
Graduate Institute of International and Development Studies

Center for Trade and Economic Integration

Working Paper Series

CTEI Working Paper No 2017-04

**Domestic value chains as stepping stones to global
value chain integration**

Cosimo Beverelli
World Trade Organization

Robert B. Koopman
World Trade Organization

Victor Kummritz
World Trade Organization

Simon Neumueller
United Nations Economic Commission for Africa

Rue de Lausanne 132
P.O. Box 136
CH - 1211 Geneva 21
Geneva, Switzerland

Domestic value chains as stepping stones to global value chain integration*

Cosimo Beverelli[†]

Robert B. Koopman^{†‡}

Victor Kummritz^{†‡}

Simon Neumueller[§]

This version: March 2017

Abstract

We analyze the role of Domestic Value Chains (DVCs) for Global Value Chain (GVC) integration. In the presence of industry specific fixed costs of fragmenting production and of switching across input suppliers, DVCs can either be stepping stones or stumbling blocks for GVCs. Focusing on backward linkages, that is the sourcing of intermediates, we provide robust empirical evidence in favour of the stepping stone hypothesis. In our benchmark specification a one standard deviation increase in DVC integration raises subsequent GVC integration by about 0.4%. To identify the mechanisms at work, we exploit two dimensions of industry level heterogeneity: product differentiation and relationship specificity. Product differentiation can be taken as a proxy of fragmentation costs, while relationship specificity can be taken as a proxy of the costs of switching between suppliers. We find that DVC integration is less conducive to GVC integration in industries that are characterized by relatively high switching costs and relatively low fragmentation costs. This finding supports our hypothesized mechanism.

Keywords: Domestic value chains; global value chains; input output linkages.

JEL Classification: F14; F15; F63.

*The opinions expressed in this paper should be attributed to its authors. They are not meant to represent the positions or opinions of the WTO and its Members and are without prejudice to Members' rights and obligations under the WTO. Any errors are attributable to the authors. This paper builds upon background research for a joint project by IDE-JETRO, OECD, RCGVC, World Bank, and WTO. Without implicating them, we thank seminar participants at the GVC Development Report 2016 Background Paper Conference, the Geneva Trade and Development Workshop, the University of Trento, the 16th RIEF meetings, and the Graduate Institute, Geneva for useful comments.

[†]Economic Research Division, World Trade Organization. Rue de Lausanne 154, 1202 Geneva, Switzerland. E-mail: cosimo.beverelli@wto.org; robert.koopman@wto.org; victor.kummritz@wto.org (corresponding author).

[‡]Graduate Institute of International and Development Studies, Chemin Eugène-Rigot 2, 1202 Geneva, Switzerland.

[§]Office for West Africa, United Nations Economic Commission for Africa, P.O. BOX 744 Niamey, Niger. E-mail: NSimon@uneca.org.

1 Introduction

Global value chains (GVCs) are an important phenomenon of 21st century trade. Not only final goods or services get traded, but intermediate products and stages get outsourced and production becomes more and more fragmented. GVCs are often developed by large firms that coordinate input sourcing and assembly decisions, establishing industry linkages across borders.¹ Seminal work by Hummels et al. (2001) unveiled the growing importance of this international production sharing. In more recent work, Johnson and Noguera (2012a, 2012b) characterize the difference between value added trade and gross trade, showing that the GVC revolution, as measured by trade in value added, is ongoing. In a similar fashion, Timmer et al. (2014) show that global fragmentation, proxied by the foreign value added content of production, has rapidly increased since the early 1990s.

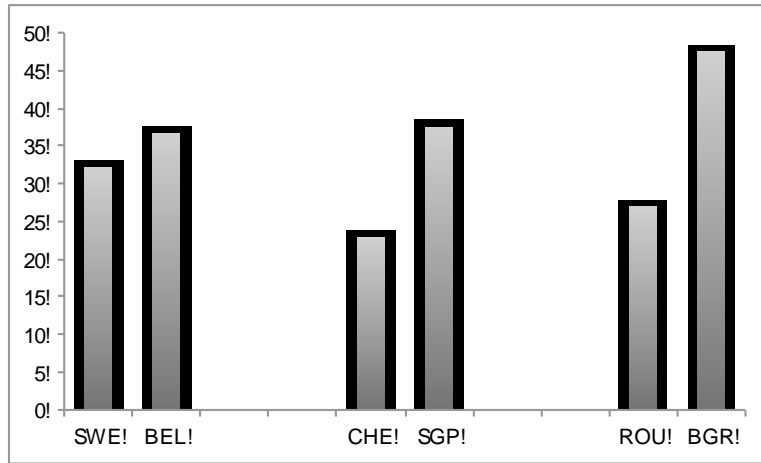
This development is of considerable interest for policy makers since both theory and empirics suggest that integrating in GVCs can lead to higher productivity and GDP. For instance, Baldwin and Robert-Nicoud (2014) show how GVCs cause productivity improvements akin to technological change by embedding the prominent features of the Grossman and Rossi-Hansberg (2008) model into a general equilibrium setting. Empirically, Kummritz (2016) finds that at the industry level higher GVC integration results in higher labor productivity and value added.

A central question that arises in this context is what determines GVC integration. Hummels et al. (2001), Johnson and Noguera (2012a), and Baldwin and Lopez Gonzalez (2015) find that structural factors such as country size, industrial structure, and location play a key role. In particular, small economies that are located close to GVC hubs such as Germany, Japan, and the United States exhibit strong linkages into GVCs. Kowalski et al. (2015) show that in addition policy matters. Countries with open trade and investment policies and sound institutions tend to integrate into GVCs more easily.

¹ In the remainder, ‘sectors’ will refer to the three aggregates of economic activity (primary, manufacturing and services), while ‘industries’ will refer to the ISIC Rev. 3 subsectors within these macro aggregates, listed in Table A-2.

A substantial part of the variation in GVC integration, however, remains unexplained. If countries are matched based on the structural and policy factors identified above, one can still see significant differences in their GVC integration patterns. Figure 1 plots, as an example, three such pairs of matched countries (Sweden and Belgium, Switzerland and Singapore, Romania and Bulgaria), showing that, especially in the last two pairs, there is a relevant difference within the pair that cannot be explained by the drivers of GVC integration identified in the literature.

Figure 1: GVC integration of matched countries



Notes: OECD data for 2008. Data averaged across industries. GVC integration measured as foreign value added in exports over total exports.

Related to this, a growing amount of research, revisiting earlier work by Hirschman (1958), discusses the positive implications of domestic linkages within and across industries.² Building on this literature, in this paper we investigate whether GVCs have their foundations in domestic value chains (DVCs), and the mechanisms behind the DVC-GVC relationship. Various papers have modeled firms' sourcing choices as either one between global offshoring and in-house production,³ or a simultaneous decision between global offshoring, domestic outsourcing and in-house production.⁴ We exploit the fact that the international fragmentation of production

² See, among others, Jones (2011), Bartelme and Gorodnichenko (2015), Bernard et al. (2015), and Dhyne and Rubínová (2015).

³ See, for example, Jones and Kierzkowski (1990, 2001), Antràs (2003), Grossman and Helpman (2003), and Fally and Hillberry (2015).

⁴ See, for example, Antràs and Helpman (2004) and Grossman and Helpman (2005).

only started to expand at a global scale in the 1990s, as a result of a dramatic fall in trade and communication costs. Domestic fragmentation, in turn, has been available to firms much longer. Therefore, we are interested in assessing empirically a sequential development, in which the amount of globally sourced intermediates is dependent on the previously determined level of domestic outsourcing.

The mechanism linking GVC and DVC integration that we focus on relates to the fragmentation costs associated with slicing up production, and to the costs of switching suppliers. We refer to fragmentation costs as all the costs paid by a firm deciding to source inputs externally, rather than producing them in-house.⁵ Here, we focus on that part of fragmentation costs that can be considered as one off fixed costs. Such fixed costs entail, among other things, the necessary codifying of tacit knowledge, the downsizing of plants and workforce, and the adaptation of the firm's structure. Once these costs have been paid for domestic fragmentation, they are not incurred again. This implies that DVC integration should serve as a stepping stone to subsequent GVC integration, particularly in industries characterized by relatively large fragmentation costs. Other things being equal, this would be reflected in a positive relationship between DVC and GVC integration.

Conversely, we refer to switching costs as the costs paid by a firm when it decides to stop sourcing an input from a supplier and starts sourcing the same input from another supplier, either located in the same country or abroad. For a given level of domestic fragmentation, high switching costs should reduce subsequent international fragmentation making DVCs a stumbling block to GVC integration. Other things being equal, this would be reflected in a negative relationship between DVC and GVC integration.

Thus, in the presence of both fragmentation costs and switching costs, the sign of the relationship between DVCs and GVCs is ambiguous and needs to be determined empirically. To that effect, we propose a novel measure of DVCs, equal to the share of domestically sourced

⁵ Fragmentation costs are incurred both if the sourcing occurs within national borders and if the sourcing occurs internationally.

inputs in domestic output, where the latter is computed excluding foreign sourced inputs. We are able to compute this measure for 59 countries and 26 industries. We show that higher levels of domestic fragmentation at the beginning of our sample (mid 1990s) positively affect GVC integration, as measured by foreign value added in exports, at the end of the sample (late 2000s). In the benchmark specification, a one unit increase in DVC integration raises subsequent GVC integration by 2.4%. This suggests that DVC integration is a stepping stone for GVC integration, and that, overall, the fragmentation cost channel dominates the switching cost channel. Moreover, by taking DVCs into account, we are able to reduce the unexplained variation in GVC integration by about 30%.

To investigate the hypothesized role of fragmentation and switching costs for the relationship between DVCs and GVCs, we exploit industry level heterogeneity along two dimensions: the degree of product differentiation and contract intensity (i.e. relationship specificity). Fixed fragmentation costs are likely to be higher in industries producing a high share of differentiated goods since these industries tend to be more innovation and skill intensive, which raises the cost of codifying tacit knowledge or downsizing. Switching suppliers, in turn, is costlier in industries characterised by a high degree of contract intensity because it involves the payment of contract termination fees and similar costs that tend to increase with the relationship specificity of inputs. Accordingly, we use Rauch (1999)’s classification for differentiated goods to proxy for fragmentation costs, and Nunn (2007)’s contract intensity measure to proxy for switching costs. The 26 industries are grouped into three categories: industries with high fragmentation and high switching costs, industries with low fragmentation and low switching costs, and industries with low fragmentation and high switching costs.⁶ In line with the suggested mechanism, we find that the positive role of DVCs for subsequent GVC integration is driven by the first two groups of industries, suggesting that fragmentation costs tend to be larger than switching costs. For the third group of industries, which is characterized by high switching costs and low fragmentation

⁶ Note that the case of high fragmentation and low switching costs is not observed in the data.

costs, the positive effect of DVCs disappears entirely.

The remainder of the paper is organized as follows. Section 2 provides details on the measures employed to proxy for DVC and GVC, describes the data used and the identification strategy. Section 3 presents the empirical results. Section 4 concludes and suggests some policy implications.

2 Empirical methodology and data

In this section we discuss the methodology to examine the role of DVCs for subsequently linking into GVCs. To do so, we postulate the following reduced form model at the country-industry level:

$$gvc_{ikt} = \alpha + \beta_1 dvc_{ikt-1} + \gamma' X_{ikt} + \varepsilon_{ikt}, \quad (2.1)$$

where i indexes industries; k indexes countries; t indexes time; X is a vector of controls (including fixed effects) and ε is a random error term. The explanatory variable of interest, dvc_{ikt-1} , is measured through different proxies for the strength of domestic intra and inter industry linkages, detailed in the next section. The dependent variable, gvc_{ikt} , is measured through different GVC proxies that are also described in more detail in the next section.

2.1 Measuring domestic and global value chain integration

The empirical GVC literature has developed several measures for GVC participation that can be split up into backward and forward linkages. The former are related to intermediates sourced from abroad. The latter are related to domestic intermediates exported abroad. Since our channel between DVCs and GVCs relates to the costs of sourcing intermediate goods, we focus on backward linkages measures. These measures are typically based on Inter Country Input Output (ICIO) tables, which are jl by ik matrices that represent supply and demand relationships within and across industries (i, j) and countries (k, l) . A generic element m_{lk}^{ji} of an ICIO matrix gives

the value of intermediate goods supplied by industry j of country l to industry i of country k . The advantage of ICIOs is that they do not only indicate cross country linkages but also within country linkages. This implies that the same data source can be used to build both our DVC and GVC integration indicators, limiting the scope for measurement error.

2.1.1 Measuring DVC integration

For DVC integration (the explanatory variable of interest in equation (2.1)) we suggest a novel indicator, applying the following approach. First, we decompose an industry's output into three parts based on the different inputs required to produce it: its own value added, domestically sourced intermediate goods, and foreign sourced intermediate goods. We refer to the combination of the former two as 'domestic output' since it is the virtual part of an industry's output that is produced with domestic content only. With this distinction at hand, we proceed to define our DVC indicator as the share of domestically sourced intermediate goods in 'domestic output':

$$dvc_{ik} \equiv \frac{\sum_j m_{kk}^{ji}}{\sum_j m_{kk}^{ji} + va_{ik}}. \quad (2.2)$$

In other words, dvc is the share of inputs in production that are not produced in-house, conditional on production taking place domestically.⁷

The reason for calculating the DVC indicator in this particular way is as follows. We only look at virtual domestic output instead of total output to avoid a mechanical correlation with the dependent variable. Our GVC indicator (see Section 2.1.2) is a subset of foreign sourced intermediate goods which, in turn, are a subset of total output as outlined in the paragraph above. Hence, using total output as denominator of our dvc measure would correlate dependent and independent variable. By considering only virtual domestic content, we break this mechanical link.⁸ An alternative solution to this problem would be the use of levels on

⁷ Note that we exclude intermediates sourced from the mining industry (ISIC Rev. 3 group C) to avoid effects stemming from price variations in commodities.

⁸ The difference between total and domestic output in 1995 was in any case minimal and, therefore, does not affect the results in a meaningful way.

both sides of the reduced form model. However, we prefer to use shares for the DVC variable to avoid an equally possible mechanically positive correlation with the GVC variable, which would be the result of any complementarity between foreign and domestic inputs in production.

To summarize, we avoid a mechanical correlation between our GVC and DVC indicators by using neither shares nor levels on both sides of our reduced form model. Instead, we adopt a mixed approach in which we regress our GVC indicator in levels on our DVC indicator in shares, and construct the latter using only virtual domestic content.⁹

2.1.2 Measuring GVC integration

The recent literature on GVCs has used various indicators to capture the rise of global production networks. Recently, Hummels et al. (2001)'s Vertical Specialization measure and its refinements by Wang et al. (2013) and Koopman et al. (2014) have emerged as standard indicators, also adopted in the present analysis.

The baseline GVC indicator is *fvax*, the foreign value added content in the production of exports. To construct this indicator, value added needs to cross at least two borders to be counted towards GVC trade. To obtain the required value added flows, it is necessary to decompose gross exports using information from ICIOs.¹⁰ In a simple two country, two industry case, the decomposition can be illustrated as follows:

$$V(I - A)^{-1}E = \begin{pmatrix} vae_{kk}^{ii} & vae_{kk}^{ij} & vae_{kl}^{ii} & vae_{kl}^{ij} \\ vae_{kk}^{ji} & vae_{kk}^{jj} & vae_{kl}^{ji} & vae_{kl}^{jj} \\ vae_{lk}^{ii} & vae_{lk}^{ij} & vae_{ll}^{ii} & vae_{ll}^{ij} \\ vae_{lk}^{ji} & vae_{lk}^{jj} & vae_{ll}^{ji} & vae_{ll}^{jj} \end{pmatrix}$$

where E is a $GN \times GN$ matrix in which the diagonal elements give each industry's gross exports for N industries and G countries, V is a $GN \times GN$ matrix in which the diagonal elements give

⁹ Summary statistics for the dependent variable and the main explanatory variable are available in Appendix A.

¹⁰ This is technically implemented using the R package *decompr* by Quast and Kummritz (2015).

each industry's value added to output ratio, and A is the $GN \times GN$ Input Output coefficient matrix, i.e. each element of A gives the intermediates that each industry supplies for \$1 of output in every other industry. The intuition behind the decomposition becomes clear by recalling that these intermediate flows are the output of other industries, which means that they consist of value added and other intermediates themselves. $(I - A)^{-1}$ approximates these indirect links between industries and when combined with the values in the V matrix gives the actual value added flows so that the elements of the vae matrix are estimates of the industry level value added origins of each industry's exports.¹¹

Our benchmark GVC indicator $fvax$ for industry i in country k is then given by:

$$fvax_{ik} \equiv \sum_l \sum_j vae_{lk}^{ji}, \quad (2.3)$$

where $l \neq k$. Thus, $fvax_{ik}$ is equal to the sum of value added from all industries j of all foreign countries l in the exports of industry i in country k .¹²

As a simple alternative indicator, used in robustness exercises, we additionally calculate the amount of imported inputs, $i2p$, following Baldwin and Lopez Gonzalez (2015). This measure implies a broader definition of GVC and can easily be derived from ICIOs as follows:

$$i2p_{ik} \equiv \sum_l \sum_j m_{lk}^{ji}, \quad (2.4)$$

where $l \neq k$.¹³

2.2 Descriptive evidence

When we take our DVC and GVC indicators to the data, we find preliminary evidence that DVC integration is a stepping stone for GVC integration. Figure 2 unconditionally correlates

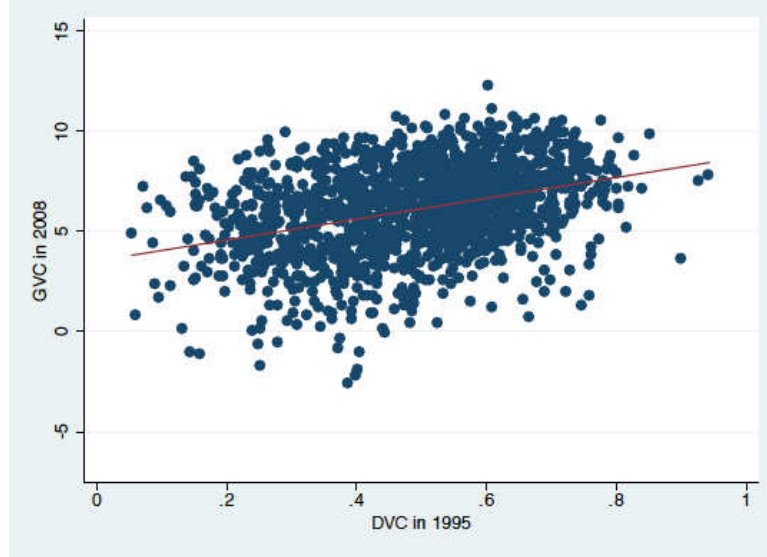
¹¹A more exhaustive explanation of the approach can be found in Wang et al. (2013).

¹² Here, too, sourcing from ISIC Rev. 3 group C (mining industry) is excluded. In addition, in Section 3.3 we use further strategies to deal with the mining industry.

¹³ Sourcing from ISIC Rev. 3 group C (mining industry) is, as usual, excluded.

DVCs in 1995 with the measure of GVCs in 2008 (in logs). The slope coefficient is equal to 0.47. This constitutes suggestive evidence that the fragmentation cost channel dominates the switching cost channel.

Figure 2: Correlation scatterplots between DVC in 1995 and GVC in 2008



Notes: OECD ICIO data. Each point is a country-industry combination. DVC measure from equation (2.2). GVC measure from equation (2.3) and in logs.

Similarly, when we look at our DVC integration indicator by country, we see that countries that are well integrated into GVCs also tend to have strong domestic linkages. Table 1 shows the top and bottom ten countries in terms of the *dvc* variable (equation (2.2)) in 1995 and broadly confirms this pattern. Interestingly, however, while the top ten is dominated by countries traditionally highly involved into GVCs, such as China, Slovakia, or Korea, it also contains countries like Croatia and New Zealand, which do not exhibit strong linkages into GVCs. The same pattern holds when examining the bottom ten. While Canada and Greece lag behind in GVC participation, Mexico is highly integrated. This suggests heterogeneity in the effects of DVCs, which will be taken into account in the empirical analysis.

Table 1: DVC integration by country in 1995

Top 10		Bottom 10	
Country	DVC	Country	DVC
China	57.73%	Austria	38.68%
Singapore	56.03%	Israel	38.11%
Czech Republic	53.59%	Canada	37.92%
Slovakia	53.14%	Greece	37.56%
Bulgaria	51.37%	Hong Kong	36.85%
Korea	50.14%	Malta	35.92%
New Zealand	49.91%	Mexico	34.69%
Estonia	48.52%	Luxembourg	29.76%
Hungary	48.07%	Cyprus	28.84%
Croatia	47.95%	Cambodia	23.50%

Notes: OECD ICIO data for 1995. Data averaged across industries. DVC measure from equation (2.2).

2.3 Identification

Estimation results of the reduced form equation (2.1) could in particular be affected by omitted variable bias. For instance, high contemporaneous GVC integration could be driven by a country’s institutions, which might have also affected initial domestic production fragmentation. To deal with this concern we use a combination of fixed effects and control variables that account for structural and policy determinants of GVC participation identified in the previous literature.

More specifically, we use industry fixed effects to control for structural differences across industries that might correlate at once with GVC and DVC integration. Heavy manufactures, for instance, are more likely to develop backward linkages than agriculture. In addition, country fixed effects take care of non time varying policy and structural differences across countries, such as size, economic development, remoteness, institutions, or endowments. Furthermore, we include: i) a dummy equal to one for comparative advantage industries, ca ; and ii) industry level ‘composite’ import tariffs, $ctau$. The comparative advantage dummy accounts for differences in the economic structure of countries that both industry and country fixed effects fail to control for. It is calculated using Balassa (1965)’s revealed comparative advantage, but on the basis of value added exports. The ‘composite’ import tariffs variable captures differences in the trade policy environment at the country-industry level. For each industry in a given country, it is calculated as the weighted average of tariffs that the inputs into the industry face, with weights

being given by the input output coefficient. We follow the literature and use United States' input output coefficient under the assumption that they are determined by technological factors as opposed to market distortions.

Considering that the aim is to examine how initial patterns in DVCs have affected subsequent GVC integration, we use dvc values for 1995 and $fvax$ values for 2008. This also addresses potential concerns about a reverse causality bias since the rapid expansion of GVCs only started around 1995 (Wang et al. 2016 show that in 1995 GVCs only accounted for 3% of global production). This limits any potential reverse effect on DVC integration values in 1995.

Our benchmark reduced form model for the effect of DVCs on GVC integration is then given by:

$$gvc_{ik2008} = \beta_1 dvc_{ik1995} + \beta_2 ca_{ik2008} + \beta_3 ctav_{ik2008} + \alpha_k + \alpha_i + \varepsilon_{ik2008}, \quad (2.5)$$

where β_1 is the coefficient of interest. Since the mechanism determining the role of DVCs for GVC integration is ambiguous as outlined in the introduction, we do not have a prior on the sign of β_1 .

While equation (2.5) can give the net effect of DVCs for GVC integration, it does not provide information on the mechanism driving the relation. Therefore, we proceed in a second step with estimating a variant of equation (2.5) that exploits the industry level variation in the data to analyze the suggested role of fragmentation and switching costs. For this purpose, we build proxies for industries' fragmentation and switching costs and then classify industries based on the relative magnitude of the costs into three groups: industries with high fragmentation and high switching costs (*HFHS* industries), industries with low fragmentation and low switching costs (*LFLS* industries), and industries with low fragmentation and high switching costs (*LFHS* industries).¹⁴

As benchmark proxy for fragmentation costs, we use Rauch (1999)'s classification for differentiated goods concorded to our industry level data. The Rauch classification treats goods

¹⁴ As argued in footnote 6, the case of high fragmentation and low switching costs is not observed.

as differentiated if they are neither reference priced nor traded on organized exchanges. The reason for this choice is that industries with a high share of differentiated goods tend to be more innovation and skill intensive.¹⁵ As a result, we can assume that codifying tacit knowledge, downsizing, and other fragmentation related activities are more costly for these industries.

Regarding switching costs, Nunn (2007)’s contract intensity (or relationship specificity) measure is a straightforward proxy. Different industries require different amounts of relationship specific inputs. When these inputs are supplied at arm’s length, complex contracts are needed to address the resulting hold up problem. Nunn (2007) shows that, as a result, industries differ in their contract intensity. A substantive share of fixed switching costs, such as contract cancellation fees, only occur when intermediates cannot be sourced from organized markets, but are sourced using contract based relations with suppliers. Nunn (2007)’s indicator measures the share of intermediates that are sourced through such contract based relations in total intermediates, and is thus a natural proxy for our exercise.¹⁶

Table 2 lists the industries separated into the three categories and shows that the selected proxies create a sensible allocation. *LFLS* industries like ‘Food and beverages’ typically source inputs from organized markets and, thus, should find it easy to switch between suppliers. At the same time, their production tends to be neither skill nor innovation intensive and so fragmentation should be equally simple. In contrast, the identified *HFHS* industries such as ‘Motor vehicles’ or ‘Electronics’ are dependent on a highly skilled workforce and complex intermediates. Lastly, *LFHS* industries such as ‘Electrical machinery’ (e.g. cables) require complex intermediates but production is homogeneous and non complex.

Having classified industries based on the incidence of fragmentation and switching costs, we can now adapt our benchmark equation to test the mechanism behind the DVC-GVC link

¹⁵ See, for example, Voigtländer (2014) for evidence on this relation.

¹⁶ Note that Nunn uses the Rauch classification to determine if an intermediate is sourced on a contractual basis. Thus, our switching and fragmentation cost proxies depend indirectly and directly on the Rauch classification. However, since the former looks at an industry’s intermediates and the latter at an industry’s output, there is no strong mechanical correlation between the two. We explain the classification of the industries in detail in Appendix B.

Table 2: Industries by category

<i>LFLS</i>	<i>HFHS</i>	<i>LFHS</i>
Agriculture	Textile and leather products	Mining and quarrying
Food and beverages	Wood products	Pulp and paper products
Coke and refined petroleum	Non metallic mineral products	Chemicals
Basic metals	Fabricated metals	Rubber and plastics
	Machinery n.e.c.	Electrical machinery n.e.c.
	Electronic and optical products	
	Motor vehicles	
	Other transport equipment	
	Manufacturing n.e.c.	

Notes: Based on the Rauch and Nunn classifications. L - low, H - high, F - fragmentation costs, S - switching costs. Industries are defined using the ISIC Rev. 3, 2 digit classification.

as follows:

$$\begin{aligned}
gvc_{ik2008} = & \beta_1 dvc_{ik1995} + \beta_2 dvc_{ik1995} \times HFHS_i + \beta_3 dvc_{ik1995} \times LFHS_i + \beta_4 ca_{ik2008} + \\
& \beta_5 \tau_{ik2008} + \alpha_k + \alpha_i + \varepsilon_{ik2008}.
\end{aligned} \tag{2.6}$$

In equation (2.6), β_1 gives the effect of DVCs on subsequent GVC integration in *LFLS* industries, which we use as baseline; β_2 gives the differential effect for *HFHS* industries, as compared to *LFLS* industries; and β_3 gives the differential effect for *LFHS* industries, as compared to *LFLS* industries.

As for the case of equation (2.5), a positive β_1 would suggest that fragmentation costs play a larger role than switching costs, while a negative β_1 would imply the opposite. We include the *HFHS* dummy as falsification test, since we expect β_2 not to be statistically significant. If the channel we propose is at work, there is no reason to believe that the effect of DVCs on GVCs should be different in *HFHS* industries as compared to *LFLS* industries. The coefficient of interest in equation (2.6) is β_3 , which is expected to be negative. This is because in *LFHS* industries the relative importance of switching costs, as compared to fragmentation costs, is higher than in the benchmark *LFLS* industries. Accordingly, DVC integration in these industries is less likely to lead to GVC integration. The overall effect in *LFHS* industries (as compared to all other industries) is given by the sum of β_1 and β_3 .

2.4 Data

For the calculation of the DVC and GVC indicators, as well as the revealed comparative advantage measure, we employ the OECD ICIO database. It is the most recent and most advanced release of ICIO tables, covering 61 countries and 34 2 digit ISIC Rev. 3 industries for the years 1995, 2000, 2005, and 2008 to 2011. To create ICIOs, the OECD combines national IO tables with international trade data. As OECD countries have a harmonized construction methodology, potential discrepancies between national IO tables should be minor. Furthermore, the advanced harmonization across countries reduces to a minimum the use of proportionality assumptions to derive the ratio of imported intermediates in an industry’s demand. The OECD has used elaborate techniques to deal with processing trade. Due to the outstanding role of processing trade in GVCs, this implies a significant improvement for the reliability of the database.¹⁷

For the tariff measure, we additionally take HS 2 digit MFN tariffs from the UNCTAD TRAINS database and concord them to the ICIOs’ ISIC Rev. 3 classification employing a concordance table provided by WITS. The Rauch classification is available at the 4 digit SITC Rev. 2 level. To concord it to ISIC Rev. 3, we need to apply a crosswalk via SITC Rev. 3. The necessary concordance tables are provided by Eurostat. In cases where ISIC industries are concorded to both homogenous and differentiated SITC commodities, we use trade weights from COMTRADE to determine if an ISIC industry is differentiated or homogenous.¹⁸

For additional specifications we employ as supplementary controls the distance of country k to the closest GVC hub (China, Germany, Japan, and the United States) from CEPII and GDP data from the World Development Indicators. We also perform several robustness checks, some of which necessitate additional data. Firstly, in one robustness exercise we replace the Rauch classification for fragmentation costs with Costinot (2009)’s measure of industrial complexity. It assesses how many days of training an average worker in a given industry needs to complete a job, and is hence a direct measure for an industry’s skill content. The data is available for

¹⁷ See Koopman et al. (2012) for an analysis of China’s processing trade.

¹⁸ See Appendix B for details.

a subset of 3 digit SIC codes at the 1972 revision. To match these with ISIC codes, we first concord them to the 1987 SIC revision using concordance tables by NBER. We then use a concordance table between SIC87 and ISIC Rev. 3 built by Statistics Canada. Secondly, in a separate exercise we replace the Nunn’s proxy for contract intensity with US capital intensity data from the OECD. In capital intensive industries, suppliers are often required to make large sunk investments. Consequently, they are likely to demand contracts with high cancellation fees. This makes capital intensity a likely proxy for switching costs. This data is readily available at the ISIC level.

The country coverage comprises developing and developed economies, allowing to examine whether the level of development plays any role in shaping the relationship between domestic and global value chains. In addition, the industry coverage includes primary, manufacturing, and services sectors. The latter play an increasingly dominant role in value chains. However, there are no tariffs nor Rauch measures available for services. Therefore, we exclude them from benchmark estimates but perform robustness checks without the tariff control, assuming that all services industries are differentiated and excluding non tradeable services industries such as education, health, or construction. Concerning the time period examined, we use 1995 and 2008 because these are the earliest and latest available data points before the start of the prolonged global financial crisis. Finally, we exclude in the benchmark estimations the oil exporting countries Saudi Arabia and Brunei Darussalam; Chinese Taipei, for which no tariff data is available; and the United States, to avoid endogeneity stemming from the construction of the weighted tariff and capital intensity variables.¹⁹

3 Results

This section is structured in three parts. We start by discussing the outcome of equation (2.5), which estimates the net effect that higher values of DVC integration have for subsequent GVC

¹⁹ Exclusion of the United States from the sample is standard practice in the literature that uses US IO weights – see for instance Beverelli et al. (2017). All available countries and industries are listed in Appendix A.

integration. In the second part, we assess the mechanism behind this effect by disentangling the role of fragmentation and switching costs as identified by equation (2.6). In the last part of the section we present a series of robustness checks.

3.1 DVCs as foundations

Table 3 reports the results for the first part of this exercise. The coefficients for the DVC indicator, *dvc*, are positive and statistically significant in all specifications, indicating that domestic value chains facilitate subsequent GVC integration.

Table 3: The net effect of DVC integration on GVC integration

	(1)	(2)	(3)	(4)
	Primary & Manufacturing		All sectors	
Dep. Variable:	<i>fvax</i>	<i>fvax</i>	<i>fvax</i>	<i>fvax</i>
<i>dvc</i>	2.566*** [0.451]	2.371*** [0.443]	2.900*** [0.379]	2.817*** [0.373]
<i>ca</i>	1.519*** [0.074]	1.348*** [0.068]	1.472*** [0.065]	1.404*** [0.059]
<i>ctau</i>	-0.002 [0.013]	-0.039** [0.017]		
Observations	1,025	1,025	1,449	1,449
R squared	0.705	0.815	0.704	0.792

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Dependent variable in natural logarithms. Columns (1) and (3) include industry fixed effects and the log of per capita GDP, log pf GDP, and log of hub distance as controls. Columns (2) and (4) include industry and country fixed effects. Columns (1) and (2) exclude services industries, columns (3) and (4) include them.

Columns (1) and (2) give the results for primary and manufacturing sectors only, while columns (3) and (4) include industries in the services sector, but at the cost of not controlling for tariffs. While all estimates are similar in magnitude and significance, we take the point estimate in column (2) as benchmark because it includes the full set of fixed effects and controls and it is comparable to the analysis in Section 3.2.

The benchmark specification suggests that a one unit increase in initial DVC integration leads to 2.4% higher subsequent GVC integration. This implies that a one standard deviation increase in DVC integration raises GVC integration by approximately 0.2 standard deviations or 0.4%. In addition, back of the envelope calculations comparing R squared of the benchmark

regression with and without the *dvc* measure suggest that DVCs can reduce the unexplained variation in contemporaneous GVC integration by about 30%.

Since our benchmark estimates only allow for within country variation, they might hide gains that stem from variation in DVC integration across countries which are emphasized by the literature on DVCs. Therefore, we additionally report in columns (1) and (3) results that only control for industry fixed effects as well as constant per capita GDP, log of GDP, and log of distance to the closest GVC hub to capture basic country characteristics such as size, development status, and remoteness. Such a setup is in line with DVC research such as Bartelme and Gorodnichenko (2015), but the estimates are potentially subject to an omitted variable bias and therefore we interpret them as upper bounds of the DVC effect. Table 3 shows that the coefficients are indeed larger in magnitude than the benchmark estimates, however the difference is not substantial.

In summary, these findings highlight a further advantage of comprehensive domestic linkages through their contribution to GVC participation. In the light of the literature that has unveiled productivity enhancing effects of GVC integration (Kummritz, 2016), our results can help explain why efficient DVCs facilitate economic development. Our findings also speak to the literature on the determinants of GVC integration. We show that differences in existing domestic linkages can account for differences in observed GVC linkages.

The descriptive evidence discussed in Section 2.1 has however illustrated that there are countries with strong DVC linkages which are not well integrated into GVCs. To unveil the heterogeneity in the GVC-DVC linkage, we now empirically assess the relevance of the mechanism related to the industry specific costs discussed in the introduction.

3.2 The role of fragmentation and switching costs

In this section, we estimate equation (2.6), which separates the effects of DVCs on GVCs in *LFHS* (low fragmentation, high switching costs) industries and *HFHS* (high fragmentation,

Table 4: Industrial heterogeneity in the effect of DVC integration on GVC integration

	(1)	(2)	(3)	(4)
	Primary & Manufacturing		All sectors	
Dep. Variable:	<i>fvax</i>	<i>fvax</i>	<i>fvax</i>	<i>fvax</i>
<i>dvc</i>	2.371*** [0.443]	2.893*** [0.683]	2.817*** [0.373]	3.256*** [0.752]
<i>dvc*HFHS</i>		-0.071 [0.941]		-0.309 [0.865]
<i>dvc*LFHS</i>		-2.401** [0.968]		-1.768* [1.033]
<i>ca</i>	1.348*** [0.068]	1.331*** [0.069]	1.404*** [0.059]	1.400*** [0.059]
<i>ctau</i>	-0.039** [0.017]	-0.041** [0.016]		
Observations	1,025	1,025	1,449	1,449
R squared	0.815	0.817	0.792	0.793
F test: $\beta_1 + \beta_3 = 0$	-	0.44	-	3.95

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Dependent variable in natural logarithms. Columns (1) and (3) are the benchmark effects presented in Table 3 and presented here for comparison. Columns (1) and (2) exclude services industries, Columns (3) and (4) include them. *HFHS* is a dummy equal to one for industries classified as having high fragmentation and switching costs. *LFHS* is a dummy equal to one for industries classified as having low fragmentation but high switching costs. The baseline *dvc* coefficient gives the coefficient for industries classified as having low fragmentation and switching costs.

high switching costs) industries, with respect to a benchmark case of *LFLS* (low fragmentation, low switching costs) industries.

As a reminder, we expect the coefficient on the *LFHS* dummy to be negative and significant and the coefficient on the *HFHS* dummy not to be significant. This is due to the fact that the former dummy captures industries in which switching costs tend to be high, which makes a change from domestic to foreign suppliers costly, but fragmentation costs low, which shuts down the stepping stone channel of DVCs for GVCs. In contrast, the latter dummy is a simple falsification test that we expect to be not statistically significant, since the relative incidence of fragmentation and switching costs is identical to the baseline case of *LFLS* industries.

Table 4 reports the corresponding results. As in Table 3, columns (1) and (2) exclude industries in the services sector, while columns (3) and (4) include them. We replicate in columns (1) and (3) the basic results presented in Table 3 for comparison, while columns (2) and (4) report the new estimates for equation (2.6).

The results are in line with our expectations. The coefficients on the interaction of the *dvc* variable with the *HFHS* dummy are not significant in both samples, while the coefficients on

the interaction with the *LFHS* dummy are negative and statistically significant. This is strong evidence in favour of our proposed channel which links initial DVC patterns to subsequent GVC integration by taking into account the varying importance of fragmentation and switching costs across industries.

Our preferred specification in column (2) suggests that in *HFHS* and *LFLS* industries a one percentage point increase in initial DVC linkages increases contemporaneous GVC integration by 2.9%. However, this positive effect of DVCs cannot be observed in *LFHS* industries. The reported F test for joint significance cannot reject the null hypothesis that the sum of the interaction and baseline point estimates ($\beta_1 + \beta_3$) is equal to zero.

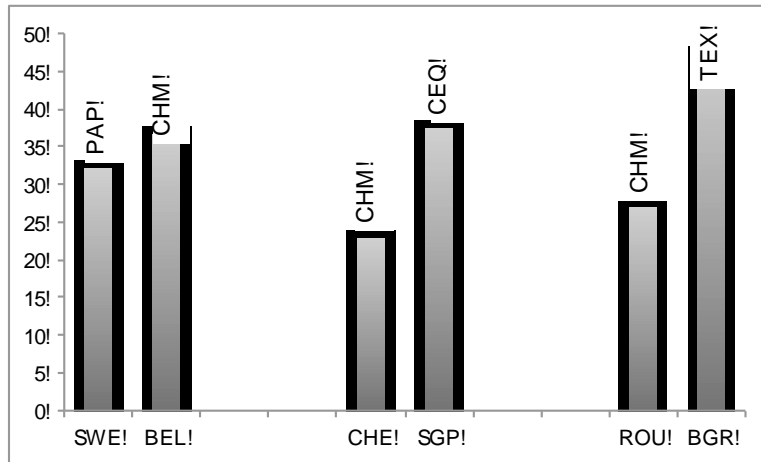
In terms of our proposed channel, these findings are further evidence for fragmentation costs being more important than switching costs for the DVC-GVC link since in industries where both costs are high (low) the positive effect of DVCs prevails. Similarly, even when switching costs are high but fragmentation costs are low, the net effect is close to zero instead of turning negative. Thus, the net effect that we found in Section 3.1 is confirmed and can be explained by the fact that fragmentation costs are more relevant than switching costs for moving from DVCs to GVCs.

These findings can also explain the observed heterogeneity in the DVC-GVC link as presented in the introduction. In Figure 3 we revisit the matched country pairs from Figure 1. There, we grouped countries based on the known structural and policy determinants of GVC integration and showed that there remains substantial unexplained variation in the data. Here, we add leading export industries to the chart. It is striking that all the leading export industries of the underperformers (respectively, Paper for Sweden, and Chemicals for Switzerland and for Romania) fall into the *LFHS* category whereas the comparison group is more specialized in *HFHS* industries (Computer, electronic and optical products in the case of Singapore, Textiles, leather and footwear in the case of Bulgaria).²⁰

²⁰ An exception is Belgium, which is also specialized in Chemicals. However, its DVC integration levels in 1995 were fairly low in this industry while Switzerland, Sweden and Romania had high values of DVC integration

This means that in these three countries the structure of the economy causes domestic linkages to prevent GVC integration, despite the fact that other factors, such as location, would facilitate GVC integration. For policy makers this implies that they need to take into account both the strength of domestic linkages and the structure of their economies when they develop GVC strategies.

Figure 3: Differences in GVC integration of matched countries – revisited



Notes: OECD data for 2008. Data averaged across industries. GVC integration measured as foreign value added in exports over total exports.

3.3 Robustness

We expose our results to a battery of robustness checks starting with the identification assumptions.²¹ While we have argued that in 1995 reverse causality from GVCs to DVCs should have been minor, since only 3% of global production were GVC related, there is evidence that in high income countries GVCs did already play a role. Therefore, we introduce into equation (2.5) an interaction term between the DVC measure and a high income dummy, equal to one if a country was classified as high income in the World Bank classification in 1995. This allows us to see if the effect is also present in developing economies, for which the assumption of the

in this industry.

²¹ This section includes the main robustness results. Several further tests are available from the authors upon request. None of these have affected the main results.

Table 5: The net effect of DVC integration on GVC integration – Robustness

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. Variable:	Benchmark <i>fvax</i>	High income <i>fvax</i>	Short run <i>fvax</i>	GVC measure <i>i2p</i>	All countries <i>fvax</i>	All sectors <i>fvax</i>	2011 <i>fvax</i>
<i>dvc</i>	2.371*** [0.443]	2.019*** [0.529]	0.568** [0.222]	2.105*** [0.408]	2.030*** [0.454]	2.851*** [0.336]	2.371*** [0.443]
<i>dvc* high inc.</i>		0.784 [0.658]					
<i>ca</i>	1.348*** [0.068]	1.342*** [0.068]	0.240*** [0.032]	0.894*** [0.056]	1.400*** [0.075]	1.385*** [0.056]	1.348*** [0.068]
<i>ctau</i>	-0.039** [0.017]	-0.037** [0.017]	0.002 [0.006]	0.005 [0.015]	-0.024 [0.019]		-0.039** [0.017]
Observations	1,025	1,025	2,896	1,026	1,078	1,883	1,025
R squared	0.815	0.816	0.748	0.831	0.824	0.807	0.815

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Dependent variable in natural logarithms. All columns excluding column (3) include industry and country fixed effects. Column (3) includes country-year, industry-year, and industry-country fixed effects. All columns excluding column (6) exclude services industries.

absence of reverse causality is not questionable. This estimation can also provide insights on a possible development dimension to our findings. Table 5 gives the corresponding results for our main robustness checks on the foundation result, with column (1) providing the estimate of the preferred specification (column (2) of Table 3) for convenience. As reported in column (2), the high income interaction term is not significant. We interpret this result (which is robust to several alternative constructions of country groups) as a strong indication that the effect of DVC on GVC integration is not driven by reverse causality.

Next, we further address concerns about omitted variable bias by fully exploiting the time variation in our data. More specifically, we additionally use data on the years 2000 and 2005 and estimate a panel version of equation (2.5). The specification includes a one period lagged *dvc* variable (following Bartelme and Gorodnichenko, 2015) and country-year, industry-year, and industry-country fixed effects. The specification without the time dimension remains our preferred model since the objective is to assess the effect of initial DVC conditions unaffected by the rise of GVCs. However, the advantage of this robustness check is that we can add a rich structure of fixed effects, controlling for any unobserved factor that might be correlated with *gvc* and *dvc* and vary across countries, industries and time. Column (3) of Table 5 shows that the *dvc* coefficient remains positive and statistically significant. Its magnitude decreases by 75%.

This can be explained by a potential linear accumulation of the effect over time.

As further robustness we test if our results are dependent on the selected *gvc* measure. For this purpose, we replace *fvax* with the *i2p* indicator of Baldwin and Lopez Gonzalez (2015), which is simply the value of intermediate imports (see Section 2.1.2). We find in column (4) of Table 5 that this variation has no relevant impact on our estimate.

We then proceed to vary the sample composition by including previously dropped countries and non tradeable services industries to examine if the results are sensitive to specific sample changes. Columns (5) and (6) of Table 5 show that this does not affect the results in any meaningful way.

In a next step, we replace the *gvc* value of 2008 with the value of 2011. This allows assessing whether the results are dependent on a specific time period, in particular whether the global financial crisis is relevant for the DVC-GVC relation. The estimates in column (7) of Table 5 suggest that neither is the case.

We now turn to a set of robustness checks concerning the mechanism behind the DVC-GVC link. Firstly, we vary the cutoff condition which classifies industries as differentiated and, indirectly, as contract intensive. For this, it is necessary to recall that the Rauch classification is at the 4 digit SITC level, while our industry classification used to construct the *gvc* and *duc* variables is the 2 digit ISIC. As a results, several SITC industries are assigned to one ISIC industry. As explained in detail in Appendix B, in the benchmark estimation, we define ISIC industries as differentiated if more than the trade weighted mean of 4 digit SITC industries within a 2 digit ISIC industry are classified as differentiated. We now use the trade weighted median as cutoff instead. This reduces our *LFHS* industries to ‘Pulp and paper products’, ‘Chemicals’, and ‘Mining and quarrying’, with the other two in the last column of Table 2 being now classified as *HFHS* industries.

Table 6 reports the robustness results for the mechanism findings of Table 4. Column (1) includes the coefficients of the preferred specification (column (2) of Table 4) for convenience,

Table 6: Industrial heterogeneity in the effect of DVC integration on GVC integration – Robustness

	(1) Benchmark	(2) Cutoff	(3) Complexity	(4) Capital intensity
Dep. Variable:	<i>fvax</i>	<i>fvax</i>	<i>fvax</i>	<i>fvax</i>
<i>dvc</i>	2.893*** [0.683]	3.076*** [0.744]	3.052*** [0.873]	2.975*** [0.658]
<i>dvc*HFHS</i>	-0.071 [0.941]	-0.571 [0.943]	0.300 [1.039]	-0.492 [1.146]
<i>dvc*LFHS</i>	-2.401** [0.968]	-2.988*** [1.141]	-2.199* [1.215]	-1.120 [0.859]
<i>ca</i>	1.331*** [0.069]	1.329*** [0.070]	1.236*** [0.070]	1.334*** [0.069]
<i>ctau</i>	-0.041** [0.016]	-0.040** [0.016]	-0.028 [0.018]	-0.039** [0.017]
Observations	1,025	1,025	911	1,025
R squared	0.817	0.817	0.838	0.815

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Dependent variable in natural logarithms. All columns include industry and country fixed effects. All columns exclude services industries.

while column (2) shows the estimates for this slightly stricter cutoff. The magnitudes of both coefficients on the baseline and interaction term slightly increase. Since we increased the cutoff, the ratio of switching to fragmentation costs in *LFHS* industries has increased. Therefore, the larger magnitude is sensible.

In the two next robustness exercises, we change the measures used to classify the industries into their respective categories. First, we use Costinot (2009)’s industrial complexity indicator to proxy for fragmentation costs. As discussed in Section 2.4, it is a proxy for an industry’s average skill intensity. As shown in column (3) of Table 6, this change has no relevant impact on our estimates. As a second variation, we use capital intensity as an alternative proxy for switching costs. In this case, as can be seen in column (4) of Table 6, the coefficient on the *LFHS* dummy in our preferred specification is correctly signed, but not statistically significant. Note, however, that in most of our alternative specifications the coefficient is not only of the correct sign but also statistically significant.

Overall, the two main results concerning DVCs as foundations for GVCs, and the mechanisms behind this link, are robust to variations in the identification assumptions, the sample composition, and to the employed indicators and proxies. Therefore, we can conclude that DVCs

and their interaction with a country’s industrial structure are an important factor for integration in GVCs.

4 Conclusions

GVCs have become a dominant factor in international trade. Recent theoretical and empirical research has shown that this development can lead to gains in productivity and welfare for countries that manage to integrate in GVCs. This begs the question what drives GVC participation. While previous research has revealed a set of important structural factors and policies, there remains substantial unexplained variation in GVC integration patterns across countries.

In this paper we shed light on a new determinant of these patterns by providing evidence that initial patterns of DVC integration affect contemporaneous GVC integration. In other words, levels of domestic fragmentation established before the rise of GVCs can explain a relevant share of current variation in GVC integration. The results hold for countries at varying stages of development, over varying time periods, and when changing the sample composition and identifying assumptions. In our preferred specification a one standard deviation increase in DVC integration raises subsequent GVC integration by 0.4%. Besides, we are able to decrease the unexplained variation in GVC integration by about 30%.

We explain this ‘foundation’ result with the presence of fixed costs of fragmentation and of switching suppliers. On the one hand, high fixed fragmentation costs allow, due their sunk nature, DVCs to act as stepping stones for GVCs. On the other hand, high fixed costs of switching suppliers should lead to a negative association between DVCs and GVCs. Our findings on the net effect suggest that the fragmentation cost channel is more important than the switching cost channel. Exploiting the industry variation in fragmentation and switching costs in the data, we confirm that this is indeed the case. The facilitating effect of DVCs is absent in industries characterized by low fragmentation costs, but high switching costs.

The policy implications are relevant and straightforward. Key barriers to GVC integration

might stem from the interplay of domestic linkages and industrial structure. These linkages should be taken into account when designing and evaluating GVC integration strategies.

References

- Antràs, P., 2003, “Firms, Contracts, and Trade Structure,” *Quarterly Journal of Economics*, 118, 1375–1418.
- Antràs, P., and E. Helpman, 2004, “Global Sourcing,” *Journal of Political Economy*, 112, 552–580.
- Balassa, B., 1965, “Trade Liberalisation and “Revealed” Comparative Advantage,” *The Manchester School*, 33, 99–123.
- Baldwin, R., and J. Lopez Gonzalez, 2015, “Supply-chain Trade: A Portrait of Global Patterns and Several Testable Hypotheses,” *The World Economy*, 38, 1682–1721.
- Baldwin, R., and F. Robert-Nicoud, 2014, “Trade-in-goods and trade-in-tasks: An integrating framework,” *Journal of International Economics*, 92, 51–62.
- Bartelme, D., and Y. Gorodnichenko, 2015, “Linkages and Economic Development,” NBER Working Paper No. 21251, National Bureau of Economic Research.
- Bernard, A. B., A. Moxnes, and Y. U. Saito, 2015, “Production networks, geography and firm performance,” NBER Working Paper No. 21082, National Bureau of Economic Research.
- Beverelli, C., M. Fiorini, and B. Hoekman, 2017, “Services trade policy and manufacturing productivity: The role of institutions,” *Journal of International Economics*, 104, 166–182.
- Costinot, A., 2009, “On the origins of comparative advantage,” *Journal of International Economics*, 77, 255–264.
- Dhyne, E., and S. Rubínová, 2015, “The supplier network of exporters: Connecting the dots,” Presented at the 2015 ETSG conference, Paris, 10-12 September. Available at <http://www.etsg.org/ETSG2015/Papers/029.pdf>.

- Fally, T., and R. Hillberry, 2015, “A Coasian Model of International Production Chains,” NBER Working Paper No. 21520, National Bureau of Economic Research.
- Grossman, G. M., and E. Helpman, 2003, “Outsourcing Versus FDI in Industry Equilibrium,” *Journal of the European Economic Association*, 1, 317–327.
- Grossman, G. M., and E. Helpman, 2005, “Outsourcing in a Global Economy,” *Review of Economic Studies*, 72, 135–159.
- Grossman, G. M., and E. Rossi-Hansberg, 2008, “Trading Tasks: A Simple Theory of Offshoring,” *American Economic Review*, 98, 1978–97.
- Hirschman, A. O., 1958, *The strategy of economic development*, New Haven: Yale University Press.
- Hummels, D., J. Ishii, and K.-M. Yi, 2001, “The nature and growth of vertical specialization in world trade,” *Journal of International Economics*, 54, 75–96.
- Johnson, R. C., and G. Noguera, 2012a, “Accounting for intermediates: Production sharing and trade in value added,” *Journal of International Economics*, 86, 224–236.
- Johnson, R. C., and G. Noguera, 2012b, “Fragmentation and Trade in Value Added over Four Decades,” NBER Working Paper No. 18186, National Bureau of Economic Research.
- Jones, C. I., 2011, “Intermediate Goods and Weak Links in the Theory of Economic Development,” *American Economic Journal: Macroeconomics*, 3, 1–28.
- Jones, R., and H. Kierzkowski, 1990, “The role of services in production and international trade: a theoretical framework,” in R.W. Jones, and A.O. Krueger (ed.), *The Political Economy of International Trade: Essays in Honour of Robert A. Mundell* . pp. 31–48, MIT Press, Cambridge, MA.

- Jones, R., and H. Kierzkowski, 2001, “A framework for fragmentation,” in S.W. Arndt, and H. Kierzkowski (ed.), *Fragmentation: New Production Patterns in the World Economy* . pp. 17–34, Oxford University Press, New York.
- Koopman, R. B., Z. Wang, and S.-J. Wei, 2012, “Estimating domestic content in exports when processing trade is pervasive,” *Journal of Development Economics*, 99, 178–189.
- Koopman, R. B., Z. Wang, and S.-J. Wei, 2014, “Tracing Value-Added and Double Counting in Gross Exports,” *American Economic Review*, 104, 459–94.
- Kowalski, P., J. Lopez Gonzalez, A. Ragoussis, and C. Ugarte, 2015, “Participation of Developing Countries in Global Value Chains,” OECD Trade Policy Paper No. 179, Organisation for Economic Co-operation and Development.
- Kummritz, V., 2016, “Do Global Value Chains Cause Industrial Development?,” CTEI Working Paper No. 2016-01, Centre for Trade and Economic Integration.
- Nunn, N., 2007, “Relationship-Specificity, Incomplete Contracts, and the Pattern of Trade,” *Quarterly Journal of Economics*, 122, 569–600.
- Quast, B. A., and V. Kummritz, 2015, “*decompr*: Global Value Chain decomposition in R,” CTEI Working Paper No. 2015-01, Centre for Trade and Economic Integration.
- Rauch, J. E., 1999, “Networks versus markets in international trade,” *Journal of International Economics*, 48, 7–35.
- Timmer, M. P., A. A. Erumban, B. Los, R. Stehrer, and G. J. de Vries, 2014, “Slicing Up Global Value Chains,” *Journal of Economic Perspectives*, 28, 99–118.
- Voigtländer, N., 2014, “Skill bias magnified: Intersectoral linkages and white-collar labor demand in US manufacturing,” *Review of Economics and Statistics*, 96, 495–513.

Wang, Z., S.-J. Wei, X. Yu, and K. Zhu, 2016, “Characterizing Global Value Chains,” available at <https://www.gtap.agecon.purdue.edu/resources/download/8178.pdf>.

Wang, Z., S.-J. Wei, and K. Zhu, 2013, “Quantifying International Production Sharing at the Bilateral and Sector Levels,” Discussion paper, NBER Working Paper No. 19677, National Bureau of Economic Research.

Appendices

A Data

Table A-1: OECD ICIO country coverage

ISO3	Country	ISO3	Country
AUS	Australia	ITA	Italy
ARG	Argentina	JPN	Japan
AUT	Austria	KHM	Cambodia
BEL	Belgium	KOR	Korea
BGR	Bulgaria	LTU	Lithuania
BRA	Brazil	LUX	Luxembourg
BRN	Brunei Darussalam	LVA	Latvia
CAN	Canada	MEX	Mexico
CHE	Switzerland	MLT	Malta
CHL	Chile	MYS	Malaysia
CHN	China	NLD	Netherlands
COL	Colombia	NOR	Norway
CRI	Costa Rica	NZL	New Zealand
CYP	Cyprus	PHL	Philippines
CZE	Czech Republic	POL	Poland
DEU	Germany	PRT	Portugal
DNK	Denmark	ROU	Romania
ESP	Spain	RUS	Russia
EST	Estonia	SAU	Saudi Arabia
FIN	Finland	SGP	Singapore
FRA	France	SVK	Slovak Republic
GBR	United Kingdom	SVN	Slovenia
GRC	Greece	SWE	Sweden
HKG	Hong Kong, China	THA	Thailand
HRV	Croatia	TUN	Tunisia
HUN	Hungary	TUR	Turkey
IDN	Indonesia	TWN	Chinese Taipei
IND	India	USA	United States
IRL	Ireland	VNM	Viet Nam
ISL	Iceland	ZAF	South Africa
ISR	Israel		

Note: Countries in **bold** excluded in benchmark estimations.

Table A-2: OECD ICIO industry coverage

Isic Rev. 3	Industry code	Industry description
01T05	AGR	Agriculture
10T14	MIN	Mining and quarrying
15T16	FOD	Food products, beverages, and tobacco
17T19	TEX	Textiles, leather and footwear
20	WOD	Wood and products of wood and cork
21T22	PAP	Pulp, paper, paper products, printing and publishing
23	PET	Coke, refined petroleum products and nuclear fuel
24	CHM	Chemicals and chemical products
25	RBP	Rubber and plastics products
26	NMM	Other non metallic mineral products
27	MET	Basic metals
28	FBM	Fabricated metal products
29	MEQ	Machinery and equipment n.e.c
30,32,33	CEQ	Computer, electronic and optical products
31	ELQ	Electrical machinery and apparatus n.e.c
34	MTR	Motor vehicles, trailers and semi trailers
35	TRQ	Other transport equipment
36T37	OTM	Manufacturing n.e.c; recycling
40T41	EGW	Electricity, gas and water supply
45	CON	Construction
50T52	WRT	Wholesale and retail trade
55	HTR	Hotels and restaurants
60T63	TRN	Transport and storage
64	PTL	Post and telecommunications
65T67	FIN	Finance and insurance
70	REA	Real estate activities
71	RMQ	Renting of machinery and equipment
72	ITS	Computer and related activities
73T74	BZS	Research and development and other business services
75	GOV	Public administration and defence
80	EDU	Education
85	HTH	Health and social work
90T93	OTS	Other community, social and personal services
95	PVH	Private households with employed persons

Note: Industries in **bold** excluded in all estimations, benchmark estimations only include industries up to ISIC 37.

Table A-3: DVC integration over time, country average across industries

ISO3	DVC in 1995	DVC in 2008	% change 1995-2008	ISO3	DVC in 1995	DVC in 2008	% change 1995-2008
LUX	0.30	0.46	53.7%	CRI	0.40	0.42	3.5%
KHM	0.24	0.34	45.5%	CHE	0.41	0.43	3.1%
MYS	0.41	0.55	35.4%	CHL	0.44	0.45	2.9%
ISL	0.41	0.50	21.4%	TWN	0.48	0.50	2.3%
AUT	0.39	0.45	17.3%	SWE	0.44	0.45	2.3%
LVA	0.46	0.53	16.1%	COL	0.39	0.40	1.7%
CYP	0.29	0.33	15.5%	AUS	0.47	0.48	0.4%
TUR	0.43	0.50	15.3%	CAN	0.38	0.38	0.3%
THA	0.44	0.50	13.9%	NZL	0.50	0.50	-0.1%
MLT	0.36	0.41	13.8%	IND	0.45	0.45	-0.9%
KOR	0.50	0.56	11.1%	PRT	0.46	0.46	-0.9%
ISR	0.38	0.42	9.4%	USA	0.43	0.42	-1.0%
CHN	0.58	0.63	9.2%	NOR	0.39	0.38	-1.5%
SVN	0.43	0.47	8.2%	GBR	0.44	0.43	-1.6%
ZAF	0.44	0.48	8.1%	ESP	0.47	0.46	-2.0%
NLD	0.44	0.47	8.0%	MEX	0.35	0.34	-2.4%
BRA	0.44	0.48	7.6%	SGP	0.56	0.54	-3.0%
VNM	0.47	0.50	7.5%	BGR	0.51	0.50	-3.2%
DEU	0.42	0.45	7.0%	HUN	0.48	0.47	-3.3%
HKG	0.37	0.39	6.4%	IRL	0.47	0.45	-3.3%
RUS	0.43	0.46	6.4%	IDN	0.43	0.41	-3.5%
BEL	0.47	0.50	6.4%	EST	0.49	0.47	-3.7%
ARG	0.39	0.41	6.0%	PHL	0.42	0.40	-5.2%
DNK	0.39	0.42	5.7%	LTU	0.45	0.42	-5.8%
FRA	0.42	0.45	5.4%	HRV	0.48	0.45	-6.5%
JPN	0.44	0.46	5.2%	SVK	0.53	0.49	-7.9%
ITA	0.46	0.49	5.1%	ROU	0.48	0.43	-10.6%
CZE	0.54	0.56	4.2%	TUN	0.39	0.35	-11.2%
FIN	0.45	0.47	3.7%	GRC	0.38	0.32	-14.9%
POL	0.48	0.49	3.5%				

Notes: Countries ranked by decreasing % change in DVC. Only countries included in benchmark estimations (listed in Table A-1) reported. DVC measure defined in equation (2.2). Country names displayed in Table A-1.

Table A-4: DVC integration over time, industry average across countries

ISIC Rev. 3	Industry code	DVC in 1995	DVC in 2008	% change 1995-2008
64	PTL	0.31	0.42	36.3%
26	NMM	0.52	0.61	17.8%
31	ELQ	0.58	0.67	15.3%
65T67	FIN	0.38	0.43	14.4%
60T63	TRN	0.44	0.50	13.8%
25	RBP	0.62	0.70	13.0%
27	MET	0.66	0.74	10.9%
24	CHM	0.60	0.67	10.5%
71	RMQ	0.31	0.35	10.5%
23	PET	0.49	0.53	8.7%
34	MTR	0.70	0.76	8.6%
28	FBM	0.54	0.59	8.4%
29	MEQ	0.59	0.63	8.2%
72	ITS	0.35	0.38	8.1%
20	WOD	0.63	0.68	8.0%
17T19	TEX	0.64	0.69	7.8%
21T22	PAP	0.58	0.62	7.0%
50T52	WRT	0.35	0.37	6.0%
35	TRQ	0.61	0.64	5.7%
15T16	FOD	0.69	0.73	4.5%
73T74	BZS	0.36	0.38	4.5%
01T05	AGR	0.41	0.42	3.2%
30,32,33	CEQ	0.59	0.61	2.1%
36T37	OTM	0.60	0.57	-3.5%
10T14	MIN	0.32	0.26	-18.8%

Notes: Industries ranked by decreasing % change in DVC. Only industries included in benchmark estimations (listed in Table A-2) reported. DVC measure defined in equation (2.2). Industry descriptions displayed in Table A-2.

Table A-5: Summary statistics for main variables

Variable	Observations	Mean	Std. Dev.	Min	Max
<i>dvc</i>	1450	0.50	0.15	0.06	0.98
<i>fvax</i>	1449	6.06	2.20	-2.65	12.23

Notes: In sample statistics exclude Brunei Darussalam, Saudi Arabia, and the United States and non tradeable industries. *dvc* data is for the year 1995, *fvax* in natural logarithms for the year 2008.

B Construction of cost proxies²²

B.1 Fragmentation costs

Rauch (1999)’s product differentiation

As discussed in section 2, we use the Rauch classification as our benchmark measure for fragmentation costs. The classification is available in two variants (liberal and conservative version) at the 4 digit SITC Rev. 2 level. We choose the liberal version, which we concord to ISIC Rev. 3 using a crosswalk via SITC Rev. 3 based on concordance tables provided by Eurostat.

For our analysis, this creates two problems. Firstly, the classification is only available for the primary and manufacturing sectors and, secondly, due to the higher disaggregation several SITC categories are matched with each individual ISIC industry. We take the first issue into account by excluding industries in the services sector from the benchmark estimates and, in addition, by including services in robustness checks in which we ad hoc label them as differentiated.

The second point is only problematic when the SITC categories concorded to ISIC industries differ in their categorization. To determine the ISIC industry’s category in this case, we use gobar trade data from WITS at the SITC 4 digit level. In our benchmark definition we classify ISIC industries as differentiated if the trade share of differentiated SITC industries matched with them exceeds the mean value across all ISIC industries. Alternatively, we use the median value for robustness checks.

²² All concordances and classifications are available from the authors upon request.

Costinot (2009)’s complexity

Costinot’s measure is available for 41 unique observations covering 85 3 digit manufacturing SIC categories. This means several SIC industries have identical complexity values. We match these with our ISIC industries using a crosswalk via the 1987 SIC revision using concordance tables by NBER and Statistics Canada. In cases where we have several complexity observations matched with one ISIC industry, we use the simple mean. Table B-1 presents the resulting industry level values of the complexity variable.

Table B-1: Industry complexity

ISIC Rev. 3	Industry code	Complexity
35	TRQ	28.23
24	CHM	26.32
30,32,33	CEQ	25.36
29	MEQ	21.98
34	MTR	21.77
28	FBM	19.42
27	MET	18.29
21T22	PAP	17.29
31	ELQ	15.84
26	NMM	15.59
20	WOD	12.47
15T16	FOD	12.38
36T37	OTM	11.41
25	RBP	10.10
17T19	TEX	5.04

Notes: Industries ranked by decreasing value of complexity. Complexity is the average number of training days a new workers requires to be prepared for a job in a given industry. Data taken from Costinot (2009) and concorded to ISIC Rev. 3. Industry descriptions displayed in Table A-2.

B.1.1 Switching costs

Nunn (2007)’s contract intensity

Nunn’s contract intensity z is given by the share of differentiated intermediates in total intermediates that an industry sources as follows:

$$z_i = \sum_j \theta_{ji} Diff_j,$$

where $\theta_{ji} \equiv m_{ji} / \sum_j m_{ji}$, and $Diff$ is a dummy equal to one if industry j is differentiated. Thus, the measure is built based on the Rauch classification and we can apply the values calculated

using the methodology described above. To simplify the empirical analysis we then transform this continuous variable into a dummy by defining each industry j as *LFHS* if z_i is at least equal to the median z of non differentiated industries. For robustness exercises we replace this measure with capital intensity data readily available from the OECD.