development Indicators Dataset

Table B4: GVC Participation Indicators - Summary Statistics (outliers excluded)

		Participation			Forward Participation			Backward Participation		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
High-Income	2000	57.1	29.4	79.1	26.1	11.7	48.8	31.1	4.4	67.4
	2010	63.8	37.4	84.0	29.1	13.4	56.3	37.7	4.1	64.6
	2018	61.3	36.8	80.7	27.7	13.6	58.5	33.6	3.2	61.9
Middle- and Low-Income	2000	40.6	0	69.8	23.4	0	50.1	17.2	0	53.9
	2010	43.5	0	70.2	25.7	0	51.7	17.7	0	42.0
	2018	42.0	0	72.6	24.1	0	50	17.9	0	39.6
Total	2000	45.6	0	79.1	26.27	0	50.1	23.3	0	67.4
	2010	52.4	0	84.0	27.2	0	56.3	25.2	0	64.6
	2018	50.5	0	80.7	25.7	0	58.5	24.8	0	61.9

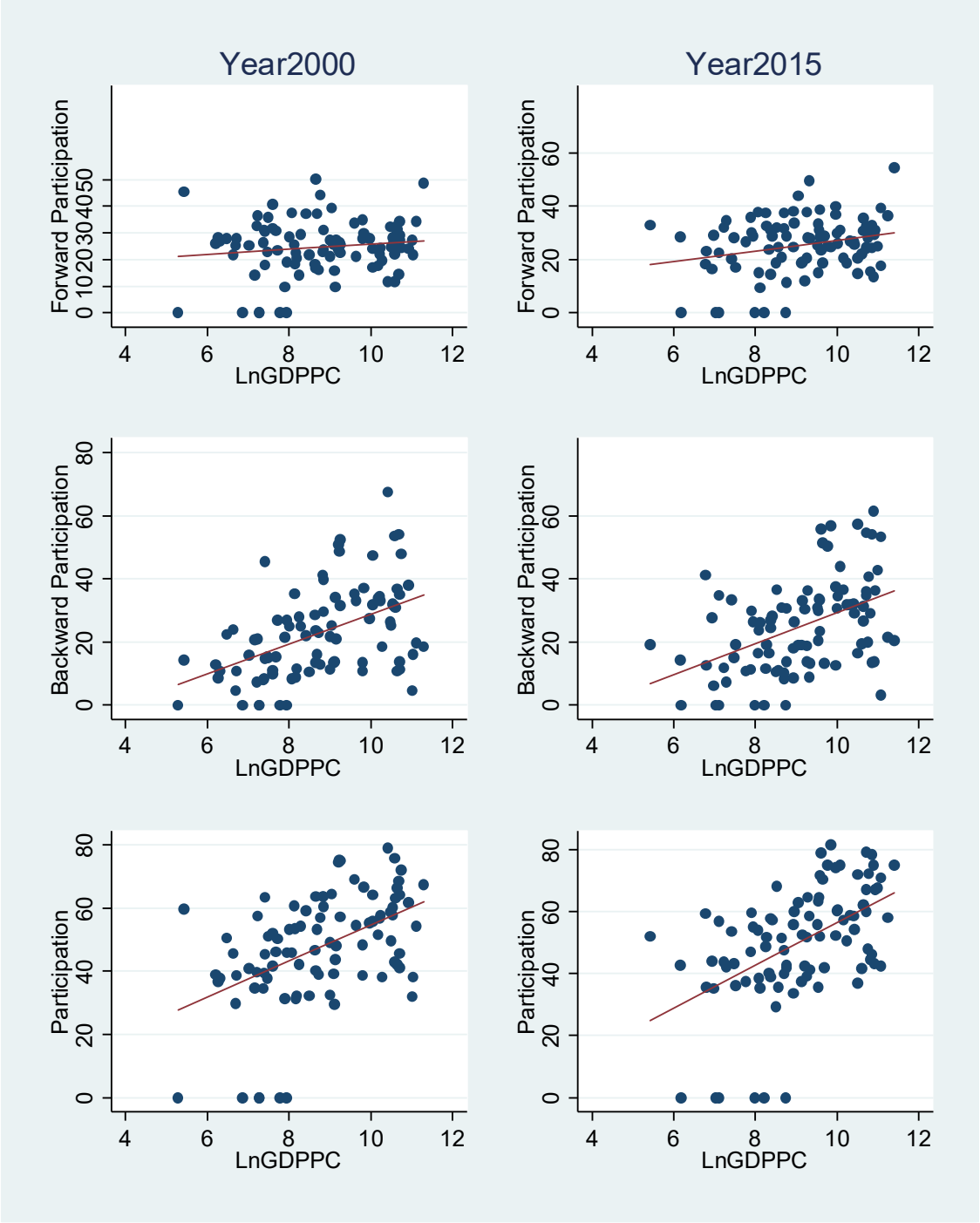
Source: Authors' own calculations using UNCTAD-EORA Global Value Chains Database, https://worldmrio.com/unctadgvc/ (accessed August 10, 2020)

Figure B2: Average EXPY over 20 years (1999-2018)



Source: Authors' own calculation

Figure B3: Participation indicators against income (without outliers), 2000 and 2015



Source: Authors' own calculations using UNCTAD-EORA Global Value Chains Database, https://worldmrio.com/unctadgvc/(accessed August 10, 2020)

Appendix C

Table C1: Regression Output

	Least Squares Dummy Variables: EXPY ('000s)		
	All countries	High Income Countries	Middle- and Low-Income Countries
	(1)	(2)	(3)
Forward Participation	11.74***	7.73*	15.19**
	(4.35)	(4.64)	(6.01)
Backward Participation	2.5	10.28***	-1.37
	(1.57)	(2.42)	(1.93)
Frontier Distance	68.34***	51.36***	105.71***
	(15.37)	(15.61)	(27.14)
HC	110.66***	146.56***	69.02
	(35.85)	(54.3)	(46.48)
FDI	4.53**	4.32**	6.07
	(1.86)	(1.92)	(7.39)
HH Index	-648.38***	-733.22***	-615.62***
	(149.85)	(266.65)	(177.25)
Trade Freedom	2.43***	3.83***	2.29***
	(0.63)	(1.3)	(0.7)
Tax Burden/ Fiscal Freedom	4.27***	1.43	4.95***
	(0.73)	(1.01)	(1.06)
Constant	-182.45	-468.53***	-9.59
	(137.58)	(161.37)	(175.03)
Country Dummies	**Yes**	**Yes**	**Yes**
N	**1332**	**660**	**675**

* p<0.1, ** p<0.05, *** p<0.01

Values in parenthesis show the standard errors

Table C2: Regression Output (Extension)

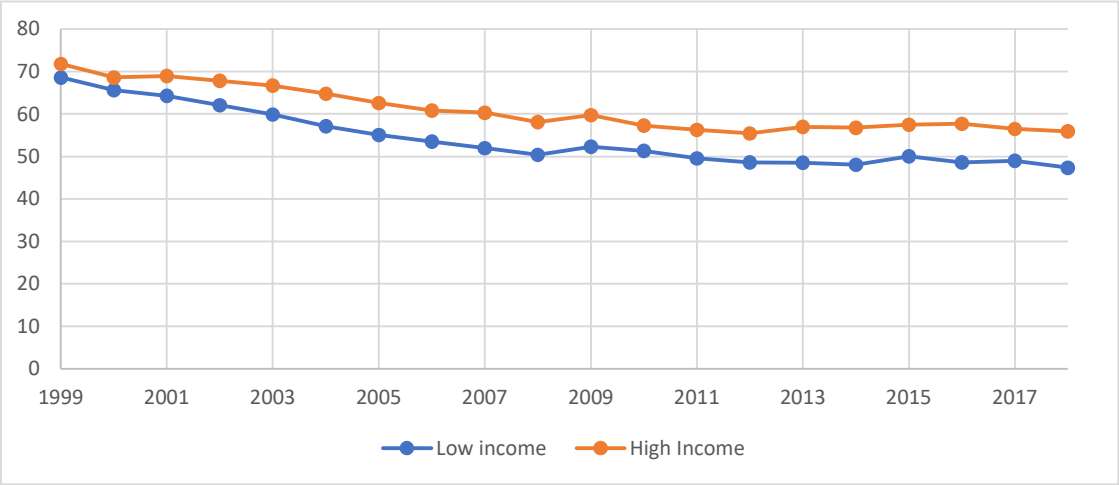
	Least Squares Dummy Variables: EXPY ('000s)					
	All countries	High Income Countries	Middle- & Low-Income Countries	All countries	High Income Countries	Middle- & Low-Income Countries
	(1)	(2)	(3)	(4)	(5)	(6)
Forward Participation (0)	13.32***	8*	17.89***	13.30***	8.63*	17.99***
	4.51	4.82	6.28	4.74	4.86	6.6
Forward Participation (-1)	9.75**	4.08	13.06**	11.20**	3.83	15.81**
	4.66	4.37	6.45	4.74	4.27	6.6
Forward Participation (-2)				9.64**	5.8	11.82*
				4.64	4.44	6.85
Backward Participation (0)	2.24	7.97**	-0.21	2.49	8.66**	-0.46
	3.03	4.01	4.6	3.04	4.23	4.51
Backward Participation (-1)	1.86	3.8	0.48	-4.32	-3.3	-4.47
	2.99	3.43	4.57	3.75	4.02	5.76
Backward Participation (-2)				7.94**	9.97***	7.08
				3.09	3.41	4.85
Frontier Distance	72.62***	49.09***	118.83***	77.80***	42.59**	131.24***
	16.31	16.59	28.98	16.96	17.98	28.63
HC	102.27***	142.82**	48.56	89.13**	141.59**	27.2
	38.43	56.22	52.84	42.02	57.53	58.93
FDI	4.55**	4.28**	6.33	4.46**	3.95**	9.31
	1.87	1.91	7.84	1.86	1.94	7.72
HH Index				-		
	-632.87***	-707.84***	-612.35***	677.94***	-749.9***	-668.05***
	164.28	268.91	197.49	172.19	270.93	208.41
Trade Freedom	2.41***	3.65***	2.42***	2.08***	2.11	2.32**
	0.65	1.37	0.74	0.78	-1.43	0.94
Tax Burden/ Fiscal Freedom	4.37***	1.56	4.59***	4.25***	1.42	3.82***
	0.86	1.22	1.24	0.98	-1.51	1.31
Constant	-210.74	-476.58***	29.94	-175.93	-387.82*	135.88
	157.18	177.89	205.04	181.67	197.59	234.31
Country Dummies	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
N	**1263**	**626**	**637**	**1194**	**592**	**602**

* p<0.1, ** p<0.05, *** p<0.01

Values in parenthesis show the standard errors

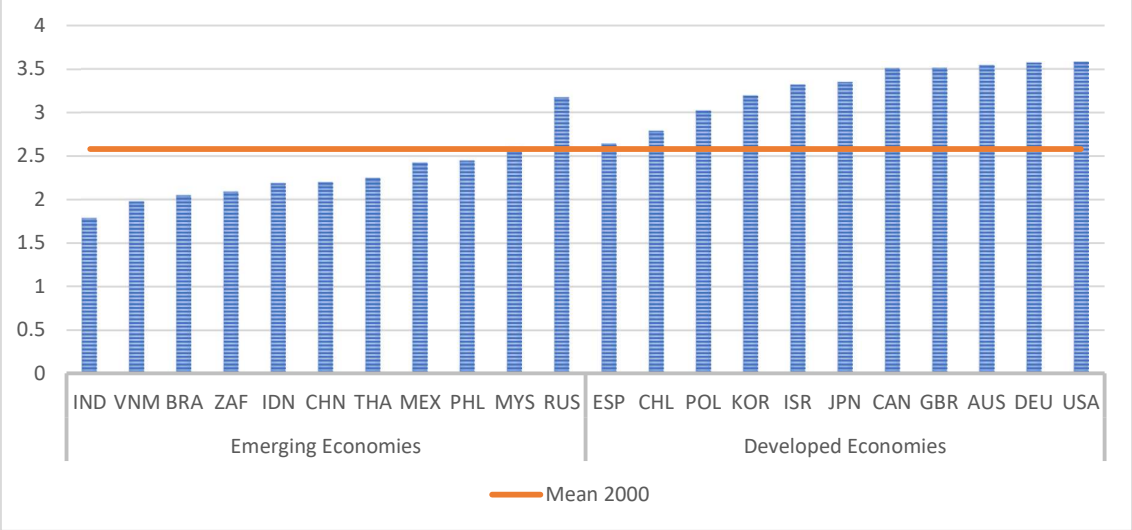
Appendix D

Figure D1: Share of intermediate merchandise imports from high income countries, 1999-2018



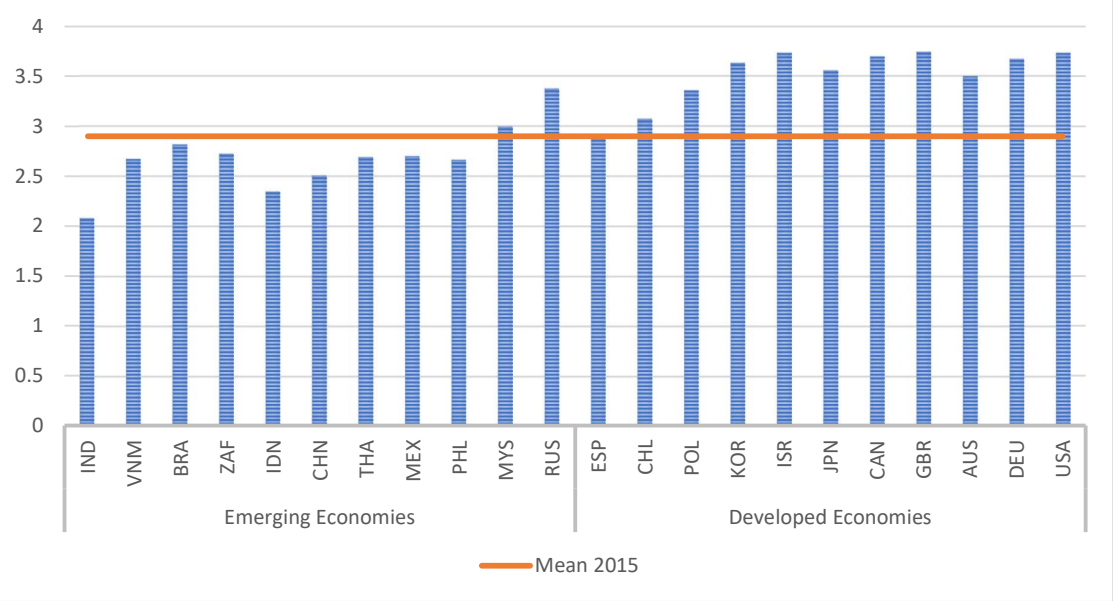
Source: Authors' own calculation using the WITS dataset, https://wits.worldbank.org/ (accessed August 20, 2020)

Figure D2: Human Capital Index for select developed and developing economies, 2000



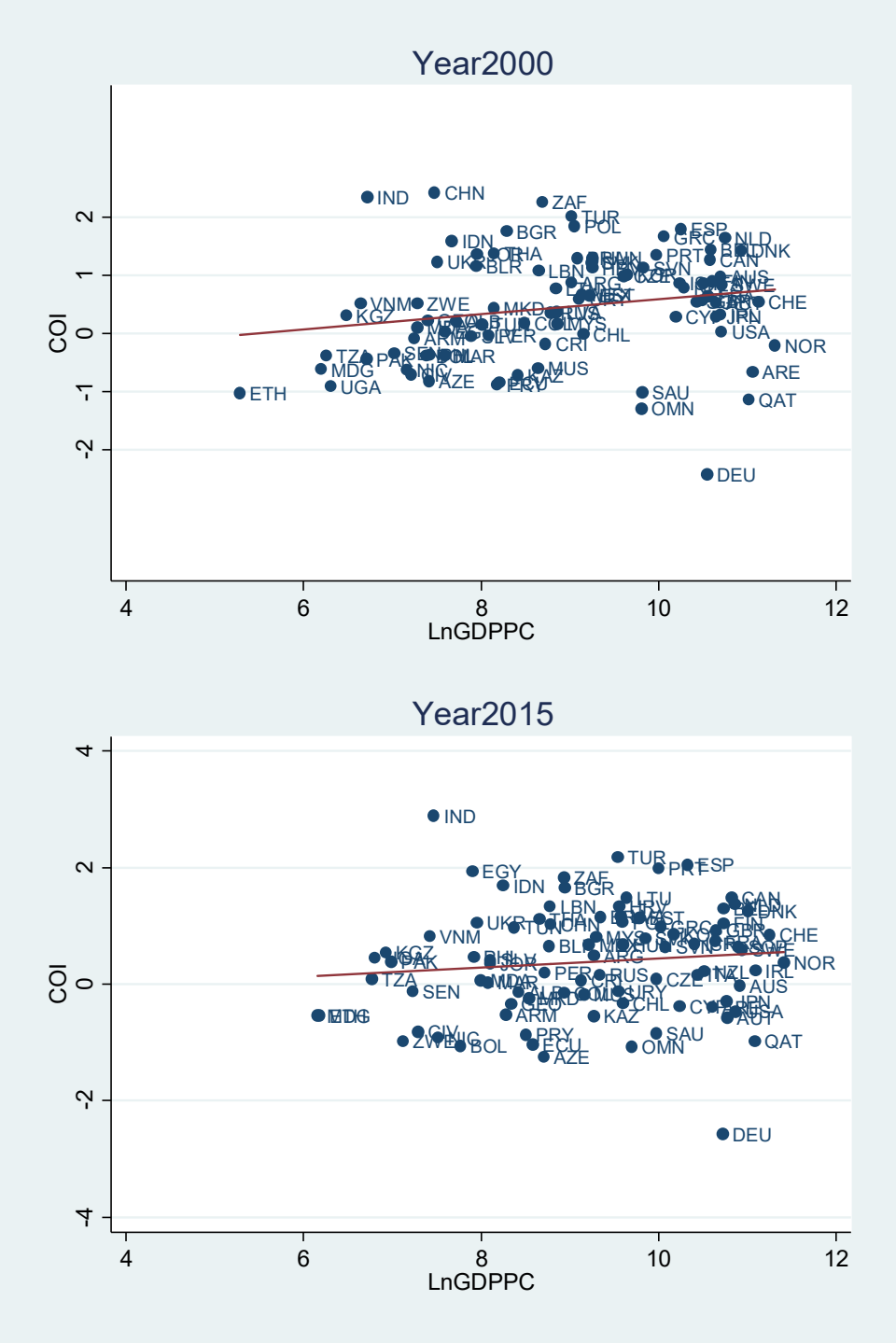
Source: Authors' own calculation using the World Bank Development Indicators and the Penn World Table. (accessed September 3, 2020)

Figure D3: Human Capital Index for select developed and developing economies, 2015



Source: Authors' own calculation using the World Bank Development Indicators and the Penn World Table (accessed September 3, 2020)

Figure D4: Human Capital Index for select developed and developing economies, 2015



Source: Authors' own calculation using the World Bank Development Indicators and the Atlas of Economic Complexity (The Growth Lab at Harvard University). (accessed September 3, 2020)