Department of Economics

DISCUSSION PAPER SERIES IN ECONOMICS

DP No.25

Determinants of Global Value Chain Participation: Cross-country Analysis

February 2020

Biswajit Banerjee
Juraj Zeman

https://www.ashoka.edu.in/ecodp

Plot No. 2, Rajiv Gandhi Education City,
National Capital Region
P.O.Rai,Sonepat Haryana-131029

Determinants of Global Value Chain Participation: Cross-country Analysis

Biswajit Banerjee[†] and Juraj Zeman[§]

Abstract

This paper examines the factors that influence the five most common measures of GVC participation for the sample of countries included in the World Input Output Database (WIOD). For this sample, backward linkage is stronger than forward linkage and is the main channel for integration into GVCs. Also, a stronger backward linkage is associated with a relatively more downstream position in GVCs. Country size and openness to inward FDI are important determinants of GVC indicators. Of all the industry groupings, the influence on all the GVC indicators is strongest for high-tech manufacturing. In both manufacturing and services, the higher is the share of the high-tech categories the greater is the backward linkage and GVC participation rate, and the GVC position is relatively more downstream. The real exchange rate is positively associated with the share of domestic value added in gross exports (VAX ratio), which is a manifestation of the exchange rate elasticity of value-added exports being smaller than the exchange rate elasticity of gross exports.

JEL code: F02, F14, F23

Key words: Global value chains, VAX ratio, Backward linkage, Forward linkage, GVC participation rate, GVC position index.

An initial version of the paper was presented at a seminar jointly organized by the OECD and Slovak Academy of Sciences in Bratislava in December 2018. The authors thank Peter Horvat, Gabriel Machlica, Nikhil Patel and the seminar participants for helpful comments. The views and results expressed in the paper are those of the authors and not necessarily of the institutions to which they are affiliated.

[†] Expert Advisor to the Governor, National Bank of Slovakia; Professor of Economics, Ashoka University, Sonepat, Haryana, India; Adjunct Senior Fellow, Research and Information System (RIS) for Developing Countries, New Delhi, India.
Corresponding author. E-mail: biswajit.banerjee@nbs.sk

[§] Senior Economist, National Bank of Slovakia. E-mail: juraj.zeman@nbs.sk

1 Introduction

The nature of international trade has undergone a marked transformation during the last few decades as a result of the growing prevalence of global value chains, GVCs (Baldwin, 2013; OECD, 2013). Different stages of production of a wide range of goods and services have become increasingly fragmented and dispersed across many countries. Under such production arrangements, components of products move through manufacturing centers with value being added at each stage. This phenomenon has been spearheaded by multinational corporations against the backdrop of a number of propitious factors that have enabled them to gain greater access to foreign markets, exploit the large productivity-adjusted wage differences between the home country and foreign countries, and overcome difficulties inherent in the long-distance coordination and monitoring of production processes. These factors include, inter alia, the liberalization of trade and capital flows by national governments, decrease in transport costs, and advances in production, information and communication technologies.

With the rise of global value chains, a growing proportion of trade in goods and services has been in intermediate goods. Consequently, conventional trade statistics do not portray accurately the contribution of gross exports to a country's value added and economic growth. In this setting, in order to obtain a proper assessment of the changes that are occurring in trade patterns and the growing interlinkages in the global economy, a major goal of researchers has been to go beyond the veil of gross trade flows and measure trade in value added and GVC participation directly (Johnson and Noguera, 2017).

The measurement of trade in value added and GVC participation requires the construction of an international input-output table by combining harmonized input-output and/or supply and use tables with estimates of balanced bilateral trade. The method of calculating trade in value added was first proposed by Hummels et al. (2001), and the accounting framework was further developed and improved by Johnson and Noguera (2012) and Koopman et al. (2010, 2014). This accounting framework facilitates the decomposition of gross exports into domestic valued added in exports, return domestic value added in import content of exports, and foreign value added in exports. On the basis of this decomposition, various concepts and metrics have been proposed for measuring trade in value added and GVC participation.

The most common indicators analyzed by researchers include the VAX ratio, a measure of the share of domestic value added in gross exports; the backward linkage index, a measure of the extent to which domestic firms use imported intermediate goods and services for exporting activity; the forward linkage index, a measure of the degree to which a given country's domestic value-added in gross exports are used by partner countries as inputs in their own exports; GVC participation rate, measured by the sum of the backward linkage index and forward linkage index; and GVC position index, measured by the ratio of the forward linkage index to the backward linkage index (see Banga, 2014).

The universal availability of several international input-output data sets developed under various data initiatives have generated considerable research on GVCs.[1] The empirical work has mainly focused on developing novel indicators to measure GVC participation, and investigating developments in these indicators for the world in the aggregate, for individual countries in the aggregate and across sectors, and for trade between bilateral partners. The methodology has encompassed documenting the trends and patterns, explaining cross-country variations by eyeballing graphical illustrations or using simple pair-wise correlation analysis with various country-specific characteristics, and estimating multivariate regressions. The econometric studies on the determinants of GVC indicators are still relatively few but increasing. As Kowalski et al. (2015) note, there is no common model-based methodology for exploring the determinants. Several studies have estimated regression equations based on the gravity model of trade (e.g., Baldwin and Taglioni, 2013; Choi, 2013; Ignatenko et al., 2019; and Johnson and Noguera, 2017). Kowalski et al. (2015) argue that the gravity model approach misses some of the key features of GVC trade and does not explain why countries engage in production networks on aggregate. Econometric studies on the determinants of GVC indicators at the aggregate country or sector level examine the role of country-specific structural and policy related factors (e.g., Kersan-Škabić, 2019; Kowalski et al., 2015; Stehrer and Stöllinger, 2015; and Vrh, 2018).

This paper adds to the small but growing number of econometric studies that have examined in a multivariate framework the determinants of GVC participation indicators at the aggregate country level. The study is based on a sample of 43 countries for the period 2000–2014 and utilizes the World Input Output Database (WIOD). The paper has three notable features. First, separate regression equations are estimated for the VAX ratio, backward and forward

[1] These data sets include the Trade in Value-Added Statistics (TiVA, covering 63 countries), World Input Output Database (WIOD, 43 countries), Eora Multi-Region Input Output (MRIO) database (189 countries).

linkages of GVC, GVC participation rate, and GVC position index. A simultaneous examination of the separate regressions for the GVC indicators sheds light on their interconnectedness. Second, export composition is classified into five groups representing low-tech manufacturing exports, medium- and high-tech manufacturing exports, low-tech services exports, medium- and high-tech service exports, and "other" exports. The results of the regression exercise confirm Banga's (2014) assertion that such a disaggregated classification of export composition is more informative in explaining cross-country variations in GVC participation than a simple two-way distinction between manufacturing and non-manufacturing exports. Third, the paper examines the impact of the real effective exchange rate (REER) on GVC participation indicators, an aspect that has not received much attention in the literature.[2] The regression exercise in this paper indicates that the REER is positively related to the VAX ratio, in effect implying that the exchange elasticity is smaller for value-added exports than for gross exports.[3]

The rest of the paper is organized as follows. Section 2 provides a selective overview of the literature. Section 3 describes the data and methodology. Section 4 presents the results of the econometric analysis, and Section 5 concludes.

2 Selective Literature Overview

The evolution of GVC participation at the global, regional, country and sector levels is well documented.[4] As countries have become more integrated into the international production processes, the VAX ratio has declined over time and the extent of backward linkage has risen. At the same time, forward linkage also has exhibited a rising trend.[5] Consequently, the GVC participation rate, measured as the sum of the backward and forward linkage indices, has increased substantially. The levels and the temporal changes in the GVC indicators vary widely across regions, countries, and sectors. An important aim of empirical studies has been

[2] However, see Caraballo and Jiang (2016). Several recent studies have noted that the impact of the conventional measure of REER on gross exports performance has weakened with the rise of GVC participation, and attention is being focused on constructing GVC-adjusted REER. (e.g., Ahmed et al., 2017; Bems and Johnson, 2015; European Central Bank, 2019; de Soyres et al., 2018; Patel et al., 2017; Powers and Riker, 2013; Uddin, 2017; and Varela and Lovo, 2016). It would seem that only Ahmed et al. (2017) have estimated the exchange rate elasticity of value-added exports, and they found it to be considerably lower than the exchange rate elasticity of gross exports.

[3] The impact of the REER on a GVC participation indicator expressed as a ratio to gross exports reflects the exchange rate elasticity of the value added component in the numerator relative to the exchange rate elasticity of gross exports.

[4] The literature is vast. Notable studies include Baldwin (2013), Banga (2014), European Central Bank (2017 and 2019), Hummels et al. (2001), Ignatenko et al. (2019), Johnson and Noguera (2012 and 2017), Kowalski et al. (2015), OECD (2013), Taglioni and Winkler (2016), World Bank (2017), and World Trade Organization (2019).

[5] The rising trend in both backward and forward linkages has reversed to a decreasing trend since 2015 on a global scale and the trend in global trade has flattened.

to identify the patterns in GVC participation and the factors influencing them. This section reviews the findings on some of the factors commonly considered in the literature. The empirical findings are mixed. The results are sensitive to methodology, country composition of the sample and time coverage.

GDP/Per capita GDP. There is considerable descriptive and econometric evidence that indicate that larger or more developed countries (proxied by GDP and per capita GDP, respectively) tend to have a higher ratio of value-added exports to gross exports and, correspondingly its flip side, a smaller share of foreign value added in gross exports (i.e., lower backward linkage).[6] However, a notable contrary result is the finding of Johnson and Noguera (2011 and 2012), based on simple correlation analysis, that aggregate VAX ratios for the 94 countries in their sample in 2004 did not co-vary strongly with GDP per capita.[7] Higher VAX ratio and lower backward linkage for larger countries are generally explained in terms of these countries having greater scope for sourcing intermediate inputs domestically (De Backer and Miroudot, 2014; Kowalski et al., 2015; Lopez-Gonzalez, 2012).

The findings on the relationship between forward linkage and country size or per capita GDP are mixed. A European Central Bank (2019) study notes that larger economies in the euro area are located more upstream than the smaller economies, reflecting the presence of production chains in which intermediate goods and services are produced by the larger economies and exported to smaller countries in the region for assembling processes. However, van der Marel (2015) did not find a significant relationship between GDP per capita and a country's location within the supply chain for his sample of 58 countries based on data for 2009/2010: the pair-wise correlation between GDP per capita and the distance from final demand in the production chain (a measure of "upstreamness") was not statistically significant. Our calculations based on estimates of forward linkage for a sample of 39 countries presented in Lopez-Gonzalez (2012) indicate that the bivariate relationship between forward linkage and real per capita GDP_PPP had changed between 1995 and 2005. In 1995, the relationship was best portrayed by a cubic function, composed of an initial inverted U-shape at lower levels of development and followed by a U-shaped relationship at higher levels. However, in 2005 there was no significant relationship between the two variables. Based on the OECD's TiVA data base for 57 countries covering the period

[6] See, for example, European Central Bank (2019), Foster-McGregor and Stehrer (2013), Hummels et al. (2001), Ignatenko et al. (2019), Kowalski et al. (2015), Stehrer and Stöllinger (2015), Taglioni and Winkler (2016) and Vrh (2018).
[7] Johnson and Noguera (2012) do not report on whether the finding was similar for other years.

1995–2009, Kowalski et al. (2015) obtained a positive significant coefficient on real GDP in the multivariate regression equation for forward linkage.

Many studies report a positive relationship between the GVC participation rate and per capita GDP. van der Marel (2015) found that in his sample of 58 countries in 2009/2010 richer countries tended to participate in GVCs at an increasing rate. Our calculations based on estimates of GVC participation rate provided by Lopez-Gonzalez (2012) indicate an inverted U-shaped bivariate relationship in both 1995 and 2005: GVC participation rate initially increased with per capita GDP and then decreased beyond a certain threshold. Using data from the EORA database for 189 countries covering the period 1990–2013, Ignatenko et al. (2019) obtained a significant positive relationship between the GVC participation rate and per capita GDP. However, they point out that this result could not be replicated if the sample was restricted to 50 countries that are typically included in other databases of value-added. In their study on euro area countries covering the period 2000–2014, European Central Bank (2019) also found the GVC participation rate to be higher for countries with higher per capita GDP, after controlling for the influence of institutional factors. Based on manufacturing sector data for 40 countries covering the period 1995–2011, Stehrer and Stöllinger (2015) obtained a significant positive relationship between the GVC participation rate and a variable measuring a country's GDP relative to that of Germany. In contrast, Kersan-Škabić (2019) observed that the influence of per capita GDP on the GVC participation rate was significant and positive for the EU-28 and EU-15 countries but not significant for EU-NMS. Also, perusing the graphical illustration of the GVC participation rate for 61 countries in 2011, Criscoulo et al. (2015) and Taglioni and Winkler (2016) concluded that participation was higher for the smaller economies.

Composition of exports. Cross-country variation in GVC indicators is to a large extent driven by variations in the composition of exports. Johnson and Noguera (2011, 2012) noted that in their sample the aggregate VAX ratio was lower for countries that had a higher share of manufacturing in total exports. They explained this phenomenon in terms manufacturing exports being characterized by a higher degree of vertical specialization (i.e., having a higher import content) than non-manufacturing exports. This feature of manufacturing exports also explains the finding of Kowalski et al. (2015) that the higher is the share of manufacturing sector in GDP, the greater is the extent of backward linkage and the lower is the degree of forward linkage.

Researchers have also documented that technological characteristics of industries and the share of services and natural resources in total exports are likely to influence participation in GVCs. Banga (2014) observed that the VAX ratio was higher and the backward linkage was lower for low-tech industries compared with medium and high-tech industries, reflecting lower fragmentation of production processes in low-tech industries. Supporting evidence is provided by estimates of VAX ratios in various technology-intensity groups in manufacturing calculated by Olczyk and Kordalska (2017) for nine central and east European countries over the period 1995–2011. As for the relationship between the overall GVC participation rate and the share of high-tech manufacturing products in total exports, Kersan-Škabić (2019) obtained contrasting results for different country groups in the European Union: the relationship was negative for the old member states (EU-15), positive for the new member states (EU-NMS) and not statistically significant for EU-28. Kersan-Škabić does not offer any explanation for the contrasting results, but it could be a reflection of EU countries being more integrated in regional than in global supply chains.

Services participate differently in GVCs than manufacturing. Since services are less prone to vertical specialization, their forward linkage is stronger than backward linkage in most countries (De Backer and Miroudot, 2013; Ignatenko et al., 2019; Taglioni and Winkler, 2016). The composition of services forward linkage vary considerably. Ignatenko et al. (2019) document that business and financial services, wholesale and retail trade, and post and telecommunication have very high forward linkages, reflecting limited used of foreign inputs in their production. Moreover, the GVC participation rate of these service activities are higher than that of manufacturing. In an econometric study on EU countries, Kersan-Škabić (2019) found that the share of services in total exports had a positive significant impact on the overall GVC participation rate in the EU-15, but a negative significant impact in the EU-NMS, suggesting that the composition of services exports in the EU-15 and EU-NMS was different.

Some studies have observed that resource-intensive countries tend to have higher VAX ratios, lower backward linkage, and higher forward linkage and GVC participation rate (European Central Bank, 2019; Foster-McGregor and Stehrer, 2013; Ignatenko et al., 2019; Taglioni and Winkler, 2016; and World Trade Organization, 2019).

Labour skill composition. Several studies have noted that the expansion of GVCs has been associated with increased demand for skilled labour. The shift away from unskilled workers towards skilled workers reflects the increased organizational and operational complexity of

supply chains and increased use of skill-intensive services inputs. Analysis of 2008 data for a sample of high- and middle-income countries from the TiVA database by Taglioni and Winkler (2016) indicate a positive correlation between share of workers with tertiary education and GVC participation from the buyer's perspective (backward linkage). In their multiple regression exercise based on data for 120 countries covering the period 2001–2014, Farole et al. (2018) found a positive and significant relationship between backward linkage and the relative demand for skilled labour (measured as wages paid to produce exports to skilled versus unskilled labour). A panel fixed effect analysis by the European Central Bank (2019), based on annual data for 35 industries in 40 countries covering the period 1995–2009, also shows that share of high-skilled labour (measured by share of high-skilled hours worked in total hours) is positively associated with backward GVC participation. In contrast, Stehrer and Stöllinger (2015) report that for manufacturing exports of 26 EU Member States during the period 1995–2011 the share of high-skilled labour had no significant impact on backward linkage, but the share of medium-skilled labour had a negative and significant impact.

Vrh (2018) obtained a negative and significant relationship between skill intensity (measured as a share of hours worked by high-skilled workers in total hours worked) and the VAX ratio in the manufacturing sector of the EU-15 and EU-NMS over the period 2000–2011. She considered this result surprising, but it is consistent with findings reported in the previous paragraph of a positive relationship between skill intensity and backward linkage.

The findings on the relationship between skill intensity and GVC forward linkage are mixed. Taglioni and Winkler (2016) note that for their sample of high- and middle-income countries in 2008 the share of workers with tertiary education was positively correlated with GVC participation from the seller's perspective. However, in their panel-cross section regression exercise, Farole et al. (2018) found a positive and significant correlation between GVC participation as a seller and the relative demand for skilled labour only for high-income countries, but no significant relationship for the other income groups and the overall sample. In the European Central Bank (2019) study, there was no significant relationship between GVC forward linkage and the share of high-skilled hours worked in total hours.

European Central Bank (2019) for euro area countries and Ignatenko et al. (2019) for a sample of 189 countries obtained a positive and significant relationship between the GVC participation rate and a measure of the educational attainment of the labour force. However, Stehrer and Stöllinger (2015) found that the share of high-skilled workers in the labour force

was negatively associated with the GVC participation rate in the manufacturing sector in EU countries.

Capital intensity. Discussions of the influence of capital intensity on GVC indicators are scant. van der Marel (2015) found a positive relationship between capital intensity and forward linkage: the pair-wise correlation between physical capital endowment relative to GDP and distance from final demand in the supply chain was positive and significant. However, physical capital endowment was not significantly related to the overall GVC participation rate. In his multivariate regression exercise, Ramondo (2016) found a positive and significant relationship between the capital-labour ratio and VAX ratio in the manufacturing sector. However, the results obtained by Landesmann et al. (2015) and Olczyk and Kordalska (2017) suggest no significant relationship between physical capital endowment and the VAX ratio. Landesmann et al. (2015) failed to find any significant relationship between an industry's export performance and its capital coefficient (measured as ratio of capital to gross output) in the European Union. Olczyk and Kordalska (2017) observed a negative and significant impact of capital coefficient on both gross exports and value-added exports of the manufacturing sector in central and east European countries, but the strength of the impact was very similar for both export measures.

Foreign direct investment. The type and extent of GVC participation is shaped by the nature of foreign direct investment. Thus, FDI driven by the resource-seeking motive is expected to be associated with higher VAX ratio and forward linkage. In contrast, vertical efficiency-seeking FDI directed towards export-processing entails considerable imports of intermediate inputs and can be expected to be positively correlated with backward linkage. If the distance from final demand in the production chain is large, there should also be high positive correlation between FDI and forward linkage.

In their regression exercises, Kowalski et al. (2015) and Stehrer and Stöllinger (2015) found a positive and significant relationship between backward linkage and inward FDI stock (as ratio to GDP). Consistent with this finding, Vrh (2018) obtained a negative and significant relationship between inward FDI stock and the VAX ratio in her sample of EU member states. Kowalski et al. (2015) found no significant impact of inward FDI stock on forward linkage, suggesting that FDI in their sample of countries was more associated with exports that were absorbed in the destination country rather than with exports for further processing in the destination country and then re-exported to third markets.

Kersan-Škabić (2019) found that the relationship between inward FDI stock (as ratio to GDP) and the GVC participation rate was negative and significant in EU-15 countries but positive and significant in EU-New Member States. Stehrer and Stöllinger (2015) report a positive association between inward FDI stock and the GVC participation rate of the manufacturing sector in EU member states. However, a European Central Bank (2019) study found that, in the euro area, the stock of FDI in a sector had no significance as an explanatory variable for the GVC participation rate of the sector.

Real exchange rate. The impact of exchange rates on trade has decreased with the rise of GVCs (Ahmed et al., 2017; de Soyres et al., 2018; and Varela and Lovo, 2016). The effect of change in REER on export performance is weaker the greater is the import content of exports. Varela and Lovo (2016) report that when the share of imported intermediates of Polish firms in gross exports was greater than 30 percent, the effect of REER on export participation faded.[8] Ahmed et al. (2017) note that the responsiveness of exports to changes in the REER was lower for countries that were more tightly integrated in German supply chains than for countries that were more loosely integrated. In addition, using a panel framework covering 46 countries over the period 1996–2012, Ahmed et al. (2017) found that the responsiveness of domestic value-added exports to changes in REER was lower compared to responsiveness of gross exports, and attributed this outcome to possible complementarities between foreign and domestic value added. This finding would mechanically imply a positive relationship between REER and the VAX ratio. Indeed, Caraballo and Jiang (2016) found a positive and significant relationship between REER and the VAX ratio for a sample of 39 countries from the WIOD data base covering the period 1995–2009. They explained the association of currency appreciation with a higher VAX ratio as a reflection of lower relative prices of foreign intermediates translating more into a domestic-foreign substitution of intermediates than into a substitution of high value-adding activities.

Institutional quality. Kowalski et al. (2015) and the 2017 Global Value Chains Report (World Bank, 2017) note that with the rising complexity of international transactions the role of institutions has become increasingly important for deepening GVC participation. Ignatenko et al. (2019) report that better contract enforcement and the rule of law facilitate both backward and forward linkages. Analysis by Taglioni and Winkler (2016) suggests that better contract enforcement may be more important for emerging market countries. In their regression exercise for the WIOD country sample, the contract enforcement variable did not have a

[8] See Albinowski et al. (2016) for the detailed study.

significant impact on GVC integration either as a buyer or seller. However, contract enforcement had a significant positive impact for the OECD country sample.

van der Marel (2015) detected a positive and significant pair-wise correlation between rule of law and the overall GVC participation rate. A European Central Bank (2019) study found that political stability boosts overall GVC participation. Dollar et al. (2016) obtained a positive correlation between the overall GVC participation rate at the industry level and all measures of institutional quality. They also found that higher technology industries were more sensitive to institutional quality and had higher participation in complex GVCs in countries that had better institutions.

3 Data and methodology

The main objective of this paper is to estimate the determinants of different indicators of GVC participation. In particular, the indicators of interest include the VAX ratio, backward linkage index, forward linkage index, GVC participation rate, and GVC position index. A set of these indicators is constructed from the 2016 release of the World Input-Output Database (see Timmer et al., 2015), applying the accounting framework developed by Koopman et al. (2010, 2014). The WIOD data base contains annual world input-output tables on 56 industries in 43 countries plus the rest of the world covering the period 2000–2014 (see Appendix table for country list).

Separate regression equations are estimated for each of the GVC participation indicators with the same set of explanatory variables. We first tested for the appropriateness of the pooled OLS approach for estimating the equations. This approach was rejected on the basis of data observation as well as the Lagrange multiplier test that indicated that a fixed effect model was more appropriate. Regressions estimated with both within- and between-country variable transformations show that between-country differences have a bigger impact on the dependent variables than within-country differences. Hence, all the regressions are estimated at the country level with time fixed effects. The Hausman test confirms that a model specification with time fixed effect is more appropriate than a random effects model. Time fixed effect specification resolves the problem of omitted variables that vary over time but are constant across countries, and allows us to test between-country differences in the influence of the explanatory variables. The exclusion of country fixed effects from the specification is justified by our goal to explain cross-sectional differences across countries, rather than uncovering causal relationships between dependent and independent variables. In all the regressions, a robust standard error estimator for panel models has been used (see Millo,

2017). This estimator is robust against both cross-sectional heteroscedasticity and serial correlation.

The regression equations take the following form:

$$\begin{aligned}\log(GVCPI_{it}) = {} & \beta_1 \log(GDP\_PPP_{it-1}) + \beta_2\, shareX\_mfgLT_{it} + \beta_3\, shareX\_mfgMHT_{it} \\ & + \beta_4\, shareX\_servLT_{it} + \beta_5\, shareX\_servMHT_{it} + \beta_6 \log(TertiaryED_{it}) \\ & + \beta_7 \log(CapCoef_{it}) + \beta_8 \log(FDI\_stock_{it-1}) + \beta_9 \log(REER_{it}) \\ & + \beta_{10}\, CorControl_{it} + \mu_t + \varepsilon_{it}\end{aligned}$$

where $GVCPI_{it}$ is the GVC participation indicator of interest relating to country i at time t; μ_t denotes time fixed effect; and ε_{it} is the error term. GDP_PPP_{it-1} refers to gross domestic product in constant 2011 international dollars lagged by one period and is a measure of the size of economy. The *shareX_* variables indicate a country's export composition and are defined as sectoral share in total exports, and *mfgLT, mfgMHT, servLT*, and *servMHT* refer to low-tech manufacturing, medium- and high-tech manufacturing, low-tech services and medium- and high-tech services, respectively. *TertiaryED* is a proxy for labour skill and is measured as the share of workers with tertiary education; *CapCoef* represents the physical capital endowment of a country and is defined as the ratio of capital stock to gross output; FDI_stock_{t-1} denotes the stock of inward foreign direct investment as percentage of GDP lagged by one period; *REER* refers to CPI-based real effective exchange rate; and *CorControl* stands for the control of corruption estimate and is a proxy for governance.[9] Definitions of the dependent and explanatory variables and the sources of data are presented in Table 1. The descriptive statistics and correlation matrix are shown in Table 2 and Table 3, respectively.

[9] Our measure of education as a proxy for labour skill is in line with Taglioni and Winkler (2016). Unlike Stehrer and Stöllinger (2015) and Vrh (2018), we do not measure labour skill by the share of hours worked by workers in particular skill groups in total hours worked because the relevant data is not available in the second release of the WIOD data base. One of the referees has noted that tertiary education may not be a good measure of actual skills of workers since education quality is very heterogeneous across countries. He suggests that measures of cognitive and non-cognitive skills based on the PIAAC (Program for International Assessment of Adult Competencies) proficiency levels for literacy may be more appropriate. Unfortunately, PIAAC data is not available for the entire sample period. The OECD only provides international data from the three rounds of PIAAC data collection that took place in 2012, 2015 and 2017 (see https://nces.ed.gov/surveys/piaac/datafiles.asp).
We exclude the lagged dependent variable from the specification since our focus is on explaining the cross-section pattern rather than time series dynamics of GVC indicators. We also do not include a measure of trade barriers as an explanatory variable because of lack of data for the entire sample period for all the countries in the sample.

Table 1 Definition of dependent and explanatory variables entered in the regression equations

Variable	Definition	Source	URL
VAX ratio	Ratio of domestic value-added in gross exports to total gross exports	WIOD, own calculations	http://www.wiod.org/database/wiots16
Backward linkage index (BL)	Ratio of foreign value added content of exports to the economy's total gross exports	WIOD, own calculations	http://www.wiod.org/database/wiots16
Forward linkage index (FL)	Ratio of domestic value added exported to third countries to the economy's total gross exports.	WIOD, own calculations	http://www.wiod.org/database/wiots16
GVC participation rate (BL+FL)	This indicator combines both backward linkage and forward linkage.	WIOD, own calculations	http://www.wiod.org/database/wiots16
GVC position index (FL/BL)	Measured as the ratio of FL to BL, this is a measure of the relative downstream of upstream position of a country.	WIOD, own calculations	http://www.wiod.org/database/wiots16
GDP_PPP	GDP at purchasing power parity measured in constant 2011 international dollars.	WDI	https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.KD
shareX_mfgLT	Share of of low-tech manufacturing exports in total exports. Low-tech manufacturing comprises NACE Rev. 2 codes C10-C18, C22-C25, and C31-C33.[10]	Socio Economic Accounts (SEA), own calculations	http://www.wiod.org/database/seas16
shareX_mfgHT	Share of medium- and high-tech manufacturing exports in total exports. Medium- and high-tech manufacturing comprises NACE codes C19-C21 and C26-C30.[10]	SEA, own calculations	http://www.wiod.org/database/seas16
shareX_servLT	Share of low-tech services exports in total exports. Low-tech services comprise NACE codes G45-G47 and H49-H53.[10]	SEA, own calculations	http://www.wiod.org/database/seas16
shareX_servHT	Share of of medium- and high-tech services exports in total exports. Medium- and high-tech services exports comprise NACE codes I, J58-J63, K64-K66, and M69-M75.[10]	SEA, own calculations	http://www.wiod.org/database/seas16
TertiaryED	Share of workers with tertiary education	EconMap_2.4	http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=11
CapCoef	Ratio of capital stock to gross output	SEA, own calculations	http://www.wiod.org/database/seas16
FDI stock /GDP	Stock of inward foreign direct investment as percentage of GDP	UNCTADstat	https://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx
REER	Annual average CPI-based real effective exchange rate index; 2010 = 100 (increase represents appreciation)	BIS	https://www.bis.org/statistics/eer.htm?m=6%7C381%7C676
CorControl	Control of Corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. Estimate gives the country's score on the aggregate indicator, in units of a standard normal distribution, i.e. ranging from approximately -2.5 to 2.5	World Bank	http://info.worldbank.org/governance/wgi/

[10] See Ignatenko (2019), Annex Table 1; Olczyk and Kordalska (2017), fn 6; and OECD (2011).

Table 2 Descriptive statistics for dependent and explanatory variables

Variable	Units	Mean	Standard deviation
VAX ratio	ratio	0,70	0,12
Backward linkage (BL)	ratio	0,29	0,12
Forward linkage (FL)	ratio	0,09	0,02
GVC participation rate (FL+BL)	ratio	0,37	0,11
GVC position index (FL/BL)	ratio	0,39	0,33
GDP_PPP	$	1,55E+12	2,84E+12
shareX_mfgLT	ratio	0,26	0,10
shareX_mfgHT	ratio	0,33	0,16
shareX_servLT	ratio	0,17	0,12
shareX_servHT	ratio	0,14	0,15
TertiaryED	ratio	0,21	0,12
CapCoef	ratio	1,53	0,33
FDI stock/GDP	%	73,78	194,96
REER	index, 2010=100	96,87	10,86
CorControl		0,90	0,95

Table 3 Correlation matrix for dependent and explanatory variables

Variable	VAX ratio	Backward linkage (BL)	Forward linkage (FL)	GVC participation rate (FL+BL)	GVC position index (FL/BL)	GDP_PPP	shareX_ mfgLT	shareX_ mfgHT	shareX_ servLT	shareX_ servHT	Tertiary ED	CapCoef	FDI stock/ GDP	REER	CorControl
AX ratio	1														
Backward linkage (BL)	-0,99	1													
Forward linkage (FL)	0,57	-0,54	1												
GVC participation rate (FL+BL)	-0,98	0,99	-0,41	1											
GVC position index (FL/BL)	0,68	-0,68	0,69	-0,61	1										
GDP_PPP	0,37	-0,45	-0,05	-0,5	0,29	1									
shareX_mfgLT	0,15	-0,12	0,1	-0,11	-0,14	-0,1	1								
shareX_mfgHT	-0,07	0,04	-0,09	0,02	-0,21	0,25	0,06	1							
shareX_servLT	0,14	-0,12	0,15	-0,11	0,17	-0,11	-0,33	-0,49	1						
shareX_servHT	-0,5	0,49	-0,42	0,45	-0,26	-0,07	-0,47	-0,4	-0,03	1					
TertiaryED	0,2	-0,24	0,18	-0,23	0,43	0,28	-0,49	0,05	0,2	-0,05	1				
CapCoef	0,06	-0,06	0,28	-0,02	0,03	-0,08	-0,01	0,29	0,06	-0,39	0,02	1			
FDI stock/GDP	-0,47	0,47	-0,3	0,45	-0,18	-0,14	-0,34	-0,29	0,04	0,65	-0,06	-0,18	1		
REER	-0,1	0,06	-0,1	0,05	-0,09	0,16	-0,34	0,25	-0,06	0,16	0,18	-0,12	0,06	1	
CorControl	-0,18	0,15	-0,13	0,14	-0,24	-0,12	-0,33	0,05	-0,07	0,31	0,35	0,03	0,08	0,31	1

4 Empirical results

The regression results displayed in Table 4 show an interesting interconnection between the results for the different GVC participation indicators. Since backward linkage is the flip side of the VAX ratio, the direction of influence of the various explanatory variables on backward linkage is opposite to that on the VAX ratio. However, we also find that the variables that had a significant influence on backward linkage in a particular direction had a significant impact in the same direction on the GVC participation rate and in the opposite direction on the GVC position index. This indicates that, for the sample of countries considered in the analysis, higher backward linkage is the path to greater GVC participation and involves a relatively more downstream position in GVCs. Also notable, the explanatory power of the equation for forward linkage is much lower than that for the other GVC participation indicators[11] and only the coefficient on high-tech manufacturing is statistically significant. This suggests that the supply side of value chains that forward linkage represents has more diverse determinants beyond those included in the regression exercise.

The evidence indicates that the larger is the size of the economy the higher is the share of domestic value added in gross exports (VAX ratio) and the lower is the foreign value added content in exports (backward linkage). Despite a strong positive bivariate correlation between the VAX ratio and forward linkage, there is no evidence of a significant association between the size of the economy and forward linkage, after controlling for the influence of other variables. This suggests that even small countries that typically source inputs from abroad have become increasingly involved in forward linkages. This can happen if fragmentation of production processes has increased and supply chains have become longer. However, larger economies are associated with a more upstream position in GVCs, as indicated by the significant positive coefficient on GDP_PPP in the equation for GVC position index. The regression results also indicate that smaller economies are more integrated in GVCs than larger economies: the relationship between GVC participation rate and the size of the economy is negative and significant. These results for the GVC positioning and GVC participation rate are in sharp contrast to the findings of the European Central Bank (2019) for the euro area that richer economies have higher GVC participation rate and are associated with more downstream positioning.

[11] Kowalski et al. (2015) also had a similar finding.

Table 4 Determinants of GVC Participation Indicators

	VAX ratio	Backward linkage (BL)	Forward linkage (FL)	GVC participation rate (FL+BL)	GVC position index (FL/BL)
log(lag(GDP_PPP))	0,06651***	-0,18848***	0,01007	-0,13644***	0,19855***
	(0.00829)	(0.02231)	(0.01673)	(0.01546)	(0.03053)
shareX_mfgLT	-0,01385	0,90298**	0,07574	0,26868	-0,82724
	(0.14604)	(0.37198)	(0.58098)	(0.20758)	(0.86666)
shareX_mfgHT	-0,67341***	2,13199***	-0,71675***	1,17152***	-2,84874***
	(0.07588)	(0.19337)	(0.22797)	(0.10126)	(0.37170)
shareX_servLT	0,06242	0,64219*	-0,15773	0,11193	-0,79992
	(0.18657)	(0.34446)	(0.40645)	(0.22649)	(0.68089)
shareX_servHT	-0,58260***	0,92001***	-0,70725	0,41703**	-1,62727**
	(0.12718)	(0.32118)	(0.54228)	(0.19431)	(0.77009)
log(TertiaryED)	0,00162	-0,10837	0,04442	-0,02396	0,15279
	(0.03103)	(0.07160)	(0.06814)	(0.04504)	(0.12668)
log (CapCoef)	0,09064*	-0,27104***	0,33117	-0,13771*	0,60220**
	(0.04981)	(0.10297)	(0.24596)	(0.07988)	(0.30430)
log(lag(FDI stock/GDP))	-0,04330**	0,09635**	-0,05377	0,06610**	-0,15013*
	(0.01936)	(0.04816)	(0.04578)	(0.02805)	(0.08314)
log(REER)	0,18059**	-0,32602	0,10543	-0,23784**	0,43145
	(0.08146)	(0.20156)	(0.29590)	(0.11416)	(0.44808)
CorControl	0,01962	0,05007	0,01077	-0,00095	-0,03930
	(0.02139)	(0.04966)	(0.06304)	(0.02763)	(0.10611)
R-Squared	0,78972	0,82538	0,35600	0,83371	0,68858
Adj. R-Squared	0,78105	0,81818	0,32946	0,82686	0,67574
F-statistics	209,556***	263,749***	30,8465***	279,764***	123,38***
N	582	582	582	582	582

Note: Robust standard errors in parentheses. *** significant at the 1 percent level; ** siginificant at the 5 percent level; * significant at the 10 percent level

Participation in GVCs varies by industry groups and their technological classification. In the regression equations, the size, sign and the statistical significance of the coefficient on a particular industry group show how the impact differs vis-a-vis the base reference industry category (viz., agriculture and natural resources). For example, in the estimated equation for backward linkage, the coefficients on all the industry groups included in the equation are positive and significant, implying that their foreign value added content is significantly higher than that for agriculture and natural resources, A comparison of the coefficients on different industry groups indicate their differential impact on GVC participation.

The VAX ratio and forward linkage are lower and the backward linkage is higher for high-tech manufacturing exports compared to exports of other industry groups. This is indicative of high-tech manufacturing exports having a higher degree of vertical specialization and a more downstream position in the supply chain. Consistent with this pattern, the GVC position index

is significantly negatively correlated with the share of high-tech manufacturing exports. Nevertheless, the integration in GVCs is greater for high-tech manufacturing exports than for other categories of exports: the coefficient on high-tech manufacturing exports in the equation for the GVC participation rate is positive and significant and its size is considerably higher than the coefficients on the other export categories.

Except for forward linkage, the pattern of the relationship between high-tech services exports and the various GVC participation indicators is similar to that for high-tech manufacturing exports, but the correlations are weaker. High-tech services value-added exports have significant foreign value added content (backward linkage), almost similar to low-tech manufacturing,[12] and are positively correlated with the GVC participating rate. But, as the insignificant association with forward linkage and the negative significant relationship with the GVC position index indicate, high-tech services exports tend to have a relatively more downstream profile.

The impact of low-tech manufacturing exports and low-tech services exports on the various GVC participation indicators are qualitatively similar. Both these categories of exports have significant positive backward linkage, but the import intensity is higher for low-tech manufacturing exports. The relationship of both categories of exports with the other GVC indicators is not statistically significant.

The larger is the physical capital endowment of a country relative to output the higher is the VAX ratio and smaller is the backward linkage. This suggests that relatively capital abundant countries have greater scope for sourcing intermediate inputs domestically. Consistent with this pattern, there is a significant negative relationship between the GVC participation rate and physical capital endowment. Although the association between physical capital abundance and forward linkage is not statistically significant, the regression results indicate that physical capital abundance is associated with an upstream GVC position.

Higher stocks of inward FDI are associated with lower VAX ratios and higher backward linkage and higher GVC participation rate. At the same time, inward FDI is not statistically significant in explaining forward linkage and is significantly associated with a more downstream position in GVCs. The results suggest that in the sample of countries covered in

[12] The null hypothesis that the coefficients on high-tech services and low-tech manufacturing were equal in the equation for backward linkage could not be rejected even at the 10 percent level of significance.

the analysis, inward FDI is mainly driven by the efficiency-seeking motive with the objective of processing imported intermediate inputs for exports to final destinations.[13]

The real exchange rate (REER) has a significant positive association with the VAX ratio, in line with the finding of Caraballo and Jiang (2016). As explained earlier in the discussion of the literature review, this finding is a manifestation of the exchange rate elasticity of export value added being smaller than the exchange rate elasticity of gross exports. REER also has a significant negative association with the overall GVC participation rate, suggesting that an appreciated real exchange rate hinders integration into GVCs.

In contrast to the findings of many earlier studies, the regression results do not show a significant role for the proxy variables for labour skill and institutional quality in explaining variations in any of the GVC participation indicators. In the equations for all the GVC participation indicators the coefficients on the share of workers with tertiary education and control of corruption estimate are not statistically significant. The inclusion of alternative proxy measures for labour skill and institutional quality do not make any difference to the results. The equations were also estimated with education measured as average years of schooling and institutional quality represented by the World Bank's government effectiveness index, but the coefficients on these alternative proxy measures also turned out to be statistically insignificant in all the equations.[14] Our finding on the lack of influence of institutional quality is in line with that obtained by Taglioni and Winkler (2016).

5 Conclusions

A number of different indicators have been proposed by researchers to measure participation of a country in GVCs and these shed light on the phenomenon from different perspectives. The most common of these indicators include the VAX ratio, backward linkage index, forward linkage index, overall GVC participation rate, and GVC position index. The GVC participation indicators are heterogenous across countries. Using one-way time fixed-effect regression analysis, this paper examines the factors that influence the various measures of GVC participation for the sample of countries included in the WIOD database. The explanatory

[13] At the suggestion of one of the referees, we estimated the regression equation for forward linkage with stock of outward FDI as an explanatory variable instead of stock of inward FDI. The results show no statistically significant relationship between forward linkage and outward FDI. The coefficient on stock of outward FDI is also not statistically significant when both inward FDI and outward FDI are included as explanatory variables.
[14] The statistically insignificant coefficient on the various measures of education suggests that formal education may not be a good proxy for labour skills as educational quality is heterogeneous across countries.

variables in the regression equations include country-specific characteristics and policy-related factors similar to those that have been highlighted in the GVC literature.

A simultaneous examination of the separate regression equations for the five GVC participation sheds light on their interconnectedness. For the sample of countries included in the analysis, backward linkage is stronger than forward linkage and is the main channel for integration into GVCs. Also, a stronger backward linkage is associated with a relatively more downstream position in GVCs.

The evidence indicates that country size and openness to inward foreign direct investment are important determinants of GVC participation indicators. Smaller countries have lower VAX ratio, stronger backward linkage, are more integrated into GVCs, and have relatively more downstream position. Inward FDI is a significant driving force for greater integration into GVCs. For the sample of countries included in this study, inward FDI is mainly related to imports of foreign intermediates for export processing and a more downstream position in GVCs.

The regression results confirm that a disaggregated classification of export composition is more informative in explaining cross-country variations in GVC participation than a simple two-way distinction between manufacturing and non-manufacturing exports. Of all the industry groupings, the influence on all the GVC indicators is strongest for high-tech manufacturing. Both high-tech and low-tech manufacturing and services exports have significant imported value added content. However, in both manufacturing and services, the higher is the share of the high-tech group the greater is the backward linkage and GVC participation rate but the GVC position is relatively more downstream.

A notable finding is the significant positive relationship between the real exchange rate and VAX ratio. This is essentially a manifestation of the exchange rate elasticity of export value added being smaller than the exchange rate elasticity of gross exports. The regression results also indicate that a more appreciated real exchange rate hinders integration into GVCs.

Relatively capital abundant countries are less integrated into GVCs and tend to have lower backward linkage. Surprisingly, although human capital and quality of institutions are highlighted in the literature as important factors that enable integration into GVCs, these two variables are not found to have a significant influence on any of the GVC participation indicators.

References

Ahmed, S., Appendino, M. and Ruta, M. 2017. Global value chains and the exchange rate elasticity of exports, *The B.E. Journal of Macroeconomics* 17(1): 1-24. https://doi.org/10.1515/bejm-2015-0130

Albinowski, M., Hagemejer, J., Lovo, S. and Varela, G. 2016. The Role of Exchange Rate and Non-Exchange Rate Related Factors in Polish Firms' Export Performance. Policy Research Working Paper;No. 7899. World Bank, Washington, DC. https://openknowledge.worldbank.org/bitstream/handle/10986/25702/WPS7899.pdf?sequence=1&isAllowed=y

Baldwin, R. 2013., Global supply chains: why they emerged, why they matter, and where they are going. In Elms, D. and Low, P. (eds.), *Global value chains in a changing world*, WTO Secretariat, pp. 13-59.

Baldwin, R. E. and Taglioni, D. 2013. Gravity chains: estimating bilateral trade flows when trade in components and parts is important. In Mattoo, A., Wang, Z. and Wei, S-J. (eds), *Trade in value added: developing new measures of cross-border trade*. World Bank, Washington, DC, pp. 161–186.

Banga, R. 2014. Linking into global value chains is not sufficient: Do you export domestic value added contents? *Journal of Economic Integration* 29 (2): 267-297.

Bems, R. and Johnson, R. C. 2015. Demand for value added and value-added exchange rates. IMF Working Paper WP/15/199. https://www.imf.org/external/pubs/ft/wp/2015/wp15199.pdf

Caraballo, J. G. and Jiang, X. 2016. Value-Added Erosion in Global Value Chains: An Empirical Assessment. *Journal of Economic Issues* L (1): 288–296. DOI 10.1080/00213624.2016.1148991

Choi, N. 2013. Measurement and determinants of trade in value added. KIEP Working Paper 13-01, Korea Institute for International Economic Policy, Seoul, Korea. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2317706

Criscuolo, C., Timmis, J. and Johnstone, N. 2015. The relationship between GVCs and productivity. Background Paper of the Global Forum on Productivity, OECD. https://www.oecd.org/global-forum-productivity/events/Relashionship_btween_GVCs_and_productivity_6_09_2016.pdf

De Backer, K. and Miroudot, S. 2013. Mapping global value chains. OECD Trade Policy Papers No. 159. https://www.oecd-ilibrary.org/docserver/5k3v1trgnbr4-en.pdf?expires=1572947789&id=id&accname=guest&checksum=7EED3CFBF14453C9B95E3B7B476F2B2B

de Soyres, F., Frohm, E., Gunnella, V. and Pavlova, E. 2018. Bought, Sold and Bought Again: The Impact of Complex Value Chains on Export Elasticities. Policy Research Working Paper no. 8535, The World Bank, July. http://documents.worldbank.org/curated/en/816441531511812643/pdf/WPS8535.pdf

Dollar, D., Ge, Y. and Yu, X. 2016. Institutions and Participation in Global Value Chains. Global Value Chain Development Report Background Paper, World Bank, Washington DC. http://rigvc.uibe.edu.cn/docs/20160407201118816062.pdf

European Central Bank. 2017. The impact of global value chain participation on current account balances – a global perspective. ECB Economic Bulletin, Issue 2, pp. 68-82. https://www.ecb.europa.eu/pub/pdf/other/eb201702_article01.en.pdf?c42a2850a26f89af720b311ebc6b4987

European Central Bank. 2019. The impact of global value chains on the euro area economy. ECB Occasional Paper Series No 221. https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op221~38185e6936.en.pdf

Farole, T., Hollweg, C. and Winkler, D. 2018. Trade in global value chains: an assessment of labour market implications. Jobs Working Paper, Issue no. 18, World Bank, Washington DC. http://documents.worldbank.org/curated/en/109621533186813850/Trade-in-Global-Value-Chains-An-Assessment-of-Labor-Market-Implications

Foster-McGregor, N. and Stehrer. 2013. Value added content of trade: A comprehensive approach. *Economic Letters* 120 (2): 354-357

Hummels, D., Ishii, J. and Yi, K-M. 2001. The nature and growth of vertical specialization in world trade, *Journal of International Economics* 54 (1): 75–96

Ignatenko, A., Raei, F. and Mircheva, B. 2019. Global value chains: what are the benefits and why do countries participate? IMF Working Paper WP/19/18. https://www.imf.org/en/Publications/WP/Issues/2019/01/18/Global-Value-Chains-What-are-the-Benefits-and-Why-Do-Countries-Participate-46505

Johnson, R. and Noguera, G. 2011. The value-added content of trade. VoxEU.org, 7 June. https://voxeu.org/article/value-added-content-trade-new-insights-us-china-imbalance

Johnson, R. and Noguera. 2012. Accounting for intermediates: production sharing and trade in value added. *Journal of International Economics* 82 (2): 224–236.

Johnson, R.C and Noguera, G. 2017. A portrait of trade in value-added over four decades. *The Review of Economics and Statistics* 99 (5): 896-911.

Kersan-Škabić, I. 2019. The drivers of global value chain (GVC) participation in EU member states. *Economic Research-Ekonomska Istraživanja* 32 (1): 1204-1218. DOI: 10.1080/1331677X.2019.1629978

Koopman, R., Wang, Z. and Wei, S-J. 2010. Give credit where credit is due: Tracing value added in global production chains. NBER Working Paper No. 16426, September. https://www.nber.org/papers/w16426

Koopman, R., Wang, Z. and Wei, S-J. 2014. Tracing value added and double counting in gross exports. *American Economic Review* 104 (2): 459-494.

Kowalski, P., Lopez Gonzalez, J., Ragoussis, A., and Ugarte, C. 2015. Participation of Developing Countries in Global Value Chains: Implications for Trade and Trade-Related Policies. OECD Trade Policy Papers, No. 179, OECD Publishing, Paris. http://dx.doi.org/10.1787/5js33lfw0xxn-en

Landesmann, M., Leitner, S., and Stehrer, R.. 2015. Competitiveness of the European Economy. EIB Working Papers no. 2015/01. European Investment Bank, Luxemburg, Luxembourg. http://www.eib.europa.eu/attachments/efs/economics_working_paper_2015_01_en.pdf

Lopez-Gonzalez, J. 2012. Vertical Specialization and New Regionalism. PhD thesis, University of Sussex. http://sro.sussex.ac.uk/id/eprint/43255/1/Lopez_Gonzalez%2C_Javier.pdf

Millo, G. 2017. Robust standard error estimators for panel models: a unifying approach *Journal of Statistical Software* 82 (3): 1–27. doi:10.18637/jss.v082.i03

OECD. 2011. ISIC REV. 3 Technology Intensity Definition. https://www.oecd.org/sti/ind/48350231.pdf

OECD. 2013. *Interconnected Economies: Benefiting from Global Value Chains*. OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789264189560-en.

Olczyk, M. and Kordalska, A. 2017. Gross exports versus value-added exports: Determinants and policy implications for manufacturing sectors in selected CEE countries, *Eastern European Economics* 55(1): 91-109. DOI:10.1080/00128775.2016.1254564

Ollivaud, P., Rusticelli, E. and Schwellnus, C. 2015. The Changing Role of the Exchange Rate for Macroeconomic Adjustment. OECD Economics Department Working Papers No. 1190, OECD Publishing, Paris.

Patel, N., Wang, Z. and Shang-Jin Wei, S-J. 2017. Global value chains and effective exchange rates at the country-sector level. BIS Working Papers No 637. https://www.bis.org/publ/work637.pdf

Powers, W. and Riker, D. 2013. Exchange rate pass-through in global value chains: The effects of upstream suppliers. Office of Economics Working Paper No. 2013-02B, U.S. International Trade Commission, Washington DC. https://www.usitc.gov/publications/332/EC201302B.pdf

Ramondo, N. 2016. Factory Asia: The determinants of multinational activity in the context of global value chains. https://aric.adb.org/pdf/events/aced2016/paper_nataliaramondo.pdf

Stehrer, R. and Stöllinger, R. 2015. The Central European Manufacturing Core: What is Driving Regional Production Sharing? FIW-Research Reports 2014/15 No 2, The Vienna Institute for International Economic Studies. https://www.fiw.ac.at/fileadmin/Documents/Publikationen/Studien_2014/Studien_2014_adapted_file_names_stoellinger/02_Stoellinger_FIW_Research_Report_The_Central_European_Manufacturing_Core_What_is_Driving_Regional_Production_Sharing.pdf

Taglioni, D. and Winkler, D. 2016. *Making Global Value Chains Work for Development.* Trade and Development series. Washington, DC: World Bank. doi:10.1596/978-1-4648-0157-0.

Timmer, M. P., Dietzenbacher, E., Los, B., and Stehrer, R. 2015. An illustrated user guide to the World Input–Output Database: the case of global automotive production. *Review of International Economics* 23 (3): 575–605.

Uddin, S.A. 2017. Value-added Trade, Exchange Rate Pass-Through and Trade Elasticity: Revisiting the Trade Competitiveness. University of Alabama in Huntsville.

https://www.aeaweb.org/conference/2018/preliminary/paper/fne8G9a8

van der Marel, E. 2015. Positioning on the global value chain map: where do you want to be? ECIPE Occasional Paper no.1/2015.
https://ecipe.org/wp-content/uploads/2015/02/Occasional-Paper-012015_Last1.pdf

Varela, G and Lovo, S. 2016. Much more to competitiveness than real exchange rates. *The Trade Post*, The World Bank Blog, December 22.
http://blogs.worldbank.org/trade/much-more-competitiveness-real-exchange-rates

Vrh, N. 2018. What drives the differences in domestic value added in exports between old and new E.U. member states? *Economic Research-Ekonomska Istraživanja*, 31 (1): 645-663,
DOI: 10.1080/1331677X.2018.1438910

World Bank. 2017. *Measuring and analyzing the impact of GVCs on economic development*. Global value chain development report 2017. Washington DC.

World Trade Organization. 2019. *Technological innovation, supply chain trade, and workers in a globalized world.* Global value chain development report 2019. Geneva.

Appendix: List of countries in the WIOD sample

Australia
Austria
Belgium
Bulgaria
Brazil
Canada
Cyprus
Czech Republic
Germany
Denmark
Spain
Estonia
Finland
France
United Kingdom
Greece
Croatia
Hungary
Switzerland
China
Indonesia
India
Ireland
Italy
Japan
Republic of Korea
Lithuania
Luxembourg
Latvia
Mexico
Malta
Netherlands
Norway
Poland
Portugal
Romania
Russian Federation
Slovakia
Slovenia
Sweden
Turkey
Taiwan
United States