Domestic Foundations of Global Value Chains*

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Abstract

We analyse the role of Domestic Value Chains (DVCs) for Global Value Chain (GVC) integration. Strong domestic linkages across firms reduce fragmentation costs but they also create a lock-in situation in relationship-specific sectors which raises switching costs. As a result, DVCs can either be stepping stones or stumbling blocks for GVCs. Focusing on backward linkages, that is 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 before the rise of GVCs raises subsequent GVC integration by about 0.4%. In addition, we exploit two dimensions of sectoral heterogeneity to identify the mechanisms at work: 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 sectors that are characterised by relatively high switching costs and relatively low fragmentation costs. This finding is in line with our hypothesised channel.

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

JEL Classification: F14; F15; F63.

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1 Introduction

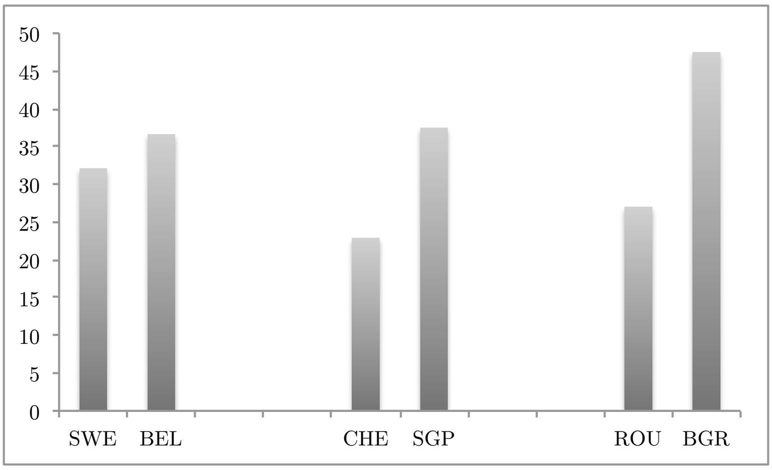
Global value chains (GVCs) are an important phenomenon of 21st century trade. Not only final goods or services get traded, but intermediate products and stages get outsourced and production becomes more and more fragmented. GVCs are often developed by large firms that coordinate input sourcing and assembly decisions, establishing sectoral linkages across borders. Seminal work by Hummels et al. (1998) and Hummels et al. (2001) unveiled the importance of this international production sharing. These papers have shown that GVCs, proxied by the amount of foreign value added in exports, have grown on average by 30% from the 1970s until the 1990s. In more recent work, Johnson and Noguera (2012a) and Johnson and Noguera (2012b) characterise 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. Similarly, Kummritz (2016) finds that at the sectoral 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 the GVC hubs China, 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.

A major 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 patters. 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



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

Independently, a growing amount of research has revisited earlier work by Hirschman (1958), showing the positive implications of domestic linkages between sectors within and across sectors.[1] Building on this literature, in this paper we argue and show empirically that GVCs have their foundations in domestic value chains (DVCs). 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. Higher domestic fragmentation lowers barriers to GVC integration due to the one-time incidence of fixed fragmentation costs. This would lead, other things being equal, to a positive relationship between DVC and GVC integration. However, domestic fragmentation also implies that GVC integration requires switching from domestic to

[1] See, among others, Jones (2011); Bartelme and Gorodnichenko (2015); Bernard et al. (2015); and Dhyne and Rubínová (2015).

foreign suppliers. This switching is also associated with fixed costs, which would suggest a negative effect of DVC integration on GVC integration. Overall, 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 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 GVC integration, as measured by foreign value added in exports at the end of the 2000s, is positively related to domestic fragmentation in the mid 1990s. In the benchmark specification, a one unit increase in DVC integration raises subsequent GVC integration by 2.4%. This suggests that DVC integration positively affects subsequent GVC integration, and that the fragmentation cost channel dominates the switching cost channel. Moreover, we are able to reduce the unexplained variation in GVC integration by about 30%.

We further exploit sectoral heterogeneity in the data to confirm the hypothesised role of fragmentation and switching costs for the relationship between DVCs and GVCs. We use the Rauch (1999) classification for differentiated goods to proxy for fragmentation costs, and Nunn (2007)'s contract intensity (i.e. relationship-specificity) measure to proxy for switching costs. To simplify the analysis, 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.[2] In line with the suggested mechanism, we find that the positive role of DVCs for subsequent GVC integration is driven by the first two categories, suggesting that fragmentation costs tend to be larger than switching costs. For the third category of industries, which is characterised by high switching and low fragmentation costs, the positive effect of DVCs disappears entirely.

The remainder of the paper is organised as follows. Section 2 presents the theoretical framework underlying the relationship between DVC and GVC integration. Section 3 provides

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

details on the measures employed to proxy for DVC and GVC, describes the data used and the identification strategy. Section 4 presents the empirical results. Section 5 concludes and suggests avenues for further research.

2 How the variation in initial DVC integration shapes subsequent GVC integration

There is a large amount of literature that analyses the trade-off between vertical integration and offshoring at arms-length. Typically, the choice is modelled as either between global offshoring and in-house production only[3] or a simultaneous decision between global offshoring, domestic outsourcing and in-house production.[4] In this paper, we exploit the fact that the international fragmentation of production has only started to expand at a global scale from the 1990s on as a result of a dramatic fall in trade and communication costs., while domestic fragmentation 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.

As outlined in the previous section, fragmentation and switching costs are expected to shape the link between DVC integration with subsequent GVC integration. The theoretical literature on outsourcing cited above has discussed the costs associated with fragmentation. 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 a higher level of DVC integration lowers the barriers to GVC integration by reducing the entry costs into international production networks.

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

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

Another insight from the theoretical literature on outsourcing cited above is that certain sectors require different amounts of relationship-specific inputs. When these inputs are supplied at arms-length, complex contracts are needed to address the resulting hold-up problem. Nunn (2007) shows that, as a result, sectors differ in their contract intensity. Switching suppliers is costlier in sectors 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. For the link between DVCs and GVCs, this means that domestic fragmentation can also increase the barriers to subsequent GVC integration. Determining the sign of the relationship between DVCs and GVCs is thus ultimately an empirical task and the focus of this paper.

3 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:

$$gvc_{ikt} = \alpha + \beta_1 dvc_{ikt-1} + \gamma' X_{ikt} + \varepsilon_{ikt}, \tag{3.1}$$

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.

3.1 Measuring domestic and global value chain integration

The empirical GVC literature has used and 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.

3.1.1 Measuring DVC integration

For DVC integration (the explanatory variable of interest in equation (3.1)) 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':

$$dvc_{ik} \equiv \frac{\sum_j m_{kk}^{ji}}{\sum_j m_{kk}^{ji} + va_{ik}}. \tag{3.2}$$

In other words, dvc is the share of inputs in production that are not produced in-house, conditional on production taking place domestically.[5]

The reason for calculating the DVC indicator in this particular way is twofold. Firstly, we only look at virtual domestic output instead of total output to avoid a mechanical correlation

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

with the dependent variable. Our GVC indicator (see Section 3.1.2) 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. We will discuss in Section 3.3 that 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. A second solution to this problem would be the use of levels on 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 summarise, 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 opt for 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 output.[6]

3.1.2 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 indicator, given by the foreign value added content in the production of exports (*fvax*), requires that value added crosses 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.[7] in a simple two-country, two industry case, the decomposition can be illustrated

[6]Summary statistics for our dependent and main independent variable are available in Appendix A.

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

as follows:

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

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 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.[8]

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

$$fvax_{ik} \equiv \sum_{l} \sum_{j} vae^{ji}_{lk}, \tag{3.3}$$

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.[9]

As a simple alternative indicator, we additionally calculate the amount of imported inputs, *i2p*, following Baldwin and Lopez Gonzalez (2015) for robustness exercises. This measure implies

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

[9] Here, too, sourcing from ISIC Rev. 3 group C (mining industry) is excluded. In addition, in Section 4.3 we use further strategies to deal with the mining sector.

a broader definition of GVC and can easily be derived from ICIOs as follows:

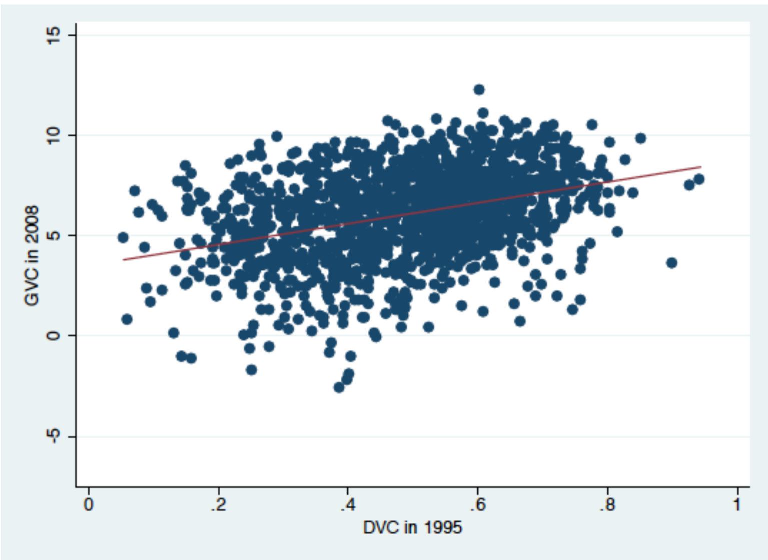
$$i2p_{ik} \equiv \sum_{l} \sum_{j} m_{lk}^{ji}, \tag{3.4}$$

where $l \neq k$.[10]

3.2 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 correlates 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 (3.2). GVC measure from equation (3.3) 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

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

the top and bottom ten countries in terms of the *dvc* variable (equation (3.2)) 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 (3.2).

3.3 Identification

Estimation results of the reduced-form equation (3.1) 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 developed downstream linkages than agriculture. In addition, country fixed effects take care of 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 country-industry pair, it is calculated as the weighted average of tariffs that its inputs face, with weights being given by the input-output coefficient. We follow the literature and use US input-output coefficient under the assumption that they determined by technological factors as opposed to market distortions.

Finally, considering that the aim it 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:

$$gvc_{ik2008} = \beta_1 dvc_{ik1995} + \beta_2 ca_{ik2008} + \beta_3 ctau_{ik2008} + \alpha_k + \alpha_i + \varepsilon_{ik2008}, \tag{3.5}$$

where β_1 is the coefficient of interest. Since the mechanism determining the role of DVCs for GVC integration is ambiguous as outlined in section 2, we do not have a prior on the sign of β_1.

While equation (3.5) can give the net effect of DVCs for GVC integration, it does not provide information on the mechanism driving the relationship. Therefore, we proceed in a second step with estimating a variant of equation (3.5) that exploits the industry-level variation in the data to analyse 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).[11]

As benchmark proxy for fragmentation costs, we use the Rauch (1999)'s classification for differentiated goods concorded to our industry-level data. The Rauch classification treats goods as differentiated if they are neither reference priced nor traded on organised exchanges. The reason for this choice is that industries with a high share of differentiated goods tend to be more innovation- and skill-intensive.[12] 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. A substantive share of fixed switching costs, such as contract cancellation fees, only occur when intermediates cannot be sourced from organised markets, but are sourced using contract-based relationships with suppliers. Nunn (2007)'s indicator measures the share of intermediates that are sourced through such contract-based relationships in total intermediates, and is thus a natural proxy for our exercise.[13]

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

[11] As argued in footnote 2, the case of high fragmentation and low switching costs is not observed.

[12] See, for example, Voigtländer (2014) for evidence on this relationship.

[13] Note, that Nunn (2007) 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.

inputs from organised 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.

Table 2: Industries by category

$LFLS$	$HFHS$	$LFHS$
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.

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 as follows:

$$\begin{aligned} gvc_{ik2008} =& \beta_1 dvc_{ik1995} + \beta_2 dvc_{ik1995} \times HFHS_i + \beta_3 dvc_{ik1995} \times LFHS_i + \beta_4 ca_{ik2008} + \\ & \beta_5 ctau_{ik2008} + \alpha_k + \alpha_i + \varepsilon_{ik2008}. \end{aligned} \tag{3.6}$$

In equation (3.6), 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 (3.5), 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 placebo test and we expect β_2 not to be statistically significant since, 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 (3.6) 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 *HFHS* industries given by the sum of β_1 and β_3 can additionally inform us on the relative relevance of switching costs vis a vis fragmentation costs.

3.4 Data

For the calculation of the DVC and GVC indicators as well as the contract intensity, GDP, comparative advantage and tariff measures 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 harmonised construction methodology, potential discrepancies between national IO tables should be minor. Furthermore, the advanced harmonisation 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.[14]

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. [15]

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 constant per capita GDP 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 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 variable 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

[14] See Koopman et al. (2012) for an analysis of China's processing trade.
[15] See Appendix B for details.

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.[16]

4 Results

This section is structured in three parts. We start by discussing the outcome of equation (3.5), which estimates the net effect that higher values of DVC integration have for subsequent GVC 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 (3.6). In the last part of the section we present a series of robustness checks.

4.1 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.

Columns (1) and (2) give the results for primary and manufacturing sectors only, while

[16] Exclusion of the United States is standard practice in the literature that uses US IO weights – see for instance Beverelli et al. (2015). All available countries and industries are listed in Appendix A.

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

	(1)	(2)	(3)	(4)
	Primary & Manufacturing		All sectors	
Dep. Variable:	*fvax*	*fvax*	*fvax*	*fvax*
dvc	2.566***	2.371***	2.900***	2.817***
	[0.451]	[0.443]	[0.379]	[0.373]
ca	1.519***	1.348***	1.472***	1.404***
	[0.074]	[0.068]	[0.065]	[0.059]
ctau	-0.002	-0.039**		
	[0.013]	[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 (3) and (4) include the service 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 4.2.

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-Squareds 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 emphasised 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.[17] 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 3.1 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 discussed in Section 2.

4.2 The role of fragmentation and switching costs

In this section, we estimate equation (3.6), which separates the effects of DVCs on GVCs in $LFHS$- (Low fragmentation, high switching costs) industries and $HFHS$- (High fragmentation, high switching costs) industries, with respect to a benchmark case of $LFLS$- (Low fragmentation, low switching costs) industries.

As a remainder, 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

[17] See, for instance, Jones (2011).

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 reduces the cost-minimising benefits from DVCs. In contrast, the latter dummy is a simple placebo 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 services industries, while columns (3) and (4) include them. We replicate in columns (1) and (3) the basic foundation results presented in Table 3 for comparison, while columns (2) and (4) report the new estimates for equation (3.6).

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 since the sum of the interaction and baseline point estimates is close to zero. In fact, the reported F-test for joint significance cannot reject the hypothesis that β_1 and β_3 jointly are 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 4.1 is confirmed and can be explained by the fact

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

	(1)	(2)	(3)	(4)
	Primary & Manufacturing		All sectors	
Dep. Variable:	*fvax*	*fvax*	*fvax*	*fvax*
dvc	2.371***	2.893***	2.817***	3.256***
	[0.443]	[0.683]	[0.373]	[0.752]
*dvc**$HFHS$		-0.071		-0.309
		[0.941]		[0.865]
*dvc**$LFHS$		-2.401**		-1.768*
		[0.968]		[1.033]
ca	1.348***	1.331***	1.404***	1.400***
	[0.068]	[0.069]	[0.059]	[0.059]
ctau	-0.039**	-0.041**		
	[0.017]	[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 sectors classified as having high fragmentation and switching costs. $LFHS$ is a dummy equal to one for sectors classified as having low fragmentation but high switching costs. The baseline *dvc* coefficient gives the coefficient for sectors classified as having low fragmentation and switching costs.

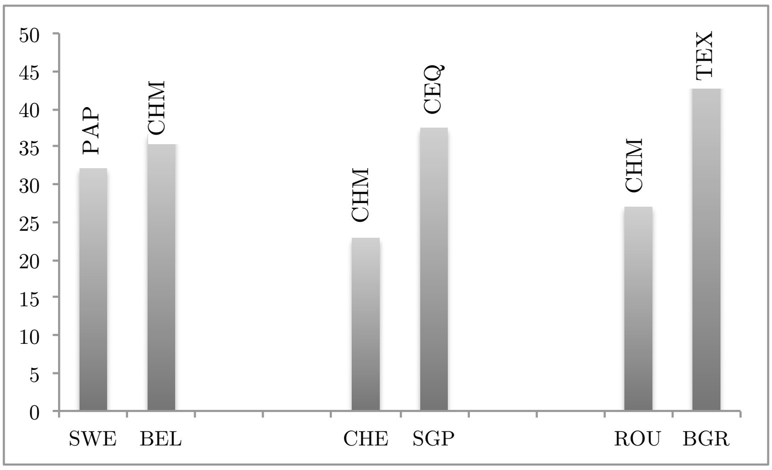
that fragmentation costs are more relevant than switching costs for moving from DVCs to GVCs.

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 countries 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 of the under-performers Sweden (Paper), Switzerland (Chemicals), and Romania (Chemicals) to the chart. It is striking that all these industries fall into the $LFHS$ category whereas the comparison group is more specialised in $LFLS$ and $HFHS$

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

This means that in the 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. GVC integration measured as foreign value added in exports over total exports.

4.3 Robustness

We expose our results to a battery of robustness checks starting with the identification assumptions.[18] 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 (3.5) an interaction term between the DVC measure and a high-income dummy, equal to one

[18] 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)
	Benchmark	High income	Short-run	GVC measure	All countries	All sectors	2011
Dep. Variable:	*fvax*	*fvax*	*fvax*	*i2p*	*fvax*	*fvax*	*fvax*
dvc	2.371***	2.019***	0.568**	2.105***	2.030***	2.851***	2.371***
	[0.443]	[0.529]	[0.222]	[0.408]	[0.454]	[0.336]	[0.443]
$dvc*high-inc.$		0.784					
		[0.658]					
ca	1.348***	1.342***	0.240***	0.894***	1.400***	1.385***	1.348***
	[0.068]	[0.068]	[0.032]	[0.056]	[0.075]	[0.056]	[0.068]
ctau	-0.039**	-0.037**	0.002	0.005	-0.024		-0.039**
	[0.017]	[0.017]	[0.006]	[0.015]	[0.019]		[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.

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 an unbiased coefficient on *dvc* 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 (3.5). 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 varies 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 3.1.2). 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 relationship. The estimates in column (7) of Table 5 suggest that neither is the case. However, we find that the crisis has brought to an end the accumulation of the effect over time which could be observed when comparing the short-run with the long-run model.

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 *dvc* 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 benchmarks 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) gives the coefficients of the preferred specification (column (2) of Table 4) for convenience, 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 3.4, 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

Table 6: Industrial heterogeneity in the effect of DVCs on GVC integration - Robustness

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

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

5 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 holds 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 0.31%. 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 domestic fragmentation implies that firms entering GVCs incur less additional costs of fragmentation since they have paid them already. On the other hand, high levels of domestic fragmentation lead to costs related to switching from domestic to foreign suppliers.

Our findings on the net effect suggest that the fragmentation cost channel is more important than the switching cost channel. In addition, we exploit the industrial variation in the data to confirm that our hypothesised mechanism is relevant. We find that the facilitating effect of DVCs is absent in industries characterised 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.

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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 sectors

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 (3.2). Country names displayed in Table A-1.

Table A-4: DVC integration over time, sector-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 (3.2). Industry descriptions displayed in Table A-2.

Table A-5: Summary statistics for main variables

Variable	Observations	Mean	Std. Dev.	Min	Max
dvc	1450	0.50	0.15	0.06	0.98
$fvax$	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 proxies[19]

B.1 Fragmentation costs

Rauch's product differentiation

As discussed in section 3, we use the liberal version of the Rauch (1999) classification as our benchmark measure for fragmentation costs. The classification is available at the 4-digit SITC Rev.2 level 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 primary and manufacturing industries 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 services industries in our benchmark estimates and, in addition, by including services in robustness checks in which we ad hoc assign them to be differentiated.

The second point is only problematic when the SITC categories concorded to ISIC industries differ in their categorisation. To determine the ISIC industry's category in this case, we use gobal 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.

Costinot's complexity

The Costinot (2009) 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

[19] All concordances and classifications are available from the authors upon request.

observations matched with one ISIC industry, we use the simple mean.

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's contract intensity

Nunn (2007)'s measure z is given by the share of differentiated intermediates in total intermediates that an industry sources as follows:

$$z_i = \sum_j \theta_{ji} \mathit{Diff}_j,$$

where $\theta_{ji} = m_{ji} / \sum_j m_{ji}$, and $Diff$ a dummy equal to one if industry j is differentiated. Thus, the measure is built based on the Rauch (1999) 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 i as $LFHS$-industry for which

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.