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Global Value Chains: Benefiting the Domestic Economy?

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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 because data availability has been limited. Using a new unique set of Inter-Country Input-Output tables with extensive country coverage, I look at the relationship between GVC participation and domestic value added at the industry-level to determine if and for whom GVCs are beneficial. I show that GVC participation is positively related to domestic value added along the value chain. However, this effect is only significant for middle- and high-income countries. Deriving novel source/destination country-specific indicators, I present evidence on theoretical transmission channels between GVCs and domestic value added that explain these results. More specifically, I find support for productivity enhancing effects through cost savings when richer countries source from low-wage countries. In contrast, low- and middle-income countries only benefit from technology upgrading and spillovers if they have sufficient levels of absorptive capacity.

JEL-Classification: F13, F14, F15, F63

Keywords: Global Value Chains, International Trade, Economic Development

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1 Introduction

Global Value Chains (GVCs) have become a central factor in trade and development policy[1]. Policy makers from different countries and institutions have placed them at the centre of their agenda and continuously emphasise their growing importance for both international trade and economic 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 trade by 15%. However, a positive effect of GVC participation on the domestic economy is not self-evident. GVC participation could reduce domestic value added and growth by replacing domestic intermediates with foreign intermediates. If domestic producers are not productive enough, the economy as a whole might suffer from the increased international competition that GVC participation might entail. Kaplinsky and Farooki (2010) argue, for instance, that GVCs could lead to stagnation in the developed and developing world with just a few large emerging countries benefitting. The concern is that developing countries are stuck in low value-added tasks while high-income countries lose their value added production to low-wage emerging countries. Similarly, Milberg and Winkler (2010) suggest that GVCs are instrumental in transmitting financial crises from the North to the South and aggravate the problem of excessive dependence on the US and the EU for developing countries. Especially in a set of low-income countries, GVCs are considered as simply a new way to promote old liberal trade policies that bring unilateral gains to the developed world[2].

In this paper, I therefore look empirically at the relationship between GVC participation and domestic value added at the industry level to determine if and for whom GVCs are beneficial. A key barrier to this has been the lack of reliable data for a large group of low- and middle-income countries. Using a new unique set of extensive Inter-Country

[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 production caused by an increasingly international organisation of production structures by firms.

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

Input-Output tables (ICIOs) provided by the OECD, I can estimate the effects of GVCs on countries across all income levels[3]. I show that GVC participation, measured as shares of value added in exports, is positively related to domestic value added at the industry level. This finding holds for indicators based on both backward linkages (i.e. foreign value added in domestic exports) and forward linkages (i.e. domestic value added in foreign exports) reflecting different stages of the value chain. It is stable across indicators based on two new databases, the World Input Output database (WIOD) and the OECD ICIOs, and robust to both the inclusion of different sets of fixed effects, that account for omitted explanatory variables, and the use of lagged GVC indicators, which account for reverse causality.

However, a finer look at the estimates reveals that the effect is significant only for middle- and high-income countries, which questions the role of GVCs for development. By deriving novel variants of standard GVC indicators that depend on the GDP per capita of the source/destination country, I find evidence for transmission channels between GVC participation and domestic value added that are discussed in theoretical contributions and can explain these findings. More specifically, I find considerable support for productivity enhancing effects through cost savings when richer countries source from low-wage countries. In contrast, I find only little evidence on gains through technology upgrading and spillovers for low- and middle-income countries. These benefits seem to be limited to countries with sufficient levels of absorptive capacity.

Nevertheless, the results overall indicate that foreign value added works as a complement rather than a substitute to domestic value added and that GVC participation benefits the domestic economy along the value chain if certain prerequisites are met. Moreover, the results show that WIOD and the OECD ICIOs produce consistent results. Possible concerns about data quality and measurement error should thus be alleviated in view of the fact that WIOD and OECD ICIOs provide similar predictions despite using different data sources and construction techniques.

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

1.1 Related literature

To my knowledge this is one of the first empirical papers that examines the effect of GVCs on domestic outcomes rigorously. The empirical literature on the subject 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' productions and has re-evaluated important indicators of trade, such as bilateral trade imbalances and revealed comparative advantage[4].

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) for short. 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 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.

Johnson and Noguera (2012a) propose a new indicator for GVCs referred to as VAX ratio. The measure is calculated as the bilateral ratio of domestic value added to exports and, thus, it is a quasi-inverse VS measure. Johnson and Noguera (2012a) find that bilateral trade imbalances measured in value added differ significantly from gross trade imbalances. Most prominently, the US–China imbalance in 2004 is 30–40% smaller when measured in value added. Johnson and Noguera (2012b) expand the VAX ratio time coverage over the years 1970 to 2009 and show that the world VAX ratio falls by ten to fifteen percentage points, with two-thirds of this decline occurring between 1990 and 2009. This is equivalent with a significant increase in GVC participation over time.

[4]See Amador and Cabral (forthcoming) for an extensive review of the literature on GVCs and outsourcing.

Timmer et al. (2013) and Timmer et al. (2014) confirm the expansion of GVCs and analyse how they shift the factor composition towards skilled labour and capital at the expense of unskilled labour. They also show that revealed comparative advantage (RCA) based on value added trade data differs substantially from standard RCAs.

Most recently, Baldwin and Lopez-Gonzalez (2013) present a portrait of the global pattern of GVC trade and its development from 1995 to 2009 using the new WIOD database. The authors distinguish between three different concepts, namely the import content of exports (i2e, which is equivalent to VS), the import content of production (i2p), and factor content trade (VA, which is equivalent to the VAX ratio). They reaffirm that production is increasingly international, which emphasises the importance of GVCs.

In related research, Koopman et al. (2014) expand the set of country-level GVC indicators by deriving a decomposition of gross exports, which Wang et al. (2013) extend to a bilateral sectoral level. The decomposition leads to many additional insights. For instance, the share of foreign value added in intermediate exports versus in final good exports can provide information about the position of a country in the value chain.

This novel 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. The aim is to determine if policy makers' immense expectations are justified and if GVCs indeed promote the domestic economy, which is the purpose of this work.

Finally, this paper relates to the empirical work on trade and industrial value added and development. This strand of the literature tries to assess the impact of trade liberalisation on industrial value added in low- and middle-income countries[5]. However, it does not incorporate the novel production structures assessed in this article.

The remainder of this article is organised as follows. Section 2 discusses theoretical channels through which GVC participation might affect industrial development. Section 3 introduces the data and discusses the various indicators of GVC participation employed in the estimation. Section 4 describes the empirical specification and presents the findings and their robustness. Section 5 concludes.

[5] See, for example, Dijkstra (2000) and Dodzin and Vamvakidis (2004).

2 The relationship between GVCs and the domestic economy in theory

The recent theoretical literature on GVCs has focused mainly on determinants and organisational issues regarding GVCs as well as on its relationship to international trade patterns[6]. However, the work on the effects of GVC participation on domestic outcomes is evolving quickly. In addition, there is extensive work on offshoring and task trade, concepts that refer to the same phenomenon. This literature discusses primarily cases in which a GVC is set up between a technologically less sophisticated low-wage country ("South") and a technologically more sophisticated high-wage country ("North"). The differences between the two countries generate incentives to trade tasks or offshore which, in turn, creates a set of benefits and disadvantages across the different models[7]. North gains primarily through productivity improvements akin to technological change caused by lower costs and increased specialisation. South gains through technology upgrading and increased specialisation, which leads to positive terms of trade effects and spillovers. However, across the different theories the gains from GVC participation are not unambiguous.

For instance, in Li and Liu (2014) South benefits through learning-by-doing that improves Southern technology but gains for the North are contingent on initial conditions[8]. In their dynamic model a final good Y at time t is produced using a continuum of tasks indexed by $z \in [0,1]$ such that the technical sophistication of the task increases with z[9]:

$$\ln Y(t) = \int_0^1 \ln x(z,t)dz, \tag{1}$$

[6]For instance, Antràs and Chor (2013) discuss the optimal allocation of ownership rights along the value chain. Costinot et al. (2013) examine the optimal specialisation patterns of stages across countries. Baldwin and Venables (2013) analyze how the GVC structure affects the relationship between trade frictions and trade volumes and, finally, Yi (2003) shows how the effect of lowering trade costs on trade flows is multiplied in the presence of Global Value Chains.

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

[8]Learning-by-doing also drives Southern gains in Liu (2013) and in an extension of Zi (2014).

[9]This convenient ordering of tasks or intermediate inputs has been a feature of the offshoring literature from early on. See for example Feenstra and Hanson (1996).

where *x(z,t)* is the amount of z produced at t. It is assumed that North has the optimal technology for all tasks but South only for a set of less sophisticated tasks. For tasks outside of South's optimal technology set, the country has a higher unit labour requirement *a(z)*, which is increasing in the task's sophistication. If no tasks were allocated to South (S), its wage rate $w_S(t)$ would drop to zero and arbitrage opportunities would become possible. Therefore, tasks up to a threshold task $\bar{z}(t)$ are allocated in each period to South until costs C in North (N) and South are equalised:

$$C_N(w_N(t), \bar{z}(t)) = w_N(t)a_N(z,t) = w_S(t)a_S(z,t) = C_S(w_S(t), \bar{z}(t)), \tag{2}$$

where $a(z,t)$ is the average unit labour requirement across all tasks performed in the country. Wages in equilibrium are given by[10]:

$$w_N(t) = \frac{1 - \bar{z}(t)}{L_N} \quad \text{and} \quad w_S(t) = \frac{\bar{z}(t)}{L_S}. \tag{3}$$

Since South's technology is inferior, it performs initially only a small share of tasks and, as long as its labour endowment is not significantly smaller than North's labour endowment, this leads to wage rates such that $w_N(t) > w_S(t)$. The no-arbitrage condition in equation (2) then requires $a_N(z,t) < a_S(z,t)$. This means that South initially performs a set of tasks for which its unit labour requirement is above North's requirement. According to Li and Liu (2014) this sets the following learning-by-doing process in motion that improves Southern technology:

$$\frac{dT(t)}{dt} = \gamma L_S \, \frac{\bar{z}(t) - T(t)}{\bar{z}(t)}, \tag{4}$$

where *T(t)* is South's set of optimal technologies at t and γ is a learning parameter. When South's optimal technology set expands, North relocates more tasks to South, which, in turn, increases the Southern wage rate. This process repeats itself until a steady state is reached and wages are equalised. The process is faster the larger the

[10] Since there is a continuum of tasks between 0 and 1, $\bar{z}(t)$ is not only the threshold task but also the share of tasks performed in South. When world expenditure ($w_N(t)L_N + w_S(t)L_S$) is normalised to one by choice of numéraire, the wage has to be set according to equation (3) for labour and product markets to clear.

cross-country differences since $z(t) - T(t)$ converge over time. Throughout the process South gains through technological upgrading and North through increased specialisation in more sophisticated tasks and lower costs. However, before the steady state is reached there is a period of decreasing welfare in North because the repeated relocation of tasks combined with a constant factor endowment creates a downward pressure on Northern wages such that the overall effect of rising GVC participation on North can be ambiguous due to this negative terms of trade effect.

In contrast, Baldwin and Robert-Nicoud (2014) focus on technology transfer for the South and productivity improvements for the North akin to technological change as transmission channels between GVCs and the domestic economy[11]. Here, the gains for South are uncertain. In the model both North and South, which have the same characteristics as in Li and Liu (2014), produce a final good X using a Leontief technology with a set of tasks as inputs:

$$X_N = A_N \; L_N \quad \text{and} \quad X_S = A_S \; L_S, \tag{5}$$

where A gives the minimum input requirement matrix and L the factor endowment. Since North is technologically superior, $A_N < A_S$. It is then assumed that offshoring becomes profitable for some tasks due to an exogenous variation in trade costs. This allows North to combine its superior technology with the low wages in South using a new input requirement matrix that represents that North now uses Southern factor endowments to produce X_N:

$$X_N = (A_N - A_O)L_N + A_O L_S \quad \text{and} \qquad X_S = A_S L_S - (A_O)^{-1} X_N \ , \tag{6}$$

where A_O represents the reduced input requirements in the North. For the law of one price in the free trade equilibrium to hold, this requires Northern wages to increase since

[11]This feature is present in many papers on offshoring. Examples include Jones and Kierzkowski (1990), Arndt (1997), Egger and Falkinger (2003), Kohler (2004), Rodríguez-Clare (2010), and most prominently Grossman and Rossi-Hansberg (2008). However, these models focus on the effects of offshoring on domestic factor rewards.

its average costs decrease. This is equivalent to a wage response caused by productivity improving technological progress and improves Northern terms of trade. In addition, Northern output rises since its effective labour endowment increases when Southern labour performs tasks that were previously performed in North[12]. This should lead to a proportional decrease in Southern output. However, Baldwin and Robert-Nicoud (2014) show in a slight extension of the model that an increase in both countries is possible if there are technology spillovers in South, which means that A_S converges to A_N. Given the extensive literature on technology spillovers, this might be sufficient to compensate for the negative effect on South such that in the model the effect on South is ambiguous[13]. Work on absorptive capacity shows though that technology spillovers require a fostering environment, which might not be guaranteed in low- and middle-income countries[14].

The central take-away and the first prediction of this work is that, independent of the exact mechanism, GVCs can generate gains for their participants. However, across the models the materialisation of these gains is uncertain for a subset of countries. Examining if the actual effect is negative or positive for all countries is thus ultimately an empirical question and the aim of this paper. The second testable prediction of the models is that these gains are triggered by cross-country differences in technology and factor rewards. I analyse this hypothesis by exploiting the extended country coverage of the OECD ICIO database. Finally, the models suggest that larger cross-country differences lead to larger gains. This presents the third and last testable hypothesis.

[12] Baldwin and Robert-Nicoud (2014) now switch to a "shadow migration" approach. That is, they express product and labour market conditions in effective terms, i.e. 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.

[13] For instance, Piermartini and Rubínová (2014) provide evidence on the role of GVC participation for innovation. Using industry-level R&D and patent data they highlight the importance of production networks for technology spillovers. Similarly, Benz et al. (2014) present firm-level evidence on spillovers induced by offshoring. This relates to a larger strand of literature that is closely related to GVCs, namely the Foreign Direct Investment (FDI) spillover literature. Javorcik (2004) and Javorcik and Spatareanu (2009) demonstrate the existence of technology spillovers from FDI through backward linkages while Harding and Javorcik (2012) show that FDI leads to export quality improvements in developing countries.

[14] See, for example, Keller (1996) and Farole and Winkler (2012) on absorptive capacity and FDI, and Taglioni and Winkler (2014) on absorptive capacity and GVCs.

3 Data and indicators

3.1 Data sources

I use two main data sources for the analysis to achieve maximal time and country coverage while minimising potential measurement error caused by database-specific methodological issues. The two data sources are the World Input-Output Database and the OECD ICIOs, which constitute two of the most recent and most advanced releases of Inter-Country Input-Output tables. Due to its extensive country coverage, the OECD ICIOs serve as primary database while WIOD is used to examine the robustness of the results. For the analysis, I exclude a set of countries whose exports are largely dominated by exports of the oil and mining industry (ISIC Rev. 3, C10T14). In addition, I harmonise WIOD's and the OECD's industry coverage and limit the sample to tradables so that it ultimately consists of 20 industries. This includes two natural resources and four services industries with the remaining ones being manufacturing industries. I include only the four years that are provided by the OECD, that is 1995, 2000, 2005, and 2008. This makes it possible to calculate GVC indicators comparable across the two databases and minimises potential measurement error issues that could arise due to WIOD's extrapolation method that aims at developing an annual time series (see below). Given that most of WIOD's years are based on such extrapolated data, the actual loss of information is in any case likely to be small. Thus, the sample covers ultimately 50 countries, 20 industries and 4 years in the period from 1995 to 2008. An exact description of the data can be found in the appendix.

3.1.1 OECD ICIOs

The ICIOs of the OECD and the resulting TiVA database are a joint effort by the OECD and the WTO. The new version of the database provides ICIOs covering 57 countries and 34 industries for the years 1995, 2000, 2005, 2008, and 2009[15,16]. This extensive country coverage is crucial in analysing how GVCs affect countries at different stages of develop-

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

ment 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. However, the OECD ICIOs do not use annual extrapolation methods and, therefore, a balanced time series is not available. This means on the other hand that the available data points are less prone to measurement error. 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 elaborate 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[17].

3.1.2 WIOD

The World Input-Output Database is the joint product of eleven European research institutions and was constructed with funding from the European Commission. It provides an international input-output matrix covering 40 countries and 35 industries from 1995 to 2011[18]. As opposed to other input-output databases, WIOD is based on original national supply and use tables instead of constructed national Input-Output tables. This prevents discrepancies due to different IO construction methods across countries. As supply and use tables are not available on an annual basis, they are benchmarked against output and final consumption series given in national accounts to create consistent time series. It is important to note then that the balanced WIOD panel is not based on annual data but on these extrapolation methods. Linking the resulting tables with international trade data results in ICIOs. To achieve a high level of precision the database employs first an extended classification scheme of the Broad Economic Categories (BEC) to split imports

[17]See Koopman et al. (2012) for an analysis of China's processing trade.
[18]Countries and industries are listed in the Appendix.

into intermediate and final goods. Subsequently, it uses proportionality assumptions to allocate the products to their respective cells within the WIOTs. This methodology is more elaborate than in previous data sources and increases the database's reliability[19]. The final tables decompose an industry's output according to its use, industry origin, and country origin. A more extensive description of WIOD and its sources, harmonisation strategies and assumptions is provided in Timmer (2012).

3.1.3 Other data sources

Data on the various control variables are taken from the databases discussed above or from data sources that are standard in the literature. That is, country size and development data (e.g. constant GDP and GDP per capita in 2005 USD, trade openness) are taken from the World Bank's World Development Indicators and tariff data comes from the joint World Bank, WTO, and UNCTAD TRAINS database. RTA data is based on de Sousa (2012) and trade costs are obtained from the World Bank UNESCAP Trade Costs Database.

3.2 GVC Indicators

The theoretical models in section 2 do not propose a specific empirical measure for the level of GVC participation. To simplify the analysis, they linearise the value chain such that a one-directional relationship arises in which South supplies intermediates to North. While this is sensible for theoretical work, it is necessary to include both sourcing and supplying relationships in empirical work to capture the full information of IO matrices. Therefore, I rely on the standard indicators of the empirical literature discussed in section 1.1 to measure GVC participation since these indicators can be divided into backward linkage/sourcing and forward linkage/sales measures. In the analysis, I use both types of measures to evaluate whether potential effects differ by the kind of activities a country's industries are engaged in. A possible explanation for a differential effect is that backward

[19] Many previous Inter-Country IO tables are derived using a simple proportionality assumption. This means that the share of an industry's imported intermediates is taken from the industry's share of imports in total domestic demand. The assumption is especially problematic for export processing zones.

linkages can carefully be interpreted as indicators with more weight on tasks close to final demand while forward linkages put more weight on upstream tasks[20]. If countries are specialised in a specific set of tasks, using only one indicator would not adequately capture their GVC participation levels.

To derive the indicators for the analysis, I follow Hummels et al. (2001) in applying the standard Leontief (1936) insight to both the OECD ICIOs and WIOD 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. This means in a simple example for a given year with two countries, *k* and *l,* and two industries, *i* and *j*, that I multiply the value added multiplier, *V (I-A)*$^{-1}$, with country-industry-level gross exports, *E*, to deduce their value added origins. The theoretical derivation and explanation of this procedure can be found in the appendix[21]:

$$V(I-A)^{-1}E = \begin{pmatrix} v_k^i & 0 & 0 & 0 \\ 0 & v_k^j & 0 & 0 \\ 0 & 0 & v_l^i & 0 \\ 0 & 0 & 0 & v_l^j \end{pmatrix} * \begin{pmatrix} b_{kk}^{ii} & b_{kk}^{ij} & b_{kl}^{ii} & b_{kl}^{ij} \\ b_{kk}^{ji} & b_{kk}^{jj} & b_{kl}^{ji} & b_{kl}^{jj} \\ b_{lk}^{ii} & b_{lk}^{ij} & b_{ll}^{ii} & b_{ll}^{ij} \\ b_{lk}^{ji} & b_{lk}^{jj} & b_{ll}^{ji} & b_{ll}^{jj} \end{pmatrix} * \begin{pmatrix} e_k^i & 0 & 0 & 0 \\ 0 & e_k^j & 0 & 0 \\ 0 & 0 & e_l^i & 0 \\ 0 & 0 & 0 & e_l^j \end{pmatrix} = \begin{pmatrix} v_k^i b_{kk}^{ii} e_k^i & v_k^i b_{kk}^{ij} e_k^j & v_k^i b_{kl}^{ii} e_l^i & v_k^i b_{kl}^{ij} e_l^j \\ v_k^j b_{kk}^{ji} e_k^i & v_k^j b_{kk}^{jj} e_k^j & v_k^j b_{kl}^{ji} e_l^i & v_k^j b_{kl}^{jj} e_l^j \\ v_l^i b_{lk}^{ii} e_k^i & v_l^i b_{lk}^{ij} e_k^j & v_l^i b_{ll}^{ii} e_l^i & v_l^i b_{ll}^{ij} e_l^j \\ v_l^j b_{lk}^{ji} e_k^i & v_l^j b_{lk}^{jj} e_k^j & v_l^j b_{ll}^{ji} e_l^i & v_l^j b_{ll}^{jj} e_l^j \end{pmatrix} = \begin{pmatrix} vae_{kk}^{ii} & vae_{kk}^{ij} & vae_{kl}^{ii} & vae_{kl}^{ij} \\ vae_{kk}^{ji} & vae_{kk}^{jj} & vae_{kl}^{ji} & vae_{kl}^{jj} \\ vae_{lk}^{ii} & vae_{lk}^{ij} & vae_{ll}^{ii} & vae_{ll}^{ij} \\ vae_{lk}^{ji} & vae_{lk}^{jj} & vae_{ll}^{ji} & vae_{ll}^{jj} \end{pmatrix} \tag{7}$$

[20]One has to be careful with such an interpretation since forward and backward linkages are not designed to measure upstreamness. They are simply supposed to proxy for GVC participation by requiring that value added crosses a border at least twice. However, the backward linkage indicator does include the last task of the value chain while the forward linkage indicator does not. On the other hand, the forward linkage indicator includes the very first task of the value chain while the backward linkage indicator does not given that the first task has by definition no foreign value added incorporated. This means that the backward linkage indicator omits the most upstream task and the forward linkage indicator the most downstream task. If there are many tasks involved in the production of a good, the difference is minimal. However, given that Fally (2012) estimates that an average good incorporates only very few tasks, this difference allows for a careful interpretation towards a downstream versus an upstream proxy.

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

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

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

v_s^c gives the share of industry s's value added, va_c^s, in output, y_s^c, and e_k^i 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. Accordingly, the elements of the $V\,(I - A)^{-1}\,E$ or vae matrix are estimates for the industry-level value added origins of each industry's exports. Equipped with this unique data, I can construct my indicators as outlined below.

Note that throughout the analysis I use the terminology by Baldwin and Lopez-Gonzalez (2013); that is, I refer to backward linkage indicators with *i2e* and to forward linkage indicators with *e2r* (exporting to re-export). Note also that indicators based on WIOD are prefixed with *w*. Finally, time subscripts are omitted in this section for convenience.

Following the standard VS approach I calculate my baseline backward indicators as:

$$i2e_k^i = \left[\sum_l \sum_j vae_{lk}^{ji} \right] * \frac{1}{exports_k}, \tag{8}$$

where $l \neq k$. This means that $i2e_k^i$ 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 normalised by country-level exports[22]. It gives thus the share the foreign value added in an industry's exports. Similarly, the baseline *e2r* values of industry i in country k for a given year are defined as:

$$e2r_k^i = \left[\sum_l \sum_j vae_{kl}^{ij} \right] * \frac{1}{exports_k} \ , \tag{9}$$

where $l \neq k$.

A major advantage to previous studies is the extensive country coverage of the OECD ICIOs. It allows me in combination with the four-dimensional export decomposition in equation (7) to calculate a set of variants of this indicator based on the income level of the source/destination country. The new indicators are given by:

$$i2e\_source_k^i = \left[\sum_l \sum_j vae_{lk}^{ji} \right] * \frac{1}{exports_k} \ , \tag{10}$$

and

$$e2r\_destination_k^i = \left[\sum_l \sum_j vae_{kl}^{ij} \right] * \frac{1}{exports_k} \ , \tag{11}$$

where $l \neq k$ and $l \in source/destination$ with $source/destination \in \{lessinc$, $moreinc$, $loinc$, $midinc, hiinc$, $lomidinc$, $himidinc$, $g5\}$[23]. The new indicators are, hence, constructed by summing only over a subset of source countries, which are in the same income group as measured by GDP per capita. $i2e\_loinc_k^i$ gives for instance the foreign value added in exports sourced from low-income countries. To this end, the countries are split into three categories, low-income, middle-income, and high-income, and combinations thereof.

[22]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 below to deal with imports from the mining sector.

[23]The income groups are based on an average GDP per capita cutoff based on the years used in the analysis. Low income countries have a GDP per capita below USD 6,000, middle income countries in between USD 6,000 and USD 20,000, and high income countries an average GDP per capita of above USD 20,000. As robustness check I use the country classification of the IMF WEO and different cutoffs. The country groups can be found in the Appendix. g5 refers to a group of countries which are responsible for the world's major share of R&D expenditure following Keller (2002). These countries are France, Germany, Japan, UK, and the US.

Since the grouping of countries according to their income levels is to some degree ad-hoc and might conceal some within-group variation, I complement this strategy in two ways. Firstly, I calculate indicators that sum across value added from all countries with less (more) income than the examined country and secondly, I weight the foreign value added by the GDP per capita gap between using and source country:

$$i2e\_source\_wtd_k^i = \left[\sum_l \sum_j vae_{lk}^{ji} * gdppc\_gap_{lk} \right] * \frac{1}{exports_k} , \tag{12}$$

and

$$e2r\_destination\_wtd_k^i = \left[\sum_l \sum_j vae_{kl}^{ij} * gdppc\_gap_{lk} \right] * \frac{1}{exports_k}, \tag{13}$$

where $l \neq k$ and $l \in source/destination$ with $source/destination \in \{lessinc, moreinc\}$. As explained in more detail in the next section, I exploit all these variants to identify the channels trough which GVC participation affects domestic value added.

3.3 Stylised facts of GVCs

Table 1 gives the summary statistics for the sourcing indicators. Differences between the databases are mainly caused by the differing country coverage. WIOD includes less low-income countries and therefore exhibits a higher *i2e* average. The within-standard-deviation shows that there is significant country-industry variation over the period from 1995 to 2008. This allows for the inclusion of a large set of fixed effects without compromising on significance.

Across countries, I confirm the standard finding that country size and export composition are good predictors for GVC participation as shown in section 1.1. Countries with strong backward linkages are for example Luxembourg, Estonia, and Slovakia. In addition, typical GVC countries like Singapore, Taiwan, Malaysia, and Hungary exhibit high *i2e* values. In contrast, large countries and natural resource exporters are rather self-sustaining, such as the US, Russia, and Brazil. Among the large countries with relatively high *i2e* ratios we find mainly heavy manufacture exporters like China, Germany,

Variable	Obs	Mean	Std. Dev.	Std. Dev. Within	Min	Max
i2e	6,612	0.86	2.18	0.66	0	39.82
i2e_lessinc	6,612	0.30	1.18	0.35	0	36.72
i2e_moreinc	6,612	0.53	1.53	0.52	0	31.94
i2e_lessinc_wtd	6,612	4,804	36,883	11,369	0	1,688,663
i2e_moreinc_wtd	6,612	10,445	34,626	11,245	0	877,951
i2e_loinc	6,612	0.16	0.41	0.18	0	8.49
i2e_midinc	6,612	0.08	0.25	0.11	0	5.95
i2e_hiinc	6,612	0.62	1.65	0.51	0	34.34
i2e_lomidinc	6,612	0.24	0.64	0.26	0	14.44
i2e_himidinc	6,612	0.70	1.84	0.56	0	35.92
i2e_g5	6,612	0.39	1.08	0.35	0	17.77
w_i2e	4,640	1.50	3.15	0.91	0	68.51

Table 1: Summary statistics of i2e indicators.
Variables can be read as i2e_source. For example, i2e_lessinc measures foreign value added in exports sourced from countries with less income, i.e. a lower GDP per capita. i2e_lessinc_wtd and i2e_-moreinc_wtd additionally weight the foreign value added by the GDP per capita gap to the source country.

or France.

Looking at the source country specific indicators, it is interesting to note that countries source more from countries within the same income group. Since these countries are often in close relative proximity and within the same RTAs, it emphasises the point that GVCs localise trade and highlights the importance of RTAs for GVCs, which is a key finding in Noguera (2012)'s gravity model for value added trade.

Across industries, *Electrical and optical equipment* (ISIC Rev.3 30T33), *Transport equipment* (34T35), and *Chemicals* (24) have the highest *i2e* ratios, while mainly service industries with the exception of *Transport and storage* (60T63) and *Financial intermediation* (65T67) are at the bottom of the ranking. Especially for low- and middle-income countries *Textiles and apparel* (17T19) also plays an important role.

Between 1995 and 2008, the weighted average *i2e* ratio has grown around 16%-32%. The major share of this growth stems from the period between 1995 and 2005. In 2008, the ratio is stagnant or grows only moderately depending on the indicator, which could be due to the beginning global trade collapse. Here, the value of the novel source country specific indicators stands out. They show that sourcing from high-income countries has become less important (-6.39%) from 2000 on but sourcing from middle-income and

Variable	**Obs**	**Mean**	**Std. Dev.**	**Std. Dev. Within**	**Min**	**Max**
e2r	6,612	0.73	1.71	0.50	0	40.91
e2r_moreinc	6,612	0.42	1.05	0.33	0	26.76
e2r_lessinc	6,612	0.77	5.92	4.36	0	205.68
e2r_moreinc_wtd	6,612	8,011	20,615	6,521	0	425,885
e2r_lessinc_wtd	6,612	13,362	103,625	72,399	0	3,517,739
e2r_loinc	6,612	0.15	0.49	0.22	0	13.88
e2r_midinc	6,612	0.11	0.34	0.11	0	10.46
e2r_hiinc	6,612	0.48	1.05	0.29	0	27.80
e2r_g5	6,612	0.21	0.51	0.15	0	14.97
e2r_lomidinc	6,612	0.25	0.80	0.31	0	23.61
e2r_himidinc	6,612	0.59	1.32	0.35	0	29.19
w_e2r	4,640	0.67	1.08	0.33	0	15.59

Table 2: Summary statistics of e2r indicators.
Variables can be read as e2r_destination. For example, e2r_moreinc measures domestic value added in exports sold to countries with more income, i.e. a higher GDP per capita, for re-exporting. e2r_-lessinc_wtd and e2r_moreinc_wtd additionally weight the foreign value added by the GDP per capita gap to the destination country.

in particular low-income countries has expanded rapidly (83% and 118% respectively) underlining the new relevance of South-South and South-North trade. Since foreign value added sourced from high-income countries in absolute terms is still much larger than value added sourced from low- and middle-income countries, the growth in the overall *i2e ratio* has nevertheless decelerated. All indicator values by country, industry, and year can be found in the Appendix.

The summary statistics in Table 2 for forward linkages show again that there is sufficient industry-country variation over time. Natural resource exporters, such as Norway, Saudi Arabia, Russia or Chile, dominate the right-hand side of the *e2r* value distribution. Developing countries specialised in downstream assembly tasks, like China, Mexico, or Thailand, have low *e2r* values while large and technologically advanced countries that serve as hubs have high *e2r* values. Examples here are Germany, Japan, and the US. Among the industries with strong forward linkages are *Mining and quarrying* (10T14) and *Basic and fabricated metals* (27T28). The forward linkages also highlight the importance of service industries as indirect exporters through their supply to manufacturers. *Business services* (71T74) and *Transport and storage services* (60T63) are two of the industries with the highest *e2r* ratio, especially when taking only high-income countries as re-exporters into account. Over time the forward linkage measure has grown by 22% exhibiting a similar pattern as the backward linkages. As in the *i2e* case, most of the growth comes from middle- and low-income countries acting as re-exporters.

Figures 1 and 2 illustrate the development of GVC participation over time proxied by both forward and backward linkages. Figure 1 shows that up to 2005 GVC participation has expanded rapidly while Figure 2 highlights that this trend was driven mainly by the growing importance of low- and middle-income countries. In addition, the figures show that both backward and forward linkages are highly correlated (0.90) and thus seem to be equally good proxies for GVC participation.

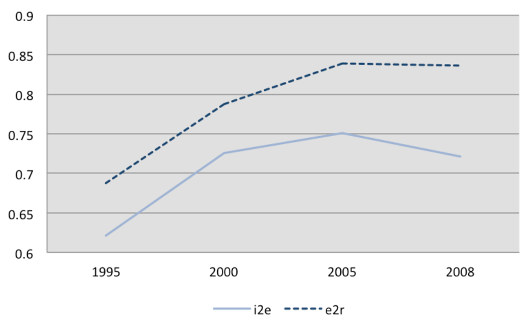

Figure 1: Development of GVC participation over time across all GVC partners.

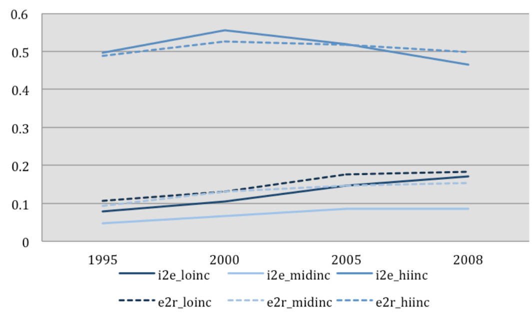

Figure 2: Development of GVC participation over time by income groups.

4 The effect of GVC participation on domestic value added

The theoretical literature in section 2 has revealed an ambiguous relationship between GVC participation and the domestic economy that is reflected in the current policy debate on GVCs. Therefore, I test firstly if GVC participation generates gains for domestic value added along the chain (i.e. sourcing and supplying side) and across different stages of development. In addition, the literature suggests transmission channels between GVCs and the domestic economy that depend on cross-country differences and their magnitudes, namely productivity gains and technology upgrading[24]. I assess these predictions in

[24]Technology upgrading and spillovers have to be regarded in a wider sense here since they do not only refer to innovation and R&D but also to simple improvements in processes and standards.

the second part of the empirical analysis. Finally, I conclude by examining potential explanatory factors for the results.

4.1 Does GVC participation benefit domestic value added?

To investigate the presence of general gains through GVC participation, I start by using the panel structure of WIOD and the OECD ICIOs to estimate a simple linear regression model according to the following specification:

$$ln\_va^i_{kt} = \alpha + \beta_1 \; x^i_{kt} + \beta^{'}_2 \; C + \; \varepsilon^i_{kt}, \tag{14}$$

where $ln\_va^i_k$ is the natural logarithm of domestic value added of industry i in country k at time t[25]. The variable of interest is $x^i_{kt} \in \left\{i2e^i_{kt} \; , \; w\_i2e^i_{kt}, \; e2r^i_{kt}, \;\; w\_e2r^i_{kt}\right\}$ with the OECD indicators representing the benchmark and the w prefix referring to WIOD date. Hence, β_1 is the coefficient of interest and C is a vector of controls that includes variables which are relevant for GVC participation according to the literature discussed in section 1.1 and the descriptive statistics in section 3.3. The variables include GDP, GDP per capita, trade openness, trade covered by RTAs, a trade-weighted average of bilateral trade costs, tariffs, and regional dummies. Finally, ε^i_{kt} is the error term.

Table 3 gives the corresponding estimates. Each cell represents a separate regression with rows differing by the applied GVC participation indicator and columns by the employed controls. The outcome variable is the natural logarithm of domestic industry-level value added. Thus, the coefficients can be interpreted as percentage changes triggered by a 1-percentage point increase of the independent variable. The table presents first evidence that the net effect of GVC participation on domestic value added is positive. Columns 1 and 2 are based on the OECD value added data while columns 3 and 4 use WIOD data. Columns 1 and 3 report basic OLS results without controls or fixed effects.

[25]Domestic value added lends itself to the analysis since it captures total factor rewards. Both technology transfers and changes in productivity have an unambiguous relationship with domestic value added and, thus, predictions of the models can be tested in a straightforward fashion. This wouldn't be the case if one were to look at labour market outcomes, such as wages, that are subject to several forces when GVC participation increases as shown by Grossman and Rossi-Hansberg (2008).

	(1)	(2)	(3)	(4)
VARIABLES	va		w_va	
i2e	0.0933***	0.0801***	0.0976***	0.0721***
	(0.0093)	(0.0073)	(0.0118)	(0.0077)
w_i2e	-0.0431***	0.0477***	-0.0438***	0.0485***
	(0.0084)	(0.0055)	(0.0083)	(0.0053)
e2r	0.3210***	0.3480***	0.3720***	0.3290***
	(0.0174)	(0.0144)	(0.0228)	(0.0155)
w_e2r	0.4830***	0.3850***	0.4940***	0.3820***
	(0.0250)	(0.0167)	(0.0244)	(0.0158)
Observations	3,978/3,028	3,342/2,729	3,033	2,734
Controls	-	GDP, GDP per capita, trade openness, trade covered by RTAs, trade costs, tariffs, regional dummies	-	GDP, GDP per capita, trade openness, trade covered by RTAs, trade costs, tariffs, regional dummies

Table 3: The effect of GVC participation on domestic value added - first evidence.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$. All level variables are in natural logarithms. The number of observations depends on the applied database with the smaller number referring to WIOD data. The w prefix refers to WIOD data. Each cell represents a separate regression with rows differing by the applied GVC participation indicator and columns by the employed controls.

Hence, they show simply the unconditional correlation between the GVC indicators and domestic value added in the panels. The OECD coefficients indicate that a 10-percentage point increase in GVC participation measured by backward linkages relates to a 0.933% higher level of domestic value added and to a 3.21% higher level of domestic value added if measured by forward linkages. Interestingly, the backward linkage indicator based on WIOD is negatively correlated to domestic value added. A likely reason is that WIOD covers mainly high-income countries, which are more affected by the stylised finding that larger countries in terms of GDP tend to have smaller backward linkages. It might also speak to the hypothesis that high-income countries benefit more from sales than from sourcing linkages. Columns 2 and 4 include country-level controls to correct for confounding factors such as country size. While the magnitude of the coefficients drops slightly, the general finding that GVC participation is related to higher domestic value added is confirmed. In addition, the negative coefficient on WIOD's backward linkage indicator now indicates a positive and significant relationship. Finally, I observe that forward linkages seem to have a stronger impact than backward linkages and that the results are consistent across the two databases. This means that the different assumptions used in the construction of WIOD and the OECD ICIOs do not translate into major differences for empirical applications of the data. Since WIOD and the OECD ICIOs are based on different data sources, namely supply and use tables versus national input-output tables, this increases the reliability of the estimates.

While the estimates in Table 3 are suggestive of a positive GVC effect, they are not sufficient since the empirical model in equation (14) is subject to a set of issues. Firstly, domestic value added is the result of many factors that might be correlated with GVC participation but cannot be measured. To account for this, I use different specifications with various sets of fixed effects. 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. Therefore, I additionally include industry-level intermediate imports as a control or, more specifically, the part of intermediate imports that is not exported subsequently. Intermediate imports can be processed and consumed domestically or exported abroad. While in the latter case the imports count towards the independent variable, the former case constitutes my control. In line with the terminology used in this article, I refer to it as *i2cd*, or imported-to-consume-domestically as opposed to imported-to-export. *i2cd* is a good predictor for different factors that might simultaneously change GVC participation and value added, such as productivity, size, comparative advantage or openness, and, as a result, minimises a potential omitted variable concern.

Furthermore, controlling for *i2cd* takes care of the second main issue. Different channels through which GVC participation might interact with value added could also be triggered simply by increased imports of intermediates[26]. For instance, knowledge spillovers might be generated by the exposure to imported varieties independent of the production network impact. By including imports in the empirical model this distorting effect is taken out but, comparable to the fixed effects, it leads to a potentially significant downward bias of the GVC estimates since some of its benefits might be attributed to imports.

[26]See, for example, Goldberg et al. (2010) and Colantone and Crinò (2014).

The reason is that some of the *i2cd* might not be simple old-fashioned trade in goods but just the last task within a value chain. Neither the forward- nor the backward-linkage indicator account for this since both require the value added to be exported. Pointing once again to Fally (2012)'s stylised finding that many value chains comprise only few tasks, there might be a considerable share of GVC trade within this term. Nevertheless, it is preferable to include it as a control since otherwise the omitted variable bias were possibly large. This implies that one has to interpret the estimated coefficients below as a lower benchmark.

The final concern is reverse causality. I intend to minimise this problem by using the respective lagged values of the GVC indicators. Given that each period covers five years, lags should reduce potential reverse causality significantly and allow for a delayed response of domestic value added. This is theoretically grounded in Li and Liu (2014)'s dynamic model, in which the effect of GVC participation on domestic value added accrues always in the next period. As this identification strategy might not fully eliminate a potential bias, the causal inference I draw could be subject to a slight bias. However, it is conceptually extremely difficult to establish valid instruments for GVC participation and this is even more the case if the instrument is supposed to capture the difference between forward and backward linkages. Therefore the combination of fixed effects and lags constitutes the best strategy to allow for a careful causal interpretation of the results.

The benchmark model I estimate is then given by:

$$ln\_va^i_{kt} = \alpha + \beta_1 \, x^i_{kt-1} + \beta_2 \, ln\_i2cd^i_{kt} + \alpha^i_k + \alpha_{kt} + \alpha^i_t + \varepsilon^i_{kt}, \tag{15}$$

where *i2cd* gives non-exported intermediate imports, α^i_k captures industry-country fixed effects, α_{kt} country-time fixed effects, and α^i_t industry-time fixed effects. In addition to this specification, I also run the model with the country-level control variables. Their effects are taken into account in the benchmark model by the country-year fixed effects but the sign and size of their coefficients is helpful to assess the relevance and relative magnitude of the GVC effect. These estimations include industry-country and year fixed

	(1)	(2)	(3)	(4)
VARIABLES	va		w_va	
i2e	0.0198**	0.0198***	0.0312***	0.0280***
	(0.0085)	(0.0066)	(0.0062)	(0.0051)
w_i2e	0.0260***	0.0230***	0.0301***	0.0267***
	(0.0059)	(0.0059)	(0.0067)	(0.0064)
e2r	0.0398**	0.0263**	0.0719***	0.0340***
	(0.0199)	(0.0118)	(0.0165)	(0.0125)
w_e2r	0.0957***	0.0541***	0.1060***	0.0602***
	(0.0157)	(0.0196)	(0.0160)	(0.0195)
Observations	2,625/2,091	2,983/2,271	2,734	3,033
Controls	i2cd, GDP, GDP per capita, trade openness, trade covered by RTAs, trade costs, tariffs, regional dummies	i2cd	i2cd, GDP, GDP per capita, trade openness, trade covered by RTAs, trade costs, tariffs, regional dummies	i2cd
Fixed effects	Year, Industry-Country	Industry-Year, Country-Year, Industry-Country	Year, Industry-Country	Industry-Year, Country-Year, Industry-Country

Table 4: The effect of GVC participation on domestic value added - benchmark results.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$. All level variables are in natural logarithms. The number of observations depends on the applied database with the smaller number referring to WIOD data. The w prefix refers to WIOD data. Each cell represents a separate regression with rows differing by the applied GVC participation indicator and columns by the employed controls.

effects.

Table 4 reports the results. The preliminary findings of Table 3 are strongly confirmed. All specifications and measures indicate a positive and statistically significant effect of GVC participation on domestic value added. Columns 2 and 4 give the results for the benchmark model in equation (15). Based on this preferred specification, I find that a 10-percentage point increase in GVC participation leads to higher domestic value added in each industry in the range of 0.198% to 0.602% depending on the type of GVC participation and sample[27]. Given the average increase of GVC participation by 15% to 30% over the sample period, this suggests a significant quantitative impact on domestic value added especially when considering that some countries such as China, Poland, Turkey, India, or Japan raised their GVC participation between 75% and 130%. However, GVCs should not be considered as panacea for development since the effect in

[27]The results using WIOD value added are again in line with the OECD results. Since this is the case for all results to come, I do not present the estimates based on WIOD value added data in the remaining parts.

absolute terms is nevertheless modest. Columns 1 and 3 allow to compare the magnitude of the GVC coefficients with other relevant trade policy variables. GVC participation has, independent of the applied indicator, a significantly larger coefficient than trade openness (-0.0056 in *i2e* regression with OECD data), trade costs (-0.007) and applied tariffs (0.0001). The share of trade covered by RTAs has a larger but negative coefficient (-0.263)[28]. This is convincing evidence that GVC participation does indeed promote domestic value added and should play a role in trade policy design.

I conclude the analysis by running equation (15) on subsets of the sample covering only low-, middle, or high-income countries to determine whether the gains are present across countries at different stages of development. The results in Table 5 suggest that the benefits of GVCs materialise only in middle- and high-income countries. For low-income countries, I find a positive but statistically insignificant effect of GVC participation proxied by forward linkages and even a negative but insignificant effect of GVC participation proxied by backward linkages. I examine this result more closely when analysing the channels. In particular, I look into potential explanatory factors for this outcome. For high-income countries both sourcing and selling relationships are positive and significant with a higher coefficient on the forward linkage indicator for both OECD and WIOD based indicators. This is further evidence that high-income countries not only have higher *e2r* ratios but also benefit more from specialising in these upstream tasks. I find the opposite pattern for middle-income countries whose coefficient is only positive and statistically significant for backward linkages, according to the OECD indicator. Interestingly, the forward linkage indicator is positive and significant when employing WIOD data. Once again, the key difference between the databases is that the OECD ICIOs cover a larger share of low-income countries, which means that the sales indicator based on WIOD data includes mainly sales from middle-income to high-income countries while the OECD indicator gives a broader picture of sourcing partners. This points to the fact that middle-income countries profit more from selling to high- than to low-income countries. I test for this hypothesis explicitly below when analysing the channels.

[28]The coefficients of the control variables can be found in the Appendix.

	(1)	(2)	(3)	(4)
VARIABLES			va	
	All countries	Low-income	Middle-income	High-income
i2e	0.0198***	-0.0036	0.0322***	0.0184***
	(0.0066)	(0.0063)	(0.0072)	(0.0065)
w_i2e	0.0230***	-0.0031	0.0184***	0.0317***
	(0.0059)	(0.0175)	(0.0059)	(0.0115)
e2r	0.0263***	0.0044	0.0148	0.0548***
	(0.0118)	(0.0148)	(0.0159)	(0.0155)
w_e2r	0.0541**	-0.0069	0.0836***	0.0531**
	(0.0196)	(0.0322)	(0.0272)	(0.0216)
Observations	2,983/2,271	720/320	897/837	1,366/1,074
Controls			i2cd	
Fixed effects		Industry-Year, Country-Year, Industry-Country		

Table 5: The effect of GVC participation on domestic value added by income groups.
Industry-Country clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All level variables are in natural logarithms. All GVC participation measures are lagged. The number of observations depends on the applied database. The w prefix refers to WIOD data. Each cell represents a separate regression with rows differing by the applied GVC participation indicator and columns by the employed controls.

4.2 The transmission channels: GVC participation, productivity effects, and technology upgrading

Let us now turn to the transmission channels suggested in section 2 to develop a better understanding of the drivers behind the findings at hand. To this end, I introduce the novel source/destination country-specific indicators. As a preliminary test, I compare the magnitude of β_1 in equation (15) across these different indicators. This means, for example in the case of productivity effects, that I estimate equation (15) with the general indicators $i2e^i_{kt}$ and $e2r^i_{kt}$ and afterwards with the indicators that take only into account foreign value added sourced from or sold to low-wage countries. If productivity effects drive the results, I expect a larger β_1 for the latter indicators. Similarly, I expect a larger β_1 for the indicators that measure value added sourced from or sold to high-income countries if technology upgrading is responsible for the results.

Table 6a shows that all sourcing indicators are positive and, with three exceptions, significant. While the coefficients are not directly comparable, it is encouraging for the theoretical channels that they are larger than the standard indicator coefficients and consistent across each other. For instance, if technology transfers and spillovers gener-

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES				va				
i2e_lessinc	0.0137							
	(0.0109)							
i2e_moreinc		0.0229**						
		(0.0105)						
i2e_lessinc_wtd			4.95e-07**					
			(1.95e-07)					
i2e_moreinc_wtd				6.74e-07				
				(4.54e-07)				
i2e_loinc					0.0809***			
					(0.0238)			
i2e_midinc						0.0325		
						(0.0362)		
i2e_hiinc							0.0270***	
							(0.00749)	
i2e_g5								0.0349***
								(0.0102)
Observations				2,983				
Controls				i2cd				
Fixed effects				Industry-Year, Country-Year, Industry-Country				

Table 6a: The effect of source-country-specific indicators of GVC participation on domestic value added. Industry-Country clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All level variables are in natural logarithms. All GVC participation measures are lagged. Variables can be read as i2e_source. For example, i2e_lessinc comprises only value added sourced from countries with less income, i2e_loinc value added sourced from low-income countries and so forth.

ate some of the GVC gains, we expect positive and significant effects when countries join GVCs of countries close to the technology frontier and even larger gains of GVCs with countries at the technology frontier. Correspondingly, sourcing from the five countries at the technology frontier (Keller (2002)'s G5) seems to generate larger gains than sourcing from all high-income countries (*i2e_hiinc* vs *i2e_g5*). The three positive but insignificant coefficients concern sourcing from countries with a lower GDP per capita, sourcing from much richer countries and sourcing from middle-income countries. The last result is broadly consistent with theory. Middle-income countries offer less in terms of technological capabilities to low-income countries and in terms of saving potential to high-income countries. The first two results shed light on the relevance of the size of the cross-country difference. $i2e\_lessinc\_wtd^i_k$ and $i2e\_lessinc^i_k$ differ only in that the former variable weights foreign value added by the GDP per capita gap. This difference is sufficient to raise the significance of its coefficient to the 1% level, which indicates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES				va				
e2r_lessinc	0.0018***							
	(0.0005)							
e2r_moreinc		0.0170						
		(0.0141)						
e2r_lessinc_wtd			1.18e-07***					
			(3.39e-08)					
e2r_moreinc_wtd				9.67e-07				
				(6.85e-07)				
e2r_loinc					0.0272			
					(0.0224)			
e2r_midinc						0.0462		
						(0.0521)		
e2r_hiinc							0.0570***	
							(0.0162)	
e2r_g5								0.0854**
								(0.0368)
Observations				2,983				
Controls				i2cd				
Fixed effects				Industry-Year, Country-Year, Industry-Country				

Table 6b: The effect of destination-country-specific indicators of GVC participation on domestic value added.
Industry-Country clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All level variables are in natural logarithms. All GVC participation measures are lagged. Variables can be read as e2r_destination, i.e. value added sold to the destination country for re-exporting. For example, e2r_lessinc comprises only value added sold to countries with less income for re-exporting.

that for the productivity effect to arise it requires large cross-country differences. In contrast, the significance of the indicator capturing value added from countries with a higher GDP per capita drops when weighted by the gap. When considering the mechanisms at work, this result is plausible. Productivity effects are driven in the models by large wage differences, which only prevail between adequately different countries. Technology transfer, on the other hand, requires a certain level of absorptive capacity. In addition, it is unlikely that high-income countries have tasks with a large skill component performed by low-income countries so the technology effect on the latter countries is presumably small.

Table 6b presents the respective results for the sales indicators. Concerning selling to specific income groups the findings of the backward linkage indicators are largely confirmed. For the remaining indicators the picture is however slightly different. Selling to countries with a lower GDP per capita is highly significant even if the measure is unweighted. A potential explanation is that the forward linkage indicator is largest for high-income countries while the sourcing indicator is largest for middle-income countries. This implies that $e2r\_lessinc^i_{kt}$ already puts a larger weight on sourcing from countries with relatively larger GDP per capita differences since the average GDP per capita difference is larger for high-income countries than for middle-income countries. This is additional evidence for the hypothesis that low- and especially middle-income countries benefit more from sourcing relationships than from forward linkages as opposed to high-income countries.

To analyse these findings more rigorously, I proceed by incorporating interaction terms into the benchmark model that capture the income-level of the examined country:

$$ln\_va^i_{kt} = \alpha + \beta_1 x^i_{kt-1} + \beta_2\ ln\_i2cd^i_{kt} + \beta_3 x^i_{kt-1} * inc_k + \alpha^i_k + \ \alpha_{kt} + \ \alpha^i_t + \varepsilon^i_{kt}. \quad (16)$$

where inc_k is a dummy equal to 1 if country k is from a specific income group. Equation (16) serves as main test for the transmission channels. As in the example above, I expect a positive and significant β_3 when $x^i_{kt} \in \{i2e\_loinc^i_{kt},\ e2r\_loinc^i_{kt}\}$ and $inc_k = 1$ for middle- and high-income countries. Similarly, I expect a positive and significant β_3 when $x^i_{kt} \in \{i2e\_hiinc^i_{kt},\ e2r\_hiinc^i_{kt}\}$ and $inc_k = 1$ for middle- and low-income countries and so on. An advantage of this specific test is that it mitigates the reverse causality issues described above. While industries with expanding domestic value added might attract also more foreign value added, it is not clear why this effect should be uneven across host countries at different stages of development.

To begin with, Table 7 looks at productivity-enhancing effects of GVCs by examining if sourcing from or selling to countries with lower income levels has a larger effect on countries with higher income levels. The evidence is strongly in favour of the presence of such productivity effects. All coefficients are positive and highly significant with only one exception. For instance, high- and middle-income countries benefit significantly more from sourcing from and selling to low-income countries than these countries themselves

	(1)	(2)	(3)	(4)
VARIABLES			va	
i2e_loinc	0.0083			
	(0.0354)			
i2e_loinc*himidinc	0.104**			
	(0.0411)			
i2e_lomidinc		0.0271		
		(0.0194)		
i2e_lomidinc*hiinc		0.0292		
		(0.0280)		
e2r_loinc			-0.0029	
			(0.0164)	
e2r_loinc*himidinc			0.105***	
			(0.0348)	
e2r_lomidinc				0.0069
				(0.0160)
e2r_lomidinc*hiinc				0.110***
				(0.0346)
Observations			2,983	
Controls			i2cd	
Fixed effects	Industry-Year, Country-Year, Industry-Country			

Table 7: Productivity effects of GVCs.
Industry-Country clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All level variables are in natural logarithms. All GVC participation measures are lagged. Variables can be read as i2e_source*using-country. For example, i2e_lomidinc*hiinc refers to the effect of value added sourced from low- and middle-income countries on domestic value added in high-income countries.

(columns 1 and 3). Similarly, the domestic value added of high-income countries rises more than the domestic value added of low- and middle-income countries when forward linkages to low-and middle-income countries increase (column 4). The exception in Table 7 concerns backward linkages of high-income countries to low- and middle-income countries (column 2), which is further indication that forward linkages drive the gains of high-income countries in GVCs as opposed to backward linkages.

The evidence regarding technology effects is less clear. In stark contrast to the results for productivity effects, Table 8 reports that all coefficients are negative with just one exception and in three cases significant. This apparently does not support the theoretical prediction of technology transfer gains through sourcing from or selling to richer countries. However, the negative and significant (columns 3, 5, and 6) and the positive (column 4) coefficients suggest that low- and middle-income countries might drive the results. The positive coefficient belongs to the indicator that places relatively less weight on these

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES				va		
i2e_g5	0.0991					
	(0.0738)					
i2e_g5*non-g5	-0.0649					
	(0.0738)					
i2e_hiinc		0.0318***				
		(0.0087)				
i2e_hiinc*lomidinc		-0.0079				
		(0.0128)				
i2e_himidinc			0.0236***			
			(0.0052)			
i2e_himidinc*loinc			-0.0324***			
			(0.0083)			
e2r_g5				0.0385		
				(0.0993)		
e2r_g5*non-g5				0.0485		
				(0.0956)		
e2r_hiinc					0.0947***	
					(0.0223)	
e2r_hiinc*lomidinc					-0.0694**	
					(0.0271)	
e2r_himidinc						0.0596***
						(0.0153)
e2r_himidinc*loinc						-0.0543**
						(0.0255)
Observations			2,983			
Controls			i2cd			
Fixed effects		Industry-Year, Country-Year, Industry-Country				

Table 8: Technology effects of GVCs.
Industry-Country clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All level variables are in natural logarithms. All GVC participation measures are lagged. Variables can be read as i2e_source*using-country. For example, i2e_himidinc*loinc refers to the effect of value added sourced from high- and middle-income countries on domestic value added in low-income countries.

countries since it includes all non-g5 countries. This means that it also includes high-income countries that are not at the technology frontier. The negative and significant coefficients on the other hand concern interaction terms excluding high-income countries. This is consistent with the earlier findings that low-income countries show no significant gains from increased GVC participation and that technology upgrading and spillover gains are negatively affected by larger GDP per capita gaps.

As mentioned above, this relates to the literature on the role of absorptive capacities for technology diffusion in low- and middle-income countries. This line of work emphasises the importance of human capital, institutions, and other factors for spillovers. The argument is that attracting foreign value added is not sufficient on its own to create positive effects on the domestic economy. In addition, countries need strong contract enforcement institutions, which incentivise foreign firms to import their advanced technologies, and human capital that matches the increased demand for skilled labour and allows the foreign firms to source inputs locally. An absence of these conditions can limit the potential of GVC linkages substantially, which could explain the insignificance of the estimates for technology transfer effects in low- and middle-income countries here.

To test for this hypothesis explicitly, I replace the GDP per capita dependent interaction term in Table 8 with measures of human capital, contract enforcement, and R&D intensity and rerun equation (16) on the sample of low and middle income countries[29]. Table 9a presents strong evidence supporting the assumption. All interaction terms are positive and, except two, significant. This means that low- and middle-income countries benefit significantly more from backward linkages to richer countries if they are equipped with larger levels of human capital, better technology, and better contracting institutions. This holds especially for human capital and contract enforcement. The coefficients suggest, for instance, that around five years of schooling are necessary for technology effects arise. R&D intensity, on the other hand, is less important for technology upgrading. Its interaction is only significant for one of the three GVC participation measures. This speaks to the fact that low- and middle-income countries benefit more from simple process improvements and less from spillovers for innovation.

In contrast, the interactions with forward linkage measures presented in Table 9b are only significant in one instance, namely R&D intensity. This is further evidence on the differing relevance that backward and forward linkages have for low- and middle-income countries. Most of the benefits that these countries extract from GVCs seems to come from sourcing relationships. This is in line with the coefficients in Table 5,

[29] I use a version of Barro and Lee (2013)'s educational attainment measure to proxy for human capital (hcap). More specifically, I use the expected years of schooling at the beginning of the sample period. Similarly, for R&D intensity (rnd) I use the earliest available values for R&D expenditure as a share of GDP by the World Development Indicators and, finally, for contract enforcement (ruleoflaw) I use the initial values of Kaufmann et al. (2011)'s rule of law measure. The initial values are used to avoid potential reverse causality bias flowing from domestic value added to human capital and institutions. However, I obtain the same results when using average values over the sample period.

	(1)	(2)	(3)
VARIABLES		va	
		Middle and low income	
i2e_g5	-0.0491	0.0134	0.0222
	(0.0382)	(0.0149)	(0.0182)
i2e_g5*hcap	0.0090**		
	(0.0039)		
i2e_g5*ruleoflaw		0.0299**	
		(0.0151)	
i2e_g5*rnd			0.0099
			(0.0198)
i2e_hiinc	-0.0306	0.0102	0.0136
	(0.0326)	(0.0118)	(0.0144)
i2e_hiinc*hcap	0.0062*		
	(0.0032)		
i2e_hiinc*ruleoflaw		0.0264**	
		(0.0135)	
i2e_hiinc*rnd			0.0174
			(0.0157)
i2e_moreinc	-0.0318	0.0055	0.0028
	(0.0257)	(0.0085)	(0.0111)
i2e_moreinc*hcap	0.0058**		
	(0.0026)		
i2e_moreinc*ruleoflaw		0.0309***	
		(0.0113)	
i2e_moreinc*rnd			0.0288*
			(0.0148)
Observations		1,617	
Controls		i2cd	
Fixed effects		Industry-Year, Country-Year, Industry-Country	

Table 9a: Technology transfer effects of backward linkages and absorptive capacity.
Industry-Country clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All level variables are in natural logarithms. All GVC participation measures are lagged. Columns differ by measures of absorptive capacity (human capital, contract enforcement, R&D intensity). Blocks differ by the applied GVC indicator, which can be read as i2e_source. For example, i2e_hiinc refers to value added sourced from high-income countries. The sample covers only middle- and low-income countries.

	(1)	(2)	(3)
VARIABLES		va	
		Middle and low income	
e2r_g5	-0.0715	0.0178	-0.0171
	(0.111)	(0.0422)	(0.0491)
e2r_g5*hcap	0.0116		
	(0.0126)		
e2r_g5*ruleoflaw		0.0098	
		(0.0520)	
e2r_g5*rnd			0.0647
			(0.0656)
e2r_hiinc	0.0214	0.0284	0.0224
	(0.0482)	(0.0213)	(0.0247)
e2r_hiinc*hcap	0.0016		
	(0.0058)		
e2r_hiinc*ruleoflaw		0.0132	
		(0.0227)	
e2r_hiinc*rnd			0.0177
			(0.0272)
e2r_moreinc	-0.0066	0.0094	-0.0069
	(0.0165)	(0.0139)	(0.0116)
e2r_moreinc*hcap	0.0024		
	(0.0033)		
e2r_moreinc*ruleoflaw		0.0151	
		(0.0110)	
e2r_moreinc*rnd			0.0452**
			(0.0229)
Observations		1,617	
Controls		i2cd	
Fixed effects		Industry-Year, Country-Year, Industry-Country	

Table 9b: Technology transfer effects of forward linkages and absorptive capacity.
Industry-Country clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All level variables are in natural logarithms. All GVC participation measures are lagged. Columns differ by measures of absorptive capacity (human capital, contract enforcement, R&D intensity). Blocks differ by the applied GVC indicator, which can be read as e2r_destination. For example, e2r_hiinc refers to value added sold to high-income countries.The sample covers only middle- and low-income countries.

which show that only backward linkages are significant for middle-income countries in the OECD sample and matches well with the literature on FDI and technology spillovers through backward linkages in middle-income countries[30]. The fact that the one significant interaction term concerns R&D intensity suggests that innovative capabilities are more important for selling intermediates than for sourcing them, which is intuitive.

Nevertheless, in general the evidence for technology upgrading effects remains, unlike the evidence for productivity effects, mixed. This holds especially for the theoretical prediction that larger cross-country differences should lead to larger gains for countries that join GVCs. Theoretical models on the effects of GVCs on domestic outcomes in low- and middle-income countries should incorporate parameters of absorptive capacity to present a more accurate picture of the relationship.

I finalise the analysis by employing the GDP per capita gap-weighted indicators. The weighted indicators are constructed in a way that is reminiscent of an interaction term on the source/destination country but it allows for within-group differences and does not require the classification of countries into income-groups:

$$ln\_va^i_{kt} = \alpha + \beta_1 x^i_{kt-1} + \beta_2\ ln\_i2cd^i_{kt} + \beta_3 z^i_{kt-1} + \alpha^i_k + \alpha_{kt} + \alpha^i_t + \varepsilon^i_{kt}, \qquad (17)$$

where $x^i_{kt} \in \{i2e^i_{kt},\ e2r^i_{kt}\}$ and $z^i_{kt} \in \{i2e\_lessinc\_wtd^i_{kt}, i2e\_moreinc\_wtd^i_{kt}, e2r\_lessinc\_wtd^i_{kt},\ e2r\_moreinc\_wtd^i_{kt}\}$. Equation (17) includes both the standard indicators and the weighted indicators and tests, like equation (16), if there is an effect additional to the general GVC effect caused by linkages to countries with a larger income-level difference as predicted by theory. The advantage to equation (16) is that it accounts for within-group differences. However, the coefficients in equation (16) have a clearer interpretation since they allow for a direct comparison of the effects between income groups and, thus, remain the benchmark for the theoretical channels.

Table 10 shows that this strategy produces largely consistent estimates. The coefficients of the indicators that examine technology transfer effects in columns 1 and

[30]See, for example, Javorcik (2004) and Javorcik and Spatareanu (2009). They present evidence for spillovers through backward linkages in Lithuania and the Czech Republic.

	(1)	(2)	(3)	(4)
VARIABLES		va		
i2e	0.0287***	0.0196**		
	(0.00844)	(0.00791)		
i2e_moreinc_wtd	-5.88e-07			
	(5.86e-07)			
i2e_lessinc_wtd		3.14e-08		
		(2.70e-07)		
e2r			0.0366**	0.0260**
			(0.0143)	(0.0116)
e2r_moreinc_wtd			-9.56e-07	
			(8.70e-07)	
e2r_lessinc_wtd				1.09e-07***
				(3.40e-08)
Observations		2,983		
Controls		i2cd		
Fixed effects	Industry-Year, Country-Year, Industry-Country			

Table 10: Technology and productivity effects of GVCs using a weighted indicator. Industry-Country clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All level variables are in natural logarithms. All GVC participation measures are lagged. Variables suffixed with *wtd* refer to value added sourced from or sold to countries with more/less income and weigted by the GDP per capita gap between the two countries.

3, $i2e\_moreinc\_wtd^i_{kt}$ and $e2r\_moreinc\_wtd^i_{kt}$, are negative and insignificant. This means that there are no technology transfer effects present between countries with strongly diverging GDP per capita levels. Columns 2 and 4 on the other hand show that the coefficients for the indicators that assess productivity effects, $i2e\_lessinc\_wtd^i_{kt}$ and $e2r\_lessinc\_wtd^i_{kt}$, are positive and in the latter case significant. This, in turn, emphasises the findings that productivity effects require a certain difference in GDP per capita levels consistent with theoretical prediction. It also stresses the fact that high-income countries, for which the largest productivity gains are expected, benefit more from forward linkages since the coefficient is only significant for these types of linkages.

To summarise, I find a positive and robust effect of GVC participation on domestic value added along the value chain. This finding holds for all indicators and across all specifications but is significant only for middle and high-income countries. Regarding the presence of technology and productivity effects, I find considerable support for the latter but only little evidence on the former. Benefits of technology upgrading seem to be hindered by large cross-country differences in GDP per capita levels. Therefore, they are limited to high-income countries and a set of low- and middle-income countries with sufficient levels of absorptive capacity. Low absorptive capacity can thereby explain the missing significantly positive effect of GVC participation on low-income countries. In contrast, productivity effects seem to require a certain difference of development levels to take effect. This is in line with the theoretical models that link these gains to wage differences. Finally, the evidence suggests that sourcing linkages drive the gains of middle-income countries in GVCs, while high-income countries profit more from forward linkages. This can be carefully interpreted as middle-income countries benefitting from downstream tasks, which are captured better by backward linkages, and high-income countries from upstream tasks.

4.3 Robustness

As mentioned above, classifying countries into income categories based on GDP per capita data requires the setting of a somewhat arbitrary cutoff. Therefore, I re-run the relevant regressions on varying cutoffs and on country classifications independent of GDP per capita, such as the IMF's country categorisation system. The results suggest that the findings are largely independent from the chosen cutoff and the classification strategy[31]. This is in line with the fact that the results for the weighted indicators, which require no classification at all, support the findings equally.

Next, I vary the sample composition first by including all natural resource exporters and then by excluding natural resource exporters based on different definitions than the one used in the main analysis[32]. Once again, I see no relevant effect on the results. Similarly, I exclude in the main analysis all value added sourced from the mining sector. To robustify the results, I include all value added and test if the results hold. In fact, most coefficients increase in magnitude indicating that excluding the value added from mining industries is necessary to avoid an upward bias of the results.

[31] Robustness results are available from the author upon request.

[32] In the main analysis 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.

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 in most cases, 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. Since the sample size drops, this leads in some cases to a lower significance level but does not affect the results otherwise.

As further robustness, I vary both the construction of the independent variable and the control variable. I start by replacing *i2e* and *e2r* with measures referred to as *rei*, re-exported imports, and *redint*, re-exported domestic intermediates. They differ from the benchmarks measures in that I do not apply the Leontief inverse to the IO table when calculating the new measures. Put differently, I do not remove re-imported domestic value added and double counting from it but instead simply use the amount of gross imports in exports as measure. The argument in favour of this procedure is that when domestic value added leaves the country to be processed somewhere else and then returns, it has become part of a GVC and should thus be included in a measure of GVC participation. However, since the theoretical benefits of GVCs described in section 2 do not apply to this logic, I use *rei* and *redint* only as robustness. Moreover, I alternate my control variable *i2cd* with gross imports. This reduces measurement error introduced when applying proportionality assumptions to gross imports in order to subtract the amount that is exported but it also increases the potential downward bias of the estimates considerably since it increases the overlap with the GVC measure. None of these strategies affect the results substantially.

Finally, I run several placebo tests that deliver the expected insignificant results. For instance, the measures of absorptive capacity have no impact when looking at the total sample that includes high-income countries. Similarly, GVC participation measures that capture sourcing from or selling to a randomised set of countries do not generate significant interaction terms with specific income groups.

5 Conclusion

This paper is one of the first attempts to assess the effect of Global Value Chain participation on the domestic economy. Using a new extensive system of ICIOs that covers countries at different levels of development, I show that industry-level domestic value added is systematically higher, the higher GVC participation. Both forward and backward linkage indicators of GVC participation generate robust and significant gains for both selling and source countries. This suggests that the positive impact of GVC participation is independent of a country's position in the value chain. Suppliers of intermediates, that are located upstream, and users of foreign inputs located downstream within the chain benefit from production networks equally. However, the evidence speaks in favour of high-income countries benefitting more from sales linkages while middle-income countries gain more through backward linkages. Another key finding is that there is no significant effect of GVC participation on low-income countries. This questions the role of GVCs in development policy. However, the result has to be treated with care since it only shows that the low-income countries in the sample on average have not benefitted. This does not imply that none of the countries gains from GVCs. For instance, it is unlikely that China's rapid rise occurred independent of the country's involvement in value chains. In addition, the result is an industry average and conceals potential heterogeneity across industries, which might be more pronounced in low-income countries. Nevertheless, the result points to the fact that absorptive capacity matters and should be accounted for in the theoretical literature.

Furthermore, the findings suggest that the new GVC databases, WIOD and OECD ICIOs, produce consistent results. The estimated coefficients are comparable across all specifications and for all outcomes. Therefore, it seems that the different construction techniques of the two databases do not lead to major differences in their application. Possible concerns about data quality should thus be alleviated in view of the fact that the databases provide similar predictions despite using different data sources.

Finally, while the results provide some convincing evidence on the role of GVCs, further research is necessary to improve our understanding of Global Value Chains. 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 positive effects of GVCs and factors that hinder their materialisation. Moreover, it is essential for theoretical research to shed further light on the linkages between GVC participation and development. Since there is currently no effect among low-income countries, research should examine the role of absorptive capacities more closely.

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A Appendix

A.1 Theoretical derivation of the Leontief decomposition

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

$$VB = V + VA + VAA + VAAA + ... = V(I + A + A^2 + A^3 + ...), \tag{18}$$

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

$$VB = V(I - A)^{-1}, \tag{19}$$

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 $V(I-A)^{-1}E$. [33] In a simple example with two countries (k and l) and industries (i and j) we can zoom in to see the matrices' content:

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

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

where

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

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

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

and

$$a^{su}_{cf} = \frac{inp^{su}_{cf}}{y^u_f} \qquad (c, f \in k, l \quad s, u \in i, j).$$

where v^c_s gives the share of industry s's value added, va^s_c, in output, y^c_s, and e^i_k indicates gross exports. b^{cf}_{su} refers to the Leontief coefficients and, finally, a^{cf}_{su} denotes the share of inputs, inp^{cf}_{su}, 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	ISO3	Country
arg	Argentina	ita	Italy
aut	Austria	jpn	Japan
bel	Belgium	khm	Cambodia
bgr	Bulgaria	kor	Republic of Korea
bra	Brasil	ltu	Lithuania
can	Canada	lux	Luxembourg
che	Switzerland	lva	Latvia
chn	China	mex	Mexico
cyp	Cyprus	mlt	Malta
cze	Czech Republic	mys	Malaysia
deu	Germany	nld	Netherlands
dnk	Denmark	nzl	New Zealand
esp	Spain	phl	Philippines
est	Estonia	pol	Poland
fin	Finland	prt	Portugal
fra	France	rou	Romania
gbr	United Kingdom	sgp	Singapore
grc	Greece	svk	Slovakia
hkg	Hong Kong	svn	Slovenia
hun	Hungary	swe	Sweden
idn	Indonesia	tha	Thailand
ind	India	tur	Turkey
irl	Ireland	twn	Chinese Taipei
isl	Iceland	usa	United States
isr	Israel	vnm	Vietnam

Table 11: Sample country coverage based on OECD ICIO.

ISO3	Country	ISO3	Country
aut	Austria	irl	Ireland
bel	Belgium	ita	Italy
bgr	Bulgaria	jpn	Japan
bra	Brasil	kor	Republic of Korea
can	Canada	ltu	Lithuania
chn	China	lux	Luxembourg
cyp	Cyprus	lva	Latvia
cze	Czech Republic	mex	Mexico
deu	Germany	mlt	Malta
dnk	Denmark	nld	Netherlands
esp	Spain	pol	Poland
est	Estonia	prt	Portugal
fin	Finland	rou	Romania
fra	France	svk	Slovakia
gbr	United Kingdom	svn	Slovenia
grc	Greece	swe	Sweden
hun	Hungary	tur	Turkey
idn	Indonesia	twn	Chinese Taipei
ind	India	usa	United States

Table 12: Sample country coverage based on WIOD.

ISIC Rev. 3	Industry
01T05	Agriculture
10T14	Mining and quarrying
15T16	Food products and beverages
17T19	Textiles, leather and footwear
20	Wood and products of wood and cork
21T22	Pulp, paper, paper products, printing and publishing
23	Coke, refined petroleum products and nuclear fuel
24	Chemicals and chemical productrs
25	Rubber and plastics products
26	Other non-metallic mineral products
27T28	Basic metals and fabricated metal products
29	Machinery and equipment n.e.c
30T33	Electrical and optical equipment
34T35	Transport equipment
36T37	Manufacturing n.e.c; recycling
50T52	Wholesale and retail trade
60T63	Transport and storage
64	Post and telecommunications
65T67	Financial intermediation
71T74	Business services

Table 13: Sample industry coverage.

Country	i2e	Country	i2e	Country	e2r	Country	e2r
lux	1.85	aut	1.09	usa	0.99	kor	0.68
sgp	1.75	dnk	1.06	lva	0.94	twn	0.66
irl	1.56	mex	1.04	gbr	0.89	ind	0.66
svk	1.56	prt	1.02	jpn	0.89	grc	0.66
mlt	1.51	che	0.95	idn	0.88	dnk	0.65
est	1.49	rou	0.91	bra	0.84	est	0.64
hun	1.44	lva	0.9	fin	0.82	prt	0.63
phl	1.42	can	0.87	deu	0.82	sgp	0.63
bel	1.42	esp	0.86	aut	0.81	svn	0.62
mys	1.41	pol	0.86	swe	0.79	bgr	0.62
twn	1.39	ita	0.84	phl	0.78	isr	0.61
cze	1.31	deu	0.83	fra	0.77	hun	0.6
svn	1.28	fra	0.81	che	0.76	irl	0.58
bgr	1.27	grc	0.76	cze	0.76	ltu	0.57
ltu	1.26	chn	0.71	pol	0.75	isl	0.55
isl	1.24	nzl	0.68	mys	0.75	tur	0.55
nld	1.24	gbr	0.67	arg	0.74	vnm	0.55
tha	1.21	tur	0.64	nld	0.74	lux	0.53
kor	1.19	idn	0.6	cyp	0.72	nzl	0.53
isr	1.16	ind	0.56	svk	0.72	chn	0.52
khm	1.16	cyp	0.55	bel	0.72	tha	0.51
hkg	1.13	jpn	0.43	rou	0.71	mlt	0.51
vnm	1.11	bra	0.39	esp	0.71	can	0.41
fin	1.11	arg	0.39	hkg	0.7	mex	0.37
swe	1.1	usa	0.37	ita	0.7	khm	0.31

Table 14: GVC backward and forward indicators averaged over time and industries by country. OECD ICIO data.

ISIC Rev. 3	i2e	ISIC Rev. 3	e2r
c30t33	5.43	c10t14	3.34
c34t35	2.43	c50t52	2.44
c24	2.34	c71t74	1.89
c27t28	2.24	c60t63	1.74
c60t63	1.94	c27t28	1.67
c17t19	1.81	c30t33	1.65
c23	1.66	c24	1.3
c29	1.41	c65t67	1.01
c15t16	1.35	c01t05	0.8
c65t67	0.89	c21t22	0.52
c50t52	0.83	c34t35	0.49
c36t37	0.83	c23	0.47
c21t22	0.72	c29	0.44
c71t74	0.7	c64	0.37
c10t14	0.68	c25	0.37
c25	0.68	c17t19	0.37
c01t05	0.65	c20	0.23
c20	0.44	c15t16	0.22
c26	0.3	c26	0.2
c64	0.13	c36t37	0.13

Table 15: GVC backward and forward indicators averaged over time and countries by industry. OECD ICIO data.

Year	i2e	Year	e2r
1995	0.84	1995	0.62
2000	0.98	2000	0.73
2005	1.02	2005	0.79
2008	1.05	2008	0.79

Table 16: GVC backward and forward indicators averaged over industries and countries by time. OECD ICIO data.

IMF Classification			GDP per capita (GDPpc) Classification		
Developing	**Advanced**	**Developed**	**Loinc**	**Midinc**	**Hiinc**
arg	cyp	aus	arg	chl	aus
bgr	cze	aut	bgr	cze	aut
bra	est	bel	bra	est	bel
chl	hkg	brn	chn	hun	brn
chn	isr	can	idn	isr	can
hun	kor	che	ind	kor	che
idn	mlt	deu	khm	ltu	cyp
ind	sgp	dnk	mys	lva	deu
khm	svk	esp	phl	mex	dnk
ltu	svn	fin	rou	mlt	esp
lva	twn	fra	rus	pol	fin
mex		gbr	tha	prt	fra
mys		grc	vnm	sau	gbr
phl		irl	zaf	svk	grc
rou		isl		svn	hkg
rus		ita		tur	irl
sau		jpn		twn	isl
tha		lux			ita
tur		nld			jpn
vnm		nor			lux
zaf		nzl			nld
		pol			nor
		prt			nzl
		swe			sgp
		usa			swe
					usa
2,436	**1,276**	**2,900**	**1,624**	**1,972**	**3,016**
3,712		**4,176**	**3,596**		**4,988**

Table 17: Country Classification.
The IMF Classification splits countries into developing countries, recently advanced countries, and developed countries. The basis here is the IMF World Economic Outlook of April 2012. The GDPpc classification splits countries into three categories based on the average constant GDP per capita over the years 1995, 2000, 2005, and 2008. The cutoffs are USD 6,000 and USD 20,000. The GDP data is taken from the World Bank's WDI.

	(1)	(2)	(3)	(4)
			Lag	
VARIABLES			va	
i2e	0.0198**			
	(0.0085)			
w_i2e		0.0260***		
		(0.00594)		
e2r			0.0398**	
			(0.0199)	
w_e2r				0.0957***
				(0.0157)
GDP per capita	1.363***	1.558***	1.345***	1.501***
	(0.323)	(0.412)	(0.325)	(0.437)
GDP	-0.181	-0.432	-0.149	-0.370
	(0.341)	(0.461)	(0.345)	(0.488)
Trade openness	-0.0057***	-0.0053***	-0.0057***	-0.00533***
	(0.0007)	(0.0009)	(0.0007)	(0.0010)
i2cd	0.192***	0.193***	0.191***	0.198***
	(0.0348)	(0.0382)	(0.0348)	(0.0399)
RTA share	-0.263***	-0.267***	-0.278***	-0.331***
	(0.0813)	(0.0856)	(0.0820)	(0.0879)
Average trade costs	-0.0070***	-0.0075***	-0.0072***	-0.0070***
	(0.0015)	(0.0017)	(0.0015)	(0.0018)
Applied tariffs	7.77e-05	-0.0067	-0.0006	-0.0069
	(0.0038)	(0.0048)	(0.0038)	(0.0049)
Observations		2,625/2,091		
Controls		Regional dummies		
Fixed effects		Year, Industry-Country		
SE clustered (IC)		x		

Table 18: The effect of GVC participation on domestic value added including control coefficients. Industry-Country clustered standard errors in parentheses if indicated. *** p<0.01, ** p<0.05, * p<0.1. All level variables are in natural logarithms. All GVC participation measures are lagged. The number of observations refers to OECD ICIO/WIOD. The w prefix refers to WIOD data.