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Do Global Value Chains Cause Industrial Development?

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Abstract

Global Value Chains (GVCs) have become a central topic in trade and development policy but little is known about their actual impact on economic performance. Using a new unique set of Inter-Country Input-Output tables with extensive country coverage, I show that an increase in GVC participation leads to higher domestic value added and productivity for all countries independent of their income levels. Causality is established by building a novel value added trade resistance index that combines third country trade costs with industry-specific technological variables leading to an exogenous variation in GVC participation. Based on the preferred IV specification, I find that a 1 percent increase in backward GVC participation leads to 0.11% higher domestic value added in the average industry. Equally, I find for forward linkages that a 1 percent increase in GVC participation leads to 0.60% higher domestic value added and to 0.33% higher labour productivity.

JEL-Classification: F13, F14, F15, F63

Keywords: Global Value Chains, International Trade, Economic Development

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1 Introduction

The expansion of Global Value Chains (GVCs) is a dominant feature in the recent evolution of globalisation.[1] Policy makers and trade research increasingly place GVCs at the centre of their agenda and emphasise their growing importance for trade and development. Correspondingly, the World Economic Forum (2013) estimates that reductions in GVC barriers, such as border administration and non-tariff barriers to trade, could raise global GDP by 5% and international trade by 15%. However, a positive effect of GVCs for participating countries is not self-evident. In high-income economies there is a widespread concern that firms use GVCs to hollow out domestic value added by offshoring employment and shifting profits abroad.[2] This is mirrored in the seminal analysis by Samuelson who famously argues that under certain conditions

> "[outsourcing] gives to China some of the comparative advantage that had belonged to the United States [and] can induce for the United States permanent lost per capita real income". Samuelson (2004, p. 137)

Similarly, at the other end of the income spectrum, low- and middle-income countries are concerned that GVCs are simply a new way to promote old liberal trade policies that bring unilateral gains to the developed world and force them to specialise in low-productivity tasks with little scope for future development.[3] Interestingly however, there is little empirical evidence so far to support either side.

Therefore, I look in this paper at the role of GVC participation for domestic value added and labour productivity to determine if concerns about GVCs are justified and for whom GVCs are beneficial. Using a new unique set of extensive Inter-Country Input-Output tables (ICIOs) provided by the OECD, I can estimate the industry-level effect of GVCs on countries across all income levels.[4] I show that an increase in GVC participation causes a rise in domestic value added and productivity both at the industry- and country-level. This finding holds for indicators based on sourcing linkages (i.e. foreign value

[1]The term *Global Value Chain* is increasingly used to summarise concepts that are commonly referred to as task trade, production fragmentation, vertical specialisation, outsourcing and so forth. It describes the rise of foreign value added in domestic output caused by an increasingly international organisation of production structures by firms.

[2]See, for example,Thompson (2010) and Roberts (2004) in The Atlantic and Business Week respectively.

[3]See, for example, Dalle et al. (2013) and UNCTAD (2013).

[4]I would like to thank the OECD, and especially Norihiko Yamano, Colin Webb, and Bo Werth, for giving me early access to and discussing the OECD ICIOs with me.

added in domestic exports) and selling linkages (i.e. domestic value added in foreign exports), which reflect different specialisation patterns within value chains and is robust to the inclusion of different sets of fixed effects and sample compositions. Causality is established using a novel bilateral and bi-industrial value added trade resistance index that combines third country trade costs with industry-specific technological variables leading to an exogenous variation in GVC participation.

In addition, a finer look at the results reveals that the gains from GVC integration are not dependent on the stage of development. By splitting the countries in the sample into two categories on the basis of their respective per capita GDPs, I find that the benefits for productivity and value added caused by GVC integration are present within both categories. This shows that potential concerns about the effects of GVC integration cannot be justified on empirical grounds. Instead, the results show that GVCs can help to stimulate growth and industrial development.

This is one of the first papers to empirically examine the effect of GVCs on domestic outcomes at the aggregate level. In that regard, this paper relates to the empirical work on trade in final goods and growth. While this literature does not incorporate the novel production structures assessed here, it is highly relevant due to its efforts to properly identify the effects of trade variables at the macro-level. In particular Feyrer (2009), building on work by Frankel and Romer (1999), has identified instrumental variables that correctly assess the effect of trade on per capita GDP and that will guide conceptionally the instrumentation strategy of this paper.

The empirical literature on GVCs on the other hand has so far focused on developing novel indicators to measure GVC participation and to describe its development and pattern over time. This work has revealed a rapid rise in the interconnectedness of nations' production and has re-evaluated important indicators of trade.[5] For instance, Hummels et al. (1998, 2001) provide in two seminal contributions initial evidence for the growth of international production sharing. They develop one of the primary GVC participation measures, namely foreign value added in exports or Vertical Specialisation (VS). Using the OECD's IO tables for 35 industries in ten developed countries from 1970 to 1990, the authors show that VS has grown on average by 30% and is responsible for a major share of the total growth in exports. They also find that smaller countries tend to have larger VS ratios and that heavy manufacturing sectors exhibit the highest vertical

[5] See Amador and Cabral (2016) for a more extensive review of the literature on GVCs and outsourcing.

integration. Based on this, Daudin et al. (2011) compute a forward linkage VS1 measure originally proposed but not calculated by Hummels et al. (2001). VS1 is the share of domestic value added in foreign exports. They show that this measure equally reveals that GVCs are on the rise.

Many of these results have been confirmed and expanded using more recent and extensive data. For example, Johnson and Noguera (2012a) find that bilateral trade imbalances measured in value added differ significantly from gross trade imbalances. This difference also arises for revealed comparative advantage indices as shown by Timmer et al. (2013) and Timmer et al. (2014), who also analyse how GVCs shift the factor composition in high-income economies towards skilled labour and capital at the expense of unskilled labour. Baldwin and Lopez-Gonzalez (2013) and Johnson and Noguera (2012b) present evidence that the expansion of GVCs is ongoing, while Koopman et al. (2014) expand the set of country-level GVC indicators by deriving a comprehensive decomposition of gross exports, which Wang et al. (2013) extend to a bilateral and sectoral level.

This work has been fundamental in examining the new phenomenon of GVCs but the next step is to investigate how it relates to other indicators of economic activity. This paper aims to do this by assessing the role of GVCs for labour productivity and domestic value added. The remainder of the article is organised as follows. Section 2 discusses theoretical channels through which GVC participation affects the domestic economy before Section 3 introduces the empirical specification and discusses the various indicators of GVC participation employed in the estimation. Section 4 explains the instrumentation strategy while Section 5 presents the data and Section 6 the results. Section 7 analyses their robustness before Section 8 concludes.

2 How GVCs affect productivity and domestic value added

Trade can boost productivity and value added at the country- and industry-level through a myriad of channels including gains from specialisation and the reallocation of resources. However, recent theoretical research shows that GVCs have changed the way trade is conducted leading to novel ambiguous effects on its participants. This literature examines typically GVCs that link low-wage countries, *South*, to technologically advanced high-wage nations, *North*. The differences between the two countries generate incentives to trade tasks or offshore which, in turn, creates a set of benefits and disadvantages depending on the assumptions in the models.[6]

For instance, in Li and Liu (2014)'s dynamic model South gains through a productivity-enhancing learning-by-doing process while Northern gains are contingent on initial conditions.[7] In the model a final good is produced using a continuum of tasks under the assumption that for each task Northern unit labour requirements are equal or below the ones of South.[8] The rise of GVCs allows North and South to specialise in tasks according to comparative advantage. The specialisation enables South to lower its unit labour requirements through a learning-by-doing process, which causes North to relocate more tasks to South in the next period. This process repeats itself until a steady state is reached in which wages and technology are equalised. Throughout the process South gains but North experiences a period of decreasing welfare because its comparative advantage deteriorates when South becomes more productive in tasks that are performed in North. Therefore, the overall effect of rising GVC participation on Northern value added can be negative.The model can thus be seen as an application of Samuelson (2004)'s famous offshoring critique to a trade-in-tasks framwork since GVCs encourage North to outsource tasks in which it used to have a comparative advantage.

In contrast, Baldwin and Robert-Nicoud (2014) propose a model in which gains and losses for the two countries are reversed. They show how GVCs cause productivity improvements akin to technological change for North but terms-of-trade losses for South by embedding the prominent features of the Grossman and Rossi-Hansberg (2008) model into a general equilibrium setting.[9] In the model, North and South compete in the production of a final good by combining a set of tasks as inputs. As before North has lower unit labour requirements for all inputs but higher wages. The rise of GVCs enables North to combine its superior technology with low wages in South through the offshoring of some task production. This decreases average production costs for North causing a

[6]Note that in the GVC and offshoring literature the term task might also refer to intermediate goods.

[7]Learning-by-doing also drives Southern gains in similar work byLiu (2013) and in an extension of Zi (2014).

[8]Such an assumption has been common in the GVC literature since the early seminal contribution of Feenstra and Hanson (1996). However, their model focused exclusively on the static gains from offshoring on domestic factor rewards not taking into account the dynamics introduced through technology tranfer or learning-by-doing.

[9]These features are present in many papers on GVCs. Examples include Jones and Kierzkowski (1990), Arndt (1997), Egger and Falkinger (2003), Kohler (2004), and Rodríguez-Clare (2010). As Feenstra and Hanson (1996) however, these models focus exclusively on the effects of offshoring on domestic factor rewards.

rise in Northern wages and output.[10] Southern final goods output on the other hand decreases since South suffers effectively from an endowment decrease when Southern labour performs tasks for Northern final goods production.[11]

However, Baldwin and Robert-Nicoud (2014) show in an extension of the model that an increase in productivity and value added of both countries is possible when there are technology spillovers from North to South. Recent empirical findings suggest that this is very likely. Piermartini and Rubínová (2014) provide for instance evidence that GVCs are a much stronger facilitator of knowledge spillovers than final goods trade. Similarly, Benz et al. (2014) present firm-level evidence on spillovers induced by offshoring. This relates to the Foreign Direct Investment (FDI) spillover literature, which is interconnected with GVCs. Amongst others, Javorcik (2004) and Javorcik and Spatareanu (2009) demonstrate the existence of technology spillovers from FDI through backward linkages in low- and middle-income countries.

To summarise, the discussed work outlines several channels through which GVC participation increases the value added and productivity of its participants. The main channels are learning-by-doing, technology transfer or spillovers, gains from specialization as well as terms of trade effects. However, across the models the materialisation of these gains is uncertain for a subset of countries since, for instance, changes in the terms of trade necessarily hurt one GVC partner. To determine whether the net effect is negative or positive is thus ultimately an empirical task and the aim of this paper.

3 Identifying the relationship empirically

The theoretical literature discussed in section 2 has revealed an ambiguous relationship between GVC participation and domestic outcomes that is reflected in the current policy debate on GVCs. Therefore, I test firstly if GVC participation causes an increase in productivity and domestic value added and, secondly, if these effects arise for countries at different stages of development.

To this end, I use a simple reduced-form model according to the following specification

[10] Grossman and Rossi-Hansberg (2008) show that this is equivalent to a wage response caused by productivity improving technological progress.

[11] Baldwin and Robert-Nicoud (2014) illustrate this using a "shadow migration" approach. That is, they express product and labour market conditions as if the Southern labour employed by North actually had migrated. This allows them to restore the classic effects of the Heckscher-Ohlin-Vanek model in a task trade setting.

to investigate the role of GVCs:

$$ln(x_{ikt}) = \alpha + \beta_1 \; ln(gvc_{ikt}) + \; \varepsilon_{ikt}, \tag{1}$$

where $ln(x_{ikt})$ is either the natural logarithm of total domestic value added or value added per worker in industry i of country k at time t. The variable of interest is gvc_{ikt}, which represents an indicator of GVC participation, making β_1 the coefficient of interest.

To develop proxies for gvc_{ikt}, I rely on the empirical literature discussed in section 1. It has developed two standard measures of GVC participation that can be divided into backward linkage/sourcing and forward linkage/selling measures. The sourcing measure looks at foreign value added in domestic exports while the selling measure looks at domestic value added in foreign exports. In the analysis, I use both types of measures since their ability to capture GVC integration depends on a country's specialisation pattern. Countries specialised in sophisticated tasks that add more value to a good, like R&D, typically have strong selling linkages. On the other hand, GVC integration of countries that focus on low value added tasks, such as assembly, is better characterised by sourcing linkages since these countries depend on foreign value added for their production. This links back to the theoretical models in section 2 in which South specialises in less sophisticated tasks and North in high value added task. Accordingly, sourcing linkages might empirically be a better measure for low- and middle-income countries, while selling linkages are a better measure for high-income countries or primary commodity exporters.

The derivation of the indicators follows Hummels et al. (2001) in applying the standard Leontief (1936) insight to Inter-Country Input-Output tables in order to derive a decomposition of gross exports into value added along the four dimensions: source country, source industry, using country, and using industry. The idea behind this insight is that the production of an industry's output requires inputs of other industries and its own value added. As supplying industries usually depend on inputs from other industries as well, this sets in motion a second round of indirect value added creation in the supplying industries of the suppliers, which is caused by the original industry's production. This goes on until value added is traced back to the original suppliers. In a simple example for a given year with two countries, k and l, and two industries, i and j, this means that I multiply the value added multiplier, $V(I\text{-}A)^{-1}$, with country-industry-level gross exports, E, to deduce their value added origins. The theoretical derivation and a detailed explanation of this procedure can be found in the Appendix:[12]

$$V(I-A)^{-1}E = \begin{pmatrix} vae_{ikik} & vae_{ikjk} & vae_{ikil} & vae_{ikjl} \\ vae_{jkik} & vae_{jkjk} & vae_{jkil} & vae_{jkjl} \\ vae_{ilik} & vae_{iljk} & vae_{ilil} & vae_{iljl} \\ vae_{jlik} & vae_{jljk} & vae_{jlil} & vae_{jljl} \end{pmatrix} \tag{2}$$

where the elements of the $V\left(I-A\right)^{-1}E$ or vae matrix are estimates for the industry-level value added origins of each industry's exports. For instance, vae_{ikjl} is the the value added of industry i from country k in the exports of industry j from country l. The decomposition then allows me to construct two standard GVC indicators.

Firstly, my backward linkage indicator - $fvax$ (foreign value added in exports) - is given by:[13]

$$fvax_{ik} = \sum_{l}\sum_{j} vae_{jlik}, \tag{3}$$

where $l \neq k$. This means that $fvax_{ik}$ 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.[14] Secondly, the forward linkage indicator - $dvar$ (domestic value added in foreign (re-)exports) - of industry i in country k for a given year is defined as:

$$dvar_{ik} = \sum_{l}\sum_{j} vae_{ikjl}, \tag{4}$$

where $l \neq k$. Thus, $dvar_{ik}$ is equal to the sum of value added from industry i of country k in the exports of all industries j in all foreign countries l. The basic idea behind these two GVC integration proxies is that they require goods to cross at least two borders to count towards GVC trade. This implies that only intermediate goods are taken into account and that the final product contains at least the value added of two countries.

Table 1 provides summary statistics for the indicators. The within-standard-deviation shows that there is significant variation in GVC participation over the period from 1995 to 2011 within a country-industry pair. This allows for the inclusion of a large set of

[12] The decomposition was technically implemented using the R package *decompr* described in Quast and Kummritz (2015), which automates the calculation of GVC indicators.

[13] Note that time subscripts are omitted in this section for convenience.

[14] Sourcing from ISIC Rev. 3 group C (mining industry) is excluded to avoid spurious effects based on oil imports. In addition, I use further strategies outlined in the section 7 to deal with imports from the mining sector.

fixed effects without compromising on efficiency in the empirical specification.

Variable	**Obs**	**Mean**	**Std. Dev.**	**Std. Dev. Within**	**Min**	**Max**
$fvax$	5,495	7.193	2.306	0.750	-5.521	14.156
$dvar$	5,500	7.116	2.294	0.667	-3.123	13.200

Table 1: Summary statistics of GVC indicators. Variables in natural logarithms.

4 Instrumenting for GVC participation

The estimation of the empirical model in equation (1) is subject to a set of identification concerns. Most importantly, domestic value added and labour productivity are the result of many factors that might be correlated with GVC participation but are not or cannot be observed. In fact, omitted variable bias has been a key obstacle in the empirical literature on trade and growth at the macro-level.[15] For this reason estimating the equation at the industry-level is highly advantageous since it allows for the inclusion of various sets of fixed effects that account for many confounding factors that prominently feature in the field, such as financial development or infrastructure. In the benchmark model, I include industry-country, country-year, and industry-year fixed effects. This comes at the cost of limiting potential gains to within-industry effects and thereby represents a lower bound of the estimates but it reduces confounding factors to industry-country-time varying variables.

A second issue arising from equation (1) is reverse causality. If growing industries are more likely to increase their GVC participation, the coefficients in equation (1) are upward biased. In addition, since the GVC indicators are based on the Leontief decomposition they represent estimates and might be subject to measurement error. I deal with these three problems jointly by using an instrumental variable (IV) approach that exploits the international fragmentation of production caused by GVCs. This allows me to estimate the causal effect of GVC integration on domestic value added and labour productivity.

[15]See Rodriguez and Rodrik (2001) for a well-known analysis of the problem.

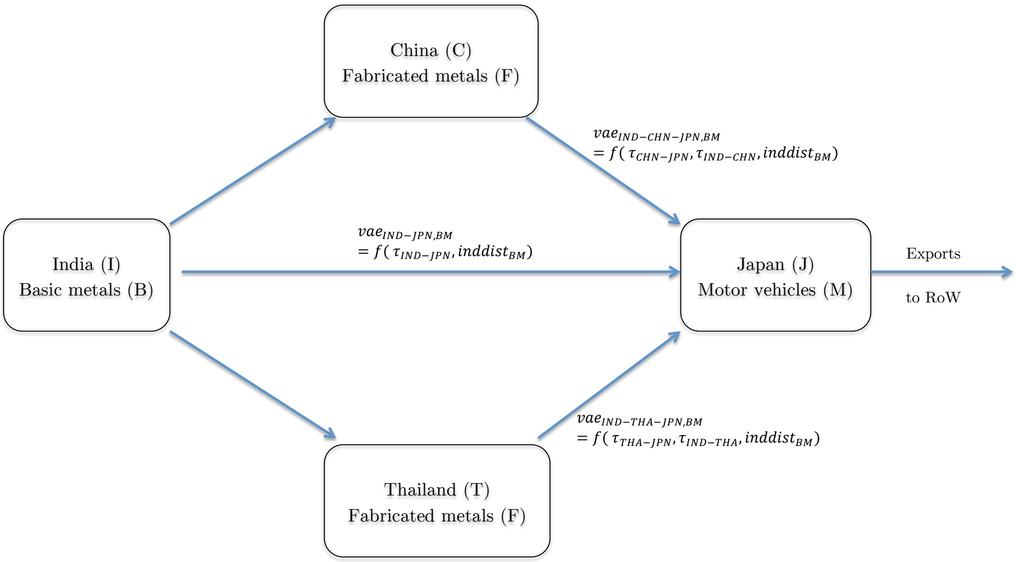

Figure 1: Instrumenting the *vae* matrix.

4.1 The instrument: An example with four countries and three industries

Recall for the instrumentation strategy that the GVC participation indicators, $fvax_{ikt}$ and $dvar_{ikt}$, are calculated by simply summing over all bilateral and bi-industrial value added trade relationships vae_{jlikt} following equations (3) and (4). This becomes clearer when looking at a simple example of a GVC with 3 industries and 4+1 countries as illustrated in Figure 1. The figure depicts a stylised car value chain and shows that the backward linkage indicator of the Japanese car industry, $fvax_{MJT}$, is composed of value added from India's steel industry, vae_{BIMJT}, and China's and Thailand's fabricated metal's industries, vae_{FCMJT} and vae_{FTMJT}, which process Indian steel into inputs for the export production of the Japanese car industry.

To explain the individual steps of the instrumentation, let me focus on one component of $fvax_{MJT}$ - the value added of the Indian steel industry embedded in Japanese car exports, vae_{BIMJT}. Figure 1 depicts how vae_{BIMJT} comes to Japan directly but also indirectly via Thailand's and China's fabricated metals industries:

$$vae_{BIMJT} = vae_{IND-JPN} + vae_{IND-THA-JPN} + vae_{IND-CHN-JPN}.$$

Each of these components might be contaminated from reverse causality or omitted variable bias but from gravity models we know that the value of these flows depends on bilateral trade costs, τ, between the countries involved:

$$\begin{aligned} vae_{IND-JPN} &= f(\tau_{IND-JPN}) \\ vae_{IND-THA-JPN} &= f(\tau_{IND-THA}, \tau_{THA-JPN}) \\ vae_{IND-CHN-JPN} &= f(\tau_{IND-CHN}, \tau_{CHN-JPN}). \end{aligned}$$

I can use these trade costs to predict the *vae* flows in order to reduce endogeneity but in particular $\tau_{IND-JPN}$ might still be biased. For instance, the Japanese car industry could lobby its government to decrease trade barriers with India in order to compensate some negative shock to its labour productivity with cheaper inputs.

However, the GVC structure of production allows me to bypass this problem. A specific characteristic of GVC-inspired value added gravity models such as Noguera (2012) is that they explicitly include bilateral trade costs between India and China or Thailand to predict India's value added in Japanese exports. This can be understood from Figure 1, which shows that these trade costs determine $vae_{IND-THA-JPN}$ and $vae_{IND-CHN-JPN}$, which are a part of vae_{BIMJT}.

Therefore, I can use these "indirect" bilateral trade costs to predict vae_{BIMJT} with the advantage that bilateral trade costs between independent countries such as India and Thailand are exogenous to the productivity or value added of the Japanese car industry. Accordingly, $\tau_{IND-THA}$ and $\tau_{IND-CHN}$ predict the exogenous component of vae_{BIMJ}, which in turn can be used to build a predicted backward linkage indicator of the Japanese car industry, $f\hat{vax}_{MJT}$. Equally, I can use $\tau_{CHN-JPN}$ and $\tau_{THA-JPN}$ to build a predicted forward linkage indicator for the Indian steel industry, $d\hat{var}_{BIT}$. These predicted values are then used as instruments in a 2SLS.[16]

The remaining problem for the instrumentation is that trade costs are at the country-level while the GVC indicators are at the industry-country level. Here, the GVC structure of production equally allows for a simple solution. As we can see in Figure 1, the value added of the steel industry travels directly and indirectly to the car industry of Japan,

[16]Conceptually this IV strategy follows the three-step approach of Frankel and Romer (1999) and Feyrer (2009) who estimate the impact of trade on growth by instrumenting bilateral trade flows using the geographical distance between two countries as IV. The aggregated predicted trade flows are then used as an instrument in a 2SLS.

while the value added of the fabricated metal industry only travels directly. The reason is that from a GVC perspective there is a larger distance between the steel and car industry than between the fabricated metals and car industry. Put differently, there are more intermediate stages to be performed after the steel stage than after the fabricated metal stage in the production of a car. I refer to the distance between the steel and car industry as $inddist_{BM}$. The larger $inddist_{BM}$, the higher the probability that third countries such as China or Thailand affect a bilateral value added trade relationship since a large distance implies more stages that third countries can occupy. Therefore, I can use the interaction of $inddist_{BM}$ with a weighted average of $\tau_{IND-CHN}$ and $\tau_{IND-THA}$ to build a bilateral, bi-industrial, and time-varying instrument for the Indian steel value added in Japan's car exports, vae_{BIMJT}.

To summarise, I instrument the amount of Indian steel value added in Japan's car exports using a factor of the Indian steel price that is exogenous to Japanese industries, namely India's bilateral trade costs with Japan's suppliers. Since these indirect trade costs have a larger effect for industries that are separated by more stages (i.e. the industries' distance), I can use the interaction between the trade costs and the distance as an instrument.

4.2 The components of the instrument: bilateral trade costs and industrial distance

As outlined in the previous section the instrument has two ingredients which need to be both relevant and exogenous. Since relevance has already been established, I can turn to exogeneity and outline the construction of the two components in more detail.

The first ingredient are the average bilateral trade costs of India with its trade partners weighted by Indian exports, e_{IT}:

$$\tau_{IJT} = \sum_{C} \tau_{ICT} * \frac{e_{ICT}}{\sum_{C} e_{ICT}},$$

where $C \in Thailand, China$ and which in general form can be expressed as

$$\tau_{lkt} = \sum_{c} \tau_{lct} * \frac{e_{lct}}{\sum_{c} e_{lct}}, \tag{5}$$

where $c \neq k, l$. The trade cost data is taken from UNESCAP, which estimates these trade costs using the inverse gravity model developed by Novy (2013). Put simply, the model compares bilateral trade patterns with domestic sales patterns to deduce the corresponding trade costs. In this way, it gives a micro-founded comprehensive trade cost figure that includes both structural factors, such as geography, and policy measures, such as tariffs. It is important to note that I exclude the trade costs between India and Japan, $\tau_{IND-JPN}$, from the trade cost aggregate and only include $\tau_{IND-THA}$ and $\tau_{IND-CHN}$. This ensures that India's bilateral trade cost aggregate is not contaminated by factors that affect Japan's domestic value added or labour productivity and can thus be used as instrument.

A positive and important side effect is that value added trade flows predicted in this way do not overlap with gross trade flows predicted using the bilateral distance between India and Japan as an instrument, which is common in the trade and growth literature.[17] This means that the results of this paper are novel and complementary to the positive effect of trade in final goods.

Regarding the exogeneity of $\tau_{IND-THA}$ and $\tau_{IND-CHN}$, let us recall that the empirical reduced-form model is, firstly, at the industry-level, which makes an involvement in third countries' trade policy extremely unlikely. Secondly, the reduced-form model includes country-year fixed effects and thus potential country-wide effects triggered by a variation in the trade costs of large trading partners, such as trade diversion, are controlled for. Thirdly, the bilateral nature of the trade costs implies that it is affected mainly by very specific changes that affect the analysed country-pair disproportionately. Examples include tariff changes limited to the involved country-pair or a new cargo flight connection between the two countries.

Moreover, third-country trade policy is a typical instrument in research on international trade suggesting that exogeneity is a common assumption in the field.[18] The advantage here is that unlike in previous cases the instrument is not just a proxy but directly affects the instrumented variable due to the GVC structure of production.

For robustness, I additionally re-calculate the trade costs aggregates dropping country triples that have entered a FTA or customs union during the sample period from the calculation of the instrument. That means if India, Thailand, and Japan would have signed an FTA during the sample period, India's trade costs with Thailand would be excluded from the prediction of vae_{BIMJT}. In addition, I exclude large countries from

[17] e.g. Frankel and Romer (1999) and Feyrer (2009).

[18] See, for example, Kee et al. (2009) and Crivelli (2014).

the estimation that might be able to affect third countries' trade policy such as the USA, China, or Japan, and especially large European countries like Germany, the United Kingdom, France, or Italy, that can unilaterally influence the EU's trade negotiation position.

The correlation between these constructed trade costs and the *vae* matrix elements is negative and highly significant (-0.33 and -0.31 for the logged versions of the $fvax$ and $dvar$ instruments respectively).

The second ingredient of the instrument, the distance between the industries within the value chain, is calculated as the inverse of the product of the source industry's upstreamness and the using industry's downstreamness employing the indices derived by Fally (2012), Antras et al. (2012), and Antras and Chor (2013):[19]

$$inddist_{ji} = \frac{1}{upstreamness_j * downstreamness_i} \tag{6}$$

where

$$upstreamness_i = 1 + \sum_j \sum_l \frac{a_{ikjl} * y_{ik}}{y_{jl}} * upstreamness_j,$$

and

$$downstreamness_i = 1 + \sum_j \sum_l a_{jlik} * downstreamness_j,$$

with y being output and a denoting the share of inputs in output. The upstreamness measure is calculated as the number of industries that use an industry's output weighted by how upstream these industries are themselves, while the downstreamness measure assesses from how many other industries an industry sources inputs weighted by how downstream these industries are themselves. Thus, the more upstream a source industry the more of its value added is in the production of more downstream industries. Similarly, the more downstream a using industry the more likely it produces with large amounts of value added from upstream industries.

The position of an industry itself can for several reasons be assumed to be exogenous in a time span of fifteen years. For instance, it is ultimately determined by inherent technological processes. A car producer will, for instance, always need raw materials

[19]Since upstreamness and downstreamness are positively correlated with the elements of the *vae* matrix, I use their inverses to derive an index that has a linear negative relationship with the *vae* matrix. I could equally use the inverse of the trade costs to derive an index with a positive correlation without changing the subsequent IV results.

such as steel for its production. It can optimise its sourcing process by looking for cheaper or better suppliers but it cannot change its downstreamness by optimising away from steel altogether. This exogeneity and sluggishness of the measures is mirrored in the stylised facts presented by Antras et al. (2012) and Fally (2012) who show that they are very stable across countries. I confirm this stability over time by calculating the measures for all countries in the sample for the five available years.

Independent of this, the industry-year and country-industry fixed effects control in any case for asymmetric impacts of the industry position on domestic value added and productivity. Therefore, there is no strict exogeneity condition on the position itself since the identification is based on the distance between supplying and using industry and not on the position. For the instrument, I use the industry-wide sample averages across countries and years. The correlations between the two variables and the elements of the *vae* matrix are positive and highly significant. The technical construction of the two components is described in detail in the Appendix.

4.3 Putting it together: The M country N industry case

I can now combine the individual components to implement the IV strategy. Due to the bilateral instrumentation the strategy includes three stages instead of the two stages of a regular 2SLS. In a "zero" stage, I instrument the *vae* flows with the interaction of the bilateral trade costs aggregates τ and industry distance *inddist* as defined in equations (5)-(6). This can be expressed in levels as follows:

$$v\hat{a}e_{jlikt} = e^{\alpha+\beta_1 \ln(\tau_{lkt} * inddist_{ji}) + \alpha_{ik} + \alpha_{kt} + \alpha_{it} + \varepsilon_{jlikt}}, \quad (7)$$

where the α terms are fixed effects at the industry-country, country-year, and industry-year level. In an intermediate step the aggregation gives the predicted GVC participation measures $g\hat{v}c_{ikt}$:

$$f\hat{vax}_{ikt} = \sum_l \sum_j v\hat{a}e_{jlikt}, \quad (8)$$

and

$$d\hat{var}_{ikt} = \sum_l \sum_j v\hat{a}e_{ikjlt}, \quad (9)$$

where $l \neq k$. These terms serve as instruments in a regular 2SLS estimation.[20]

Table 2 shows the results for the estimation of the logged versions of equation (7) or the "zero"-stage. It shows that the estimated average elasticities between the instruments and the vae flows are -0.8 and -1.0 respectively. Trade costs seem thus to play a slightly bigger role for GVC participation through forward linkages but they are highly relevant and statistically significant for both types of participation.

With the coefficients of Table 2, I predict exogenous $\hat{vae}$s, which I aggregate following equations (8) and (9). As a result, I have values for $\hat{fvax}_{ikt}$ and $\hat{dvar}_{ikt}$, which I can use to estimate the causal effect of GVC integration on productivity and domestic value added using 2SLS.

	(1)	(2)
VARIABLES	vae_{jlikt}	vae_{ikjlt}
$\tau_{lkt} * inddist_{ji}$	-0.820***	
	(0.0047)	
$\tau_{klt} * inddist_{ij}$		-1.095***
		(0.0055)
Observations	8,113,075	8,093,125
Fixed effects	Industry-country, Country-year, Industry-year	
R-squared	0.97	0.96

Table 2: The "zero" stage - value added in exports versus the instruments.
Industry-country-pair clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Variables are in natural logarithms.

5 Data sources

I use the new OECD ICIOs as the main data source for the GVC indicators and the industry position indicators. The OECD ICIOs constitute the most recent and most advanced release of Inter-Country Input-Output tables. The new version of the database provides ICIOs covering 61 countries and 34 industries for the years 1995, 2000, 2005, and 2008 to 2011.[21] This extensive country coverage is crucial for analysing how GVCs

[20]Note that since the instruments are estimated and not observed data, the standard errors of the second stage might be downward biased. Frankel and Romer (1999) propose a correction for this bias but their method is technically not feasible in the presence of too many fixed effects as discussed by Feyrer (2009). For the majority of the results presented in Section 6 this is not a concern since the significance margins are large but it should be kept in mind for the results that are only marginally significant.

[21]Countries and industries are listed in the Appendix. Note that in the analysis 2009 and 2010 are excluded due to the global crisis.

affect countries at different stages of development over time, a feature that has not been possible due to limited data availability in previous databases. The empirical literature discussed above shows that especially the extended coverage of Asia is important. 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 the use of proportionality assumptions to derive the ratio of imported intermediates in an industry's demand to a minimum. In addition, the OECD has used elabourate techniques to deal with China's processing trade. Due to China's outstanding role in GVCs and processing trade, this implies a significant improvement for the reliability of the database.[22]

Bilateral trade costs are the central element of the instrumentation strategy. The respective data is taken from UNESCAP, which estimates bilateral trade costs on the basis of the inverse form of the gravity model developed by Novy (2013). Put simply, the model compares bilateral trade patterns with domestic sales patterns to deduct the corresponding trade costs. In this way, it gives a micro-founded comprehensive trade cost figure that includes both structural factors, such as geography, and policy measures, such as tariffs. An extensive description of the database can be found in Arvis et al. (2013).

To construct the labour productivity measure, value added per worker, I use employment data from the World Input Output Database (WIOD), which provides estimates at the industry level. In addition, UNIDO data is used for robustness since it has a larger country coverage. Unfortunately WIOD provides employment data only for 40 countries and up to 2009 while UNIDO covers only manufacturing and agriculture so that the results for productivity are based on smaller samples.

For the final analysis, I also exclude a set of countries whose exports are largely dominated by the oil and mining industry (ISIC Rev. 3, C10T14). In addition, I harmonise the OECD's 34-industry coverage with WIOD's 35 industries and limit the sample to tradeables so that it ultimately consists of 20 industries. This includes two natural resources, four services, and fourteen manufacturing industries. Thus, the sample covers ultimately 54 countries, 20 industries and 5 years in the period from 1995 to 2011.

[22]See Koopman et al. (2012) for an analysis of China's processing trade.

6 Results

As explained in sections 3 and 4, the benchmark reduced-form model I estimate to examine the relationship between GVC participation and domestic outcomes is given by:

$$ln(x_{ikt}) = \alpha + \beta_1 \, ln(g\hat{v}c_{ikt}) + \alpha_{ik} + \alpha_{kt} + \alpha_{it} + \varepsilon_{ikt}, \tag{10}$$

where $ln(x_{ikt})$ is the natural logarithm of total domestic value added or value added per worker of industry i in country k at time t. gvc_{ikt} is proxied by either $f\hat{va}x_{ikt}$ or $d\hat{va}r_{ikt}$ and instrumented following section 4, α_{ik} captures industry-country fixed effects, α_{kt} country-time fixed effects, and α_{it} industry-time fixed effects. This specification gives the causal effect of GVC linkages on domestic value added and labour productivity.

Note that there is a final identification issue not addressed by the IV strategy when estimating equation (10) at the industry-level with domestic value added as dependent variable. A positive effect on the average industry could be outweighed by compositional or factor reallocation effects at the country-level. This is particularly relevant in a GVC setting because they might cause cross-industry factor reallocations. For instance, if an industry decides to offshore upstream stages of production, its foreign value added in exports (i.e. one of the GVC participation indicators) tends to go up. At the same time, some of the now available domestic factors might be reallocated to other industries, thereby decreasing domestic value added in their original industry. This would imply a negative coefficient even though national GDP is unaffected since the factors are absorbed by other industries. To account for these general equilibrium (GE) effects, I aggregate the variables at the country-level and re-estimate equation (10). Since the aggregation reduces the number of feasible fixed effects, the industry-level estimation remains the preferred specification but the country-level estimates can provide evidence that compositional or GE effects do not reverse the results if their coefficients have the same sign as the industry-level coefficients.

Subsequently, I split the sample into a high-income and a low-/middle-income category on the basis of the World Bank country classification in 1995, the beginning of the sample period. This is in line with the theoretical models in Section 2 and allows me to identify potential heterogeneous effects of GVC integration dependent on the stage of development, a key concern of both high- (*North*) and low-/middle-income (*South*) countries.

6.1 Do GVCs promote domestic value added and labour productivity?

Tables 3 and 4 report the full sample results for domestic value added and labour productivity respectively. They show that an increase in GVC participation causes a rise in both dependent variables at the industry- and country-level. All coefficients are positive and with one exception statistically significant in OLS and IV specifications.

Focusing on the results for domestic value added in Table 3, I find strong evidence in favour of GVC integration. Columns 2 and 4 present the results for the IV model. Based on the preferred industry-level specification in column 2, I find that a 1 percent or 1.28 standard deviations increase in backward GVC participation leads to 0.11% higher domestic value added (upper panel). Equally, I find for forward linkages that a 1 percent or 1.33 standard deviations increase in GVC participation leads to 0.60% higher domestic value added (lower panel). Forward or selling linkages do thus play a larger role for sectoral GDP.

The estimates for labour productivity in Table 4 paint a similar picture. According to the preferred industry-level specification in column 2, I find that a 1 percent or 1.28 standard deviations increase in forward GVC linkages raises labour productivity by 0.33%. The effect for backward linkages is equally positive with a point estimate of 0.06 but not significant at convenient confidence levels. This means that, in line with effects on domestic value added, forward linkages generate larger gains from GVC integration for labour productivity.

The relevant first stage Kleibergen-Paap F-statistics reject the weak instrument hypothesis. All Stock and Yogo (2005) critical values are exceeded indicating a neglible bias in the IV estimates. In addition, the IV estimates are of similar magnitude as the OLS estimates. There is only a statistically significant difference for the industry-level domestic value added estimations using the sourcing linkage. Here, the IV estimate is smaller than the OLS estimate. This suggests that the instrumentation is necessary to correct for an omitted variable bias in the industry-level OLS estimate.

Finally, the country-level IV estimates in column 4 are significantly above the industry-level estimates. This can partially be explained by the lack of adequate controls in the absence of country-year fixed effects, which could cause an omitted variable bias.[23] However, the fact that they are also above the industry-level OLS estimates suggests that

[23]Recall that the instrumentation strategy potentially requires country-year and industry-year fixed effects to eliminate endogeneity. Therefore only the industry-level estimates can be interpreted as causal.

	(1) OLS	(2) IV	(3) OLS	(4) IV
	Domestic value added			
	Industry-level		Country-level	
fvax	0.183***	0.106**	0.355***	0.417***
	(0.025)	(0.047)	(0.054)	(0.069)
First stage F-test		160.3		183.2
R2	0.816	0.813	0.869	0.867
dvar	0.602***	0.600***	0.744***	0.813***
	(0.031)	(0.180)	(0.058)	(0.078)
First stage F-test		310.5		122.3
R2	0.909	0.901	0.929	0.928
Observations	5500	5500	275	275
Fixed effects	Industry-Year, Country-Year, Industry-Country		Country, Year	

Table 3: The effect of GVC participation on domestic value added - benchmark results.
*** p<0.01, ** p<0.05, * p<0.1. All variables are in natural logarithms. Robust standard errors clustered at industry-country/country-level. Kleibergen-Paap cluster-robust first stage F-statistics reported.

	(1) OLS	(2) IV	(3) OLS	(4) IV
	Value added per worker			
	Industry-level		Country-level	
fvax	0.053**	0.057	0.443***	0.462***
	(0.026)	(0.037)	(0.075)	(0.084)
First stage F-test		47.3		164.7
R2	0.802	0.802	0.835	0.835
dvar	0.419***	0.327***	0.781***	0.798***
	(0.041)	(0.111)	(0.110)	(0.138)
First stage F-test		115.7		95.45
R2	0.848	0.846	0.900	0.900
Observations	3033	3033	152	152
Fixed effects	Industry-Year, Country-Year, Industry-Country		Country, Year	

Table 4: The effect of GVC participation on productivity - benchmark results.
*** p<0.01, ** p<0.05, * p<0.1. All variables are in natural logarithms. Robust standard errors clustered at industry-country/country-level. Kleibergen-Paap cluster-robust first stage F-statistics reported.

compositional and factor reallocation effects magnify the gains of GVC integration. The industry-level coefficients report the effect on the average industry but if the effect is larger for industries that have a larger share in a country's GDP, then they underreport the true country-level coefficient. The country- and industry-level estimates can thus be interpreted as lower and upper bounds for the true country-level coefficient.

The positive coefficients for both productivity and domestic value added also show that a positive impact on one of the variables does not come at the expense of the other. A key concern for policy makers in low-income countries has been that GVCs lead to a specialisation in simple tasks with low productivity. This can boost total domestic value added through scale economies but might come at the expense of productivity and skills. On the other hand, a concern in high-income economies has been that GVCs lead to a hollowing-out of production. When firms offshore more and more production stages, the ensuing positive effect on the productivity of the remaining workforce might not materialise in value added terms if less factors are employed. The results show however that neither is the case for the average country.

6.2 Does the stage of development matter?

In the previous section we have found a positive effect of GVC participation on the average country. This does however not exclude a negative effect on a specific subset of countries. The theoretical literature in section 2 proposes that the stage of development is relevant for specialisation patterns within GVCs and terms of trade shifts, which both affect potential gains from GVC integration. Therefore, I continue by estimating industry-level equation (10) on country subsamples differentiated into high- and low-/middle-income countries on the basis of the 1995 World Bank classification.

Table 5 presents the results for domestic value added. They show that the gains from GVC integration are present in both income categories (columns 2 and 3). All coefficients are positive and statistically significant. The magnitude of the coefficients is larger for high income countries albeit only significantly in the case of backward linkages (upper panel). In addition and in line with full sample, I observe for both country groups larger gains from forward integration (lower panel). The evidence leads to the conclusion that all participants, independent from their income-level, benefit from GVCs in terms of sectoral GDP.

The results for labour productivity shown in Table 5 equally present only little evi-

	(1)	(2)	(3)
	Domestic value added		
	All countries	Low-/Middle-income	High-income
fvax	0.106**	0.089*	0.213***
	(0.047)	(0.051)	(0.073)
First stage F-test	160.3	148.9	114.3
R2	0.813	0.844	0.735
dvar	0.600***	0.575***	0.675***
	(0.180)	(0.079)	(0.102)
First stage F-test	310.5	265.0	53.9
R2	0.901	0.918	0.884
Observations	5500	2900	2600
Fixed effects	Industry-Year, Country-Year, Industry-Country		

Table 5: The effect of GVC participation on domestic value added by income groups.
*** p<0.01, ** p<0.05, * p<0.1. All variables are in natural logarithms. Robust standard errors clustered at industry-country level. Fvax and dvar instrumented. Kleibergen-Paap cluster-robust first stage F-statistics reported.

	(1)	(2)	(3)
	Value added per worker		
	All countries	Low-/Middle-income	High-income
fvax	0.057	0.076*	-0.035
	(0.037)	(0.043)	(0.048)
First stage F-test	47.3	37.6	149.2
R2	0.802	0.813	0.797
dvar	0.327***	0.287**	0.493***
	(0.111)	(0.142)	(0.113)
First stage F-test	115.7	82.2	148.5
R2	0.846	0.845	0.884
Observations	3033	1439	1594
Fixed effects	Industry-Year, Country-Year, Industry-Country		

Table 6: The effect of GVC participation on productivity by income groups.
*** p<0.01, ** p<0.05, * p<0.1. All variables are in natural logarithms. Robust standard errors clustered at industry-country level. Fvax and dvar instrumented. Kleibergen-Paap cluster-robust first stage F-statistics reported.

dence that a country's income level matters for gains from GVCs. For forward linkages, I find positive and significant effects that do not differ significantly between the two income groups. Interestingly, for backward linkages there are only significant gains for low- and middle-income countries while the point estimate for high-income countries is negative.

This could be driven by the fact that the forward linkages measure *dvar* is a better indicator for countries specialising in high value-added tasks, which tends to be the case for high-income countries. The backward linkage $fvax$ indicator would in this case be less meaningful for high-income countries. A similar separation cannot be made for low- and middle-income countries since they are more heterogenous in terms of specialisation patterns. Countries such as China that specialise in assembly typically have high $fvax$ values but countries that supply primary inputs like Chile have relatively high *dvar* values. The positive and significant coefficients for both indicators in low- and middle-income countries support this hypothesis.

To summarise, I find a positive, robust, and causal effect of GVC participation on domestic value added and labour productivity along the value chain. This finding holds for both indicators and across all specifications with consistently larger effects caused by forward linkages. The results also show that high- and low-income countries both benefit from GVC integration. Results with samples split by income class do not suggest significant differences. Consequently, public concerns about the role of GVCs for productivity or GDP cannot be vindicated empirically.

7 Robustness

The results in the previous section depend on the validity of the instrument and, as mentioned before, the exogeneity of the instrument rests on the assumption that bilateral trade costs between two countries are exogenous to industry-level outcomes in third countries. To ensure that this assumption is valid I exclude in a first step large countries from the sample which might be able to interfere in the trade policy of independent countries. In particular I drop China, France, Germany, Japan, USA, and the United Kingdom from the sample. In a second exercise, I combine this robustness check with a re-calculation of the instrument that excludes country triples that have signed an FTA or entered a customs union during the sample period since the exogeneity of third-country trade costs might not hold for these cases. Columns 1 and 2 in Tables 7 and 8 show that these additional restrictions do not affect the results. The coefficients are both quantitatively and qualitatively in line with the benchmark estimates.

Next, I robustify the results by further varying the sample composition. In the benchmark regressions, I exclude all countries whose exports from the mining sector (ISIC Rev. 3, C) account for more than 30% of total exports. This is the case for Australia, Brunei Darussalam, Chile, Norway, Russia, Saudi-Arabia, and South Africa. Instead, I include first all natural resource exporters and then I exclude natural resource exporters based on definitions different from the one used in the main analysis. Looking at the results for all countries in column 3, I find that the estimates are largely consistent with the benchmark. The only relevant difference is that the backward linkage indicator becomes significant for labour productivity.

Turning to the sectoral sample composition, I exclude in the main analysis all value added sourced from the mining sector. I complement this strategy by examining if the results hold when all value added is included. Column 5 suggests that the results do not change. Both coefficients show no statistically significant difference from their benchmark counterparts.

Another key problem in international trade data, and therefore in ICIOs, is the absence of recorded statistics on services trade. Instead, the missing data is imputed using gravity models, which can cause significant measurement error. As the problems relating to imports from the mining industry mentioned above are also sector-specific, I address them jointly by excluding first the primary sector and subsequently the primary and the services sector from the regressions such that the sample covers only manufacturing industries. Column 4 presents the results for manufacturing only. The coefficients increase slightly for domestic value added and the backward linkage indicator turns significant again for labour productivity.

Another robustness checks deals with the labour productivity results only. To address the a potential sample composition effect, I replace the employment data based on WIOD with data of UNIDO. The reason is that WIOD covers only 40 mostly middle- or high-income countries. The country coverage of UNIDO is significantly larger but only covers agriculture, mining, and manufacturing industries. Column 6 shows that the estimates are consistent with the benchmark results and confirm the positive role of GVC integration.

Finally, classifying countries into income categories always requires a somewhat arbitrary classification scheme. Therefore, I re-run the relevant regressions on varying cutoffs

	(1)	(2)	(3)	(4)	(5)
	Domestic value added				
	No Large	No Large/No FTA	All	Manufacturing	Mining
fvax	0.109**	0.111**	0.093**	0.202**	0.110**
	(0.047)	(0.047)	(0.038)	(0.095)	(0.048)
First stage F-test	160.2	169.1	235.6	68.2	147.8
R2	0.807	0.807	0.817	0.800	0.814
dvar	0.598***	0.599***	0.449***	0.634***	-
	(0.064)	(0.064)	(0.079)	(0.063)	-
First stage F-test	319.3	278.6	359.1	241.3	-
R2	0.906	0.906	0.897	0.903	-
Observations	4900	4900	6100	3575	5500
Fixed effects	Industry-Year, Country-Year, Industry-Country				

Table 7: The effect of GVC participation on domestic value added - Main robustness checks.
*** p<0.01, ** p<0.05, * p<0.1. All variables are in natural logarithms. Robust standard errors clustered at industry-country/country-level. Kleibergen-Paap cluster-robust first stage F-statistics reported.

	(1)	(2)	(3)	(4)	(5)	(6)
	Value added per worker					
	No Large	No Large/No FTA	All	Manufacturing	Mining	UNIDO
fvax	0.058	0.058	0.067**	0.143*	0.059	0.080
	(0.038)	(0.038)	(0.034)	(0.077)	(0.038)	(0.082)
First stage F-test	46.4	49.9	52.71	31.6	47.7	24.5
R2	0.800	0.800	0.810	0.784	0.802	0.778
dvar	0.325***	0.319***	0.330***	0.320***	-	0.268**
	(0.110)	(0.113)	(0.110)	(0.121))	-	(0.121
First stage F-test	118.7	108.3	113.7	100.2	-	140.5
R2	0.843	0.843	0.852	0.824	-	0.791
Observations	2553	2553	3193	1969	3033	2202
Fixed effects	Industry-Year, Country-Year, Industry-Country					

Table 8: The effect of GVC participation on productivity - Main robustness checks.
*** p<0.01, ** p<0.05, * p<0.1. All variables are in natural logarithms. Robust standard errors clustered at industry-country/country-level. Kleibergen-Paap cluster-robust first stage F-statistics reported.

and country classifications based on GDP per capita or other factors, such as the IMF's country categorisation system based on lending. The results suggest that the findings are largely independent of the chosen cutoff and the classification strategy.[24]

Overall these exercises strongly confirm the positive benchmark results. If any difference is observed, it points to a more positive effect than observed in the preferred specifications in section 6. In particular, the previously insignificant coefficient of the backward linkage indicator becomes significant in a set of robustness checks. The positive role of GVC integration on industrial development is thus robust.

8 Conclusion

The role of GVCs for development is increasingly disputed reflecting an ambiguity in predictions by economic theory. This paper is one of the first attempts to assess their impact empirically to inform the policy debate and provide objective evidence. Using a new extensive system of ICIOs that covers countries at different levels of development, it shows that industry- and country-level domestic value added and labour productivity are systematically higher, the higher GVC participation. Both forward and backward linkage indicators of GVC participation generate robust, significant, and, especially, causal gains for participating countries with a larger effect stemming from forward linkages.

By combining bilateral trade costs between third countries with industry-specific technological variables, I create an exogenous predictor for trade in value added that allows me to cleanly identify the relationship between GVCs, productivity, and industrial development. Depending on the type of GVC integration, the benchmark IV specification suggests that a 1-percent increase in GVC participation causes a rise in domestic value added in the range of 0.10% to 0.60% and in labour productivity of 0.33%.

The results also highlight that both upstream suppliers of intermediates and downstream users of foreign inputs benefit from production networks equally. Moreover, the results show that such gains from GVCs are independent of a country's per capita income level. When I split the countries in the sample into two categories on the basis of their respective per capita GDPs, I find that the benefits for productivity and value added caused by GVC integration are present within both categories.

While these findings provide convincing evidence on the beneficial role of GVCs, fur-

[24]Further robustness results are available from the author upon request.

ther research is necessary to improve our understanding of their functioning. Optimally, we would like to analyse firm-level data to see how firms respond to new competition through GVCs and how firms within GVC networks benefit from each other. In particular, such data could inform us about factors that might amplify the gains from GVCs and factors that hinder their materialisation.

Furthermore, it is essential for theoretical research to shed further light on the transmission channels between GVC participation and development. It is central to understand which effects dominate under which conditions and which policies could help to overcome barriers to gains from GVCs. Moreover, dynamic models could explore ways to move into higher value added stages within value chains, a key interest of policy makers. Such models could then again provide testable hypotheses for future empirical work.

Finally, a positive effect on sectoral GDP and labour productivity does not exclude negative side effects from GVC integration in other areas. The role of GVCs on environmental and labour standards is another central area for future analysis before the public and policy makers can endorse GVC integration.

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A Appendix

A.1 Theoretical derivation of the Leontief decomposition

This exposition follows Koopman et al. (2014) and Wang et al. (2013) but the tools to derive the Leontief decomposition date back to Leontief (1936) who showed that, with a set of simple calculations, national Input-Output tables based on gross terms give the true value added flows between industries. The idea behind this insight is that the production of industry i's output requires inputs of other industries and i's own value added. The latter is the direct contribution of i's output to domestic value added. The former refers to the first round of i's indirect contribution to domestic value added since the input from other industries that i requires for its own production triggers the creation of value added in the supplying industries. As supplying industries usually depend on inputs from other industries, this sets in motion a second round of indirect value added creation in the supplying industries of the suppliers, which is also caused by i's production. This goes on until value added is traced back to the original suppliers and can mathematically be expressed as

$$VB = V + VA + VAA + VAAA + ... = V(I + A + A^2 + A^3 + ...), \tag{11}$$

which, as an infinite geometric series with the elements of $A < 1$, simplifies to

$$VB = V(I - A)^{-1}, \tag{12}$$

where V is a NxN matrix with the diagonal representing the direct value added contribution of N industries, A is the Input-Output coefficient matrix with dimension NxN, i.e. it gives the direct input flows between industries required for 1$ of output, and $B = (I - A)^{-1}$ is the so called Leontief inverse. VB gives thus a NxN matrix of so called value added multipliers, which denote the amount of value added that the production of an industry's 1$ of output or exports brings about in all other industries. Looking from the perspective of the supplying industries, the matrix gives the value added that they contribute to the using industry's production. If we multiply it with a NxN matrix whose diagonal specifies each industry's total output or exports, we get value added origins as absolute values instead of shares.

The application of the Leontief insight to ICIOs as opposed to national Input-Output tables for our Leontief decomposition is straightforward and was pioneered by Hummels et al. (1998, 2001). V refers now to a vector of direct value added contributions of all industries across the different countries. Its dimension is correspondingly $1xGN$, where G is the number of countries. A is now of dimension $GNxGN$ and gives the industry flows including cross border relationships. Since we are interested in the value added origins of exports we multiply these two matrices with a $GNxGN$ matrix whose diagonal we fill with each industry's exports, E, such that the basic equation behind the source decomposition is given by $V(I-A)^{-1}E$. .[25] In a simple example with two countries (k and l) and industries (i and j) we can zoom in to see the matrices' content:

$$V(I-A)^{-1}E = \begin{pmatrix} v_{ik} & 0 & 0 & 0 \\ 0 & v_k^j & 0 & 0 \\ 0 & 0 & v_l^i & 0 \\ 0 & 0 & 0 & v_l^j \end{pmatrix} * \begin{pmatrix} b_{kk}^{ii} & b_{kk}^{ij} & b_{kl}^{ii} & b_{kl}^{ij} \\ b_{kk}^{ji} & b_{kk}^{jj} & b_{kl}^{ji} & b_{kl}^{jj} \\ b_{lk}^{ii} & b_{lk}^{ij} & b_{ll}^{ii} & b_{ll}^{ij} \\ b_{lk}^{ji} & b_{lk}^{jj} & b_{ll}^{ji} & b_{ll}^{jj} \end{pmatrix} * \begin{pmatrix} e_{ik} & 0 & 0 & 0 \\ 0 & e_k^j & 0 & 0 \\ 0 & 0 & e_l^i & 0 \\ 0 & 0 & 0 & e_l^j \end{pmatrix} =$$

$$\begin{pmatrix} v_{ik}b_{kk}^{ii}e_{ik} & v_{ik}b_{kk}^{ij}e_k^j & v_{ik}b_{kl}^{ii}e_l^i & v_{ik}b_{kl}^{ij}e_l^j \\ v_k^j b_{kk}^{ji}e_{ik} & v_k^j b_{kk}^{jj}e_k^j & v_k^j b_{kl}^{ji}e_l^i & v_k^j b_{kl}^{jj}e_l^j \\ v_l^i b_{lk}^{ii}e_{ik} & v_l^i b_{lk}^{ij}e_k^j & v_l^i b_{ll}^{ii}e_l^i & v_l^i b_{ll}^{ij}e_l^j \\ v_l^j b_{lk}^{ji}e_{ik} & v_l^j b_{lk}^{jj}e_k^j & v_l^j b_{ll}^{ji}e_l^i & v_l^j b_{ll}^{jj}e_l^j \end{pmatrix} = \begin{pmatrix} vae_{kk}^{ii} & vae_{kk}^{ij} & vae_{kl}^{ii} & vae_{kl}^{ij} \\ vae_{kk}^{ji} & vae_{kk}^{jj} & vae_{kl}^{ji} & vae_{kl}^{jj} \\ vae_{lk}^{ii} & vae_{lk}^{ij} & vae_{ll}^{ii} & vae_{ll}^{ij} \\ vae_{lk}^{ji} & vae_{lk}^{jj} & vae_{ll}^{ji} & vae_{ll}^{jj} \end{pmatrix}$$

where

$$v_c^s = \frac{va_c^s}{y_c^s} = 1 - a_{kc}^{is} - a_{kc}^{js} - a_{lc}^{js} - a_{lc}^{is} \qquad (c \in k, l \quad s \in i, j),$$

$$\begin{pmatrix} b_{kk}^{ii} & b_{kk}^{ij} & b_{kl}^{ii} & b_{kl}^{ij} \\ b_{kk}^{ji} & b_{kk}^{jj} & b_{kl}^{ji} & b_{kl}^{jj} \\ b_{lk}^{ii} & b_{lk}^{ij} & b_{ll}^{ii} & b_{ll}^{ij} \\ b_{lk}^{ji} & b_{lk}^{jj} & b_{ll}^{ji} & b_{ll}^{jj} \end{pmatrix} = \begin{pmatrix} 1-a_{kk}^{ii} & -a_{kk}^{ij} & -a_{kl}^{ii} & -a_{kl}^{ij} \\ -a_{kk}^{ji} & 1-a_{kk}^{jj} & -a_{kl}^{ji} & -a_{kl}^{jj} \\ -a_{lk}^{ii} & -a_{lk}^{ij} & 1-a_{ll}^{ii} & -a_{ll}^{ij} \\ -a_{lk}^{ji} & -a_{lk}^{jj} & -a_{ll}^{ji} & 1-a_{ll}^{jj} \end{pmatrix}^{-1},$$

and

$$a_{cf}^{su} = \frac{inp_{cf}^{su}}{y_f^u} \qquad (c, f \in k, l \quad s, u \in i, j).$$

[25] When using the leontief_output function, the value added multiplier is instead multiplied with each industry's output.

where v_s^c gives the share of industry s's value added, va_c^s, in output, y_s^c, and e_{ik} indicates gross exports. b_{su}^{cf} refers to the Leontief coefficients and, finally, a_{su}^{cf} denotes the share of inputs, inp_{su}^{cf}, in output. The elements of the $V(I-A)^{-1}E$ or vae matrix are our estimates for the country-industry level value added origins of each country-industry's exports.

A.2 Sample coverage and descriptive statistics

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

Table 9: Sample country coverage.
Countries in **bold** excluded from benchmark estimations. WB Class shows the income classification according to the World Bank in 1995. H indicated high-income economies whole LM indicates low- and middle-income economies.

ISIC Rev. 3	Abbr.	**Industry**
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
27T28	BFM	Basic metals and fabricated metal products
29	MEQ	Machinery and equipment n.e.c
30T33	EOQ	Electrical and optical equipment
34T35	TRQ	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
71T74	BZN	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**

Table 10: Sample industry coverage. Industries in bold excluded from estimations.

Country	$fvax$ 1995	$fvax$ 2011	Change	Country	$dvar$ 1995	$dvar$ 2011	Change
IND	14,648	335,092	2187.61%	CHN	68,176	1,536,311	2153.44%
VNM	6,672	142,133	2030.23%	VNM	4,422	75,995	1618.74%
KHM	498	9,192	1746.48%	IND	26,791	435,415	1525.24%
POL	22,751	302,976	1231.68%	LTU	1,834	20,352	1009.57%
TUR	14,179	182,451	1186.77%	LVA	1,545	15,611	910.39%
CHN	229,082	2,627,298	1046.88%	ROU	7,740	72,042	830.77%
SVK	13,870	136,462	883.85%	POL	30,847	248,281	704.89%
LVA	1,827	16,904	824.97%	SVK	9,449	72,277	664.94%
HUN	28,644	234,613	719.05%	IDN	47,140	350,493	643.52%
CZE	38,851	309,065	695.51%	EST	1,927	14,100	631.74%
ROU	7,702	59,334	670.42%	CHL	20,138	146,854	629.22%
LUX	31,655	220,747	597.36%	BRA	50,558	359,115	610.30%
LTU	2,721	17,991	561.26%	HUN	13,480	88,678	557.85%
ARG	6,751	42,805	534.04%	CZE	24,035	150,502	526.18%
KOR	142,639	855,384	499.68%	PHL	16,367	98,119	499.49%
ISL	2,041	11,604	468.63%	IRL	30,097	175,867	484.34%
BGR	9,013	48,694	440.29%	BGR	4,853	27,792	472.61%
BRA	22,140	118,841	436.78%	ISL	1,805	10,334	472.40%
IRL	88,808	457,456	415.11%	GRC	10,759	60,377	461.15%
THA	75,737	383,067	405.78%	ISR	16,672	86,049	416.13%
EST	4,689	22,421	378.15%	SGP	53,242	273,731	414.12%
CHL	12,170	57,090	369.10%	TUR	26,033	132,779	410.04%
GRC	12,774	54,964	330.27%	TWN	97,629	485,076	396.86%
DEU	378,394	1,561,092	312.56%	KOR	128,583	638,045	396.21%
ESP	115,432	463,033	301.13%	THA	40,632	192,829	374.57%
JPN	114,953	450,688	292.06%	PRT	15,558	72,482	365.90%
MYS	115,765	453,149	291.44%	ESP	94,960	439,099	362.40%
TWN	173,811	650,493	274.25%	KHM	732	3,285	348.97%
MEX	115,147	398,008	245.65%	CRI	2,877	12,801	344.91%
CRI	5,353	18,137	238.86%	SVN	7,255	32,113	342.64%
CHE	95,143	317,874	234.10%	CAN	112,912	497,317	340.45%
TUN	8,991	29,850	232.02%	MEX	48,171	208,928	333.72%
ISR	26,736	88,423	230.72%	ARG	15,133	63,535	319.85%
PRT	31,549	102,848	226.00%	MYS	62,458	262,034	319.53%
HRV	4,797	14,914	210.91%	LUX	11,057	46,211	317.93%
ZAF	22,507	69,659	209.50%	MLT	1,121	4,591	309.35%
DNK	67,319	198,218	194.45%	TUN	4,757	19,387	307.53%
ITA	228,153	660,337	189.43%	NZL	9,825	39,612	303.16%
FIN	51,909	147,065	183.32%	CHE	103,275	415,709	302.53%
IDN	33,064	93,483	182.74%	ZAF	42,009	157,687	275.36%
SGP	164,082	458,897	179.68%	CYP	2,382	8,647	263.09%
SVN	15,940	44,472	178.99%	HKG	40,981	145,949	256.14%
FRA	272,909	750,730	175.08%	HRV	3,932	13,570	245.11%
USA	401,144	1,067,021	165.99%	DNK	50,386	167,958	233.35%
AUT	79,926	212,133	165.41%	AUT	67,454	223,869	231.88%
GBR	270,168	703,817	160.51%	USA	746,270	2,374,163	218.14%
SWE	122,101	287,046	135.09%	SWE	92,289	286,456	210.39%
CYP	4,252	9,772	129.81%	DEU	561,875	1,728,073	207.56%
CAN	235,467	514,821	118.64%	GBR	299,830	911,943	204.15%
HKG	53,721	115,248	114.53%	ITA	222,372	663,634	198.43%
NZL	13,945	28,789	106.45%	NLD	147,497	388,317	163.27%
BEL	190,145	332,541	74.89%	FRA	303,214	778,118	156.62%
PHL	36,278	59,970	65.31%	JPN	575,078	1,463,993	154.57%
NLD	176,444	239,017	35.46%	FIN	47,534	118,448	149.19%
MLT	6,818	9,052	32.77%	BEL	115,636	283,336	145.02%

Table 11: Development of GVC indicators over time. Values in current USD millions.

A.3 Construction of the Instrument

As explained in section 4, the trade cost aggregate is given by

$$\tau_{lkt} = \sum_c \tau_{lct} * \frac{e_{lct}}{\sum_c e_{lct}},$$

where $c \neq k, l$. This means that in a given year I calculate a weighted average of country l's bilateral trade costs with the rest of the world excluding k with l's export share being the weight.

Due to the sample constraints of the OECD ICIOs, I collapse all countries not in the OECD ICIOs into the RoW (Rest of World) composite which is the 61th region in the ICIOs. To avoid variations in trade costs stemming from the dropping or adding of trading partners, I limit the calculation to dyads for which trade costs are observed in the majority of periods. As it turns out this is not an issue since there is regular trade between the 61 sample countries. Finally, I use trade cost data of 2010 for 2011 since 2011 is the most recent year in the UNESCAP database and still contains a considerable amount of missings and I extrapolate the data for Belgium and Luxembourg for the year 1995 since individual data for these countries is not reported in 1995 due to their customs union arrangement.

The construction of the upstreamness and downstreamness measure follows one to one the work by Antras and Chor (2013) for downstreamness and Antras et al. (2012) for upstreamness. The only difference is that I use the more aggregated OECD ICIOs instead of the IO tables of the BEA. I collapse the country and time dimension to get one value per industry but in any case I do not observe much variation across time or countries. The resulting values are highly correlated to comparable exercises by for instance Fally (2012).