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The impact of global value chains on the euro area economy

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Contents

Abstract

The studies summarised in this paper focus on the economic implications of euro area firms' participation in global value chains (GVCs). They show how, and to what extent, a large set of economic variables and interlinkages have been affected by international production sharing. The core conclusion is that GVC participation has major implications for the euro area economy. Consequently, there is a case for making adjustments to standard macroeconomic analysis and forecasting for the euro area, taking due account of data availability and constraints.

Keywords: international trade, global value chains, vertical specialisation, international interlinkages, euro area.

JEL codes: F6, F10, F14, F16, E3.

Executive summary

In recent decades, production processes have undergone a profound transformation, driven by the fall of transportation costs and a reduction in obstacles to international trade. Stages of production that used to take place within a country have become dislocated, having shifted beyond national borders. Firms source their intermediate inputs where it is most efficient to produce them and transform them into other goods or services that are likely to cross borders several times before they are finally consumed.

The expansion of global value chains (GVCs) remains a widespread phenomenon, although it broadly slowed in the years following the Great Recession. It therefore poses new challenges to economic analysis and policy making. This paper focuses on two major changes that the increasing fragmentation of production processes has brought about: (i) the rise in importance of trade definitions based on the value added at each stage of the production process (as opposed to conventional gross trade), which affects how a number of economic indicators are computed and examined; and (ii) the increase in trade in intermediates that, on the one hand, is driving the dynamics of trade responsiveness to global demand and, on the other, is leading to greater interconnectedness among firms and sectors in different countries. This has important consequences for activity, prices, productivity and the labour market, for instance.

This paper focuses mainly on the participation of the euro area in GVCs (although some of the studies presented in this paper also cover other European Union countries). By “GVC participation” we mean the proportion of the gross exports of euro area economies (or the euro area taken as a whole) absorbed by two components: (i) the domestic value added embedded in third-country exports (forward, or “upstream” GVC participation); and (ii) the foreign value added embedded in own exports (backward, or “downstream” GVC participation).

Against this backdrop, the paper:

1. analyses how and to what extent a broad range of economic variables and interlinkages have been affected by euro area participation in GVCs;

2. assesses whether such analysis might justify any adjustments to standard macroeconomic analysis and, in some cases, forecasting for the euro area;

3. makes specific recommendations on how the paper’s conclusions may be implemented in macroeconomic analysis and forecasting, taking due account of data availability and constraints.

To use GVC terminology, it could be said that the main “value added” of some of the studies presented in this paper consists not in adding new findings to the GVC literature, but rather in “assembling” its most robust findings into a “final product”: the possible adjustments to be made to the analysis of the euro area. It could also be noted that these studies are located “downstream” in the GVC literature and include

considerable “foreign value added”. However, other contributions to the paper introduce completely fresh approaches and findings that add upstream value to the GVC literature.

The following is a brief account of the topics explored in this paper after an introductory chapter (Chapter 1).

Real effective exchange rates (REERs), which are commonly used measures of price competitiveness, are conventionally based on gross trade flows. With the increasing fragmentation of production processes, imports are widely used to produce exports, with countries often competing against each other at specific stages of the value-added chain. This presents a challenge to conventional REERs, which assume that countries compete to sell products using only domestic inputs. To account for the presence of GVCs, measures of GVC-adjusted REERs for euro area countries are proposed as a complement to the traditional REER indicators (Section 2.1).

The distinction between value-added and gross exports is also relevant when considering export market shares. The contribution of a country to global production should indeed take into account the source of value added in the production process. In this paper, value-added export market shares are compared with conventional gross export market shares in the analysis of competitiveness trends among euro area countries and in the investigation of the determinants of the recent trends (Section 2.2).

The section on euro area rebalancing addresses the question of what role GVC participation might have played during the build-up of intra-euro area trade imbalances and their subsequent adjustment (Section 2.3).

Trade in general and GVCs in particular have been shown to be important channels for technology transfer across countries. Indeed, the opportunities for transferring know-how, technology and process innovation through participation in GVCs are vast: firms can access the new technology embedded in imported inputs and benefit from new varieties of intermediate goods by expanding the set of inputs used in production and improving the degree to which they complement one another. The section devoted to GVCs and technology spillovers provides new evidence on the role of GVC participation in the upgrading of technology and in productivity growth, with the focus on central and eastern European (CEE) countries that are members of the European Union (and five of which are in the euro area). In addition, the paper shows that the main channel for technology transfer in the CEE region is the import of intermediate inputs from parent economies, most of which are in the euro area (Section 3.1).

The global income elasticity of trade has declined since the Great Recession: while in the early 2000s global trade grew at approximately twice the rate of gross domestic product (GDP), the ratio of global trade to GDP growth has fallen to about unity since 2012. The weakening of the relationship between economic activity and global trade, and hence euro area foreign demand, has implications for macroeconomic projections. The contribution of GVCs to the change in the income elasticity of trade is analysed in another section of this paper. The lack of further expansion of GVCs removes a factor that had pushed trade elasticity significantly above unity before the

Great Recession. There is evidence that the structural drivers that had boosted trade in the decades before the financial crisis are now waning, and it appears that these structural trends have accounted for about half of the decline in the income elasticity of global trade in recent years (Section 3.2).

Business cycle synchronisation across developed countries (including the euro area countries) has increased significantly over the past five decades. At the same time, trade flows of intermediate inputs have been increasing rapidly. Between 1990 and 2015, the average ratio of intermediate goods exports to GDP increased more than twofold globally and nearly fourfold in the euro area. In this section, the relationship between the increase in intermediate input trade and business cycle movement is assessed. The degree of business cycle co-movement across countries is a key indicator for many macroeconomic policies. For example, the extent to which the euro area can be considered an optimum currency area also depends on the synchronisation of the business cycles of its member countries (Section 3.3).

As the world's economies have become interlinked through trade in GVCs, it is increasingly important to understand how economic disturbances are transmitted across countries. This paper focuses on the role of input-output linkages for transmitting disturbances across sectors and countries. The importance of these links and the extent to which they can be attributed to certain large hub sectors of the global economy is investigated. Evidence is found to suggest that the activities of related downstream and upstream sectors are relevant to the activity of a sector as a whole, and stylised facts on spillover transmission are presented (Section 3.4).

In recent years, prices appear to have become highly synchronised globally, suggesting that domestic inflation might also be influenced by foreign determinants. On the one hand, increased consumption of foreign products has a direct impact on domestic prices. On the other, foreign prices influence domestic prices through the use of foreign inputs in the production of goods consumed domestically. This paper disentangles domestic and foreign determinants of inflation in euro area countries by focusing on the role of production networks in transmitting foreign price shocks (Section 4.1).

Another study in this paper adopts an approach that is focused more strongly on aggregates and investigates the role of foreign economic conditions for domestic prices in a Phillips curve framework. Previous studies have found that foreign slack has a significant bearing on the Phillips curve. In this paper, the importance of foreign slack is assessed using a thick modelling approach that corrects multicollinearity problems. In addition, the part played by GVCs in the relevance of foreign slack is examined, and the "goodness of fit" of the augmented model is evaluated (Section 4.2).

Turning finally to the labour market impact of GVCs, the emergence of trade in GVCs changes the scope of tasks being performed in each industry and can potentially affect the level of employment and compensation per hour for different types of worker. This paper analyses the relationship between recent labour market developments and different measures of GVC participation across different sectors. A panel fixed effect analysis shows that participation in GVCs is associated with a shift towards

high-skilled workers and that more downstream sectors are more reactive to GVC participation. As regards compensation per hour, remuneration of both high-skilled and low-skilled workers seems to have increased with backward-looking participation (imported input content of exports) (Section 5.2).

All in all, the core conclusion of this paper is that GVC participation has major implications for the euro area economy. Consequently, there is a case for making adjustments to standard macroeconomic analysis and forecasting for the euro area, taking due account of data availability and constraints.

1 Introduction and main findings[1]

1.1 The importance of global value chains for the euro area

Production processes are nowadays structured in several stages, which often take place in more than one country. To manufacture a final product, firms source intermediate inputs from a number of providers, and in many cases these providers are located abroad. Value is added at each stage of the production process, and products might cross borders several times before being finally consumed. This kind of international production sharing arrangement is known as a "global value chain" (GVC). Box 1 provides some key definitions and measures.

Efficiency motives and cost considerations are behind the decisions taken by firms to use foreign inputs or to locate production stages – including final assembly – overseas. A classic example of a global production chain is the manufacture of a smartphone. Research and development of the smartphone might take place in an advanced economy, while the final product is assembled where labour costs are comparatively low (e.g. China), and components, such as semiconductors and processors, are provided by countries that specialise in producing them, such as South Korea and Japan. Each of the countries involved in the production process contributes – albeit in different proportions – to the total value added of the final product. However, trade statistics on the value of shipped products do not reflect each country's individual contribution to a product's value.

The decline in transportation and transaction costs, the increase in openness of emerging market economies and the removal of trade barriers have all helped to drive the development of GVCs. Technological advances have allowed firms to unbundle production processes and to reduce coordination costs by facilitating communication. At the same time, improvements in transportation and logistics have dramatically lowered trade costs. In addition, the establishment of the World Trade Organization (WTO) and, in particular, the accession of China to the WTO and the ensuing free-trade agreements have – at least until recently – mitigated or even removed impediments to trade such as tariff and non-tariff barriers.[2]

Box 1
GVCs: measures of participation and position, and related datasets

Recent strands of the literature on GVCs have made use of global input-output tables to trace value-added flows through the various stages of production.[3] The first goal is to decompose gross export flows of goods and services in order to disentangle the sources of value added from what merely constitutes back-and-forth trade in intermediate products ("double-counting").[4] Figure A

1 By Ettore Dorrucci and Vanessa Gunnella. For an introduction to global value chains, see also ECB (2017a) and ECB (2017b).

2 See Baldwin (2016) for further details.

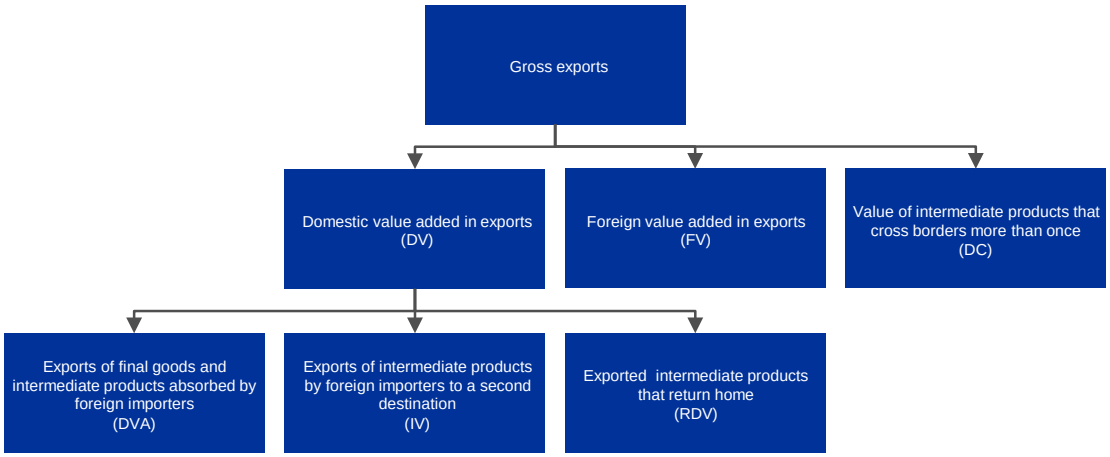
3 See Koopman, et al. (2014) and Wang et al. (2013).

4 Double-counting arises when an intermediate input crosses a border more than once.

identifies the three main components of statistics on gross export flows: (i) domestic value added (DV), (ii) foreign value added (FV) and (iii) a double-counting term (DC). Domestic value added reflects the use of domestic inputs in the production of exports and therefore captures what may be called the "genuine contribution of exports to GDP". Foreign value added refers to the use of foreign inputs in the process of export production. The third component consists of the value of intermediate products that cross borders more than once, thus representing double-counted flows.

Figure A

Decomposition of gross exports into value-added components



Source: Based on Koopman et al. (2014).
Notes: The value of intermediate products that cross borders more than once is the value incorporated in all those intermediate inputs produced in country A that are exported to country B (and are therefore counted as an export of country A) so that country B can make products for another country (either A itself or a third country C). These intermediate inputs originally produced in country A are therefore counted again in country B's gross exports.

Within the domestic value-added component, it is important to further distinguish between those trade flows that are absorbed abroad for final consumption or investment (DVA) and those that are re-exported to other countries (IV) and thus depend on the demand of those countries.[5] Finally, returned domestic value added (RDV) refers to exports that are used as inputs in production processes abroad, but then return and are consumed domestically.

Value-added accounting makes it possible to gauge a given country's or sector's involvement in cross-border production chains. Backward (or downstream) participation in GVCs can be measured as the value added embedded in the foreign inputs (FV in Figure A) utilised in the production of exports. Forward (or upstream) participation can be measured as the value added in intermediate products which are exported to a trade partner and then reprocessed and exported further by the trade partner (IV in Figure A).

Synthetic measures of GVC participation and the GVC position can be derived from this decomposition. The extent of a country's or sector's involvement in GVCs can be defined as the sum of GVC-related components divided by gross exports (E_{ijt}), i.e.:

$$GVC\_Participation_{ijt} = \frac{FV_{ijt}}{E_{ijt}} + \frac{IV_{ijt}}{E_{ijt}}$$

[5] DVA and IV stand for domestic value added absorbed and indirect value added, respectively.

An alternative measure of GVC participation, proposed by Johnson and Noguera (2012), is the value-added content in exports (VAX ratio), which captures the domestic content of exports. The lower the VAX ratio, the higher the participation in GVCs:

$$VAX_{ijt} = \frac{DVA_{ijt} + IV_{ijt}}{E_{ijt}}$$

A measure of the relative downstream or upstream position of a country or a sector can be derived by considering the relative importance of sourcing of inputs and processing of output:

$$GVC\_Position_{ijt} = ln\left(1 + \frac{IV_{ijt}}{E_{ijt}}\right) - ln\left(1 + \frac{FV_{ijt}}{E_{ijt}}\right)$$

A higher share of foreign value added from upstream input providers would indicate a downstream position and lead to the index having a negative value. Conversely, a higher share of value added in re-exported intermediate products travelling further down the value chain would be an indication of an upstream position, and in this case the GVC position index would be positive. Measures of both GVC participation and GVC position can be computed for bilateral trade relations involving countries/sectors i and j or as an aggregate indication for a country or a sector. Closely related to the GVC position measure are indicators for the length of the value chain, which distinguish between backward value chain length (i.e. the average number of production processes before the product reaches the sector) and forward value chain length (i.e. the number of production processes between the sector and final demand).[6]

Global input-output tables are needed to decompose gross trade into its value-added components. In most of the analyses in this paper, the World Input-Output Database (WIOD)[7] is used. Two releases are available: the 2013 release, which includes 40 countries and the rest of the world as an aggregate for the period 1995-2011; and the 2016 release, which presents a more detailed sectoral decomposition and covers 43 countries and the rest of the world for the period 2000-14.

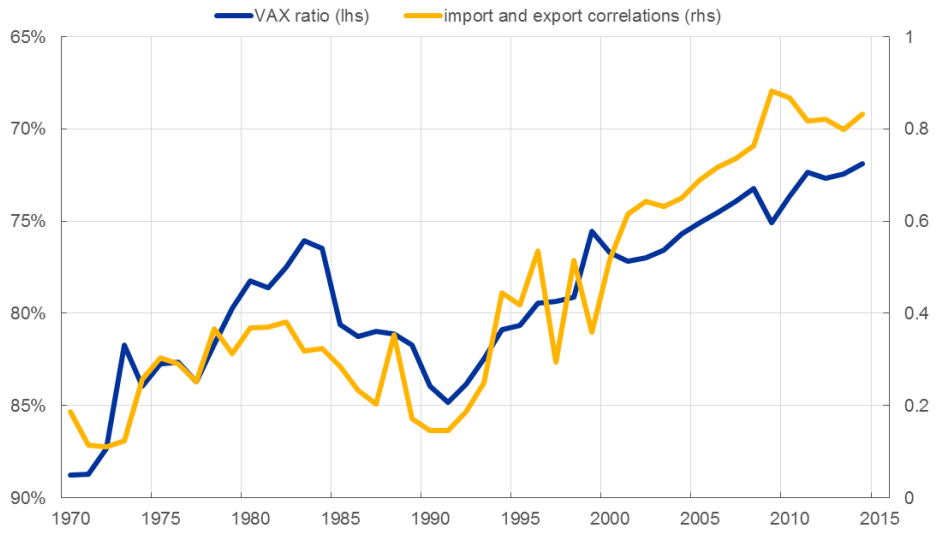
GVCs were expanding steadily at the turn of the millennium, but the expansion stalled after the Great Recession. The two indicators plotted in Chart 1 show a gradual increase in countries' involvement in GVCs starting in the 1990s. The import content of exports has become more predominant. Consequently, the correlation between imports and exports has increased (yellow line), as has the foreign content of countries' exports (blue line). However, since the Great Recession and in particular during the trade slowdown observed in 2011, the pace of GVC development has decelerated (see Timmer et al., 2016). Labour costs in key emerging market economies have increased, firms have reconsidered the risks associated with long supply chains, and protectionist measures such as local content requirements have been pushing firms to partly reconsider their participation in GVCs (see Box 2 for further details). In addition, in countries such as China, demand has been shifting towards services, which tend to be less trade-intensive than goods, while robotisation

6 See Wang et al. (2016).

7 See www.wiod.org.

may lead to renewed localisation of production, especially in the most advanced economies. Nonetheless, GVCs remain a key defining feature of the global economy.

Chart 1
GVC development



Sources: Johnson and Noguera (2016), World Input-Output Tables (2016 release) and World Bank indicators.
Notes: The VAX ratio's scale is inverted to show how a decline in domestic value added in exports is an increase in GVC participation. The measure is calculated for 22 countries available in Johnson and Noguera (2016), the WIOD and the World Bank indicators. The export/import correlations are computed on the basis of year-on-year percentage changes across ten-year windows and exclude extreme values (+- two standard deviations).

Box 2
What has been driving the global GVC slowdown in recent years?

Prepared by Alexander Al-Haschimi, Frauke Skudelny, Elena Vaccarino and Julia Wörz

The levelling-off in GVCs after their dramatic global expansion is a geographically widespread phenomenon. Looking at the data on intermediate goods, an absence of GVC expansion over recent years can be observed across most countries and regions. For advanced economies (AEs), GVCs measured by the share of intermediate goods gradually declined from 2011 levels in the period up to 2014. Emerging market economies also recorded a slight decline over this period, whereas China recorded a more protracted downturn in GVC-related activity. Except in the case of China – where the downturn may have been a counterpart to the shortening of GVCs in AEs, at least to some extent – an explanation of the drivers behind the change in GVC participation is unlikely to lie in country or region-specific factors.

Global supply chains are increasingly organised on the basis of factors other than cost minimisation. The 2011 earthquake and tsunami in Japan caused severe uncertainty and disruptions in the car manufacturing sector, as a number of key suppliers of parts were located in the affected regions. In fact, a large number of companies did not know their suppliers' networks, as subcontractors in turn employed further subcontractors, with the result that supply chains lacked transparency. Consequently, supply risk became difficult to manage. In response, some companies are reported to have reduced the length of their supply chains so as to better manage risk (OECD, 2013), in turn dampening GVC participation.

Local content requirements and other regulatory measures are also headwinds to GVC expansion. These new barriers are often more subtle than previous tariff and non-tariff measures and are aimed at reducing imports by, for example, tailoring licence requirements in such a way as to promote domestic purchases or provide tax incentives for local procurement (Bhatia, Evenett and Hufbauer, 2016). These localisation measures induce companies to onshore[8] their manufacturing facilities to their export markets. For instance, European manufacturer Volkswagen reduced its production share in Germany from 62% to 43% over this period, shifting production instead towards export markets and notably China. The same dynamics can be seen across other major car companies. While such moves initially lead to increases in trade in intermediate components, McKinsey (2014) argues that, once global manufacturers reach a sufficient scale in the new regions, major suppliers will move towards these regions. In addition to policies encouraging local sourcing, this dampens trade growth. Therefore, while the car industry remains characterised by long supply chains, McKinsey (2014) finds that between 2000 and 2012 carmakers moved their production capacity towards their export markets on a significant scale.

Euro area companies also report localisation measures as being a driver for onshoring production to export markets. In a recent survey of large euro area firms conducted by the ECB, two-thirds of respondents cited local content requirements as one of the main reasons for relocating production outside the European Economic Area. As a result, sourcing and producing in local markets are replacing earlier trade flows.

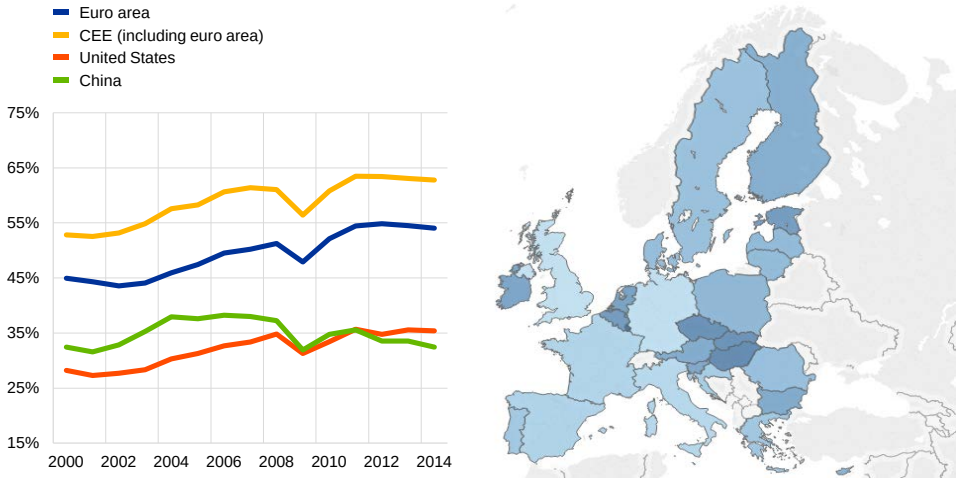
Despite the global GVC slowdown, euro area countries – where the slowdown has been much less pronounced or even absent (see Section 2.3) – remain extensively involved in cross-border production chains, and their GVC participation is relatively high compared with the world average and most other economies. Overall, the participation of the euro area in GVCs is significantly higher than in the United States and China, and is second only to that of central and eastern European (CEE) countries (an overlapping category that itself includes five small euro area economies – see Chart 2a). For an analysis of the factors driving euro area participation in GVCs, see Box 3. The smaller euro area countries need to source a greater share of inputs from abroad, so their participation in GVCs is higher than that of the bigger economies (Chart 2b). In addition, the euro area countries are more involved in regional than in global supply chains. Chart 3 shows a comparison between two GVC participation indices: one calculated as a combination of euro area countries' indices and one that considers the euro area as a bloc vis-à-vis foreign countries. It is evident that the involvement of the euro area in production chains with extra-euro area countries is much less marked. It is also important to notice that, after 2011, the integration of euro area countries into regional supply chains has declined to a lesser extent than its GVC participation with other countries (ECB, 2017).

8 Onshoring consists in transferring parts of the intermediate production processes close to the customers' location.

Chart 2

Euro area/European Union GVC participation

(percentage points)

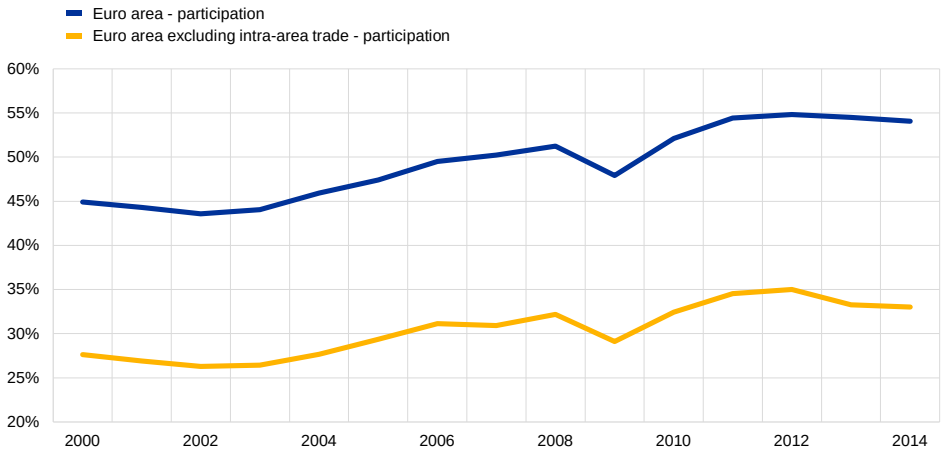


Sources: World Input-Output Tables (2016 release), Koopman et al. (2014) and authors' calculations.
Note: CEE is the abbreviation for central and eastern Europe (including five euro area countries: Estonia, Latvia, Lithuania, Slovakia and Slovenia).

Chart 3

Euro area's global vs regional GVC participation

(percentages)



Sources: WOID (2016 release), Koopman et al. (2014) and authors' calculations.
Notes: The chart shows two GVC participation indices: one computed by summing up individual euro area countries' GVC indices (blue line) and one that considers the euro area as a bloc vis-à-vis foreign countries, i.e. by aggregating intermediate and final trade flows of euro area countries before computing GVC participation (yellow line). See Box 1 for details on the computation of the GVC indices.

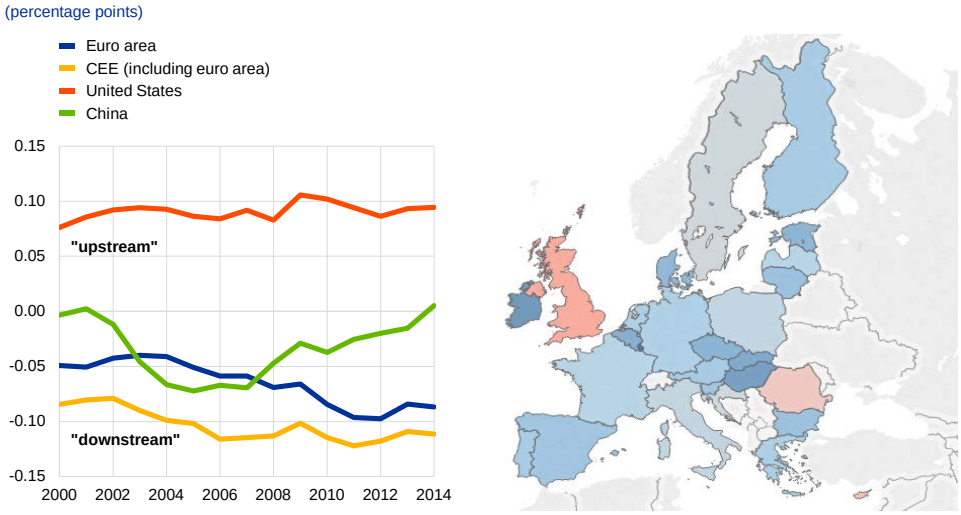
Larger euro area economies tend to lie more upstream in the global production chain than small euro area countries. Compared with the world average, euro area countries are moderately downstream, meaning that the foreign content of euro area production is larger compared with the inputs supplied by the euro area to other countries.[9] Countries such as the United States are positioned more upstream, mainly because of their activity in sectors such as natural resources, research and development (R&D) and financial services, which provide intermediate inputs to other

9 See Box 1 for details on measures of GVC position. For a detailed description of the role of a number of euro area countries in GVCs, see also Section 2.3.2.

sectors. Within the euro area, larger economies are located more upstream compared with small countries, highlighting the presence of pan-European production chains in which intermediate goods and services are produced by the former and then fed into the assembling processes taking place in small euro area countries or, more recently, the CEE region.

Chart 4

Euro area/European Union GVC position



Sources: World Input-Output Tables (2016 release), Koopman et al. (2014) and authors' calculations.
Notes: In the right-hand panel, blue indicates a downstream position, whereas red indicates an upstream position. CEE is the abbreviation for central and eastern Europe (including five euro area countries: Estonia, Latvia, Lithuania, Slovakia and Slovenia).

Box 3

What drives GVC participation and position in the euro area?

Prepared by Benedetta Di Lupidio and Joachim Schroth

The GVC participation and position of euro area countries seem to be affected by factors such as market size, labour force skills and institutional features. To identify the factors influencing integration into and positioning within GVCs, we use a panel comprising the WIOD sectors in the euro area countries, and, following Van der Marel (2015), regress value added participation and positioning in these countries on a set of country characteristics such as population and domestic demand (as proxies for market size), GDP per capita, education and institutional indicators such as the economic complexity index, union density, tax wedges, barriers to trade, spending on active labour market policies (ALMPs) and R&D. A dummy for the year 2009, when there was a collapse in world trade, is included, along with country-sector fixed effects to capture individual characteristics of sectors. Estimates are shown in Table A. A drawback is that most institutional indicators and country characteristics used to explain the participation and position of sectors relate to the country level and are not available at the sector level, hampering the exploitation of the cross-sectoral variation.

Higher participation in GVCs is associated with higher levels of tertiary education, political stability, market size and GDP per capita, whereas it is negatively related to labour market mismatches. Tertiary education in the labour force supports GVC participation, while higher spending on ALMPs as a proxy for labour market mismatches has a negative bearing on GVC participation. Union density, unemployment benefits and taxation are found not to play a significant

role in explaining participation. While higher political stability is found to boost participation, parameter estimates for the economic complexity index and for the "doing business" component measuring ease of cross-border trade were not statistically significant. We also find that the stock of foreign direct investment in the sector has no significance as explanatory variable for sector participation. In contrast to Van der Marel, the share of R&D expenditure in GDP is found to have a highly significant impact on participation.[10] After controlling for institutional indicators and other country characteristics, participation is found to be higher for larger markets (as proxied by population) and countries with higher per capita income.

Table A

Institutional factors explaining GVC participation

(sample 2000-14)

	GVC participation		GVC position	
	coeff.	t-value	coeff.	t-value
Population	0.458	3.2	-0.182	-2.2
GDP/capita	0.047	3.4	-0.025	-3.6
Share tertiary educ. In LF	0.050	2.1		
Share secondary/tertiary educ.			-0.075	-3.1
ALMP spending	-0.025	-2.8		
Political stability index	0.022	4.3		
Doing business overall score			0.137	4.7
Crisis dummy	-0.026	-7.8	0.05	2.8
observations	10,364		9,720	
R^2	0.106		0.048	

Note: Country-level fixed effects are included.

An upstream position in GVCs is related to higher ease of doing business, while a negative correlation is found for a higher level of education. Estimates of the drivers of positioning within GVCs suggest that a higher share of secondary and tertiary education in the labour force is associated with a more downstream position, which might be related to some of the most upstream sectors (forestry, mining and warehousing) not having high skill requirements. By contrast, a higher overall doing business indicator would point to a more upstream position, which could be explained by deregulated countries being a preferred destination for outsourcing of upstream services and the production of intermediates. For all other variables mentioned above, including R&D and political stability, which was significant in explaining participation, there is no evidence of any significant impact on the GVC position. Larger market size seems to be associated with a more downstream position, as does a larger per capita income for a country. The crisis dummy is positive, reflecting the lower foreign value added in production due to trade disruptions, which are reflected in a move upstream in the position indicator.

From an analytical and policy perspective, investigating GVC integration and its consequences for the euro area is of primary importance. An investigation of economic concepts and economic relations based solely on standard trade statistics is

[10] The results of the regression including R&D expenditure are not shown. This is because of gaps in the R&D variable entailing a substantial loss in observations.

not sufficient. Analysis based on gross trade flows fails to gauge many relevant aspects. Some important examples are (i) the value-added contribution of each country to production, (ii) the extent to which countries compete with each other in global markets and (iii) the way trade reacts to changes in aggregate demand. As explained above, modern production processes consist of many stages and involve firms located in several countries. The establishment of these production networks increases the interlinkages between economies. Therefore, this paper analyses the consequences of GVC integration through specific studies on a number of economic topics of interest, namely exchange rates; competitiveness and cross-country rebalancing (Chapter 2); output and demand (Chapter 3); prices and costs (Chapter 4); and labour markets (Chapter 5). The next section summarises the content and main findings of each study.

1.2 Main findings of this paper

1.2.1 Real effective exchange rates

The integration of countries into GVCs poses a challenge to conventional real effective exchange rates (REERs). Conventional methodologies for the calculation of REERs assume that countries compete to sell products using only domestic inputs. However, imports are widely used to produce exports, and countries often compete against each other at specific stages of the value-added chain.

GVC REERs are constructed by taking into account value-added trade flows and trade in intermediate inputs. Gross trade does not measure the amount of value added exchanged between countries, and bilateral value-added trade patterns may differ significantly from gross trade patterns. To take this into account, value-added real effective exchange rates (VAREERs) are constructed. GVCs also imply that countries trade intermediate inputs intensively. Consequently, an appreciation vis-à-vis a trading partner from which a country largely imports intermediate goods may be beneficial for the competitiveness of that country as it reduces the cost of intermediate goods imports. To account for this effect, input-output real effective exchange rates (IOREERs) are computed.

Absolute differences between gross trade weights on the one hand, and IOREER and VAREER weights on the other, are non-negligible, although there is very high correlation between them: compared with gross trade weights, IOREER weights tend to differ more on average than VAREER weights. Differences in trade weights tend to be larger for small, open economies. Trading partners in close proximity to a country tend to lose importance when value-added trade is considered, while large but remote economies, such as the United States, become more important trading partners

GVC REERs largely deliver similar messages on price competitiveness compared with conventional REERs, although they deliver different magnitudes for past appreciation/depreciation episodes. A comparison of GVC-based REERs

of euro area countries – produced consistently with the official method of the ECB – with conventional REERs of euro area countries shows that differences between the indicators over time are fairly small. However, for most euro area countries VAREERs indicate a slightly less pronounced appreciation (or more pronounced depreciation) compared with conventional REERs since 1999, while IOREERs indicate a somewhat stronger appreciation (or less pronounced depreciation) than both the VAREER and the conventional REER. In addition, stressed euro area countries recorded larger appreciations – particularly in IOREERs – in the run-up to the crisis, followed by larger improvements in IOREERs during the adjustment period.

Based on this analysis, it seems advisable to carefully assess the feasibility of calculating GVC-adjusted REERs. While consideration may be given to prioritising the computation of IOREERs, as they tend to yield larger differences, from a technical point of view the calculation of high-quality IOREERs may turn out to be more demanding. If this is the case, it may make sense to calculate VAREERs as a first step towards computing a larger set of REERs.

1.2.2 Export market shares

In a world characterised by cross-border production chains, export market shares computed with gross trade flows may not fully reflect a country's contribution to global production. Production processes are increasingly fragmented, and the distinction between production and assembly should be taken into account to correct gross exports for the source of value added.

Adopting a weighting scheme based on the value-added concept does not alter the assessment of market share development substantially. Export market shares of euro area CEE countries have increased considerably at the expense of previous euro area members' market shares, highlighting the role played by the outsourcing of production processes. However, in terms of value added, new euro area countries' market share gains are less pronounced, and this might reflect the low value-added content of assembling and processing activities.

The analysis of the drivers of market share dynamics changes substantially when the value-added concept is taken into account in calculating global market shares. Changes in market shares can be decomposed into three determinants: shifts in production chains, price factors and residual non-price factors. Such a decomposition shows that the contribution of residual non-price factors is lower for value-added market shares than for gross export market shares and highlights the importance of shifts in production chains.

Using value-added export market shares may change the assessment of countries' competitiveness and the factors that drive it. Therefore, global market shares calculated on the basis of value-added exports should be closely monitored.

1.2.3 Intra-euro area rebalancing

In the years preceding the crisis, a number of "vulnerable" euro area countries accumulated external imbalances. We look at the subsequent rebalancing process from a particular angle, namely the role that the GVC activities of these countries have played in the correction of such imbalances.

On average, vulnerable countries participate to a similar extent and occupy similar positions (slightly downstream) in the value chain as Germany and France. Their GVC participation increased somewhat even after 2008, and not only in the pre-crisis years as was the case in all other countries. This is different from both Germany – where GVC participation remained virtually unchanged – and the general global trend which, as described in Chapter 1, went in the opposite direction.

Vulnerable countries moved further downstream on average between 2008 and 2014. This may have contributed to improvements in their value-added trade balances, while we do not find evidence of any positive role played by stronger participation in GVCs. Since the positions of Germany and France remained virtually unchanged over the period, the move downstream of some peripheral countries also helped their rebalancing relative to the core countries. Results suggest that the trade rebalancing of Spain and Greece may have been supported by changes in their GVC activities, while for Cyprus and Slovenia, GVCs may have contributed negatively.

This initial study provides some additional insight into the analysis of trade balance dynamics and highlights the importance of considering integration in GVCs when assessing rebalancing policies. While preliminary in nature, this analysis, which also provides sectoral breakdowns, suggests that input-output linkages may have implications for the external adjustment process.

1.2.4 Technology frontier and productivity

Trade in general and GVCs in particular have been shown to be important channels for technology transfer across countries. The opportunities for transferring know-how, technology and process innovation through participation in GVCs are vast: firms can access new technology embedded in imported inputs and benefit from new varieties of intermediate goods by expanding the set of inputs used in production and reaching a better degree of complementarity between them.

New technology diffuses across countries in two stages. First, the newly created technology at the global frontier is absorbed by the national frontier firms in the host economies via GVCs. In a second stage, the technology, which has by then been adapted, is transferred to the rest of the (non-frontier) firms in the host economy through domestic production networks. This process is mainly driven by the import of intermediate inputs by host firms, rather than the export of inputs to parent firms.

The benefit of participating in GVCs, in terms of total factor productivity (TFP) growth, depends ultimately on the absorptive capacity of host firms. Participation in GVCs also fosters collaboration in R&D, enables product

diversification and forces upstream firms to invest more to meet the quality standards of parent companies. However, to benefit from these spillovers, host firms must enhance their absorptive capacity with investments in R&D and human capital.

Given their deep integration in GVCs, CEE countries have been particularly exposed to two recent developments with a direct impact on their TFP growth. The first is the slowdown in the TFP growth of non-CEE European Union (EU) frontier firms that are linked to the most productive firms in CEE countries via GVCs. The second is the global phenomenon known as the "shortening of GVCs" (or slowdown in GVC participation growth rate), which is evident also for CEE countries from 2011 onwards.

This study provides evidence of the importance of GVCs as a channel for technology diffusion. For firms in CEE countries, the main transmission channel within GVCs is the import and use of parent companies' intermediate products, which enables access to new technology and a wide variety of inputs.

Additionally, the disruption of technology diffusion from parent economies is identified as the main factor behind the sharp post-crisis slowdown in TFP growth of CEE countries. This disruption was the result of two concurrent phenomena. The first was a drop in technology creation by non-CEE EU parent firms during the post-crisis period. The second was the decrease in the absorptive capacity of host firms in CEE countries, which may have been related to the observed reduction in R&D investment in CEE countries, particularly after the crisis.

1.2.5 Global income elasticity of trade

The lack of further expansion of GVCs removes a factor that had pushed trade elasticity significantly above unity before the Great Recession. There is evidence that the structural drivers that had boosted trade in the decades before the financial crisis are now waning. Over recent decades, the rapid integration of emerging market economies into the world economy boosted the expansion of GVCs. That process of fragmenting production across borders appears to be maturing, however, as discussed in Section 1.1, Box 2.

At the same time, other structural factors that had facilitated global trade in the last couple of decades – declining transportation costs and the removal of trade barriers through lower tariffs – had already levelled off before the Great Recession. Diminishing marginal support from financial deepening as a factor facilitating export capacity has also weighed on global trade. Some of these explanatory factors are interconnected: for example, reduced transportation costs/tariffs and financial deepening have partly enabled firms to expand their GVCs. An assessment of the marginal contribution of each factor to the trade weakness therefore requires a degree of judgement. Nonetheless, it appears that these structural trends have accounted for about half of the decline in the income elasticity of global trade in recent years.

Overall, evidence suggests that the recent weakness in trade may constitute a "new normal" for medium-term global trade growth. Some of the structural factors

that supported rapid trade expansion in the past, such as expanding GVCs, reduced transport costs, declines in tariffs and support from financial deepening, seem to have largely run their course. In this sense, the buoyant trade dynamics in the 1990s and early 2000s may have been the exception, rather than the slowdown during the post-crisis period.

1.2.6 Trade in intermediates and co-movement in business cycles

Business cycle synchronisation across developed countries and euro area countries has increased significantly over the past five decades. In the Organisation for Economic Co-operation and Development (OECD) countries, the correlation of GDP fluctuations at business cycle frequencies rose steadily from about 11% in the 1960s to more than 60% for the period ranging from the first quarter of 2006 to the first quarter of 2016. In euro area countries, the rise follows a similar trend with a correlation of about 16% at the beginning of the period and reaching more than 67% in the most recent years. Overall, countries within the euro area have seen a sharp increase in their synchronisation.

At the same time, trade flows of intermediate inputs have been increasing rapidly. Between 1990 and 2015, the average ratio of intermediate goods exports to GDP increased more than twofold globally and nearly fourfold in the euro area.

Trade in intermediate inputs plays an important role in synchronising GDP fluctuations across countries, while trade in final goods is found to play at most a very minor role. This result holds both at business cycle and medium-term frequencies. Pairs of countries that increased their trade in intermediates experienced an increase in their business cycle co-movement, while an increase in trade in final goods is not associated with any change in synchronisation. The association between trade in intermediates and GDP co-movement is stronger at lower frequencies, suggesting that trade integration may have a long-lasting impact on cross-country interdependence.

Therefore, when assessing international linkages and the potential for cross-country spillovers, special attention should be devoted to trade in intermediate goods.

1.2.7 Sectoral spillovers and network effects via global production linkages

The global economy is a network characterised by sectoral hubs that are disproportionately large suppliers or purchasers of inputs of/to many other sectors. Hubs matter not only because they supply and use inputs from many other sectors, but also because they connect otherwise unrelated sectors.

According to the study, activity in a sector is strongly related to activity in its GVC. On average, a 1% change in activity in the global network translates into an

impact of about 0.3 percentage points on an industry. The sectors considered to be hubs upstream in the value chain are those active in equipment leasing, computer activities, R&D, finance and raw materials in the United States, the United Kingdom, Germany and Russia. The hubs downstream in the value chain are largely active in the areas of transport equipment, machinery, basic metals and construction in Germany and China. When the ties between the global hubs and all other sectors are severed, spillovers strongly diminish and vanish after the top 16 hubs are removed. This highlights the importance of certain global sectors in interlinking the global economy.

Further consideration should be given to the national, regional and global sectoral interlinkages of the euro area economy. Economic activity spills over through production linkages in GVCs and might translate into aggregate volatility via large global hub sectors. Therefore, when assessing the potential for spillovers in economic activity to the euro area, the focus should be not only on macroeconomic aggregates but also on assessing economic developments in a handful of sectors in some countries.

1.2.8 Network effects in the transmission of cost shocks

Inflation rates across countries have become increasingly synchronised since the 1990s, which may reflect a range of factors including the pursuit of similar credible monetary policies across countries and the impact of global commodity price movements. International input-output linkages may also have contributed to the synchronisation of inflation rates by intensifying the spillovers from foreign cost shocks.

The direct and indirect influence of foreign prices on euro area inflation has increased over time. The foreign content of euro area final consumption has increased steadily since the 2000s, reflecting the growing direct impact of final goods and services imports on euro area inflation. At the same time, the indirect effects of foreign costs shocks on euro area producer prices via global supply chains have also intensified. The impact of both broad-based and sector-specific shocks on producer prices is largely heterogenous across euro area countries. However, as would be expected, the impact is particularly strong for small open euro area economies.

Although foreign influences through global supply chains have increased, they remain relatively limited for the euro area. Instead, spillovers emanating from domestic sectors account for the bulk of the supply chain impact on euro area inflation rates.

Monetary policy should therefore take domestic cost pressures into account primarily, although foreign cost pressures have become increasingly relevant with the expansion of global supply chains.

1.2.9 The role of foreign slack and GVCs for the dynamics of euro area inflation

Recent studies suggest that foreign slack may be a strong driver of domestic inflation, although other findings find weaker evidence for the role of foreign economic conditions. The theoretical reasoning is based partly on simple considerations of increasing openness, but also goes further to include the argument that globalisation has increased the contestability of labour and product markets, with competition from low-wage and low-cost countries putting pressure on consumer price inflation worldwide.

A thick modelling approach which handles multicollinearity problems present in standard Phillips curve specifications delivers mixed results. Depending on the specification, foreign slack is relevant in only 30% to 60% of the Phillips curve regressions. In addition, the integration of countries in GVCs increases the influence of foreign conditions only in few cases. The inclusion of the foreign slack variable seems to improve the fit of Phillips curve-based forecasts, but the improvement is fairly small.

1.2.10 Labour market impact of GVCs

Looking at aggregate trends in the euro area, the share of value added from labour in gross output and in exports fell between 1997 and 2011, with a pronounced shift towards higher-skilled workers at the expense of their low-skilled counterparts. This shift in skill composition is partly due to a change in the composition of sectors, but also within sectors. For example, sectors that were already relatively highly skilled 1997 experienced a further pronounced shift towards high-skilled workers.

Over the same period, GVC participation increased for all countries, both within and outside of the euro area. In terms of a country's relative position in the supply chain, results are heterogeneous, with some countries moving down (for instance Luxembourg, Poland and Germany), while others moved up (for instance Russia, Brazil, Lithuania and Canada).

A panel fixed effect analysis shows that participation in GVCs is associated with a shift towards high-skilled workers. Disentangling the effects of backward-looking participation indices on the one hand and forward-looking participation indices on the other, this shift looks to be mainly driven by the increased use of imported inputs (backward participation). Such a shift in employment might stem from a combination of both offshoring and skill-biased technical change at the sector level.

Separating sectors by their position in the global value chain reveals that more downstream sectors are more reactive to GVC participation: they experience a larger shift towards high-skilled workers. In line with the study for all sectors, this effect is mainly driven by backward-looking participation (share of foreign value added in exports), rather than the forward-looking part of GVC participation. The fact that

downstream sectors are more affected is consistent with the other finding that participation in GVCs impacts labour usage mostly through the choice of inputs.

As for compensation per hour, remuneration of both high and low-skilled workers seems to have increased with backward-looking participation (share of foreign value added in exports), which is consistent with previous studies at the firm level. The association is found to be stronger for more downstream sectors.

2 Exchange rates, competitiveness and external rebalancing

2.1 Real effective exchange rates[11]

2.1.1 Introduction

REERs are commonly used measures of international price and cost competitiveness. The effective exchange rate is computed as an average of the bilateral exchange rates of a country *vis-à-vis* its major trading partners weighted by the share of the trading partner in the total trade of the country. Conventionally, in this context trade is based on bilateral gross value trade flows. Under certain rather strong assumptions, such as uniform trade elasticities, this allows for the effective exchange rate to be used in models of aggregate exports or imports of a country (including, in addition to the exchange rate, foreign or domestic demand), as an alternative to aggregating the results of bilateral models for trade with each of the trading partners. This implies that the REER based on gross value trade has some information content with respect to the export and import performance of a country.

In principle, many alternative weighting schemes can be used for aggregating bilateral exchange rates into a measure of the effective exchange rate. In fact, there is no single "correct" effective exchange rate, but instead the analysis of different aspects of economic and financial activity may benefit from differently designed effective exchange rate indices. This also becomes apparent from the practice of calculating effective exchange rates across major institutions.

- For instance, institutions differ in the way they implement the gross value trade weights by considering either only export weights or only import weights, aggregating export and import weights into a single total trade weight or applying "double-export" weights, which account for competition between two countries in a third market.
- In addition, some institutions compute effective exchange rates using GDP weights. One reason for doing so is to indirectly capture third-market effects, as large countries are more likely to act as competitors in third countries.
- Taking a different perspective, Lane and Shambaugh (2007) construct effective exchange rates using financial weights which are based on measures of bilateral financial integration. Analogously to trade-weighted effective exchange rates having some information content with respect to the evolution of trade, financial-weighted effective exchange rates carry information on the evolution of the international investment position of a country in terms of valuation changes stemming from exchange rate movements.

[11] By Michael Fidora and Martin Schmitz.

More recently, effective exchange rates based on weights that take into account the anatomy of GVCs have attracted increasing attention for the following reasons.

- Bilateral value-added trade patterns may differ significantly from gross trade patterns. As a result, gross value trade weights may overstate or understate the degree of bilateral competition for value-added exports.

- Since GVCs imply that countries trade intermediate inputs intensively, an appreciation *vis-à-vis* a trading partner from which a country largely imports intermediate goods may actually be beneficial for the competitiveness of that country as the appreciation reduces the cost of intermediate goods imports and hence the cost production of domestic value-added.

A number of recent studies are aimed at incorporating the role of GVCs in the computation of REERs and the resulting assessment of competitiveness. In this study, we follow the methodology of Bems and Johnson (2015), who base trade weights on value-added data to derive two indicators dealing with the two above-mentioned issues:

- **VAREERs,** which are based on bilateral value-added trade data (as opposed to gross trade data in conventional REERs);

- **IOREERs,** which in addition consider the role of imported intermediate inputs.

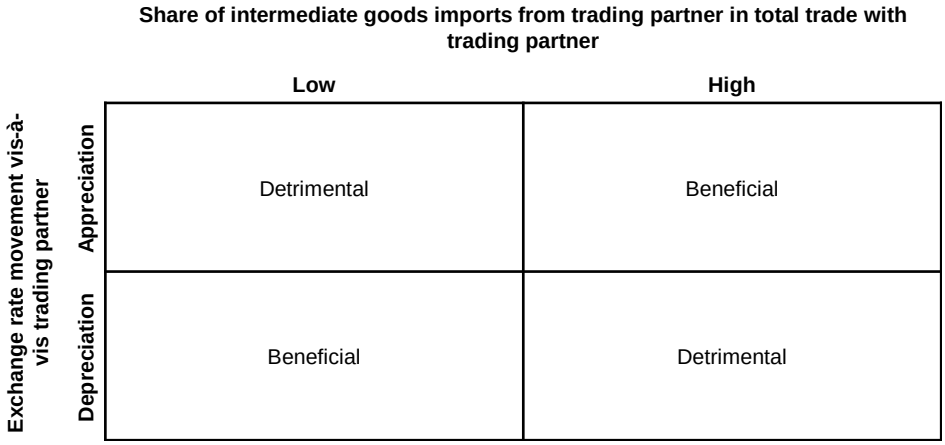
In the case of IOREERs, the underlying idea is that an appreciation vis-à-vis a trading partner from which a country largely imports intermediate goods may actually be beneficial for the competitiveness of that country since it reduces its cost of production. Conversely, a depreciation vis-à-vis such trading partner may be detrimental for the competitiveness of the country, since it increases the cost of intermediate goods imports. Therefore, IOREERs consider two different channels through which exchange rates have an opposite impact on competitiveness: (1) an appreciation increases the price of domestic goods relative to foreign goods and (2) an appreciation reduces the cost of domestic production relative to foreign production via intermediate goods import prices. The latter channel is not taken into account in conventional REERs. The share of intermediate goods imports from a trading partner in total trade with this trading partner determines which of the two channels prevails.[12] This is illustrated in Figure 1. If intermediate goods imports are low (or, as in the case of conventional REERs, not explicitly taken into account), an appreciation will be detrimental for the competitiveness of a country (upper left-hand segment of Figure 1). Conversely, a depreciation in this case will be beneficial in terms of competitiveness (lower left-hand segment). However, taking into account the intermediate goods import channel, an appreciation may turn out to be good for the

[12] With regard to IOREER weights, the question arises as to why final goods imports should be treated differently from intermediate goods imports. The proponents of IOREER weights argue that cheaper intermediate goods imports are beneficial for the competitiveness of the country because they reduce the cost of production, whereas cheaper final goods imports are not beneficial for the competitiveness of the country because they harm the competitiveness of domestic final goods production. It is important to note that this line of reasoning is ultimately based on the assumption that there are domestic producers of final goods that compete with foreign final goods producers, whereas there are no domestic producers of intermediate goods that compete with foreign intermediate goods production.

country's competitiveness if intermediate goods imports from the trading partner are large enough (upper right-hand segment), while a depreciation may be detrimental in this case (lower right-hand segment).

Figure 1

Impact of bilateral exchange rate movements on the IOREER measure of price competitiveness



Source: ECB staff.

Technically, the indicator is therefore based on weights that are smaller than conventional weights if a trading partner is an important provider of intermediate goods (relative to the total trade with the trading partner). Whereas conventional REER weights (w_i^{CON}) are a positive function of exports (X) and imports (M) between two countries, the IOREER weights are a function that increases in exports and final goods imports (FGM), but decreases in intermediate goods imports (IGM) as follows:

$$w_i^{CON} = f\begin{pmatrix} X, & M \\ + & + \end{pmatrix},\ w_i^{IO} = f\begin{pmatrix} X, & FGM, & IGM, \\ + & + & - \end{pmatrix}$$ [13]

In this way, an appreciation *vis-à-vis* a trading partner from which a country imports large quantities of intermediate goods leads to less of an increase in the effective exchange rate of that country. If intermediate goods imports from a certain trading partner are large enough, the trading partner's weight becomes negative such that any appreciation *vis-à-vis* that trading partner leads to a decrease in the effective exchange rate.

In order to assess the relevance of these new indicators for the euro area by comparing them with conventional REERs, we generate an infrastructure that simultaneously recomputes the VAREERs and IOREERs of Bems and Johnson (2015) and the conventional REERs calculated according to official ECB methodology. In doing so, we slightly adapt both Bems' and Johnson's methodology and the ECB's official methodology to ensure full comparability. In particular, we ensure that the only difference between the VAREER and IOREER calculation

[13] Note that for the sake of clarity of exposition, this is a heavily simplified formula aimed at providing an illustration only.

processes lies in the application of the different sets of weights.[14] In this way, we ensure maximum comparability of value-added trade data-based indicators and the ECB's official (gross trade data-based) indicators. While in principle we can consider a large set of different deflators to be applied to the ECB's official REER as well as to the IOREER and the VAREER, in this study we focus exclusively on GDP deflators as the relative price measure since it reflects best the "price of value added" (e.g. as it is the most direct summary measure for capital and labour costs).

In the following, we first summarise the main properties of the three different sets of weights in Section 2.1.2. Then in Section 2.1.3 we compare the ECB's official REERs with the IOREERs and VAREERs in order to assess whether GVC-based REERs can add new insights to the assessment of euro area countries' competitiveness.

2.1.2 Differences in trade weights

IOREER and VAREER weights are highly correlated with gross trade weights. Across all countries considered, the coefficient of correlation between gross trade weights and IOREER and VAREER weights is high and only in three cases (Lithuania, Luxembourg and Slovakia for IOREER) falls below 80% (see Table 1).

Table 1

Coefficient of correlation with gross trade weights: IOREER and VAREER weights

	AT	BE	CY	DE	ES	FI	FR	GR	IE	IT	LT	LU	LV	MT	NL	PT	SI	SK
IOREER	0.92	0.91	0.90	0.88	0.94	0.84	0.91	0.94	0.92	0.94	0.65	0.50	0.91	0.85	0.94	0.97	0.87	0.71
VAREER	0.97	0.97	0.87	0.93	0.91	0.87	0.93	0.83	0.97	0.93	0.88	0.83	0.92	0.93	0.92	0.96	0.96	0.93

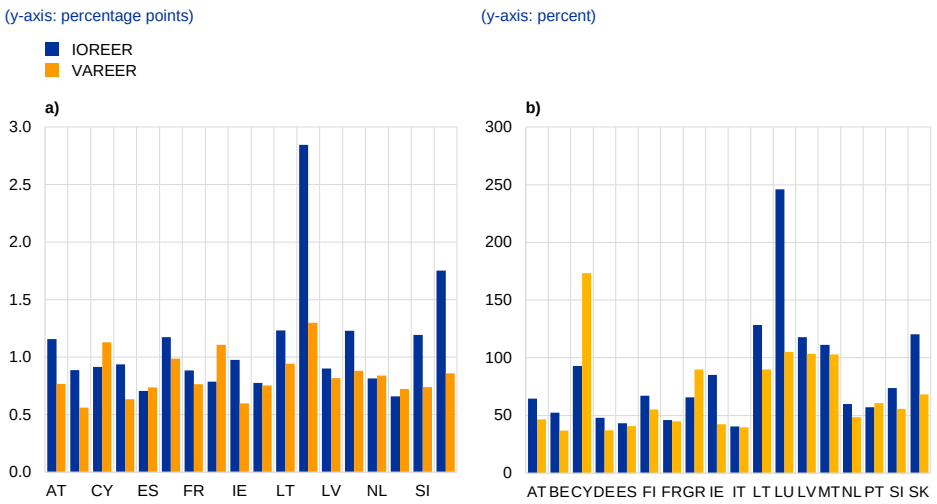
Sources: Bems and Johnson (2015), ECB and ECB staff calculations.

Despite the high degree of correlation, absolute differences between gross trade weights on the one hand, and IOREER and VAREER weights on the other, are non-negligible. Across all countries, the absolute average difference amounts to about 1 percentage point (see Chart 5a). Given that for a trading partner basket of 39 countries, which underlies the computations, the average trade weights of individual partner countries are fairly small, the deviation is sizeable. In relative terms, IOREER and VAREER weights deviate by between 50% and 100% on average from the corresponding conventional trade weights (see Chart 5b). The following points should also be taken into account.

[14] Most importantly, we (i) recompute the ECB's official REER based on a smaller set of trading partners than included in the published ECB REER, as Bems' and Johnson's IOREER and VAREER weights are based on (and only available for) this smaller set of countries; and (ii) re-compute Bems' and Johnsons' IOREER and VAREER based on three-year non-overlapping averages of the IOREER and VAREER weights, as the gross trade weights underlying the ECB's official REER are based on three-year non-overlapping average data. More details are presented in the appendix.

Chart 5

Average absolute deviation of IOREER and VAREER weights from conventional trade weights



Sources: Bems and Johnson (2015), ECB and ECB staff calculations.

Compared with gross trade weights, IOREER weights tend to differ more, on average, than VAREER weights. Differences tend to be larger for small, open economies. The fact that IOREER weights differ more might be partly explained by the fact that in addition to considering value-added trade instead of gross value trade they also consider input linkages and their effect on export and import elasticities, and thus conceptually deviate more from the conventional weights.

Generally, trading partners in close proximity to a country lose importance when value-added trade is considered. This is because, among neighbouring countries, goods with relatively low value added are often shipped across borders. This in turn reflects two factors. First, geographical proximity may lead to frequent gross trade flows of the "same" good at various stages of its production (an illustration is the chain existing between the crop-grower in country A, the miller in country B, the baker in country A, the wholesaler in country B and the restaurant in country A, all located in close proximity to the international border). Second, geography may imply that one country acts as an entry port for another country (for instance, Spain is an entry port for goods shipped from other euro area countries to Portugal). Chart 6 gives an example of one country – in this case, Germany – in close proximity to another – in this case, Austria – losing importance when value-added trade is taken into account.[15] In the case of IOREER, Germany's weight declines even further, reflecting large trade flows of intermediate products to Austria.

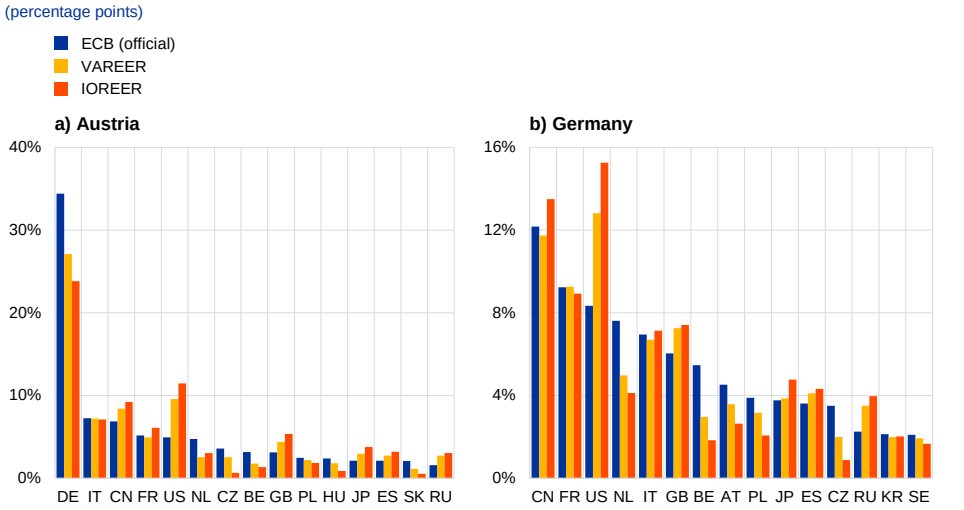
Large but remote economies on the other hand, such as the United States, become more important trading partners, as shown by the examples of Germany and Austria (see Chart 6). IOREER and VAREER therefore tend to affect in particular

[15] In the case of these two countries, an intuitive example of low value-added trade is online retail sales. About half of Austria's total online retail sales volume is accounted for by imports from Germany. For instance, purchases made on the website amazon.at are in fact serviced from the multinational's warehouses located in Germany, which in turn are supplied with final consumer goods from third countries.

the weights of some countries that are either very large economies or are nearby economies that are large relative to the home country.

Chart 6

Comparison of IOREER and VAREER weights with conventional trade weights



Sources: Bems and Johnson (2015), ECB and ECB staff calculations.

This in turn explains why, despite the significant absolute differences between gross trade weights on the one hand, and IOREER and VAREER weights on the other, their correlation remains high, as the ranking of country weights is less affected.

2.1.3 Do GVC-adjusted REERs provide new insights into euro area countries' competitiveness?

Conventional REERs are highly correlated with IOREERs and VAREERs, and this correlation is even stronger than the correlation between the underlying gross value trade weights on the one hand and the IOREER and VAREER weights on the other (see Table 2). This reflects the fact that, in addition to the weights, the bilateral exchange rates are also – independently from the weighting scheme – highly correlated. For instance, given that the Hong Kong dollar is pegged to the US dollar, any shift between the trade weights that a country attaches to the United States and Hong Kong does not affect the country's effective exchange rate. This effect is particularly pronounced when one considers the REERs of the individual euro area countries, since a large share of euro area countries' trade takes place within the euro area and therefore at constant nominal exchange rates.[16]

[16] In fact, even in the absence of fixed exchange rate regimes or specific exchange rate policies that may lead to high correlation of exchange rates, it can be theoretically argued that bilateral exchange rates should display a fairly high degree of correlation. This would be the case because the exchange rate is defined as the relative price of a country's currency vis-à-vis the currencies of other countries, and movements in the (latent) price of the home currency, reflecting idiosyncratic shocks, are directly reflected in the movements of all bilateral exchange rates.

Table 2

Coefficient of correlation with REERs: IOREER and VAREER

	AT	BE	CY	DE	ES	FI	FR	GR	IE	IT	LT	LU	LV	MT	NL	PT	SI	SK
IOREER	0.86	1.00	0.99	0.96	1.00	0.76	0.99	0.97	0.98	0.97	0.98	0.82	0.99	0.97	0.97	1.00	0.96	1.00
VAREER	0.97	0.99	0.9	0.99	1.00	0.98	1.00	0.99	1.00	0.99	0.97	0.99	0.99	0.98	0.99	0.99	0.99	1.00

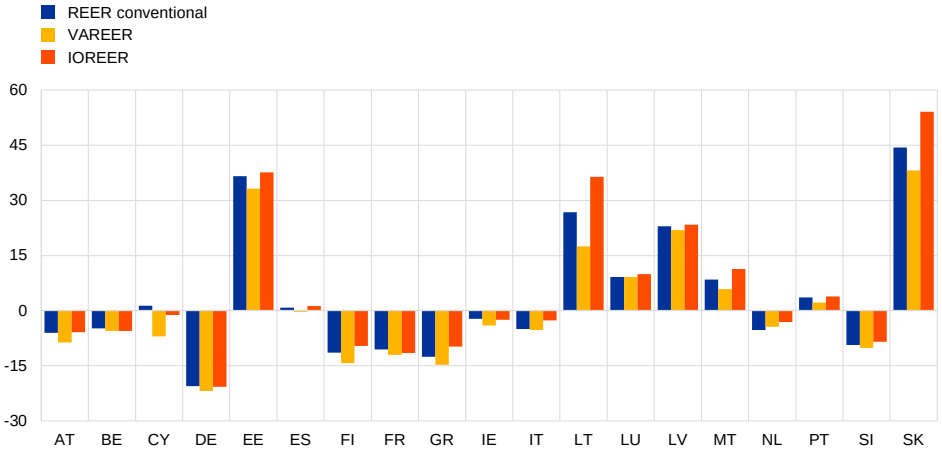
Sources: Bems and Johnson (2015), ECB and ECB staff calculations.

Compared with conventional REERs, both IOREERs and VAREERs largely deliver consistent messages on competitiveness, as the difference between the indicators in terms of their evolution is quantitatively fairly small (see Chart 7). The ECB's official REERs therefore offer broadly equivalent information on competitiveness trends without taking value-added trade explicitly into account.

Chart 7

Changes in conventional REER, IOREER and VAREER

(percentage change, Q1 1999-Q3 2015)



Sources: Bems and Johnson (2015), ECB and ECB staff calculations.

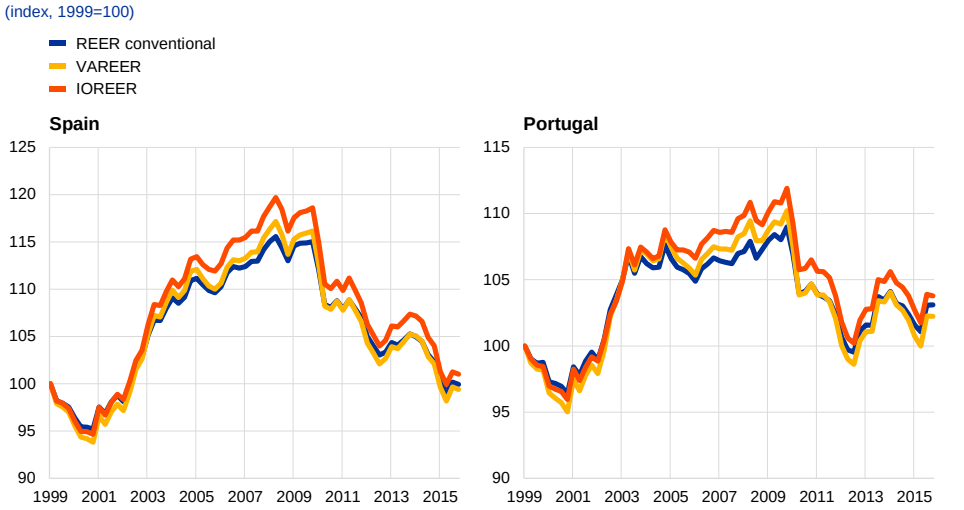
However, a clear pattern emerges in the differences between the different effective exchange rates.

- **Since the introduction of the euro, VAREERs have, for most countries, indicated a slightly less strong appreciation (or more pronounced depreciation) compared with conventional REERs.** This implies that the real exchange rates of euro area countries have tended to be weaker vis-à-vis high-value-added economies compared with other economies over the period concerned.
- **At the same time, IOREERs have indicated somewhat stronger appreciation (or less pronounced depreciation) than VAREERs and conventional REERs.** This in turn implies that real exchange rates vis-à-vis economies from which the euro area mainly imports intermediate goods have performed more weakly.
- **In addition, stressed euro area countries recorded larger appreciations, particularly in IOREERs, in the run-up to the crisis, followed by larger**

improvements in IOREERs during the adjustment period (see Chart 8). This suggests that differences in the evolution of REERs may bring insights into the analysis of price competitiveness trends. For instance, further analysis may show whether IOREERs reflect changes in competitiveness in a more pronounced way than traditional REERs.

Chart 8

Comparison of IOREER and VAREER and conventional REER indices



Sources: Bems and Johnson (2015), ECB and ECB staff calculations.

To further illustrate the source of the differences in development among the three indicators, we examine a decomposition of the differences between the changes in conventional REERs and changes in VAREERs and IOREERs. Consider that the change in the real effective exchange rate ($REER$) is defined as the weighted sum of bilateral real exchange rate changes (RER_i) as follows:

$$\Delta lnREER = \sum_{i=1}^{n} w_i \Delta lnRER_i$$

where w_i are the trade weights. Then the difference between the changes in two REERs, say $REER^{GVC}$ and $REER^{CON}$, which are calculated on the basis of two different sets of weights, w_i^{GVC} and w_i^{CON}, is the following:

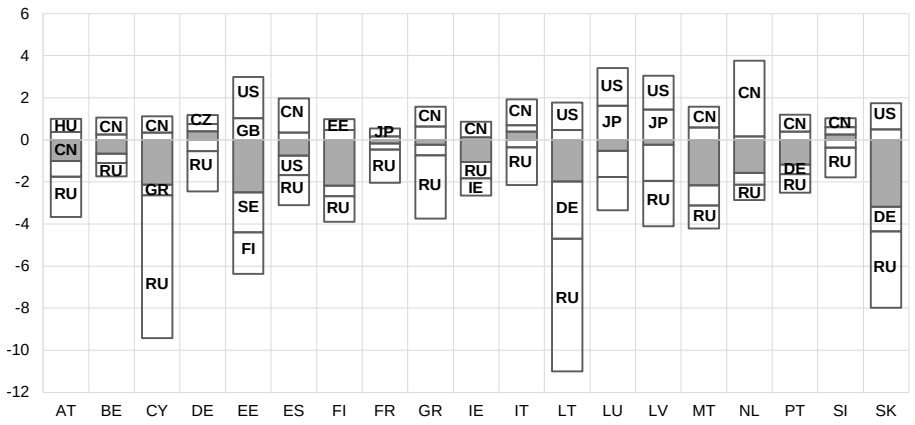
$$\Delta lnREER^{GVC} - \Delta lnREER^{CON} = \sum_{i=1}^{n} (w_i^{GVC} - w_i^{CON}) \Delta lnRER_i$$

From this expression it follows that differences between the effective exchange rates are larger (i) the more the weight of a trading partner deviates and the same time (ii) the more the exchange rate vis-à-vis the currency of this trading partner moves. Charts 9 and 10 below show the largest positive and negative contributions of the bilateral exchange rate movements to the differences between the changes in VAREERs (and IOREERs) relative to conventional REERs. For the sake of visibility, the contribution of the currencies of the remaining trading partners is aggregated in grey bars. The following can be observed.

Chart 9

Contributions to differences between the changes in VAREERs relative to conventional REERs

(percentage contribution)

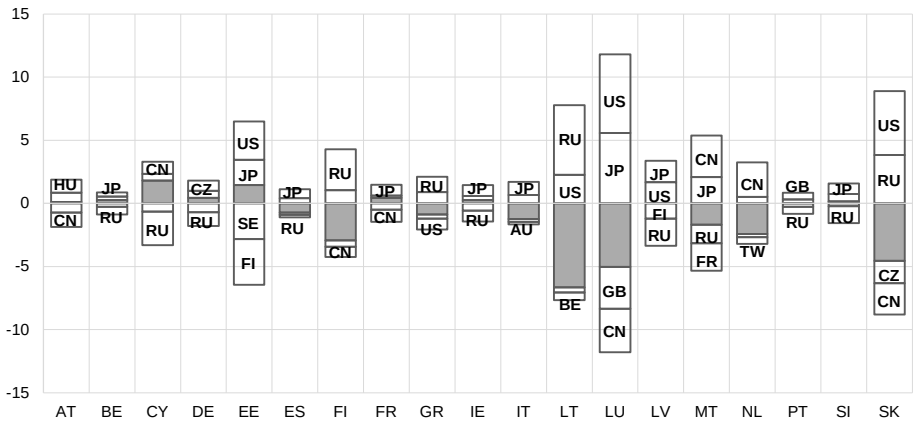


Sources: Bems and Johnson (2015), ECB and ECB staff calculations.

Chart 10

Contributions to differences between the changes in IOREERs relative to conventional REERs

(percentage contribution)



Sources: Bems and Johnson (2015), ECB and ECB staff calculations.

Since the introduction of the euro, euro area countries have fared better in terms of competitiveness when a GVC-based measure of the effective exchange rate is used. This is largely because of the very substantial real appreciation of the rouble. Over the period under review, 1999 to 2016, the rouble appreciated by more than 100% in real terms *vis-à-vis* the euro. Its higher weight in the value-added based effective exchange rate therefore results in a large negative contribution to the GVC-based REER, more than compensating for the reduction in the weight of China.

Considering the role of trade in intermediate goods (i.e. the negative impact on competitiveness of depreciation vis-à-vis intermediate goods producers' currencies), it turns out that the rouble's appreciation had a more limited beneficial effect than suggested by VAREERs on the competitiveness of euro area countries. This reflects the fact that Russia is largely an intermediate goods exporter. At the same time, the real appreciation of China for some countries is reflected in a larger improvement in competitiveness. On the one hand, the low value added of Chinese products results in China having a lower weight in the VAREER, which reduces the positive impact of China's appreciation on the competitiveness of euro area countries compared with when the focus is placed on gross trade. On the other hand, the relatively high share of final consumption goods in Chinese products increases China's weight in the IOREER. As a result, the depreciation *vis-à-vis* China appears to have a more beneficial impact on competitiveness when considering IOREERs than when considering VAREERs or conventional REERs.

Box 4
Adaptation of Bems and Johnson (2015) to the ECB's methodology

In line with standard practice, REERs of the euro area for instance are calculated as geometric weighted averages of bilateral nominal exchange rates which are deflated using relative price or cost measures:

$$REER^t = \prod_{i=1}^{N} \left(\frac{d_{euro}^t e_{i,euro}^t}{d_i^t} \right)^{w_i}$$

where N stands for the number of competitor countries in the reference group of trading partners, $e_{i,euro}^t$ is an index of the average exchange rate of the currency of partner country i *vis-à-vis* the euro in period t, d_{euro}^t and d_i^t are, respectively, the deflators for the euro area and partner country i, and wi is the trade weight assigned to the currency of trading partner i. Specifically, we calculate the indicators in this study in the following way.

1. While the ECB's gross trade weights are based on manufacturing trade from various data sources, Bems and Johnson use data from the WIOD, which provides information on bilateral value-added trade.

2. The ECB's list of trading partners comprises 57 countries (including all EU countries), while Bems and Johnson cover only 40 countries (including all EU countries – except for Croatia), covering around 95% of ECB trade weights.[17] As a benchmark, we thus recalculate the ECB official effective exchange rates for Bems' and Johnson's country sample. In doing so we can isolate the effect from using VA and IO weights, without this assessment being blurred by differences in the country sample.

3. Bems and Johnson compute annual trade weights over the period 1995-2011, which we make consistent with the ECB's methodology by using three-year non-overlapping trade weights.

[17] In contrast with the EER-38 – a broad group of 38 partner countries against which the ECB computes nominal and real effective exchange rate indices – Algeria, Argentina, Chile, Croatia, Hong Kong, Iceland, Israel, Malaysia, Morocco, New Zealand, Norway, Philippines, Singapore, South Africa, Switzerland, Thailand and Venezuela are missing from Bems' and Johnson's dataset.

4. In line with Bems and Johnson, we use the GDP deflator as our relative price measure, as the literature establishes this to be the soundest deflator theoretically when value-added trade is considered.

2.2 Export market shares[18]

2.2.1 Introduction

GVCs and outsourcing of production diminish the domestic content of exports, which implies that the distinction between production and assembly is crucial. Consequently, the traditional gross export market shares are no longer an adequate representation of a country's ability to produce goods for the world market. This chapter reports the changes in market shares of the euro area countries when value-added content is taken into account. More importantly, we show that focusing on trade in value added alters our understanding of the driving forces behind global market shares.

Our methodology has some similarities to that of the VAREER proposed by Bems and Johnson (2015) and discussed in Section 2.1, since we also use weights based on the trade in value added. However, we differ in several important aspects. First, we work with highly disaggregated trade data, which allows us to relax some restrictive assumptions: changes in individual product prices can differ from the aggregated price index, and the elasticity of substitution varies for each commodity. Second, in addition to price factors we evaluate the following contributions to observed market shares: changes in the extensive margin, shifts in global demand structure and global production chains, changes in the set of competitors and, finally, residual non-price factors that can to a large extent (but not solely) be attributed to changes in product quality and consumer taste. In this way we obtain a complex view of a country's global market share over time.

We combine data from two sources. First, we make use of highly disaggregated bilateral trade data from the UN Comtrade database (HS six-digit level, i.e. more than 5,000 products for each possible pair of trading partners). The use of detailed trade data allows us to disentangle price and non-price drivers of export market share changes, since we can interpret unit values as prices of cross-border transactions. However, trade data disregard international production fragmentation, which may alter the assessment of a country's performance on the global market. Therefore, we also make use of the WIOD (2016 release, see Timmer et al., 2015 and Timmer et al., 2016). Although available at a lower level of disaggregation and with a time lag, it still allows us to infer something about the performance of euro area producers in external markets and thus improves our understanding of competitive strengths and weaknesses.

[18] By Konstantins Benkovskis and Julia Wörz.

2.2.2 Improving the measure of global market shares

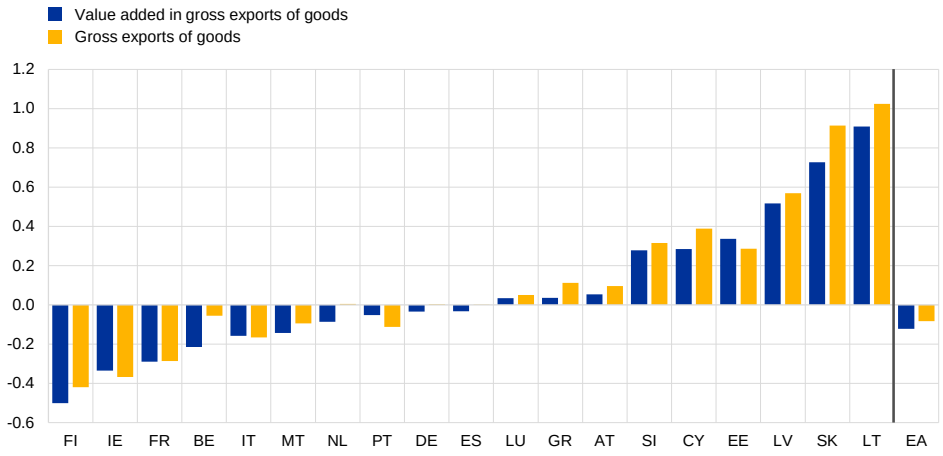
To account for the ongoing fragmentation process, gross exports data can be corrected for the source of value added. We therefore suggest focusing on the market shares of value added in exports of goods (the lack of detailed data on service exports does not allow us to use value added in exports of goods and services).

The measure called "value added in exports" traces gross exports by producer country (see, for example, Koopman et al., 2010 and Box 1). By combining the information on the country structure of value added with detailed UN Comtrade trade data, we calculate the share of country A in the production of country B's exports of good C, i.e. we focus on market shares of value added in exports. The lower level of disaggregation in WIOD compared with UN Comtrade presents some difficulties, and we need to assume an equal structure of value added for all HS six-digit level products within a broad CPA category. This is a strong assumption, but we have no alternative for the analysis at the macro level.

Moving to the analysis based on the value added does not alter the general picture much. Chart 11 reports the changes in euro area countries' market shares of value added in exports of goods and compares it with the dynamics of conventional global market shares based solely on trade data. Value-added shares deliver the same message as gross trade shares: between 2000 and 2014, old euro area countries lost global market share while new euro area member countries gained global market share . In addition, changes in global market shares are usually similar for gross exports and value-added concepts.

Chart 11

Changes in global market share of euro area countries between 2000 and 2014



Sources: WIOD, UN Comtrade, Latvijas Banka and Oesterreichische Nationalbank staff calculations.
Note: Cumulative log changes in global market shares are shown.

Market share gains are somewhat smaller for several new euro area countries, namely Lithuania, Slovakia, Latvia and Slovenia, when the source of the value added is taken into account. In the case of Slovenia and, especially, Slovakia, the difference can be explained by the outsourcing of the final assembly of motor vehicles from old EU countries. Although the process is less intensive, we also note a similar

shift in the manufacture of food products, chemistry and wood products to Lithuania and Latvia. However, it is more difficult to explain the higher losses suffered by Belgium and Netherlands in terms of value added.

2.2.3 Methodology

We can dig further and uncover the determinants of changes in global market shares. Given the detailed information on prices and volumes of trade flows at a highly disaggregated level, we can decompose changes in global market shares further using a methodology developed in Benkovskis and Wörz (2015). First, we distinguish between the extensive and intensive margin of export growth. Intensive margin growth can be decomposed further into shifts in global demand structure and growth in bilateral trade relationships.

Three important components can in turn be extracted from the latter effect.

- **Contribution of shifts in production chains.** A change in a country's value-added contribution in export activities may affect value-added global market share. This can be achieved either by a change in the domestic content of a country's own gross exports of final products, or by different involvement in GVCs and value-added share in other countries' exports of goods.
- **Contribution of price factors.** This component is analogous to changes in the REERs (although positive effects become negative, and vice-versa) using value-added weights. In contrast to the analysis in Section 2.1, we use export prices derived from unit values, which are available at the most detailed level of disaggregation. Unfortunately, information on input costs is unavailable at such disaggregated level, so we are forced to assume that final price changes are equally distributed at all stages of production.
- **Contribution of residual non-price factors.** This component can be loosely related to factors such as relative product quality or the value attached by consumers to trade products. Although these characteristics are statistically unobservable, their contribution can be calculated as a residual at the disaggregated level.

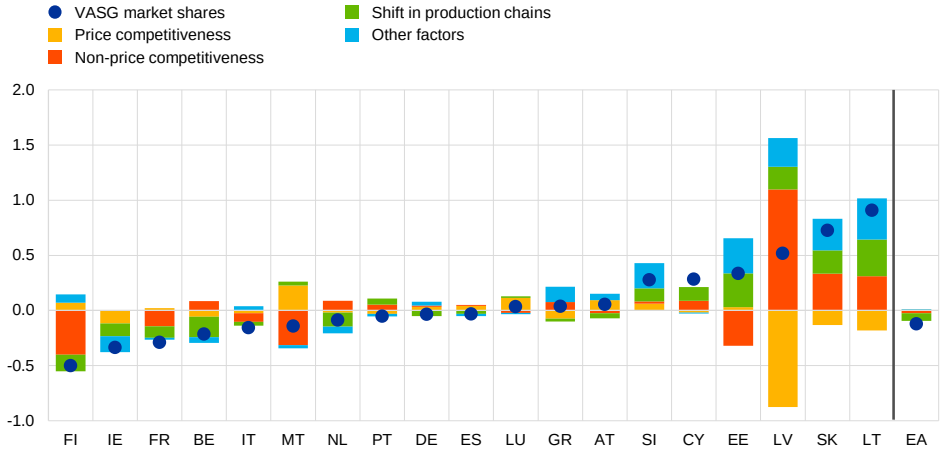
2.2.4 Major factors behind changes in market shares

Price and residual non-price factors contribute most strongly to changes in market shares of value added in exports of goods (Chart 12). However, shifts in global production chains also exert a non-negligible negative contribution to changes in market shares of old euro area members (with the only exception for Portugal). Outsourcing production to other countries directly implies losses of global market shares. In the period under review, this outsourcing was mainly directed towards developing countries outside the EU (China, Turkey) and CEE countries (Czech Republic, Slovakia, Poland, Hungary). At the same time, shifts in global production

chains substantially increased the value-added market shares of new euro area countries.

Chart 12

Decomposition of value added in goods export market share changes between 2000 and 2014



Sources: WIOD, UN Comtrade, Latvijas Banka and Oesterreichische Nationalbank staff calculations.
Notes: Other factors include extensive margin, set of competitors and shift in demand structure. Cumulative log changes of global market shares are shown.

The analysis of other factors also delivers useful insights: in most cases we observe a positive contribution from residual non-price factors to value-added market share gains of new euro area members. Although residual non-price factors reflect the unexplained part of the analysis, they can be related to changes in the relative quality of production or consumer taste. For instance, most of the new euro area members experience a significant positive contribution from non-price factors, which more than compensates for losses in price competitiveness over the same period. In other words, a relative increase in the price of value added of those countries is accompanied by even higher growth in relative quality or consumer taste.

Results for the old euro area countries broadly mirror those for new ones. A substantial part of losses in value-added export market shares arise from residual non-price factors (except in the cases of Belgium, the Netherlands and Germany), while prices and costs are of secondary importance. If it is assumed that residual non-price factors mostly reflect quality and taste, then developed countries face a decline in the relative quality of their value added in world trade or in the value attached by consumers to their products.

2.2.5 The impact of GVC integration on market share growth

As mentioned above, the difference between changes in value added in gross exports and gross export market shares is fairly small for most countries in our sample. Therefore, international fragmentation of production does not change the evaluation of competitiveness per se. However, taking GVCs into account changes our understanding of the factors driving competitiveness. Table 3 provides a comparison

between price and non-price competitiveness evaluations in two cases: one where GVCs are taken in to account and one where the focus is solely on gross exports. To make the comparison more meaningful, countries are sorted according to the contribution of shifts in production chains.

Table 3

The contribution of price and non-price competitiveness to value added in gross exports and to changes in gross export market share between 2000 and 2014

		Price competitiveness			Non-price competitiveness		
Country	Shift in production chains	Value added in gross exports	Gross exports	Difference	Value added in gross exports	Gross exports	Difference
Lithuania	0.33	-0.18	-0.25	0.07	0.31	0.55	-0.24
Estonia	0.31	0.03	-0.29	0.32	-0.32	-0.03	-0.29
Slovakia	0.21	-0.13	-0.02	-0.12	0.33	0.41	-0.08
Latvia	0.21	-0.88	-0.96	0.08	1.10	1.44	-0.35
Cyprus	0.12	-0.02	-0.20	0.18	0.09	0.33	-0.25
Slovenia	0.12	0.06	-0.09	0.15	0.02	0.28	-0.26
Portugal	0.06	-0.03	-0.04	0.01	0.05	0.16	-0.10
Malta	0.04	0.23	0.24	-0.01	-0.32	-0.47	0.15
Luxembourg	0.01	0.11	0.15	-0.03	-0.02	-0.22	0.20
Greece	-0.03	-0.08	-0.17	0.09	0.08	0.21	-0.14
Spain	-0.03	0.04	0.04	0.00	0.01	0.03	-0.02
Italy	-0.03	-0.03	-0.07	0.05	-0.08	-0.06	-0.02
Austria	-0.05	0.09	0.01	0.08	-0.03	0.05	-0.07
Germany	-0.05	0.03	0.06	-0.02	0.01	-0.03	0.04
France	-0.11	0.02	0.08	-0.06	-0.14	-0.31	0.17
Ireland	-0.11	-0.12	-0.18	0.06	0.00	-0.04	0.04
Netherlands	-0.13	-0.02	0.00	-0.02	0.09	0.13	-0.04
Finland	-0.15	0.07	0.04	0.03	-0.40	-0.56	0.15
Belgium	-0.18	-0.06	-0.09	0.04	0.08	0.12	-0.03

Sources: WIOD, UN Comtrade, Latvijas Banka and Oesterreichische Nationalbank staff calculations.
Note: The contribution to cumulative log changes in global market shares is shown.

The story behind market share drivers changes significantly when GVCs are included in the analysis. The conventional analysis (ignoring international fragmentation of production) tends to exaggerate the importance of residual non-price factors. Typically, non-price competitiveness gains are overestimated for new euro area economies: relative taste and quality gains diminish when attention is shifted from gross exports to value added in exports – even though these improvements remain impressive.

Taking international fragmentation of production into account reduces unexplained gains in global market shares. However, the positive contribution of residual non-price factors still signals an important role for quality improvements. We interpret this finding from two different angles. First, outsourcing positively affects the competitiveness of new euro area members. Therefore, an apparent increase in relative quality or the value attached by consumers to their export goods does not fully reflect quality improvements in their domestic production but is also influenced by the

possibility of processing higher-quality inputs or incorporating higher-quality production stages within the production chain. Note that the greatest decline in the contribution of residual non-price factors is observed for countries that experience large positive shifts in production chains. Second, the role of residual non-price factors tends to be overstressed in conventional analyses, since taking GVC integration into account improves our ability to explain market shares dynamics by changes in relative prices.

At the same time, the negative contributions of residual non-price factors to market share dynamics of the old euro area countries tend to be reduced when market shares are calculated in terms of value added. This reflects the indirect contribution of developed countries to the production of high-quality products in emerging and developing market economies. The most striking cases are France and Finland. However, we also observe several old euro area countries – Netherlands, Austria and Italy – where the contribution of residual non-price factors was slightly lower in value added terms compared with gross exports during the period under review.

Although the pattern is less obvious, the contribution of price and cost factors to market share gains of new euro area Member States is usually underestimated when international fragmentation of production is ignored. Despite the fact that we use unit values instead of the GDP deflator, this finding is in line with the results reported by Chart 7 in Section 2.1: VAREERs tend to indicate smaller appreciation compared with traditional REERs. As for the old members, shifting our focus to value added in exports does not affect the contribution of price and cost factors significantly.

2.2.6 Concluding remarks

Taking the value-added content of exports into account does not alter our traditional wisdom about global market share developments: new euro area countries are gaining market share at the expense of old euro area economies. But acknowledging international fragmentation alters the underlying story to a considerable extent, which carries important policy implications.

First, our results show that the global production process is gradually shifting towards CEE and emerging market economies, so outsourcing as such is contributing positively to market share changes (in terms of value added) in those countries and is eroding rich euro area countries' market shares.

Second, the concept of value added in exports and the switch to a weighting scheme based on value added in exports reduces the contribution of residual non-price factors in explaining market share gains and losses. As a result, cost and price factors explain a larger fraction of the dynamics of market shares. In the conventional view (based on gross exports), relative price changes explain only a small part of the changes in global market shares, and the largest contribution comes from residual non-price factors. This unexplained part can be loosely associated with changes in quality or taste. Therefore, the trend in the relative quality of old euro area Member States' and other developed countries' exports is declining in gross trade,

while new euro area members and developing countries are showing large gains in the relative quality of their exported products. When we assess export strength in terms of value added, the gains in non-price competitiveness by new euro area countries' producers often become smaller while a positive impact from shifts in global production is observed. In addition, the apparent decline in price competitiveness of these countries appears less of a concern when the value-added viewpoint is adopted.

2.3 Global value chains and intra-euro area rebalancing[19]

2.3.1 Introduction

In the years preceding the crisis, several euro area countries (Greece, Ireland, Portugal, Cyprus, Spain, Slovenia and Italy) accumulated macroeconomic imbalances. This included an unsustainable current account deficit (albeit to different degrees), including vis-à-vis intra-area trading partners. Since then, these countries (which we refer to in this paper as "vulnerable" countries) have undergone a process of external rebalancing; all of them except for Greece and Cyprus are now running current account surpluses.

In this section we look at this rebalancing process from a particular angle, namely the role that vulnerable countries have been playing in the pan-European contribution to international production sharing. We focus on nominal trade in goods and services, leaving aside the other components of the current account.

The value-added concept, as opposed to the gross trade concept, allows us to disentangle the purely domestic contribution of vulnerable countries' net trade to GDP from the foreign value added embedded in their exports. As explained in the introduction to this paper, the increasing fragmentation of production processes across the globe has resulted in large increases in trade in intermediates and rendered the gross trade flows measured by trade statistics less informative than in the past. We therefore focus on the domestic value added that is exported and used in final demand abroad, which increases the value-added trade balance whereas foreign value added embedded in the same exports does not.[20]

Tracing the different value-added components of trade flows also allows us to examine in detail the role of imports in the vulnerable countries' international production sharing. Using the complete set of World Input-Output Tables (currently available at yearly frequency over the period 2000-14, covering 56 sectors and 43 countries/country groups) from the WIOD, GVC metrics for exports and imports are developed. The inclusion of imports is very important in the context of this study, given their importance for rebalancing.

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19 By Benedetta Di Lupidio, Sebastian Franco-Bedoya and Joachim Schroth.

20 See e.g. Gereffi (2014) for a discussion and examples.

Another key feature of this analysis is that we focus on the value added of individual sectors. In doing so, we capture the direct contribution (via exports of the sector) and indirect contribution (via inputs to exports of other domestic sectors) of each sector to external trade.

Against this backdrop, we assess the role that changes in the activities of the vulnerable countries in GVCs have played in recent years in correcting external imbalances. To control for general trends in GVCs, we also look at the other countries that feature in the WIOD. In particular, we use as benchmarks the two largest euro area countries, France and Germany.

This section is structured as follows: in Section 2.3.2 we break down sector-level gross exports into various value-added components and double-counted items, and present some results for the vulnerable countries of metrics derived from this decomposition, computed from the WIOD data; in Section 2.3.3 we then analyse the adjustment in value-added exports and imports since the start of the crisis in the vulnerable countries, taking account of GVC indicators.

2.3.2 Vulnerable countries and GVCs

In this section we look at the decomposition of exports and the related GVC indicators of vulnerable countries, as introduced in Box 1, applied to all bilateral sector-level gross exports in the WIOD. Although we show results for the vulnerable countries and the two benchmark countries only, we have also run a comparison with the remainder of the WIOD dataset to determine whether the results reflect general patterns shared across all countries or whether they are specific to the euro area.

The results of this decomposition can be used to analyse the GVC developments of each country-sector pair. For example, the manufacture of chemicals and chemical products is one of the major export sectors in the euro area, accounting for more than 5% of gross exports in five out of the nine (vulnerable plus two benchmark) countries examined in detail here. Gross exports of the sector experienced a positive trend over the period 2008-14, growing at double-digit rates in four out of nine countries. Looking at value added instead of gross trade changes the picture substantially. On average, increases in the sector's value-added exports were almost zero, and Italy for instance moved from increases to double-digit decreases. The industry is, on average, significantly less important in value added terms than in gross trade terms. It is positioned slightly upstream in the value chain for most countries, and GVC participation is higher than in other sectors, mostly via greater foreign value added embedded in exports, although the picture varies across countries. The foreign value added appears to be mostly relevant for final goods exports, and predominantly originated from intermediate inputs of direct trade partners, in particular the United States. Both the length of the supply chains and the distance to final demand lengthened during the period 2008-14. While all of these observations can be refined further to identify direct and indirect trade counterpart countries and sectors for value added, in this analysis we are interested in the impact

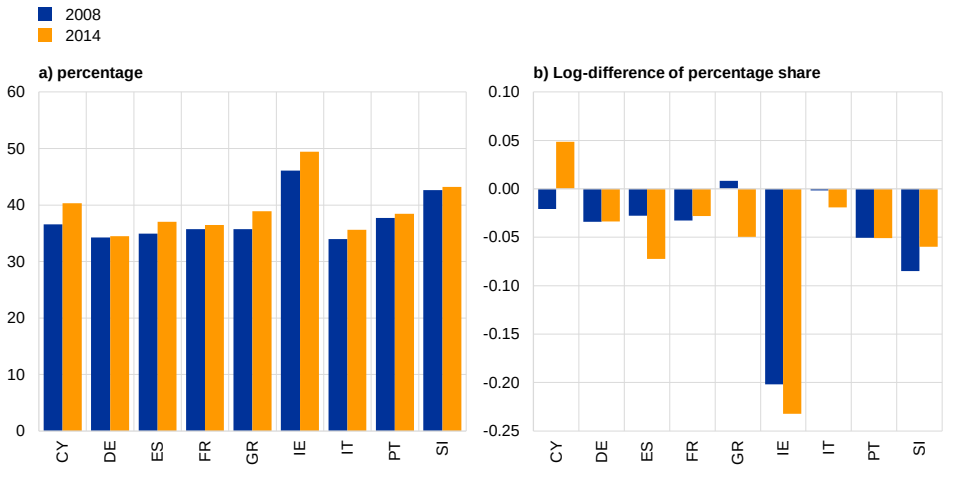
that all of these individual developments taken together had on the trade balance in the period under review.

We aggregate the GVC indicators across sectors, using export shares to identify some stylised facts about the involvement in GVCs of sectors in the vulnerable countries. We find that, on average, the sectors in the vulnerable countries show value chain participations slightly *higher* than those of Germany and France, with the exceptions of Italy, which shows participation similar to the two benchmark countries, and Ireland, where participation is significantly higher.

Interestingly, GVC participation increased slightly across the vulnerable countries after 2008 (as it did in the pre-crisis years since the beginning of the sample in 2000), in contrast to Germany, where it was virtually unchanged, and to the general global trend, which, as we have seen in Chapter 1, went in the opposite direction. Most of the increase in participation came from higher foreign value added embedded in exports.

Chart 13

Average GVC participation and positioning across vulnerable countries (2014 vs 2008)



Sources: WIOD 2014 and ECB staff calculations.

Looking at the average positioning of the vulnerable countries within value chains (using the Koopman formula from Box 2), we note that, on average, these countries occupy similar positions to Germany and France, i.e. they are slightly downstream by global standards. Ireland is an outlier in this case, too: it is far more downstream in the value chain, mainly because some of its services sectors are downstream, while in the other countries these sectors occupy upstream positions. Spain, Greece and Italy have moved downstream since 2008. For Spain, this has been mainly driven by car manufacturing, as described above. For Greece, this is largely a composition effect arising from downstream sectors having gained export share from upstream ones. For Italy, the move downstream is smaller but broadly based across sectors. France, Cyprus and Slovenia have by contrast moved upstream since 2008, partly reflecting a repositioning of some of their main export sectors, and partly reflecting composition effects. As positioning is a zero-sum game

from a global perspective[21] (as opposed to participation, where countries can jointly increase/decrease), the movements of some sectors over time, particularly downstream, are also due to the increasing integration of non-European countries in the value chains (in particular Brazil, Russia, India and China) and, therefore, do not necessarily signal structural changes in the countries under consideration.

Looking at the details of the composition (see Table 4), the share of foreign value added (backward participation) is somewhat higher in the vulnerable countries than in Germany and France, except in the cases of Italy and Cyprus. However, this may be partly attributable to country size: larger countries tend to have less need to source inputs from abroad (see Van der Marel, 2015 and Box 1 in this paper). In terms of domestic value added re-exported by the trade partner (as a proxy for forward participation), again the vulnerable countries are close to or slightly above Germany and France, except in the case of Ireland – reflecting its position far downstream in the value chain.

Table 4

Summary indicators for GVC participation and positioning across countries, 2014

	GVC positionin, all sectors	GVC integration, all sectors	Ind DVA exports, all sectors	FVA, all sectors	GVC positioning, medium/ high-tech	GVC integration, medium/ high-tech	Ind DVA exports, medium/ high-tech	FVA, medium/ high-tech
Cyprus	0.05	40.3	23.1	17.1	-0.24	41.5	6.7	34.8
Germany	-0.03	34.5	15.3	19.2	-0.08	35.7	13.5	22.2
Spain	-0.07	37.0	14.0	23.0	-0.15	45.0	13.4	31.6
France	-0.03	36.5	16.5	20.0	-0.11	41.4	14.0	27.4
Greece	-0.05	38.9	16.3	22.6	-0.01	32.8	16.2	16.5
Ireland	-0.23	49.4	10.0	39.4	-0.23	52.2	11.5	40.6
Italy	-0.02	35.6	16.7	18.9	-0.05	38.3	16.0	22.3
Portugal	-0.05	38.4	16.0	22.4	-0.15	48.2	14.8	33.5
Slovenia	-0.06	43.2	17.9	25.3	-0.16	44.8	12.4	32.4

Sources: WIOD (2016 release) and Wang et al. (2013).
Note: Positive (negative) values imply an upstream (downstream) position in GVCs.

Looking specifically at the medium-to-high-tech and high-tech sectors,[22] these show above-average participation in GVCs, as could be expected. For these sectors, France shows a significantly higher participation than Germany, whereas Greece stands out for having a relatively low participation and a more upstream position than for its economy as a whole. The GVC position indicator can be complemented by another indicator explicitly measuring the length of the value chain, separated by backward value chain length (i.e. the average number of production processes before the product reaches the sector) and forward value chain length (i.e. the number of production processes between the sector and final demand).

To sum up, the vulnerable countries are participating somewhat more than Germany and France in GVCs and occupy similar, albeit rather more

[21] This is the case although, as mentioned in Box 2, the "neutral" position according to the measure chosen is not zero, but slightly in the downstream area.

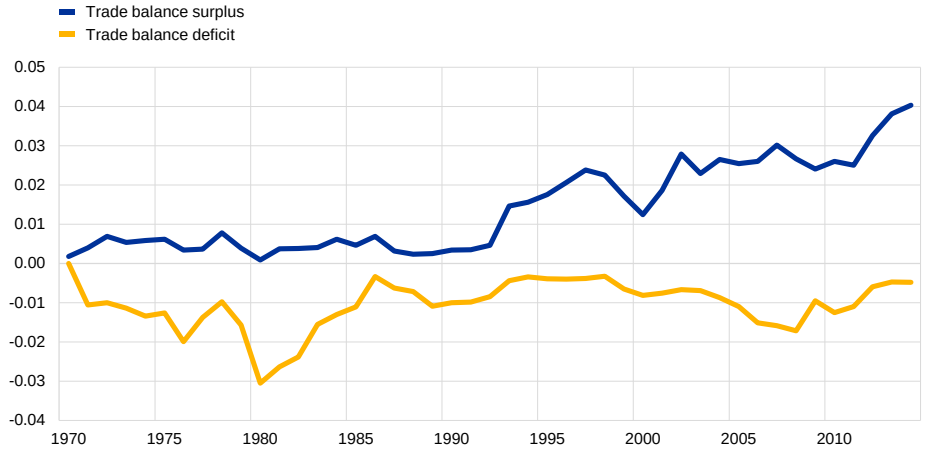
[22] Chemicals and chemical products and all kinds of machinery and equipment.

downstream, positions. In the next section we relate these results to the external rebalancing which has taken place in the vulnerable countries since the crisis.

2.3.3 GVCs and rebalancing in the vulnerable countries

In this section we shed some light on the role of GVCs in the trade rebalancing of the vulnerable euro area countries (depicted in Chart 14).

Chart 14
Trade balances of euro area surplus and deficit countries (ratio to GDP)



Source: World Development Indicators (World Bank).

To do so, we make use of two methodological approaches. First, we present the results of an accounting framework that decomposes changes in trade balances into different factors and allows us to assess the relative importance of final demand shifts, competitiveness trends and changes in international production structures in the rebalancing in the vulnerable countries. We then look explicitly at the role of GVCs in the rebalancing process. We do this by augmenting trade equations, expressed in value added terms with the GVC metrics presented above, in a cross-country, cross-sector panel.

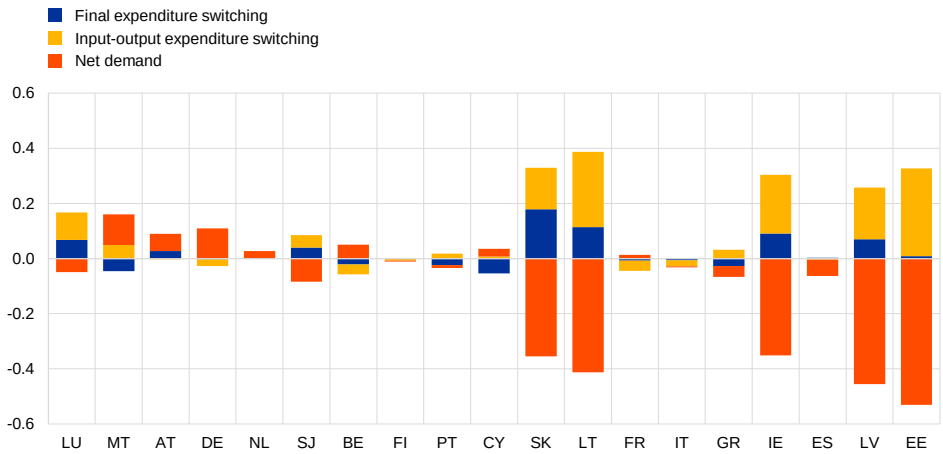
In the following part, we present an accounting framework that sheds some light on the drivers of trade imbalance dynamics, implicitly taking into account the GVC dimension. This approach distinguishes changes in trade balances due to changes in domestic versus foreign final demand (relative demand) and changes in the share of foreign (domestic) expenditure on domestic (foreign) goods (expenditure switching). The approach is based on the same sector-country WIOD information as the GVC indicators presented in the previous section. It takes into account forward and backward linkages of each country and the whole domestic and international production network. However, instead of decomposing value added in exports according to their role in GVCs, this approach looks at gross trade, including imports, and how it is affected by changes in final demand and shifts in the use of domestic and foreign inputs in the world input-output production structure.

Taking aggregate demand as given, the expenditure switching component can be interpreted as a measure of trade performance. It can be decomposed further into two components, one being an expenditure shift in final demand, and the other an expenditure shift in intermediates. A change in the share of domestic goods in final demand (absorbed domestically or by trading partners) may reflect, among other things, price and non-price factors affecting domestic competitiveness, while shifts between domestic and foreign intermediates at a given demand reflect changes to the domestic and international input-output structure of production, which may be associated with activities in GVCs. Here we follow Franco-Bedoya (2018): in a multi-country, multi-sector framework we control for the total final demand changes to obtain the trade performance components in final goods. Changes in the coefficient matrix are assigned to the trade performance given that final demand does not affect these coefficients. We use sector-level data and then aggregate up to the trade balance-to-GDP ratio.[23] [24] Note that the approach does not establish an explicit link between competitiveness indicators or GVC metrics on the one hand and the trade balance on the other. Furthermore, it does not disentangle price and volume effects or identify individual value chains.

The relative ("net") demand and – to a larger extent – the two trade performance components play a different role for each country. The analysis covers the periods from 1995 to 2007 ("pre-crisis") and from 2007 to 2014 ("crisis"). Charts 15 and 16 show the results for all euro 19 countries. The three components played different roles in both periods across countries. In most cases the relative or net demand component (i.e. the difference between foreign and domestic demand dynamics) can explain most of trade balance adjustment during both the pre- and the post-crisis period. Between 2007 and 2014, the sign of the relative demand component is positive for most countries, reflecting more dynamic final demand in the rest of the world compared with the euro area.

Chart 15

Trade balance dynamics by components ("pre-crisis period": 1995-2007, percentage points of GDP)

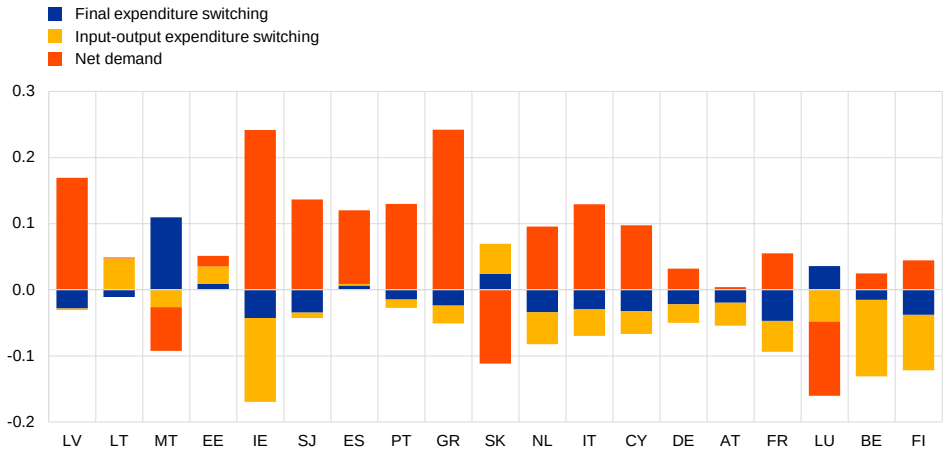


[23] The methodology is explained in full detail in Franco-Bedoya (2017).

[24] See Patel et al. (2017) for a discussion on the importance of the sectoral dimension in GVCs.

Chart 16

Trade balance dynamics by components ("crisis period": 2007-14, percentage points of GDP)



The expenditure switching component had a negative impact on the vulnerable countries' trade balances. Both parts of the trade performance component, final demand and input-output expenditure switching (the latter being the most closely related to GVCs), contributed negatively to the trade balance, in particular in Ireland. Spain is the only exception among the vulnerable countries, having marginal positive contributions to the trade balance over the period 2007-14. The other vulnerable countries, as well as Germany and France, saw negative contributions from both trade performance components, with the share of the input-output expenditure switching being somewhat larger than final demand expenditure switching. One possible reading of the negative contribution of final expenditure switching is that the negative impact on nominal exports resulting from price competitiveness gains achieved over the period could not be fully compensated for by market share gains in real terms, e.g. because non-price competitiveness did not follow suit. At the same time, the negative contribution from input-output expenditure switching to the trade balance may reflect that the increase in participation of vulnerable countries in GVCs over the period 2007-14 mostly came via higher foreign value added embedded in exports, which can have a negative effect on the trade balance.

These results provide some insights into factors which drove trade balance adjustments and highlight the importance of considering integration in GVCs when assessing rebalancing policies. By disentangling the relative role of (the two components of) trade performance and demand growth, this analysis sheds light on the way in which imbalances have been corrected. However, the accounting framework just presented does not clearly identify whether changes in the trade balance are GVC-related – for example, significant changes in the domestic production process would also show as input-output expenditure switching, even if there were no GVCs involved.

In the following part we therefore return to the GVC measures introduced in Box 2, and empirically test their role in the improvement in trade balances. To do

so, we include GVC participation and positioning, as well as additional metrics to characterise the length of value chains, in a standard export equation estimated over the period 2008-2014, with annual changes in exports depending on demand and competitiveness indicators. We use a euro area panel of all WIOD sectors and examine whether GVC indicators can add to the explanation of export developments. As these are defined in terms of value added, we use value-added exports instead of gross exports as left-hand side variable. We include country-sector fixed effects and time dummies, using robust standard errors. The results are shown in Table 5.

Table 5

Estimates of drivers of annual change in components of the value-added trade balance

(sample 2008-14)

	Domestic value added in exports		Foreign value added in imports	
	coeff.	t-value	coeff.	t-value
Prices				
Terms of trade manuf.	0.893	2.1		
Terms of trade services			-0.565	-4.1
Unit labour costs by industry	-0.039	-0.7	-0.041	-2.1
Fuel prices			0.315	5.7
Demand				
Domestic demand			1.124	22.0
Industry-specific world dem.	0.620	7.1	0.403	14.0
GVC indicators				
GVC participation, change	-0.413	-1.9	0.071	2.3
GVC position, change	-1.540	-2.5	-0.073	-1.6
[*memo:* GVC position squared]	-0.443	-4.5		
Backward value chain length	-1.055	-2.9		
Forward value chain length	0.776	4.9		
Constant	0.028	2.8	0.032	8.2
Observations	5,984		6,044	
R^2	0.175		0.579	

We find value-added exports to be heavily driven by global demand for the products of the respective sector, with elasticity of 0.62 (Table 5, first column). Overall world demand by country was found not to provide additional explanatory power – which may not be surprising as euro area countries have the same main trading partners and very similar business cycles – so it was dropped. To capture prices and competitiveness, we use the terms of trade in manufacturing for the manufacturing sectors and the total economy terms of trade for the other sectors, as well as unit labour costs for which a more granular breakdown is available. We find that value-added exports rise as terms of trade in manufacturing increase (which suggests that increases in export prices are not fully compensated for by market share losses), while estimates for the other sectors are not significant. Lower sectoral unit labour costs do not significantly increase value-added exports over the sample.

However, as they are significant when including the pre-crisis sample, we keep them in the regression.[25]

Turning to the GVC indicators, the downstream movement seen in most vulnerable countries between 2008 and 2014 was beneficial for their value-added exports during the rebalancing process. Changes in GVC participation after the crisis are estimated to have had a negative (in contrast to the majority view of the literature) but not statistically significant impact on growth in value-added exports over the sample period. However, as in the case of unit labour costs, the effect of these changes turns significant when the pre-crisis period is included and is therefore kept in the regression. Changes in GVC position are found to have a significant impact over the sample, with a move downstream increasing value-added exports. In contrast, the level of participation and positioning do not seem to play a significant role in explaining the adjustment in value-added exports over the sample. To test the hypothesis of a u-shaped value-added curve, we include quadratic terms for the GVC position, but since the parameter estimate did not yield the expected sign over different samples and after outlier elimination, they were dropped. As regards the length of the value chains on the sourcing side and the demand side, we find the distance to final demand to have a highly significant positive impact and the length of the sourcing chain to have a significant negative impact on value-added exports. While the latter may be read as downstream movements over the sample period having had particularly positive impacts on value-added exports in value chains where upstream parts of the value chain have become more fragmented, the former might relate to sectors entering value chains for more sophisticated products with value added concentrated downstream (GVC upgrading). However, these results are to be interpreted with caution as they are not very robust to variation of sample and specification.

The finding that changes in net demand made a major contribution to the vulnerable countries' improvement in trade balances suggests that imports should be included in the analysis.[26] As pointed out by Wang, Wei and Zhu (2016), sectoral analysis also makes it possible to identify the processing of foreign inputs into intermediate or final products which enter domestic demand, i.e. value added in imports contains some information on GVCs, although this is more limited than in the case of exports. Therefore, we run a panel regression for the euro area countries on value-added imports so as to gauge the impact of GVCs on the value-added trade balance. In line with the value added perspective applied in the earlier sections, we look at the foreign value added contained in imports. For price indicators, we use terms of trade and unit labour costs as above, plus the oil price. The impact of terms of trade is only significant for the services sectors, and not for manufacturing. Fuel prices have a significant impact too, which is stronger than expected, possibly capturing some cyclical developments. As for demand variables, we include domestic demand of the importer, but also keep world demand by industry as a proxy for the sector-specific demand preferences applying to exports and domestic demand alike.

---

25 To capture non-price competitiveness, we also included the competitiveness indicator, a composite measure capturing different competitiveness aspects, although it turned out not to be significant.

26 The GVC literature has so far neglected value-added imports because these are located far downstream or outside of value chains. Analysis has focused on the import content of domestic demand, which is a similar concept but differs in that it includes both domestic and foreign value added.

We find coefficients for both demand variables to be highly significant, with domestic demand explaining a larger share of movements in value-added imports.

As regards GVC indicators, the increased participation of the vulnerable countries over recent years may have weighed on their value-added trade balances. We find that higher participation leads to more value-added imports. A downstream movement in the value chain significantly increases value-added imports when the pre-crisis period is included, which seems plausible if it lengthens the sourcing chain. However, the effect turns very small and insignificant over the period 2008-14. Adding GVC length indicators does not yield significant results. Taking into account only those results which are significant over the 2008-14 sample and are robust, the analysis would suggest that the countries with larger downstream movements, namely Spain, Greece and Ireland, have benefited from this effect, while the same countries, together with Italy, may have had smaller downward impacts from stronger participation.

To sum up, both analyses presented in this section suggest that the contraction in domestic demand and the recovery in world demand play a major role in explaining the improvement in the value-added trade balance of the euro area countries. Evidence on the role of relative price adjustments is less clear-cut. If these contributed at all to the trade balance adjustment, results would suggest a much smaller impact compared with changes in demand.

We find evidence that GVC activity in euro area countries impacts on the trade balance. Changes in GVC participation and positioning are estimated both to have a bearing on the trade balance, while the forward and backward length of value chains may also have an impact. The size and statistical significance of these effects is somewhat smaller in the post-crisis period compared with the full 2000-14 sample.

Results suggest that the role of GVCs in the adjustment of vulnerable countries' trade balances was limited, uneven across countries and in most cases not clearly positive. While the moderate increases in GVC participation may have negatively affected the value-added trade balance, possibly because this was driven by a stronger use of foreign value added, those countries registering a downstream move are estimated to have benefited from it. Furthermore, changes in the length of international value chains, in particular a shortening of sourcing chains in certain sectors, may have positively affected the trade balance. Overall, the results of the two analyses suggest that Spain and Greece may have experienced beneficial effects from their GVC involvement, while for Slovenia and Cyprus the adjustment in the trade balance may have been higher without GVC involvement. For the other countries the effects are ambiguous given the uncertainty surrounding the estimates. A number of caveats must also be kept in mind. For example, in the light of the non-linearities between GVC positioning and value added, the results from linear estimates are likely to have been distorted, and it seems worth exploring a wider range of non-linear approaches. In addition, the fact that some parameters of GVC indicators were significant over the whole sample but not for the period 2008-14 may point to crisis-induced changes in relationships which may not be captured by regression results over the short post-crisis sample.

3 Output and demand

3.1 Technology frontier and productivity[27]

3.1.1 Introduction

Trade linkages and, in particular, GVCs are a relevant channel for cross-country knowledge transfer and thus productivity growth within the EU, given its deep trade integration and tight firm-to-firm connectivity. On the one hand, exporting provides exposure to new ideas and incentives to upgrade. On the other hand, import activity allows complementarities between domestic and foreign capabilities to be exploited and can increase access to technology and its embedded know-how. GVCs therefore offer a high degree of exposure to, and learning from, the fast-evolving, technology-enabled, business models that characterise fragmented production chains, even without the need for participating firms to engage in ownership arrangements.

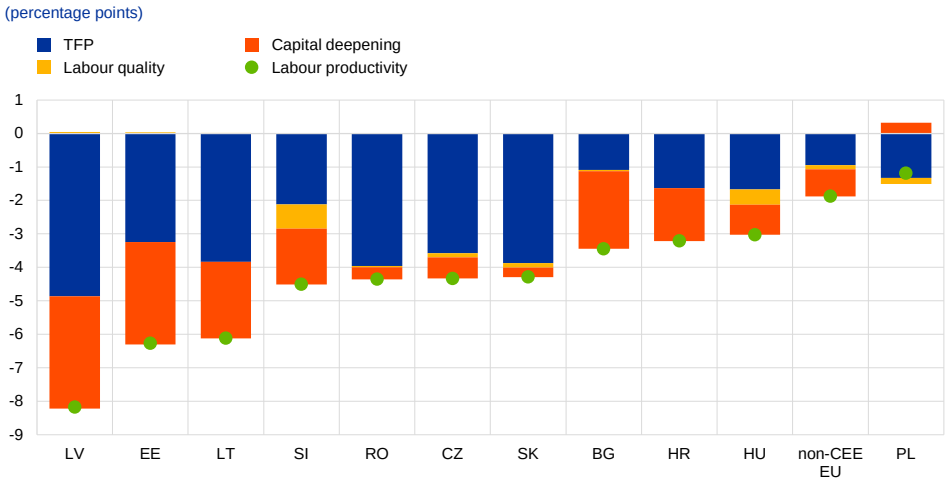
This chapter examines the role of openness and GVC participation for technology diffusion across EU countries and its link with the observed TFP growth slowdown in CEE countries. A number of papers have highlighted the role played by (the lack of) technology diffusion from global frontier firms to other firms in explaining the recent drop in productivity growth (e.g. OECD, 2015). In this connection, this chapter investigates whether the productivity slowdown in CEE countries after the crisis can be partially attributed to a change in the cross-country diffusion of technology within GVCs.

The choice of countries is dictated by two distinct features of CEE countries: higher GVC participation rates than non-CEE EU countries and a pronounced drop in productivity growth since 2007. Total GVC participation in CEE countries has been persistently above the euro area average since 2000 (Chart 2). In addition, CEE countries have experienced a sharper decrease in annual labour productivity growth than other EU countries since the onset of the crisis, driven fundamentally by very weak TFP performance (Chart 17). We therefore argue that, owing to their deep integration in GVCs, CEE countries have been particularly exposed to two recent developments that are highly correlated with their TFP growth performance: (i) weaker TFP growth of parent firms, which has reduced the new knowledge generated in parent firms and transmitted to host firms through GVCs; and (ii) a global slowdown in the growth rate of GVC participation, which has decreased the opportunities for technology transfer.

[27] By Francesco Chiacchio, Katerina Gradeva and Paloma López-García.

Chart 17

Difference in annual labour productivity growth and its contributors between the crisis (2008-15) and the pre-crisis period (2000-07)



Source: ECB staff calculations based on Conference Board data.
Note: Non-CEE EU refers to the unweighted average of Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.

Under a Neo-Schumpeterian approach, a country's productivity growth depends on its exposure to the global technological frontier and distance to the frontier. In our empirical framework, we depart from the Neo-Schumpeterian model (e.g. Aghion and Howitt, 2006; Saia et al., 2015) and expand it to accommodate the specific characteristics of GVCs. More precisely, we assume that the relevant global technology frontier firms are the GVC parent firms operating in non-CEE EU countries and that only firms participating in GVCs in the host economies benefit directly from direct exposure to the frontier. The remainder of the firms in the host countries benefit indirectly from exposure to firms engaged in GVCs. This second stage is crucial for the technology diffusion to the rest of non-frontier firms in the host economies and is consistent with the evidence of a two-stage technology diffusion process put forward by Bartelsman et al. (2013), Van der Wiel et al. (2008), and Iacovone and Crespi (2010).

Using CompNet and WIOD data, we find that GVC participation plays a key role in explaining the TFP performance of host firms in CEE countries. Our results show that technology diffuses first from parent firms in non-CEE EU countries to the most productive firms in CEE countries via GVCs and in a second step to the rest of firms in the host economy. The main channel of technology diffusion is the import of intermediate inputs by host firms, rather than the export of inputs to parent firms. Finally, we find that the pronounced slowdown in TFP growth in CEE countries after the financial crisis is related to a decrease in technology creation at parent firms and to a fall in the absorptive capacity of host firms. We show that the latter could be related to the drop in R&D investment in the CEE region after the crisis.

This chapter is structured as follows. Section 3.1.2 presents a stylised framework for the analysis of the role of GVCs for technology transfer, while Section 3.1.3 covers

the empirical strategy. Results are shown in Section 3.1.4, while a conclusion is presented in Section 3.1.5.

3.1.2 Framework for the analysis

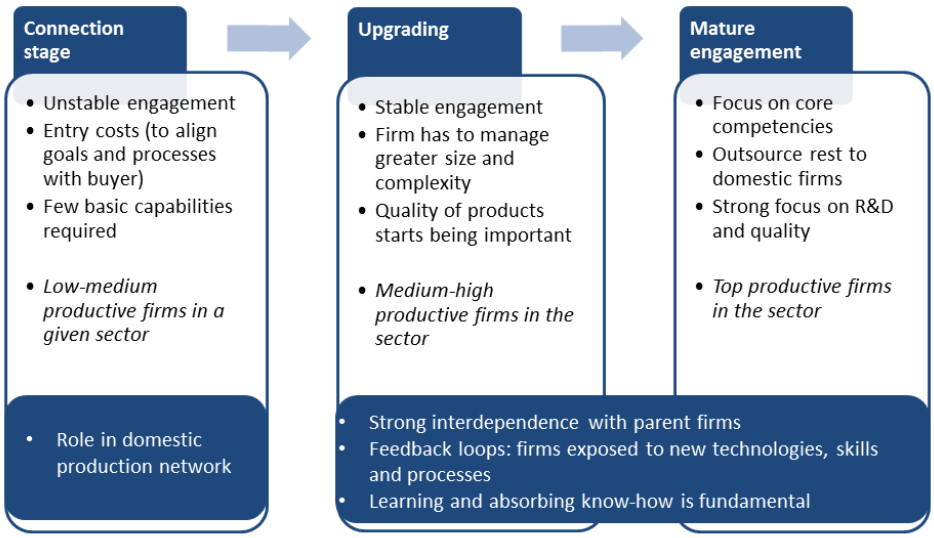
Recent papers have highlighted that technology diffuses across countries in two stages. According to the two-stage technology diffusion process unveiled by Bartelsman et al. (2013) among others,[28] technology is first transferred from global frontier firms to national frontier firms. Global frontier firms learn predominantly through their own radical innovation, R&D and patenting activity, and from addressing untapped needs of sophisticated customers. These firms usually engage in international production and trade through establishing linkages with the most productive firms in a target country, which we call the "national frontier firms". In a second stage, the new technology already adapted to the national idiosyncrasies by national frontier firms spills over to non-frontier firms in the same country, predominantly through domestic networks. To adapt this set-up to the GVC framework, we assume that in countries with very high GVC participation, the relevant global frontier, i.e. the source of new technology, is what we call the "GVC frontier", which includes frontier firms in non-CEE EU country sectors having tight GVC links with CEE country sectors.

We distinguish between three types of firms in the host country according to their capabilities: national frontier firms, mid-productivity firms and laggards. Each type of firm will in turn play a different role in the GVC and will therefore be exposed to a different degree to parent firms. Initial entry into a GVC, at what Mariscal and Taglioni (2017) call the connection stage, implies unstable engagement in GVCs and involves firms with basic capabilities (low to mid-productivity firms in a given sector). These firms will eventually enter a process of upgrading, conditional on the firm being able to manage larger size and complexity, in which there is a more stable relationship with parent firms. Lastly, mature engagement in GVCs implies that host firms focus on core competencies and outsource other tasks to local, less productive, firms. At this stage, there is a strong focus on R&D, quality and direct connection with parent firms. Only the most productive firms in a given sector of the host country, the national frontier firms, have the capabilities required to play this role (see Figure 2).

[28] See also Van der Wiel et al. (2008) and Iacovone and Crespi (2010).

Figure 2

Integration in GVCs and host firms' capabilities



Source: Simplified version of the taxonomy developed by Mariscal and Taglioni (2017).

3.1.3 Empirical strategy

Consistent with the framework set out above, TFP growth of national frontier firms in the host economy depends on their direct exposure to technology creation at the GVC frontier. We adopt a distance-to-frontier approach (e.g. Griffith et al., 1996) and assume that knowledge created at frontier firms is captured by their TFP growth rate, while learning from the frontier (the "pass-through" effect) is approximated by the correlation between TFP growth at any firm in the host economy and at the frontier. This indirect method of measuring knowledge flows has the advantage of implicitly accounting for non-patentable innovations, which are prevalent within GVCs. TFP growth at national frontier firms in the host economy will also depend on their technological distance to the frontier (the catch-up effect), measured by the lagged TFP ratio of host and frontier firms. Lastly, we control for the fact that the concentration in a given sector of many firms participating in GVCs could have an additional (positive) impact on the TFP growth of firms operating in that sector. This is because inputs are of better quality than in other sectors, thereby potentially generating positive externalities. Hence, TFP growth of the most productive or national frontier firms in a given sector in CEE countries is estimated through the following equation:

$$
\begin{aligned}
TFP\ growth_{z,j,i=top\ 20\%,t} &= \alpha_{zj} + \beta_1\, TFP\ growthGVCfrontier_{z,j,t} \\
&+ \beta_2 ln\left(tfp\frac{level\ GVCfrontier_{z,j,t-1}}{tfp\ level_{z,j,i=top\ 20\%,t-1}}\right) + \beta_3 GVC\ growth_{z,j,t} \\
&+ \delta_1 crisis_t + \delta_2 postcrisis_t + u_{z,j,t}
\end{aligned}
\tag{1}
$$

where $TFP\ growthGVCfrontier$ captures the TFP growth of the GVC frontier of macro-sector j in host country z at time t. $ln(tfp\ level\ GVCfrontier_{z,j,t-1}/tfp\ level_{z,j,i=top\ 20\%,t-1})$ measures the lagged TFP distance to the GVC frontier. The crisis and post-crisis variables are from 2008 to 2010 and from 2011 onwards, respectively, and capture cross-country common developments during the two periods that might explain a change in TFP growth relative to the pre-crisis period.

In a second stage, technology diffuses from national frontier firms participating in GVCs to other local firms in the host economies through domestic production networks. Hence, TFP growth of laggard firms in a given sector of the host economy depends on their exposure to the technology created at the national frontier and on the distance to the national frontier. As mentioned earlier, laggard firms can also, in the initial stages of their GVC engagement, have sporadic contact with parent companies in non-CEE EU countries. Accordingly, we also control for TFP growth at the GVC frontier and distance to the GVC frontier:

$$
\begin{aligned}
TFP\ growth_{z,j,i=bottom\ 20\%,t} &= \alpha_{zj} + \beta_1 TFP\ growthNational\ frontier_{\ z,j,t} \\
&+ \beta_2 ln(tfp\ levelNational\ frontier_{\ z,j,t-1} \\
&/tfp\ level_{z,j,i=bottom\ 20\%,t-1}) + \beta_3\ TFP\ growthGVCfrontier_{z,j,t} \\
&+ \beta_4 ln(tfp\ level\ GVC\ frontier_{z,j,t-1} \\
&/tfp\ level_{z,j,i=bottom\ 20\%,t-1}) + \beta_5 GVC\ growth_{z,j,t} + \delta_1 crisis_t \\
&+ \delta_2 postcrisis_t + u_{z,j,t}
\end{aligned}
\tag{2}
$$

$TFPgrowthNational\ frontier_{\ z,j,t}$ proxies for technology creation at the national frontier, while $ln(tfp\ levelNational\ frontier_{\ z,j,t-1}/tfp\ level_{z,j,i,t-1})$ controls for the catch-up to the national frontier. As before, $GVC\ growth_{z,j,t}$ represents the GVC participation growth of a given macro-sector, $TFPgrowthGVC\ frontier_{\ z,j,t}$ captures technology creation at the GVC frontier and $ln(tfp\ level\ GVC_{z,j,t-1}/tfp\ level_{z,j,i,t-1})$ is the lagged distance to the GVC frontier.

Box 5
Data and variable definitions

Data on TFP growth of frontier and non-frontier firms in parent and host countries are taken from the CompNet micro-aggregated database. CompNet is a research network originally created in 2012 within the European System of Central Banks and devoted to the analysis of competitiveness from a multidimensional perspective. The CompNet database is based mainly on administrative data from firm registries and constructed following a micro-distributed approach due to the confidential nature of firm-level information in most countries (Bartelsman et al., 2004). The database provides harmonised cross-country information on all deciles of the distribution of a number of variables related to firm performance and competitiveness, including productivity, in a given country, sector and year. For more information on the dataset and coverage, see Chiacchio et al. (2015). TFP is estimated using a semi-parametric approach controlling for unobserved productivity shocks to

address the simultaneity bias stemming from the fact that firms know their productivity when choosing inputs for production.[29]

Our final sample includes nine CEE countries[30], nine non-CEE countries[31] (used for constructing the GVC frontier), nine macro-sectors and a ten-year period (2003-12). Data refer to non-financial corporations with at least one employee (20 employees in Poland, Romania and Slovakia) operating in all non-financial business economy sectors.

Both the weights for the GVC frontier and participation in GVCs are computed using data from the recent release of the WIOD (2016). Exposure to the GVC frontier depends on the GVC links between a "parent" country/macro-sector and a "host" country/macro-sector, measured either by the backward position of sectors in GVCs (based on the imports of intermediate inputs) or by their forward position (based on the exports of intermediates). Our baseline measures of GVC links follow a "gross" definition[32] and are based either on the imports or exports of intermediate inputs of a given host country/macro-sector:

$$GVC\ participation_{z,j,t} = \frac{Imports\ of\ intermediates_{z,j,t}}{Domestic\ supply\ of\ intermediates_{z,j,t}}$$

$$GVC\ participation_{z,j,t} = \frac{Exports\ of\ intermediates_{z,j,t}}{Domestic\ supply\ of\ intermediates_{z,j,t}}$$

The GVC frontier is calculated as the weighted average of TFP growth of frontier firms in non-CEE EU countries, where the weights depend on the GVC links between non-CEE EU frontier country-sectors and CEE country-sectors:

$$GVC\ frontier_{z,j,t} = \sum_{p \in P} TFP_{p,i=p80-p90,t} \cdot \frac{Imports\ of\ intermediates_{p \to z,j,t}}{\sum_{p \in P} Imports\ of\ intermediates_{p \to z,j,t}}$$

p is a parent country/macro-sector (e.g. manufacturing in Austria) from the set of all parents P and $p \to z, j, t$ is the flow of intermediate imports from parent country/macro-sector p to host country z, sector j, at time t. According to the GVC participation measure based on exports of intermediates, we also compute the GVC frontier using as weights the ratio of exported intermediate inputs to total supply of intermediates:

$$GVC\ frontier_{z,j,t} = \sum_{p \in P} TFP_{p,i=p80-p90,t} \cdot \frac{Exports\ of\ intermediates_{z,j,t \to p}}{\sum_{p \in P} Exports\ of\ intermediates_{z,j,t \to p}}$$

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29 Following Olley and Pakes (1996), Levinshon and Petrin (2003), Ackenberg et al. (2006), Wooldridge (2009), and Galuscak and Lizal (2011).

30 Croatia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

31 Austria, Belgium, Denmark, Finland, France (20+ employees), Germany, Italy, Portugal and Spain.

32 We opted not to use the GVC measures proposed by Wang et al. (2014), based on value-added flows, because their decomposition does not provide information on the sector of origin-to-sector-of-destination flows, which are needed to construct the GVC frontier.

3.1.4 Results

Both the growth of technology creation at the GVC frontier and distance to the frontier are relevant determinants of TFP growth of frontier firms in CEE countries (see Table 6, columns (1) and (5)). The results presented in Table 6 confirm the importance of GVCs for TFP growth in the host economy (Equation (1)): technology creation by parent companies and the catch-up process are significantly correlated with the TFP growth performance of the most productive firms in any given sector of the host economies (the national frontier).

Table 6

TFP growth of national frontier firms

	Import-based GVC participation				Export-based GVC participation	
			R&D-intensive sectors	Less R&D-intensive sectors		
	(1)	(2)	(3)	(4)	(5)	(6)
2008-10 dummy	-0.046***	0.033	0.027	0.013	-0.049***	0.010
	(0.010)	(0.032)	(0.038)	(0.084)	(0.010)	(0.029)
Post-2010 dummy	0.004	0.073*	0.088*	0.084	0.001	0.052
	(0.011)	(0.039)	(0.043)	(0.087)	(0.010)	(0.034)
TFP growth GVC frontier	0.430***	0.445***	0.677**	0.416	0.156***	0.182***
	(0.058)	(0.118)	(0.255)	(0.265)	(0.044)	(0.062)
TFP growth GVC frontier *2008-10 dummy		0.045	-0.320	0.005		0.031
		(0.145)	(0.250)	(0.347)		(0.108)
TFP growth GVC frontier *post-2010 dummy		-0.245*	-0.494**	0.028		-0.232**
		(0.143)	(0.212)	(0.274)		(0.089)
Lagged gap TFP GVC frontier to national frontier	0.364***	0.386***	0.530***	0.511***	0.281***	0.294***
	(0.054)	(0.052)	(0.090)	(0.108)	(0.044)	(0.041)
Lagged gap *2008-10 dummy		-0.030***	-0.024*	-0.027		-0.024**
		(0.010)	(0.014)	(0.023)		(0.010)
Lagged gap *post-2010 dummy		-0.028**	-0.023*	-0.036		-0.020
		(0.012)	(0.012)	(0.029)		(0.013)
GVC participation growth	0.199**	-0.080	-0.183	-0.538	0.079**	0.027
	(0.079)	(0.107)	(0.148)	(0.444)	(0.036)	(0.069)
GVC participation growth *2008-10 dummy		0.358***	0.618**	1.217*		0.094
		(0.134)	(0.250)	(0.631)		(0.089)
GVC participation growth *post-2010 dummy		0.317*	0.344*	1.069		-0.003
		(0.181)	(0.191)	(0.713)		(0.082)
Observations	642	642	184	185	642	642
Adjusted R-squared	0.334	0.355	0.461	0.408	0.224	0.235

Notes: Robust standard errors are given in parentheses, clustered at the country-sector level. Country-sector fixed effects and a constant are included.
*** p<0.01, ** p<0.05, * p<0.10.

GVC participation increases TFP growth above and beyond the "pass-through" and "catch-up" effects, mainly through importing intermediate inputs. Firms operating in sectors where GVC participation is growing rapidly experience faster TFP growth than firms in other sectors. This could be due to the existence of positive externalities stemming from the higher quality of inputs in these sectors. Moreover, the impact of the various GVC participation variables on TFP growth of frontier firms is larger when the definition of GVC participation is based on CEE countries' imports, rather than exports, of intermediate products (columns (1)-(2) vs (5)-(6)). This result suggests that technology is transferred from parent to host firms via imported inputs, rather than exports of intermediates.

Furthermore, we find that the absorptive capacity of CEE frontier firms dropped significantly in the post-2008 period relative to pre-crisis levels. In order to explore whether the capacity to learn from direct exposure to new technology and the catch-up process have changed over the crisis and post-crisis periods relative to pre-crisis levels, we interact all explanatory variables with the crisis and post-crisis period dummies in columns (2) and (6) (Table 6). We find that the impact of both the pass-through and catch-up effects on TFP growth of frontier firms decreased significantly in the post-crisis period. The results also indicate that sectors with higher GVC participation growth have actually been more resilient than other sectors to the crisis (and post-crisis) slowdown.

We provide suggestive evidence that the drop in absorptive capacity is partially related to the decrease in R&D investment of frontier firms in host economies. In columns (3) and (4) (Table 6), we split sectors depending on their R&D intensity[33], defined as being above or below the country-year median. The idea is that only in very R&D-intensive sectors will the absorptive capacity of firms suffer if R&D investment drops. We find that that the decrease in absorptive capacity of host frontier firms in the post-crisis period is indeed present only in R&D-intensive sectors, while there is no evidence of a change in elasticities for firms operating in less R&D-intensive sectors. This is suggestive evidence that the drop in R&D investment in host firms in the aftermath of the crisis has reduced their capability to learn from frontier firms, i.e. it has slowed down technology diffusion.

Turning to TFP growth of non-frontier firms in host economies, we find evidence supporting the two-step diffusion process put forward by Bartelsman et al. (2013) and others. In Table 7, we investigate the determinants of TFP growth of non-frontier CEE firms (Equation 2), defined as being in the bottom percentiles of productivity distribution. We find that their TFP growth is influenced by technology creation at the national frontier, i.e. at the most productive firms in CEE countries, rather than at the GVC frontier. This important finding confirms that new technology flows first from the global to the national frontier, via GVCs, and then from the national frontier to non-frontier firms via domestic production networks. In contrast to the most productive firms, the strength of these correlations did not change over the crisis or post-crisis periods.[34] Finally, similar to our findings for the most productive firms, the

[33] R&D intensity is defined as fixed capital formation in R&D as a share of sectoral value added, sourced from Eurostat.

[34] This is not shown in Table 8 but can be found in Chiacchio et al. (2018), on which this chapter is based.

deeper the integration of sectors in GVCs, the higher the TFP growth of firms in those sectors due to the existence of positive externalities.

Table 7
TFP growth of laggard firms

	GVC participation based on imports	GVC participation based on exports
	(1)	(5)
2008-10 dummy	-0.025***	-0.029***
	(0.008)	(0.008)
Post-2010 dummy	-0.022**	-0.027***
	(0.008)	(0.008)
TFP growth national frontier	0.920***	0.947***
	(0.049)	(0.051)
Lagged gap TFP national frontier to laggards	0.569***	0.560***
	(0.080)	(0.077)
TFP growth GVC frontier	0.151***	0.060*
	(0.041)	(0.036)
Lagged gap TFP GVC frontier to national frontier	0.010	0.041
	(0.024)	(0.026)
GVC participation growth	0.203**	0.068**
	(0.079)	(0.032)
Observations	642	642
Adjusted R-squared	0.736	0.727

Notes: Robust standard errors in parentheses, clustered at the country-sector level. Country-sector fixed effects and a constant included. *** p<0.01, ** p<0.05, * p<0.10

3.1.5 Conclusion

In this chapter, we provide evidence that GVCs are an important channel for technology diffusion across countries. We show that the main channel of technology diffusion is the technology embedded in imported inputs, rather than the upgraded quality standards when exporting intermediates to parent firms. When tested on data for CEE countries, we find that the main factor behind the large post-crisis slowdown in TFP growth of CEE countries is the disruption of technology diffusion from parent economies brought about by two phenomena: (1) a drop in technology creation of non-CEE EU parent firms; and (2) a reduction in the absorptive capacity of host economies, which is correlated to their reduced investment in R&D. Lastly, our results confirm the idea that technology created at the global frontier is diffused to other economies via a two-stage process. National frontier firms are directly involved in GVCs and exposed to new technology, while non-frontier firms benefit indirectly from the participation of more productive firms in GVCs through domestic production networks as well as, to a lesser extent, from direct contact with parent companies.

3.2 Global income elasticities of trade[35]

3.2.1 Introduction

As a stylised fact of the post-war era up until the global financial crisis, world trade growth considerably surpassed global GDP growth, leading to an elasticity of global trade to income of well over one in most years.

In this section, we focus on the empirical importance of vertical specialisation – or GVC participation – for the elasticity of global trade to income. Due to lack of appropriate data on GVC integration, no empirical estimates of the specific impact of production fragmentation on the trade-income relationship exist to date. However, the magnitude of this factor is relevant in obtaining an unbiased estimate of the income elasticity of trade in view of flattening dynamics in GVC expansion. We therefore estimate a standard import demand function and augment it by measures of GVC participation for the 39 countries included in the WIOD over the period 1995-2014.[36]

The next section reviews some stylised facts about global trade and the relationship between trade and GDP, followed by the drawing of conclusions in Section 3.2.5.

3.2.2 Evolution of the trade-GDP ratio over time

In the second half of the twentieth century, the ratio of global trade to GDP increased notably, reaching a maximum of around 2.5 in the mid-1990s, before falling to 1.2 over the period 2011-14. This strong rise was followed by a continuous decline in the ratio, which became particularly pronounced with the outbreak of the global financial crisis. In the recent economic downturn, the ratio even dropped below one in some years – notably in 2012 and 2013 when the EU entered a double-dip recession (see Chart 18). Taking a longer-term perspective and excluding the immediate crisis years, it can be observed that while global imports grew on average by almost twice as much as global GDP over the period 1981-2007, this ratio fell to 1.2 for the period 2011-14. However, Chart 18 also makes clear that the growth differential already started to decline some ten years before the crisis hit.[37] Hence, the drop in the ratio is not a consequence of the crisis, but is rooted in more structural factors.

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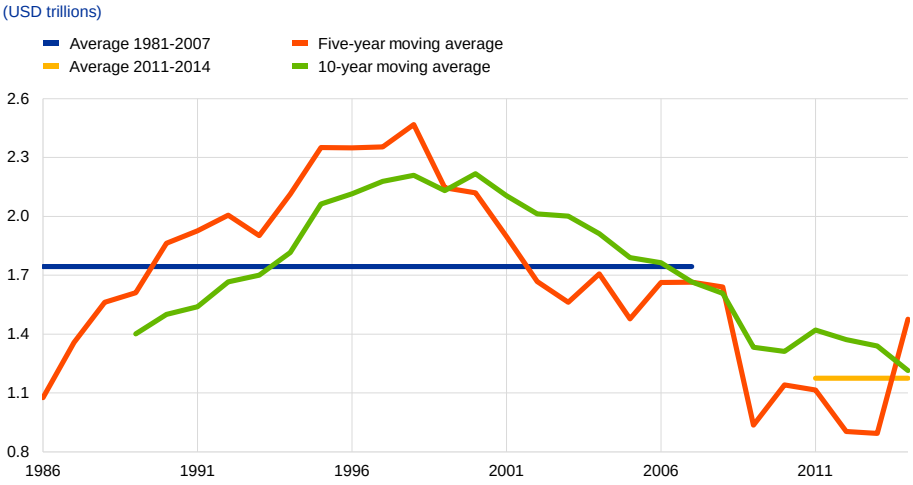
35 By Alexander Al-Haschimi, Frauke Skudelny, Elena Vaccarino and Julia Wörz.

36 We base our estimations on both vintages of the WIOD database in order to obtain longer time series. See Timmer et al. (2015) and Timmer et al. (2016) for a description of the database.

37 Note that in Chart 17 the five-year moving average of the trade-growth ratio rose sharply in Q4 2014 because the Q4 2008 observation, which entailed a highly negative observation on import growth, drops out of the average.

Chart 18

Ratio of global import growth to GDP growth

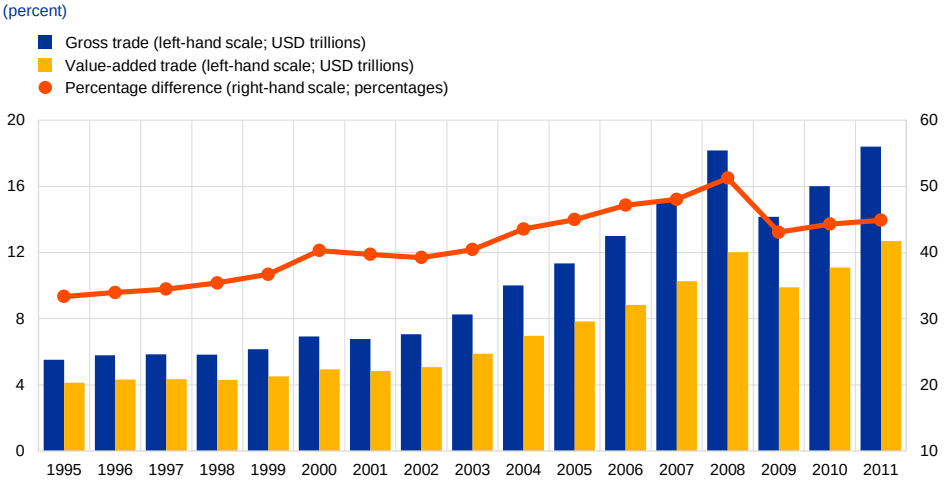


Source: ECB staff calculations.
Notes: The last observation refers to Q4 2014. The grey line shows the ratio of the average growth rate of global imports of goods and services to global GDP over a rolling five-year window (the green line is based on a ten-year window).

One of the structural factors behind the fall of the trade-GDP ratio is likely related to GVC expansion. The rising international fragmentation of production and the emergence of internationally fragmented production networks in which intermediate inputs are outsourced to foreign suppliers has certainly been a driving force behind faster trade growth compared with GDP growth in recent decades. In a sense, this also had statistical reasons, as customs statistics increasingly included "double-counted" value-added trade by recording flows of intermediate goods crossing international borders more than once during the production process. Consequently, gross trade flows as recorded by customs statistics exceeded value-added trade flows (i.e. measured net of imported value added) by one-third in 1995 and more than doubled them in 2008 (see Chart 19).

Chart 19

Global gross versus value-added trade



Sources: WIOD and ECB calculations.
Note: The orange line represents the percentage difference between gross and value-added trade.

3.2.3 Brief review of the existing literature

An early strand of the literature on GVCs analysed the role of vertical specialisation in trade and trade growth. As the fall in tariff barriers – although substantial in the immediate post-war period – could not explain the sharp increase in the trade-to-income ratio, several authors concluded that vertical specialisation and the consequent rise in intermediate goods trade was behind the increase in the trade-to-income ratio observed from the mid-1980s onwards (Yi, 2001; Hummels, Ishii and Yi, 2001). This view was supported by the high share of vertically specialised trade: Daudin, Rifflart and Schweisguth (2011) postulate, for example, that vertically integrated trade accounted for 27% of international trade in 2004.

With respect to the mechanism through which GVCs impact income elasticity, Gangnes et al. (2014) identify two possible channels: a composition and a supply chain effect. The composition effect refers to the high concentration in durable goods that is characteristic of GVC trade. Durable goods industries traditionally have high income elasticities, meaning aggregate trade becomes more sensitive to foreign income shocks as the importance of GVCs grows.. The supply chain effect refers to higher inventory holdings in GVC trade than in traditional trade, which drives up income elasticities. The empirical literature finds evidence for both effects: Eaton et al. (2011) confirm the composition effect hypothesis by demonstrating that a shift away from spending on durable goods in 2008/2009 aggravated the downturn. Alessandria et al. (2010) show that inventories of imported inputs are used to continue production in economic downturns and purchases of new imported inputs are reduced, causing an increase in income elasticities over the cycle. Gangnes et al. (2014) identify the composition effect as important for China – an important downstream producer – but find no evidence for the supply chain effect. Altomonte et al. (2012) also confirm the adjustment of inventories in supply chains and term this phenomenon the “bullwhip effect”. Finally, Bems et al. (2012) find that the crisis had a strong impact on trade via inventory adjustment, which was further aggravated by a lack of credit.

Taking a longer-term perspective, Constantinescu et al. (2015) point to a slowdown in GVC expansion that started long before the global financial crisis as an important factor behind the decline in the trade-to-GDP ratio, based on the results of an error correction model. In contrast, Ollivaud and Schwellnus (2015) claim that elasticity did not decline when measuring both GDP and trade flows at market exchange rates and excluding intra-euro area trade. Hence, they do not see a need for a structural explanation such as GVC expansion.

3.2.4 Empirical model and results

Similar to Anderton et al. (2007), our analysis is based on an import demand model as described in the equation below:

$$Tln(M_{ijt}) = \alpha_{ij} + \alpha_1 ln(GDP_{it}) + \alpha_2 ln\left(\frac{P_{jt}}{P_{it}}\right) + \alpha_3 ln(ER_{ijt}) + \alpha_4 ln(GDP_{it}) * ln\left(GVC\_part_{it}\right) + \varepsilon_{ijt}$$

Our dependent variable M_{it} is the import volume of country i at time t, deflated by the respective export price deflator and expressed in US dollars. GDP_{it} is the real gross domestic product of the importing country. P_{it} and P_{jt} are the producer prices of the importing and exporting countries, respectively, and ER_{ijt} is the bilateral nominal exchange rate. All data are taken from International Monetary Fund (IMF) databases. GVC_part_{it} is an index of GVC participation that captures both backward and forward linkages. The index is derived from the export decomposition proposed by Koopman (2014) and calculated using WIOD data (Timmer et al., 2015 and Timmer et al., 2016). We make use of a decomposition by Borin and Mancini (2015), so the index is adjusted for commodity price effects.

We use a fixed effects estimator with AR(1) disturbance terms. In addition to showing the results for the full sample, we also run the estimations for emerging and advanced market economies separately. In both cases, the total sample of countries represents the partner countries.

Table 8

Regression results for total sample, advanced and emerging market economies

	World imports		Imports advanced economies		Imports emerging economies	
	(1)	(2)	(1)	(2)	(1)	(2)
Aggregate demand	1.66***	1.10***	1.86***	1.31***	1.43***	0.75***
GVC * aggregate demand		0.18***		0.14***		0.23***
Relative prices	-0.39***	-0.41***	-0.26***	-0.26***	-0.45***	-0.51***
Exchange rate	-0.29***	-0.37***	-0.32***	-0.38***	-0.35***	-0.48***
Constant	0.12*	0.046	-1.25***	-1.01***	1.77***	1.74***
Elasticity		1.75		1.85		1.6
GVC contribution		0.66		0.54		0.85
Observations	713	713	510	510	203	203
Number of countries	39	39	28	28	11	11
Year fixed effects	yes	yes	yes	yes	yes	yes

Source: Authors' estimations.

GVC participation plays a role in increasing import elasticity to aggregate demand. Turning first to our control variables, relative prices and exchange rates show the expected negative relationship with import demand, with both price variables having a statistically significant impact on imports. Controlling for relative prices and exchange rate movements, we find that the overall elasticity of imports to GDP is roughly 1.7 on average over the period 1995-2014 and thus in line with the observed ore-crisis average. The elasticity is somewhat higher in advanced economies than in emerging market economies. GVCs exert a non-negligible contribution to this high sensitivity of imports to GDP, as evidenced by the lower GDP coefficient when we control for GVC participation. The contribution of GVCs is indicated by the coefficient on the interaction term multiplied by the average sample value for GVC participation.

More precisely, GVC participation pushes up elasticity by around 38% on average (a GVC contribution of 0.66 to an overall elasticity of 1.75) over the entire period. GVC participation plays a more important role for elasticity in emerging market economies (a contribution of more than 50%) than in advanced economies (a contribution of 29%). This seems plausible when we assume that import demand in advanced economies is more strongly driven by final consumption, as these countries still represent the major global consumer markets.

Our quantitative estimate is in line with the estimated impact of the expansion of GVCs on global trade elasticity derived from the decomposition of Borin and Mancini (2015), which suggests that the effect of GVCs on trade elasticities was between 0.3 and 0.5 from 1996 to the early 2000s (see IRC Trade Task Force, 2016).

Recent data on GVC participation suggest that the expansion of GVCs has stalled since 2011. This could well explain the lower global trade elasticity observed in recent years. For an elaboration of the impact of GVCs on euro area export elasticities, see Box 6.

Box 6
GVCs and euro area export elasticities

Prepared by E. Frohm and V. Gunnella

This box investigates whether the responsiveness of extra-euro area exports to movements in foreign demand and the effective euro exchange rate has changed with further integration in GVCs. Participation in GVCs could increase the foreign demand elasticity of extra-euro area exports, as relatively more intermediate inputs are demanded and, at the same time, lead to a more muted responsiveness of the REER. Arguments for such an "exchange rate disconnect" relate to the increasing use of imported inputs in exports and exports of inputs that are re-exported by the first trading partner. Put simply, any export price competitiveness gained by currency depreciation is partly offset by increasing costs of imported inputs used in the production of exports. In addition, the value of the domestic currency may not actually determine the final destination of re-exports by trading partners.[38] Since exchange rates and their impact on prices and trade volumes is one notable channel of transmission for monetary policy, it is important to understand whether the relationship has weakened.[39]

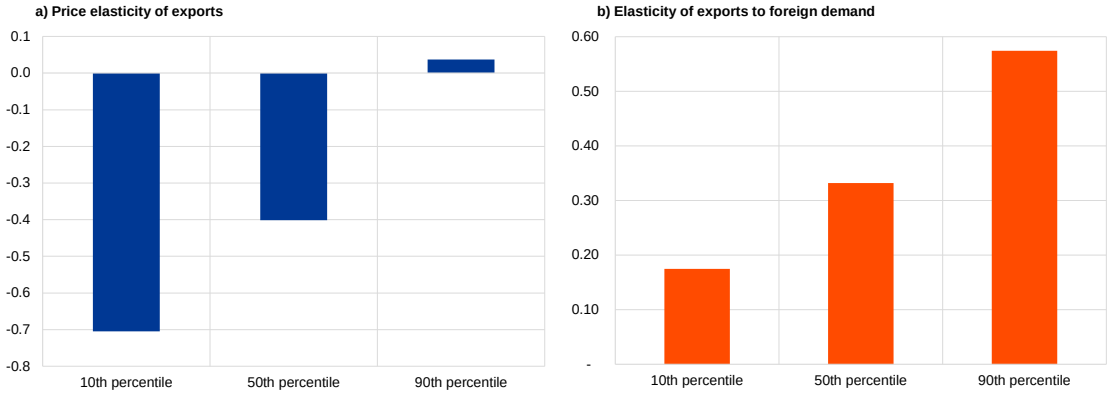
[38] Ollivaud, P., Rusticelli, E. and Schwellnus, C. (2015), "The Changing Role of the Exchange Rate for Macroeconomic Adjustment", *OECD Economics Department Working Papers*, No 1190, OECD Publishing. and Ahmed, S., Appendino, M., and Ruta, M. (2015), "Global Value Chains and the Exchange Rate Elasticity of Exports", *IMF Working Paper*, No 15/204, International Monetary Fund.

[39] For a more in-depth analysis of the impact of GVCs on exchange rate elasticities, please refer to 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 WPS8535, World Bank.

Chart A

Impact of intermediate goods trade on the elasticity of exports

(long-run coefficient)



Source: ECB projections database.
Notes: The long-run coefficients are computed over various percentiles. The elasticities are obtained from a panel error correction model and estimated with various definitions of the REER (Harmonised Index of Consumer Prices (HICP), GDP deflator and export deflator). The chart shows the average elasticities of the three models. Whereas unit labour costs are also significant for the demand elasticities, prices are not and are hence excluded from the chart.

To address this issue, an augmented standard export equation is estimated for a panel of 13 euro area countries from Q1 2000 to Q4 2015. The export equation explains quarterly extra-euro area export growth, $\Delta Y_{i,t-1}$, with two standard determinants: trade-weighted imports of trading partners (FOD) and the REER. In addition, a proxy for trade in GVCs (the share of a country's total goods trade that is in intermediate goods) is included alongside its interactions with the other determinants. These interactions are the focus of this box, since they help shed light on how – and if – increasing trade in intermediate goods changes the relationship between exports, foreign demand and the REER. The regression also includes dummies for the 2008/2009 Great Recession.

$$ln\Delta Y_{i,t} = c + c_1 GVC_{i,t} + \beta ln\Delta Y_{i,t-1} + \alpha_1 ln\Delta REER_{i,t} + \alpha_2 ln\Delta FOD_{i,t} + \rho ln\Delta Y_{i,t-1} * GVC_{i,t} + \rho_1 ln\Delta REER_{i,t} * \mathrm{GVC}_{i,t} + \rho_2 ln\Delta FOD_{i,t} * \mathrm{GVC}_{i,t} + \delta lnY_{i,t-1} + \delta_1 lnREER_{i,t-1} + \delta_2 lnFOD_{i,t-1} + \gamma lnY_{i,t-1} * GVC_{i,t} + \gamma_1 lnREER_{i,t-1} * \mathrm{GVC}_{i,t} + \gamma_2 lnFOD_{i,t-1} * \mathrm{GVC}_{i,t} + \varepsilon_{i,t}$$

Higher shares of intermediate goods trade seem to be associated with less price-elastic exports and greater foreign demand elasticities. The results from the regression imply that when the share of intermediate goods trade increases from the lowest tenth percentile (at around 52%) to the 50th percentile (with an intermediate goods trade share of around 57%), the price elasticity of exports declines by around half (see Chart Aa)).[40] This estimate is slightly above those obtained in studies conducted on sectoral data and based on manufacturing exports alone.[41] However, the qualitative pattern seems to be the same – more trade in GVCs is associated with less price-elastic exports.[42] Conversely, the foreign demand elasticity of exports seems to be increasing along various percentiles of intermediate goods trade (Chart Ab)).[43] These results suggest that the increasing participation of the euro area in GVCs in the 2000s had a positive impact on the foreign demand

40 In the sample, intermediate goods trade as a share of total trade in goods varies between around 48% and 69%.

41 Ahmed, S., Appendino, M., and Ruta, M. (2015), "Global Value Chains and the Exchange Rate Elasticity of Exports", *IMF Working Paper*, No 15/204, International Monetary Fund.

42 This result is irrespective of the domestic cost indices used for the REER. REERs based on relative export prices also yield similar results.

43 While the impact of intermediate goods trade shares on price elasticity is fairly robust across estimation methods (pooled OLS, fixed effects and with or without an error correction term), the reduction in the demand elasticity of exports is only significant in the ECM specification.

elasticity of extra-euro area exports during this period, whereas it reduced the responsiveness to changes in the REER.

While euro area GVC participation increased over the 2000s, the expansion seems to have slowed recently. Developments since 2011 suggest that participation of the euro area in GVCs might have slowed or even declined slightly[44].

3.2.5 Conclusions

In this section, we assess the impact of GVCs on the elasticity of world trade to global GDP. Unexpectedly weak dynamics in global trade flows in 2012 and 2013 and a historically low trade-to-GDP ratio led to a renewed discussion of a potential structural change in global trade drivers since the Great Recession in 2009, in addition to the cyclical weakness caused by subdued investment. Our analysis is based on an import demand model, using a panel data model for imports of advanced and emerging market economies. In addition to standard demand variables, we add an interaction term between demand and GVC participation. Our results suggest that demand elasticity tends to be higher for advanced economies than for emerging market economies. In addition, demand elasticity has been impacted by participation in GVCs: expanding GVC participation contributed about 0.4 to the global trade-income elasticity between 1995 and 2014. The impact was higher in emerging market economies, whose import demand seems to be more strongly driven by final demand from third countries, whereas import demand from advanced economies is likely to be more tilted towards final consumption goods.

In addition, we observe that the structural drivers that boosted trade beyond GDP growth in the decades before the financial crisis are now waning. In recent decades, the rapid integration of emerging markets into the world economy has boosted the expansion of GVCs. This process of fragmenting production across borders appears to be maturing, as labour costs in key emerging markets have increased and firms have reconsidered the risks associated with long supply chains and increasingly moved towards onshoring production to export markets. The lack of further expansion of GVCs removes a factor that pushed trade elasticity significantly above unity before the Great Recession.

While we should not expect a return to income elasticities of two and beyond – as observed up until the mid-1990s – the significant impact of GVC participation on the income elasticity of trade will lead to pronounced cyclical swings in this ratio in the years to come. As GVCs have the potential to compound cyclical swings – through inventory adjustment and due to the importance of investment and durable goods in GVC trade – we should expect a reasonable degree of cyclicality in the income elasticity of trade as long as the global economy remains sufficiently well integrated.

[44] See Chart 1 in the Introduction and Box 1 for an account of the factors behind the levelling up of GVC expansion.

3.3 Co-movement in business cycles and trade in intermediate goods[45]

3.3.1 Introduction and stylised facts

The degree of business cycle co-movement across countries is a key indicator for many macroeconomic policies. For example, the extent to which the euro area can be considered an optimum currency area largely depends on the synchronisation of business cycles among all member countries. In this study, we assess the relationship between the rise of intermediate input trade and business cycle movement.

The average correlation of GDP at different frequencies has increased significantly over the past five decades. To illustrate this point, we used quarterly GDP data for a sample of 26 OECD countries from 1960 to 2016 and computed the GDP correlations for each pair of countries using a ten-year rolling window. In Chart 20, each point on the two graphs represents the average correlation of GDP across all country pairs in the ten years preceding the point. The graphs present the correlation in GDP using two filters: we first analysed business cycle frequency by using the standard Hodrick-Prescott (HP) filter; we then refined the analysis by using the Baxter-King (BK) filter to extract medium-term fluctuations as suggested by Comin and Gertler (2006). Note that quarterly data for GDP is not available for many countries in the earliest years, which limits the number of countries included in this analysis.[46] Focusing on 16 countries in the euro area (right-hand graph in Chart 20)[47], the picture is somewhat similar, if not stronger, for those economies. The increase in GDP co-movement is approximately the same as that estimated for the OECD sample described above, with an average correlation multiplied by more than three in the 2000s compared with the level in the 1960s.

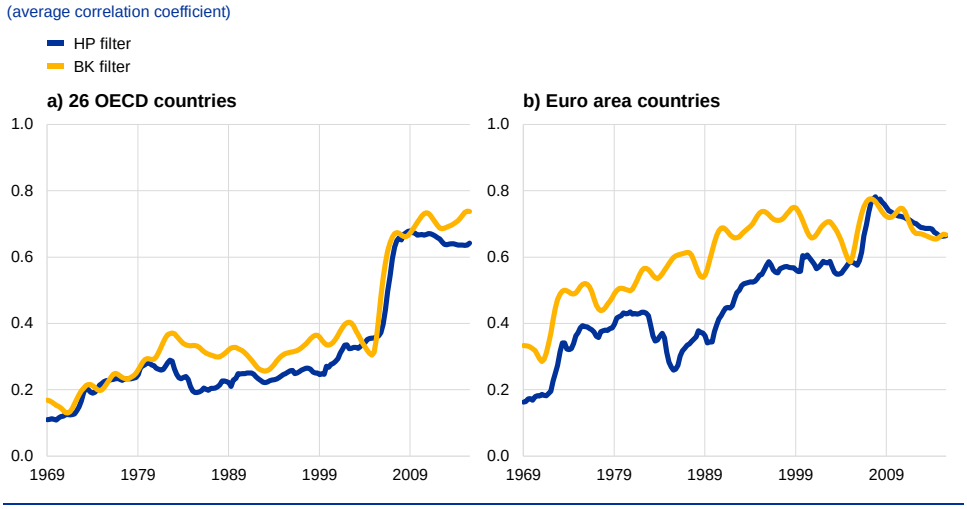
45 By François de Soyres.

46 Due to data limitations, the countries included in this analysis are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Portugal, South Africa, Spain, Switzerland, Turkey, United Kingdom and United States.

47 European countries taken into account are: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain.

Chart 20

Average pairwise correlation of GDP, evolution from Q1 1960 to Q1 2016



Sources: OECD Quarterly National Accounts (QNA) data, de Soyres (2016) and ECB staff calculations.
Notes: The correlation is computed for each country pair over a rolling window of ten years. Due to data limitations, the countries included are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Portugal, South Africa, Spain, Switzerland, Turkey, the United Kingdom and the United States.

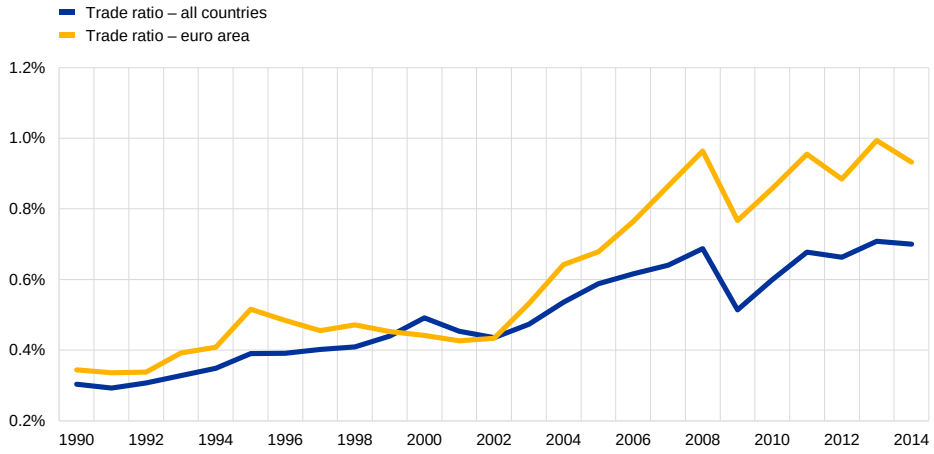
The increase in GDP synchronisation described above has been accompanied by a significant surge in intermediate input trade across countries. Several explanations for this process have been identified in the literature, including vertical specialisation (Hummels, Ishii and Yi, 2001), international joint production (Chang, Ethier and Kemp, 1980) or GVCs and different ways to measure them in the data. In this section, we take the simplest approach and separate trade flows into two groups based on the Broad Economic Categories (BEC): final and intermediate goods.[48] Chart 21 shows the evolution of the ratio of international trade in intermediate inputs to GDP. The ratio is computed for all country pairs and then averaged for each year using trade flows as weights. To construct the blue line in Chart 21, we used all 110 countries available in the OECD Structural Analysis (STAN) database, resulting in a total of 14,812 (non-directed) country pairs. For all pairs, the average ratio of trade in intermediates to GDP rose from 0.25% in 1990 and to 0.66% in recent years. Focusing on the 19 countries that constitute the euro area today (implying a total of 342 pairs), the evolution of the ratio is even more striking. As shown by the yellow line in Chart 21, it increased from 0.27% of GDP in 1990 to 0.95% in recent years, meaning that the ratio has been multiplied by a factor of 3.5 over a period of 25 years.

[48] For simplicity, intermediate goods comprise both intermediate and capital goods in the BEC tables. Both categories encompass the notion of input/output linkages across countries.

Chart 21

Evolution of the intermediate trade-to-GDP ratio

(average ratio of exports of intermediate inputs to GDP average across countries)



Sources: OECD QNA and Comtrade data and ECB staff calculations.
Note: The ratio is computed for each country pair/year, with the yearly average weighted by trade flows.

3.3.2 Trade and business cycle co-movement in the literature

The seminal contribution to this topic was made by Frankel and Rose (1998) when studying the endogeneity of optimum currency area criteria. Since then, many authors have refined the empirical findings and highlighted the importance of total trade in business cycle co-movement.[49]

Financial linkages could also have an impact on business cycle synchronisation. Kalemli-Ozcan, Papaioannou and Peydró (2013) assess the effect of financial integration on international business cycle synchronisation by using a confidential database on banks' bilateral exposure and employing an instrumental variables approach based on country pairs. They find that countries that become more integrated over time have less synchronised growth patterns, conditional on global shocks and country-pair factors.

Baxter and Kouparitsas (2005) investigate the determinants of business cycle co-movement between over 100 countries, both developed and developing. They search for variables that are "robust" in explaining co-movement using the approach of Leamer (1983). Variables considered are (i) bilateral trade between countries, (ii) total trade in each country, (iii) sectoral structure, (iv) similarity in export and import baskets, (v) factor endowments, and (vi) gravity variables. They find that bilateral trade is robust in explaining co-movement. By comparison, our analysis refines the role of trade and separates final and intermediate goods, showing that only the latter are significantly related to business cycle co-movement.

[49] As well as the papers discussed in the main text, see also Clark and van Wincoop (2001), Otto et al. (2001), Calderon et al. (2002) or Duval et al (2016).

di Giovanni and Levchenko (2010) use sectoral data and find that input-output linkages are important in the cross-section of gross output co-movement. We differ from this strand through our focus on value added (which is, at the aggregate level, equal to GDP) and the use of panel data in order to control for time-invariant fixed effects as well as time trends. Finally, di Giovanni, Levchenko and Méjean (2015) investigate the role of individual firms in international business cycle co-movement using data covering the universe of French firm-level value added, bilateral imports and exports and cross-border ownership over the period 1993-2007. At the micro level, controlling for firm and country effects, they find that trade in goods with a particular foreign country is associated with a significantly higher correlation between a firm and that foreign country. They also emphasise the important role of foreign multinational affiliates operating in France in the correlation with the source economy, which is outside the scope of the present analysis.

From a more theoretical side, the significant relationship between trade and GDP fluctuation constitutes an important issue commonly referred to as the "trade co-movement puzzle". Initiated by Kose and Yi (2001 and 2006) and developed by many authors since,[50] this literature is based on the finding that traditional international business cycle models such as Backus, Kehoe and Kydland (1993) are unable to account for the quantitative role of trade in propagating shocks. Several factors have been shown to help in solving the puzzle, including the presence of profits in the computation of value added as well as adjustments along the extensive margin.[51]

3.3.3 Empirical results: assessing the role of different types of trade

Since the seminal work by Frankel and Rose (1998), it is well known that international trade is a robust determinant of business cycle co-movement across countries. In this section, we disentangle the influence of trade flows in inputs from final goods trade and show that the former is strongly associated with GDP synchronisation, while the latter has no statistical significance. We use a sample of 20 OECD countries and update the initial Frankel and Rose (1998) estimation using data from 1995 to 2014. Using quarterly data from the OECD for GDP, we compute the correlation of HP-filtered GDP for all pairs of countries for four time windows of five years each. For each year, we then construct a symmetric measure of bilateral trade intensity between countries i and j using total trade flows as:

$$Total_{ijt} = \frac{Total\ Trade_{ijt}}{GDP_{it} + GDP_{jt}}$$

This index is taken from Frankel and Rose (1998) or Kose and Yi (2001, 2006) and is a symmetric measure of "trade proximity" between two countries. It is then averaged within each of the four time windows to get one value per country pair. Moreover, in order to disentangle the influence of trade flows in inputs from final goods, we

50 For quantitative studies, see Kose and Yi (2001, 2006), Burstein, Kurz and Tesar (2008), Arkolakis and Ramanarayanan (2009), Johnson (2014), Drozd and Nosal (2015) or Liao and Santacreu (2015), among others.

51 See de Soyres (2016) for a quantitative solution to the trade co-movement puzzle.

construct the indices “Final” and “Intermediate” with the same formulation but taking into account only the trade flows in final and intermediate goods in the numerator of the index.[52]

Based on the following equations, we then assess the respective roles of final and intermediate goods:

$$corr\left(GDP_{it}^{filtered}, GDP_{jt}^{filtered}\right) = \alpha_T + \beta_T \, log\left(Total_{ijt}\right) + controls + \varepsilon_{ijt}$$

$$corr\left(GDP_{it}^{filtered}, GDP_{jt}^{filtered}\right) = \alpha_{IF} + \beta_I \, log\left(Intermediate_{ijt}\right) + \beta_F \, log\left(Final_{ijt}\right)$$

The results are provided in Tables 9 and 10 below and are comparable to what is found in de Soyres (2016). This analysis shows that while total trade is strongly GDP correlation relates solely to trade in intermediate inputs and not final goods trade.

As in previous studies, we find that an increase in the index of trade proximity is associated with an increase in GDP correlation in the cross-section, as shown in column (1) in Table 9. Moreover, controlling for country-pair fixed effects and using only country-pair variations, the strong relationship between trade and GDP correlation still holds, with the point estimates in columns (3) and (5) showing that a doubling of the median index is associated with an increase in GDP correlation of between 0.101 (column (5)) and 0.166 (column (3)).

Table 9

Regression of HP-filtered GDP correlation on indices of intermediate and final goods trade proximity

	Dependent variable: correlation of HP-filtered GDP					
	No controls		Country-pair FE		Country-pair FE + time trend	
	(1)	(2)	(3)	(4)	(5)	(6)
log(Total)	0.046***		0.239***		0.146*	
t-stat	4.3		3.61		1.93	
log(Intermediate)		0.076***		0.330***		0.269***
t-stat		3.25		3.88		3.02
log(Final)		-0.026		-0.094		-0.137
t-stat		-1.28		-1.17		-1.64
Country-pair FE	No	No	Yes	Yes	Yes	Yes
Time trend	No	No	No	No	Yes	Yes
N	756	756	756	756	756	756
R-squared	0.023	0.027	0.024	0.029	0.031	0.041

Sources: OECD QNA and Comtrade data, authors’ computations.

To investigate further the relationship between trade and GDP co-movement at business cycle frequency, columns (2), (4) and (6) of Table 9 disentangle the effect of trade in intermediate inputs from trade in final goods. The results

[52] We use trade data from the OECD STAN database, which allows us to decompose trade flows according to their end-use codes.

highlight the specific role of trade in intermediate inputs, which are characteristic of global supply chains, both in the cross-section and in the panel dimensions. In all specifications, the index of trade proximity in intermediate goods is high and significant, with a doubling of the intermediate trade index associated with an increase in GDP correlation of between 0.053 (column (2)) and 0.229 (column (4)) depending on the controls. Those numbers are economically very large and imply that moving from the 25th to the 75th percentile of trade proximity in intermediate inputs in the sample is associated with an increase in GDP correlation of 0.5, once country-pair fixed effects and time trend are controlled for.[53]

These findings are also robust when looking at lower frequencies, as shown in Table 10. In this analysis, we use the Baxter-King filter to isolate GDP frequencies between 32 and 200 quarters as suggested by Comin and Gertler (2006). In such a case, the key message that trade in intermediate inputs captures all statistical significance is preserved, with an even larger point estimate. This finding suggests a long-lasting impact of cross-country production linkages on GDP fluctuations.

Table 10

Regression of BK-filtered GDP correlation on indices of intermediate and final goods trade proximity

	Dependent variable: correlation of BK-filtered GDP					
	No controls		Country-pair FE		Country-pair FE + time trend	
	(1)	(2)	(3)	(4)	(5)	(6)
log(Total)	0.055***		0.275***		0.298**	
t-stat	4.17		2.59		2.33	
log(Intermediate)		0.135***		0.454***		0.464***
t-stat		4.73		3.39		3.45
log(Final)		-0.071**		-0.159		-0.152
t-stat		-2.91		-1.23		-1.1
Country-pair FE	No	No	Yes	Yes	Yes	Yes
Time trend	No	No	No	No	Yes	Yes
N	756	756	756	756	756	756
R-squared	0.021	0.036	0.225	0.036	0.022	0.037

Sources: OECD QNA and Comtrade data, authors' computations.

Finally, the insignificant to negative role of trade in final goods is an interesting result that highlights the role of competition when traded goods are substitutes. In such a case, a productivity increase in one country can potentially decrease the value added produced in other competing sectors, which in turn can lead to negative synchronisation of fluctuations. Typical values for the elasticity of substitution between final traded goods range between three and ten (Broda, Greenfield and Weinstein, 2006), which implies a certain degree of substitution. For intermediate goods, estimates for this elasticity are lower and generally below one,

53 Moving from the 25th to the 75th percentile of the sample means multiplying the index of trade proximity by seven, which is associated with an increase in GDP co-movement of log(7)*0.269=0.52 – using the natural log as in the empirical analysis.

implying that goods are complements (see Saito, 2004 or Burstein, Kurz and Tesar, 2008), leading to positive synchronisation between countries.

3.3.4 Robustness checks

In order to assess the robustness of the results presented above, we compute an alternative measure of trade proximity, similar to Drozd and Nosal (2018). The idea is to have a measure that takes a high value whenever the amount of trade is large for at least one of the countries in the pair. It is defined by:

$$Total_{ijt} = max\left(\frac{Total\ Trade_{ijt}}{GDP_{it}}, \frac{Total\ Trade_{ijt}}{GDP_{jt}}\right)$$

This measure has the advantage of taking a high value whenever one of the two countries depends heavily on the other for its imports or exports. Performing the same analysis with this measure does not change the message: business cycle co-movement is positively associated with trade in intermediate inputs, but is not correlated with trade in final goods.

Table 11

Regression of HP-filtered GDP correlation on alternative indices of intermediate and final goods trade

	Dependent variable: correlation of HP-filtered GDP					
	No controls		Country-pair FE		Country-pair FE + time trend	
	(1)	(2)	(3)	(4)	(5)	(6)
log(Total)	0.044***		0.137**		0.032	
t-stat	4.41		2.1		0.46	
log(Intermediate)		0.069***		0.260***		0.196**
t-stat		3.07		3.07		2.25
log(Final)		-0.022		-0.142*		-0.188**
t-stat		-1.11		-1.7		-2.21
Country-pair FE	No	No	Yes	Yes	Yes	Yes
Time trend	No	No	No	No	Yes	Yes
N	756	756	756	756	756	756
R-squared	0.024	0.027	0.025	0.027	0.041	0.037

Sources: OECD QNA and Comtrade data and ECB staff calculations.

Table 12

Regression of BK-filtered GDP correlation on alternative indices of intermediate and final goods trade

	Dependent variable: correlation of BK-filtered GDP					
	No controls		Country-pair FE		Country-pair FE + time trend	
	(1)	(2)	(3)	(4)	(5)	(6)
log(Total)	0.042***		0.166		0.15	
t-stat	3.36		1.57		1.25	
log(Intermediate)		0.114***		0.374***		0.363***
t-stat		4.09		2.78		2.68
log(Final)		-0.066***		-0.206		-0.214
t-stat		-2.68		-1.57		-1.55
Country-pair FE	No	No	Yes	Yes	Yes	Yes
Time trend	No	No	No	No	Yes	Yes
N	756	756	756	756	756	756
R-squared	0.014	0.025	0.015	0.028	0.015	0.028

Sources: OECD QNA and Comtrade data and ECB staff calculations.

3.3.5 Conclusions and avenues for future research

When assessing international linkages and the potential for cross-country spillovers, further consideration should be given to trade in intermediate goods, which is strongly associated with business cycle co-movement across countries. Conversely, it should be noted that trade flows of final goods are only weakly correlated with business cycle co-movements. This may stem from the fact that typical values for the elasticity of substitution between final goods are higher than those observed for intermediate inputs. When goods are substitutes, supply shocks can lead to negative synchronisation of sales and value added while demand shocks give rise to positive spillovers.

The rise of GVCs implies not only that firm-to-firm trade has increased, but also that production takes place in a network fashion. The relative position of countries within input-output tables at the global level may have different consequences depending of the level of “upstreamness” or on the import content of exports. Such topics could constitute fruitful avenues for future research, as they would increase our understanding of the consequences of recent changes in the organisation of production.

Using data on the value added produced for each sector of the economy as well as the detailed World Input-Output Tables, it would be interesting to look at the impact of individual sector integration in GVCs on aggregate GDP co-movement. Depending on the network properties and the precise position of sectors within the network, the effect of sector-specific changes on aggregate variables could be very different, which would in turn imply that countries with different

sectoral composition do not face the same consequences of an increase in GVC participation.

Finally, disaggregated data could also be helpful in measuring several structural parameters that are key for the propagation of shocks across countries, namely: (i) the elasticity of substitution across varieties from the same sectors but different countries; (ii) the elasticity of substitution across sectors and across countries; and (iii) the price elasticity of demand faced by each industry, which encompasses the demand addressed to other firms as well as the demand coming from final consumers.

3.4 Sectoral spillovers and network effects via global production linkages[54]

3.4.1 Introduction

The global economy is a network of very complex production linkages. Firms purchase inputs from upstream suppliers, add value and sell intermediate inputs to other firms, who in turn add value before the product is sold for final consumption. As the world has become increasingly interconnected following decades of rapid globalisation, these previously national production networks have gradually turned into GVCs and incorporated firms in different countries and across many different sectors.

The structure of these production networks matters. As a recent strand of research has shown, shocks to seemingly small individual firms or sectors can cause spillovers to other industries through production networks, and even be a candidate for the origins of aggregate movements in economic activity.[55] Although an industry's share of total value added is one important reason why a sector could impact aggregate activity, it is not the complete story. Cross-sector spillovers also depend on the degree to which some sectors supply/purchase inputs to/from other sectors and how they bring sectors that do not otherwise trade directly closer to each other, acting as conductors of shocks and causing "cascade" effects.[56] These sectors are commonly called "hubs". How – and if – activity spills over and has aggregate consequences depends in part on the presence of these hubs in the global production network.

To assess the importance of spillovers in economic activity through GVCs, we use a non-linear threshold panel data model similar to Kapetanios, Mitchell and Shin (2014). In this model, the most relevant sectors for all other sectors, the so-called

54 By Erik Frohm and Vanessa Gunnella.

55 See for example Carvalho (2010), Gabaix (2011), Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi (2012), Jones (2010), Carvalho (2014), Acemoglu, Akcigit and Kerr (2015).

56 We refer here to network distance, which measures the shortest path between any two sectors in the network, i.e. the number of other partners through which two sectors trade with each other. If the network is characterised by hubs, distance should be lower than in the absence of them.

hubs, are endogenously determined based on goodness of fit. First, this model allows for an assessment of the average spillover on a sector stemming from the activity of sectors involved in its production chain. Second, it pinpoints the sectors in the global network that are most important to other sectors (the hubs), both as upstream suppliers and downstream users. Third, the model allows for an assessment of transmitted exogenous shocks and their direction through the GVC. For the purpose of our analysis, two types of shocks are considered, a demand shock (government spending) and a supply shock (shock to TFP).[57]

In the following, Section 3.4.2 outlines the properties of the global input-output network and provides some stylised facts. Section 3.4.3 estimates the activity spillovers through the GVC using the model described above and looks into the transmission of the two types of shock (supply and demand). Section 3.4.4 concludes and provides recommendations.

3.4.2 The network properties of the global economy

In much of the macroeconomic literature, starting with Lucas (1977), it is argued that shocks to individual firms or industries in the economy will have very little – if any – impact on aggregate activity. When the economy is disaggregated enough, the argument goes, a shock to one industry will be broadly offset by a shock of the opposite sign to another industry and, in the aggregate, these idiosyncratic shocks will tend to "average out". However, as Gabaix (2011) pointed out, when an economy's firm-size distribution is "fat-tailed", idiosyncratic shocks to large firms may not be negated by shocks of the opposite sign to smaller firms and could thus translate into macroeconomic fluctuations. Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi (2012) expanded on this idea and showed that not only does the firm-size distribution matter, but also the production structure of the national input-output network. If some sectors are disproportionately large suppliers or purchasers of many other sectors, idiosyncratic shocks may not average out and could cause aggregate volatility. Although national production structures, which have been the focus of much of the literature, are interesting, they do not capture the full set of international interlinkages between sectors and countries in the age of GVCs. Therefore, the analysis in this section will focus on sectoral interlinkages – both within and across countries – by utilising data in the World Input-Output Tables.

With the rise of GVCs, the global input-output network has become increasingly integrated over time. This can be seen in Chart 22, which illustrates the direct trade flows between all country sectors in the World Input-Output Tables in a) 1995 and b) 2011. The grey arrows in the chart indicate the monetary value of trade flows between country sectors. Although these figures only show direct linkages between various sectors and do not take into consideration indirect linkages through the value chain, it is remarkable how much denser the network has become over time (increasing

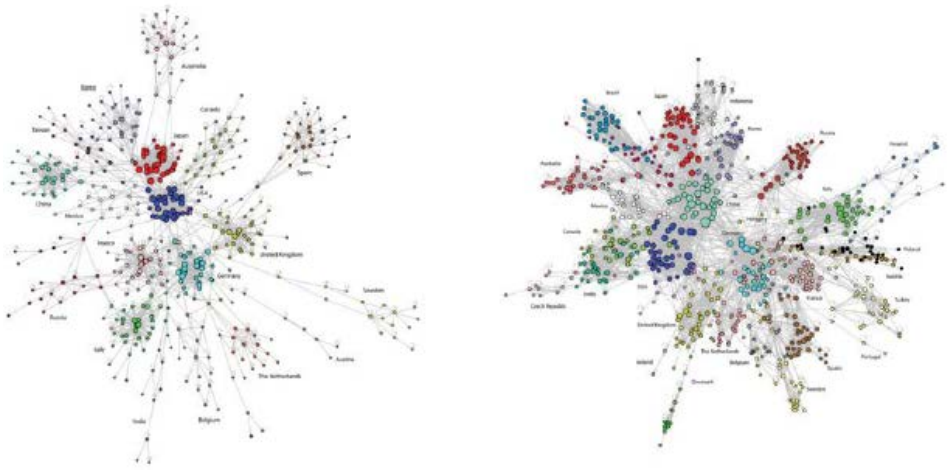
[57] According to a theoretical Cobb-Douglas production function setting, there is a clear direction of transmission of demand vis-à-vis supply shocks. Demand shocks should propagate "up" the value chain while supply shocks propagate "down".

presence of grey arrows in the charts). Moreover, the growing importance of China in trade and as a domestic economy (green dots) is particularly noticeable in panel b).

Chart 22

Network representation of the World Input-Output Tables

(in 1995) (in 2011)



Sources: Cerina, F., Zhu, Z., Chessa, A., and Riccaboni, M. (2015), World Input-Output Network, PLOS One, 10(7).
Notes: Each dot represents a country sector. The size of the dot represents the importance of that particular sector for the supply/purchase of inputs. The lines between the sectors show the direction of trade; only those higher than USD 1 billion are shown.

A few hub sectors that are either large suppliers or purchasers of inputs from many other sectors are clearly present in the global economy. Given the level of aggregation in the World Input-Output Tables, very few sectors have no connection whatsoever to other sectors (those that do are largely private households with employed persons), as shown in Chart 23.[58] The average weighted total degree[59] in 2009 across all sectors was 0.9. Examples of sectors around this average are the pulp and paper industry in Italy and France, electricity, gas and water supply in the United Kingdom, and chemicals and chemical products in Canada. Large input-supplying/purchasing sectors appear above the 95th percentile and include financial intermediation in the United States and the United Kingdom, R&D, computer activities and renting in the United States, France and Italy, mining and quarrying in Russia as well as wholesale trade in the United States and China.

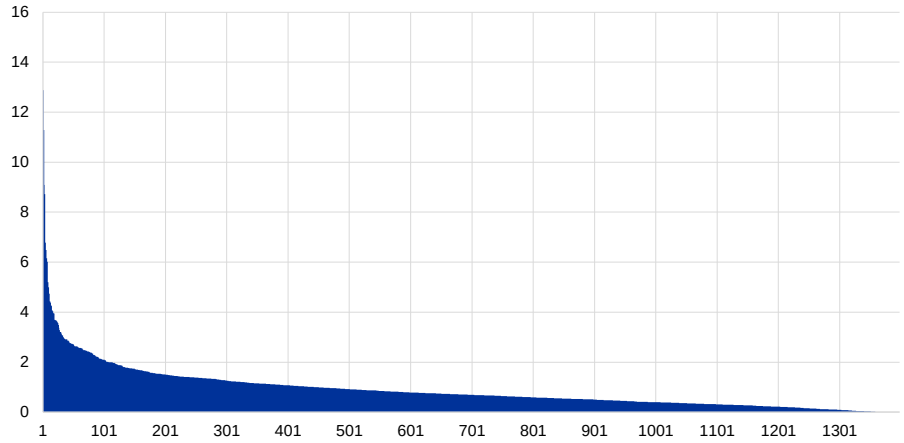
58 If the global production network was fairly equally distributed (i.e. all sectors broadly traded equal amounts with all other sectors) or self-sufficient (i.e. sectors only used primary inputs to produce final goods), the total degree across sectors would simply be a horizontal line in the chart. If the network is characterised by global hubs, we would expect to see a left-skew (as observed in Chart 2a)) in the distribution of sectors, meaning that a small number of industries have relatively strong input-supplying/purchasing relationships with many other sectors in the network.

59 The weighted degree for each country sector pair in the global network is defined as $d^i = \sum_{i=1}^{n} \omega_{i,j},$, i.e. the sum of all weights of all links attached to a sector *i*. The measure captures sector *i's* connectivity through (binary) input/purchasing relationships but also the strength of these relationships (the monetary value). In other words, the measure assigns a large value to sectors supplying/purchasing inputs of many other sectors in the network.

Chart 23

Weighted degree distribution

(cumulated percentage)



Source: Frohm and Gunnella (2017).
Notes: The figure shows the sum over all weights of the network in which a sector is a direct and indirect input supplying or purchasing sector in 2009.

However, it could also be that the weighted degree is simply a reflection of a sector's size in relation to the global economy. If so, movements in these disproportionately large sectors would be the purely accounting reason as to why sectoral activity might have a large impact on aggregate measures of activity. While there is some correlation between a sector's contribution to global value added and its total degree, it is not the full story. For example, just over a fifth of sectors above the 95th percentile in terms of total degree have very low shares of global value added (less than 0.01%). These sectors are typically mining and quarrying activities in Europe, Russia and Asia, and R&D, renting and computer activities in western and eastern Europe.

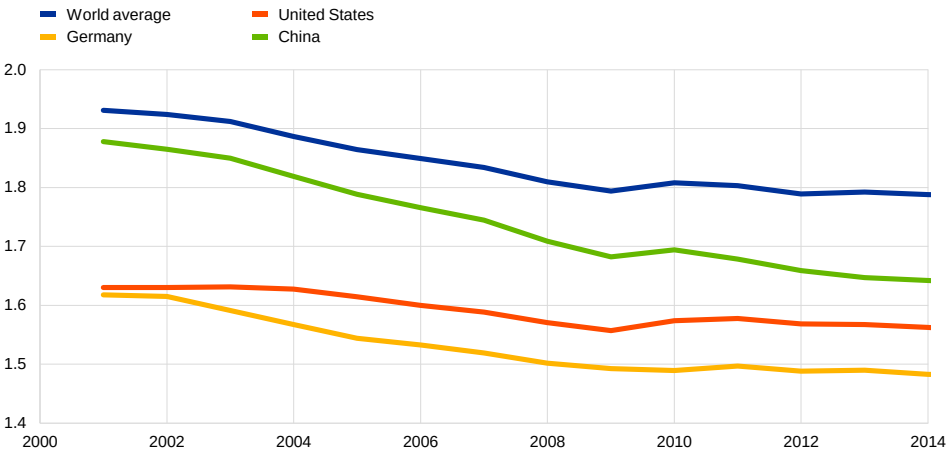
For the most part, the increasing presence of these hub sectors has shortened the average distance[60] in the global network. In less integrated networks, the distance is typically larger, as inputs travel through more stages before they reach their final destination. Conversely, in an integrated economy with some large hub sectors, each sector is only a few trades away from other sectors through the hub. The blue line in Chart 24 shows that the average pairwise distance between country sectors in the World Input-Output Tables has fallen over time, albeit with a short disruption in the aftermath of the global financial crisis. This is an indication of ongoing economic integration over the 2000s and an increasing presence of hub sectors in the global network.

[60] Distance is measured as the shortest path between any two sectors in the network, i.e. the number of times inputs from one sector are sold in order to reach another sector. If the network is characterised by hubs, the distance should be lower than in the absence of them.

Chart 24

Evolution of network distance

(average distance to each of the other countries)



Source: Frohm and Gunnella (2017).

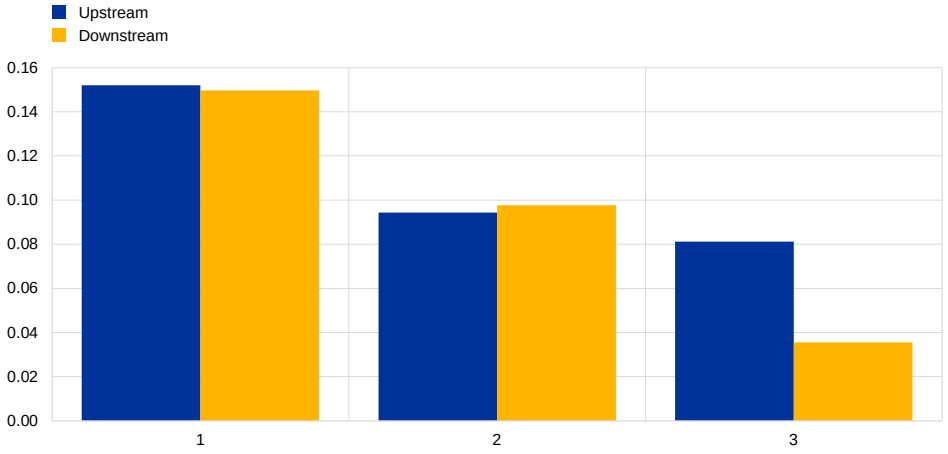
As well as being the source of economic spillovers, hub sectors can also act as conductors of shocks from elsewhere in the global network. When the average distance in the network is shorter, we would expect to see higher correlations in activity between pairs of country sectors (Carvalho, 2014). As an example, in the manufacturing of a car, the sector producing tyres should correlate more with car production, not only because the tyres contribute to the finished car's total value added but also because the tyre industry directly sells intermediate inputs to the car industry. Chart 25 shows the average pairwise correlations of real value added, employment and labour productivity over 1995-2009 for all country sectors and across various distances in the global network, both upstream and downstream in the supply chain. As expected, activity correlates more strongly when two sectors trade more directly with one another. This is important, because we argue that not only do hubs cause spillovers because they are large suppliers or purchasers of inputs, but also because they shorten the distance between otherwise unconnected sectors. This could also help explain why activity across sectors co-moves within a country, but also across countries, even without the presence of aggregate shocks.

Overall, the global network constructed from data in the World Input-Output Tables seems to be characterised by sectoral hubs and there has been a clear evolution over time towards tighter economic integration globally, although most supply chains still have clear regional characteristics (WTO 2013). The relevant question now is whether there exists a statistically and economically significant relationship between activity in a given sector and activity in its global supply chain.

Chart 25

Synchronisation of real value added and network distance

(correlation coefficient vs distance for upstream and downstream sectors)



Source: Frohm and Gunnella (2017).

3.4.3 Sectoral spillovers in the global economy

To investigate how economic activity spills over in GVCs, we utilise an econometric, non-linear panel data model. In the model, the current activity of a sector in a country, say sector i, is determined by its past activity and a weighted average of the activity of a group of sectors included in its GVC. The weights are assigned according to the value added contribution of the other sector to sector i's output and the network distance of the other sector from sector i. As explained in the previous section, more weight is attributed to sectors which have a higher share of value added in sector i's production and have a shorter distance to sector i in the World Input-Output Network.

Formally, the model specification is:

$$y_{it} = \eta_t + \rho^{lag} y_{i,t-1} + \rho^{up} \tilde{y}^{up}_{i,t-1} + \rho^{down} \tilde{y}^{down}_{i,t-1} + \beta' x_{it} + \varepsilon_{it} \quad (1)$$

where y_{it} is the value added of sector i at time t, $\beta' x_{it}$ is a set of controls and $\tilde{y}^{up}_{i,t-1}$ is the upstream value added of other sectors defined by:

$$\tilde{y}^{up}_{i,t-1} = \sum_{j \neq i} 1\left(w^{up}_{ij,t-1} \geq r^{up}\right) w^{up}_{ij,t-1} y_{j,t-1}$$

$\tilde{y}^{down}_{i,t-1}$ is the downstream value added of other sectors defined by:

$$\tilde{y}^{down}_{i,t-1} = \sum_{j \neq i} 1\left(w^{down}_{ij,t-1} \geq r^{down}\right) w^{down}_{ij,t-1} y_{j,t-1}$$

The split between sectors' supply and use relationships makes it possible to trace the impact of economic shocks (see Section 4). To construct the weights that define the

"downstream" and "upstream" relationships, we take into account both the value added contribution and the network distance:

$$w_{ij,t-1}^{up} = \frac{VA_{j\to i,t-1}}{VA_{*\to i,t-1}} \times \frac{1}{\mathrm{d}_{ij,t-1}^{up}}$$

$$w_{ij,t-1}^{down} = \frac{VA_{i\to j,t-1}}{VA_{i\to *,t-1}} \times \frac{1}{\mathrm{d}_{ij,t-1}^{down}}$$

where VA is the value added contribution to the total output, i.e. the value added by a sector to another sector's production, and d is the shortest distance between two sectors. Through the Leontief insight[61], the gross output used in all intermediate stages of production can be traced. Therefore, value added does not only take into consideration the direct connection via each sector's production chain, but also the second and higher-order interconnections to other sectors via direct trading partners. Moreover, the panel model allows us to control for observed and unobserved common factors that could cause value added growth in sector i not driven by spillovers. As such, the estimated spillover coefficient will just pick up the influence of other sectors on the value added of sector i.[62]

The estimated impact on a sector's activity stemming from its GVC is statistically and economically significant, as shown in Table 13. The addition of control variables reduces the fairly large coefficients but does not compromise their significance. A 1% change in value added in the global network translates into an impact of about 0.3% on an industry, on average. This shows that while aggregate and global factors do play an important role in driving fluctuations at the sector level, they are not the only source of sectors' co-movements, which are also transmitted through the production chain.

61 Algebraically, $VA_{j\to i,t}$ is an entry of the matrix vLY, where v is a (NC*NI x NC*NI) diagonal matrix with value added vector on the diagonal, L is the Leontief matrix (NC*NI x NC*NI) and Y is a (NC*NI x NC*NI) diagonal matrix with gross output on the diagonal. NC is the total number of countries and NI is the total number of industries. The Leontief matrix is computed as $L = (I - A)^{-1}$, with the dimension NI*NC x NI*NC, where NI represents the total number of sectors and NC the total number of countries. I is the identity matrix and A is the NI*NC x NI*NC technical coefficient matrix, corresponding to the use of intermediate goods in the production of one unit of output and computed from the global input-output matrix Z as A=Z*inv(Y).

62 The unobserved common factors are modelled as in Pesaran (2006), i.e. with the cross-sectional averages of the dependent variable and the regressors.

Table 13

Regression results

	Baseline	Unobs. factors + controls	Unobs. factors + controls + global bc	Government (demand) shock	TFP (supply) shock
Lag	0.027***	-0.033***	-0.032***	-0.033***	0.038*
	(0.012)	(0.012)	(0.012)	(0.012)	(0.021)
Upstream	0.705***	0.185***	0.198***	0.307	0.001
	(0.015)	(0.069)	(0.069)	(1.671)	(0.007)
Downstream	0.407***	0.125**	0.123**	1.330**	0.004
	(0.051)	(0.058)	(0.058)	(0.626)	(0.022)
Own				0.060	-0.036*
				(0.054)	(0.024)
Country		0.152***	0.129***	0.224***	0.099**
		(0.027)	(0.026)	(0.015)	(0.043)
Employment		0.455***	0.453***	0.456***	0.457***
		(0.015)	(0.015)	(0.015)	(0.033)
Agriculture			-0.056*		
			(0.032)		
Fuel			-0.030*		
			(0.017)		
Metal			0.011		
			(0.023)		
Interest rate			-0.078		
			(0.226)		
Year effects	N	Y	N	Y	Y
Obs.	17,511	17,511	17,511	17,511	4,950

Notes: The table shows the estimated coefficients from regression (1), where the dependent variable y_{it} is the log difference of value added. The average of the dependent variables is considered as a common factor in the error term. Standard errors are reported in brackets.

Apart from better controlling for observed and unobserved factors driving fluctuations, another interesting novelty of this approach is that it endogenously determines the most important sectors (hubs) globally. The threshold search[63] identifies two parameters, which are then used to identify the sectors included in $\tilde{y}_{i,t-1}^{up}$ and $\tilde{y}_{i,t-1}^{down}$. These hubs are identified as those sectors entering most often into the group of relevant sectors for any sector i. This makes it possible to draw up ex post a rank of sectors according to their prominence in the production network and to follow its evolution over time. In Table 14, the top ten sectors in 1997 and 2009, both upstream and downstream in the GVC, are shown.

Looking at the upstream ranking, the top sectors are the renting of equipment and other business services (encompassing R&D and computer activities), raw materials and finance in the United States, Germany and Russia. This country-sector rank is fairly intuitive. We expect such sectors to be located upstream as they provide primary inputs to the production processes of many other sectors. As regards the sectors situated downstream in the production network, the ranking is

[63] As the threshold used for the grid search minimises the sum of squared errors, we ensure that the final model best fits the data. To ensure that the size of the threshold does not affect the results, we also run the regression without the thresholds.

dominated by manufacturing (transport equipment, machinery and electrical and optical equipment), construction and government (in the United States).

Interestingly, in the downstream ranking we can see the rise of Chinese sectors as the most important sectors at the expense of those in the United States in recent years: three industries in the United States have been replaced by three Chinese industries.

Table 14

Ranking of sectors in the global production network

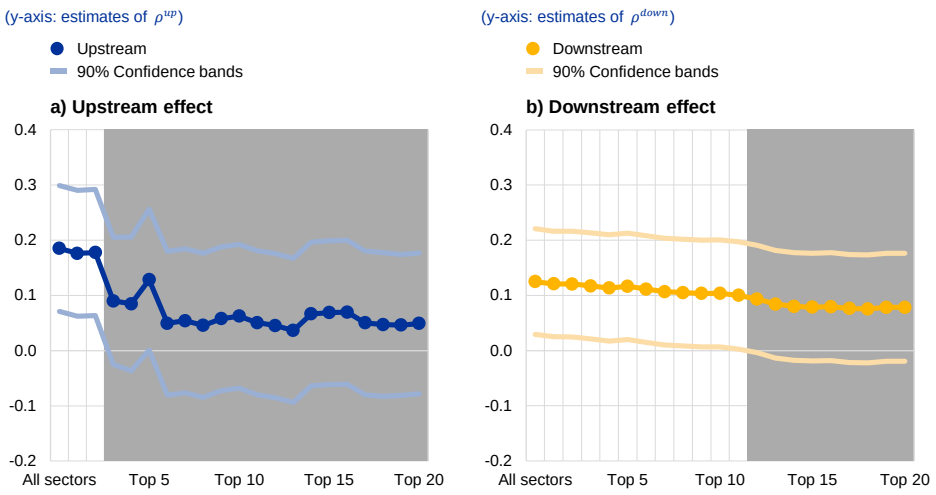
(top ten sectors according to presence in other sectors' functioning)

Upstream 1997	Upstream 2009	Downstream 1997	Downstream 2009
USA – renting of m&eq and other business activities	DEU – renting of m&eq and other business activities	DEU – transport equipment	DEU – transport equipment
DEU – renting of m&eq and other business activities	USA – renting of m&eq and other business activities	USA – transport equipment	CHN – electrical and optical equipment
RUS – inland transport	RUS – mining and quarrying	DEU – construction	CHN – basic metals and fabricated metal products
DEU – basic metals and fabricated metal products	GBR – renting of m&eq and other business activities	USA – public admin and defence; compulsory social security	USA – public admin and defence; compulsory social security
RUS – mining and quarrying	DEU – basic metals and fabricated metal products	USA – construction	DEU – construction
RUS – wholesale trade and commission trade, excluding motor vehicles and motorcycles	USA – financial intermediation	DEU – machinery, nec	DEU – machinery, nec
DEU – chemicals and chemical products	FRA – renting of m&eq and other business activities	USA – electrical and optical equipment	CHN – construction
RUS – coke, refined petroleum and nuclear fuel	RUS – wholesale trade and commission trade, excluding motor vehicles and motorcycles	DEU – basic metals and fabricated metal products	DEU – basic metals and fabricated metal products
USA – financial intermediation	NLD – renting of m&eq and other business activities	USA – basic metals and fabricated metal products	FRA – transport equipment
USA – wholesale trade and commission trade, excluding motor vehicles and motorcycles	DEU – chemicals and chemical products	JPN – construction	USA – transport equipment
GBR – renting of m&eq and other business activities	RUS – inland transport	USA – renting of m&eq and other business activities	CHN – textiles and textile products

In a counter-factual exercise where the ties between these global hubs and other sectors are severed, spillovers through the GVC become significantly smaller. Through the ex post ranking in Table 14, it is possible to assess spillovers in the absence of some these hubs in the global production network. Using the ranking, we gradually eliminate the top sectors one by one until spillovers through the network are insignificant. Chart 26 shows these estimates together with 90% confidence bands. The magnitude of the network coefficients (upstream and downstream combined) falls by almost a fifth when the top five global hubs upstream and downstream are severed from the rest of the network. The network effects stemming from upstream in the GVCs become insignificant when the top three global upstream hubs are removed, and the downstream impacts disappear completely when the top 12 hubs are removed. This highlights the importance of the sectoral hubs in synchronising activity within and across countries through GVCs.

Chart 26

Value added spillovers through the GVC when removing global hubs



Source: Frohm and Gunnella (2017).

Do supply and demand shocks propagate according to theory? Following Acemoglu, Akcigit and Kerr (2015), we also utilise our model to test the direction of two plausibly exogenous shocks. We consider one demand shock (government spending) and one supply shock (to TFP). According to a theoretical Cobb-Douglas production function setting, supply shocks should propagate from upstream sectors to those downward in the supply chain, as downstream sectors are reliant on inputs from sectors further up the value chain. Similarly, a demand shock should propagate from downstream sectors to upstream ones, as their sales of inputs are directly tied to the demand for the final product. The results reported in the last two columns of Table 13 support the upward propagation of demand shocks (government spending), whereas results for supply (TFP) shocks are not conclusive. However, we should remark that the supply shock regression utilises a smaller sample because of lack of data for TFP, both cross-sectionally and over time.

3.4.4 Conclusions and recommendations

The global economy is a network of complex production interlinkages, characterised by large sectoral hubs. These hubs are important suppliers or users of inputs globally. Their increasing importance over time has further integrated global production, also by shortening the distance between otherwise unrelated sectors. Upstream in the GVC, the most important sectors (in 2009) are estimated to have been computer activities, R&D, finance and raw materials in the United States, the United Kingdom, Germany and Russia. The top ten sectors have not changed significantly over time. Downstream in the value chain, however, sectors in China (electronics, basic metals and construction) have become significantly more important over the 2000s. Together with transport equipment, machinery, construction and basic metals in Germany, transport equipment in France and the United States as well as the public sector in the United States, they constitute the most important purchasers of inputs of other sectors in the global economy.

Activity transmits through these hubs in the GVCs. Empirical estimates confirm the statistical and economic significance of GVCs in transmitting activity across sectors and countries. Such estimates indicate that a 1% change in economic activity in the GVC translates into an impact of around 0.3 percentage points on the activity of an industry, on average. Notably, the effect stemming from other sectors in the production network is larger than that arising from the aggregate activity in the country to which the sector belongs. This highlights the importance of global interlinkages in transmitting economic disturbances across countries. However, it is not production linkages per se that cause the relatively large spillovers, but rather the presence of large global hub sectors. When these global hub sectors are gradually removed, average spillovers through the GVC are significantly reduced; after eliminating the top 16 hub sectors, the spillovers vanish.

Overall, this analysis suggests that increasing integration in GVCs has contributed to synchronised activity across sectors and countries. In this sense, global hub sectors are instrumental in contributing to higher correlations in activity across country sectors. Moreover, these large hubs could act as powerful sources of economic shocks and as conductors of shocks coming from smaller, seemingly unrelated sectors.

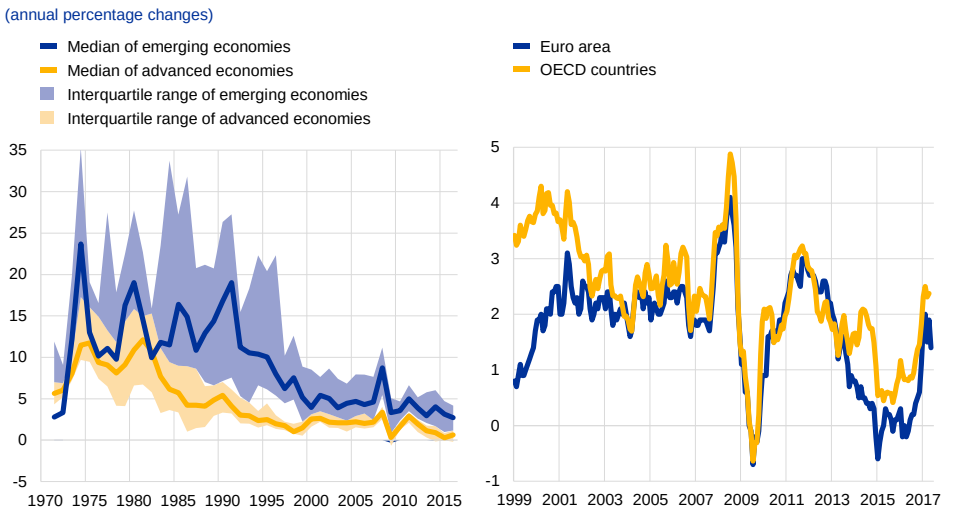
These results stress the importance of not only focusing on aggregate – or global – shocks when assessing cross-country spillovers, but also taking into account sectoral global production linkages. Moreover, in better understanding aggregate (co-)movement, aggregate analysis could be further combined with more granular approaches to understand the transmission of shocks through global hub sectors and their spillovers across countries.

4 Prices and costs

Euro area inflation rates have become highly synchronised with global developments. In the last two decades, a synchronisation of inflation developments can be seen across a large group of advanced and emerging market economies (Chart 27). Euro area inflation has also been very strongly correlated with inflation in the countries of the Organisation for Economic Co-operation and Development (OECD), with two exceptions: from 1999 to 2002, when there was a period of low inflation following the introduction of the euro and, to a lesser extent, between 2014 and 2015 (see Chart 27). This synchronisation can likely be explained to an important degree by the pursuit of similar credible monetary policies across economies (Mishkin, 2009) and movements in global commodity prices. Some, however, argue that at least a portion of the international inflation co-movement can be attributed to increasing trade (Monacelli and Sala, 2009), a larger role of global slack in domestic inflation (Borio and Filardo, 2007) or tighter production linkages across countries (Auer, Borio and Filardo, 2017 and Auer, Levchenko and Sauré, 2017).

Chart 27

Inflation developments in advanced and emerging market economies



Sources: a) Haver Analytics; b) OECD, Eurostat and ECB calculations.
Notes: a) The interquartile range covers 50% of the samples of emerging and advanced market economies. The sample includes 17 advanced economies (Australia, Austria, Belgium, Canada, France, Germany, Greece, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland and the United States) and 25 emerging market economies (Bolivia, Chile, Colombia, Côte d'Ivoire, Ecuador, Egypt, El Salvador, Guatemala, Honduras, Indonesia, Israel, Jamaica, South Korea, Malaysia, Mauritius, Mexico, Nigeria, Paraguay, the Philippines, Singapore, South Africa, Taiwan, Thailand, Tunisia, Turkey). Only countries for which data going back to 1970 are available have been included. The latest observation is for 2017 (annual data); b) The latest observation is for August 2018 for the euro area and July 2018 for the non-euro area OECD countries (monthly data).

In this chapter, we analyse the potential role of GVC integration in the synchronisation of euro area and global inflation developments. Section 4.1 takes a more micro-based view and looks at changes in import content of euro area consumption as well as at the pass-through of cost shocks via producer prices. Part 4.2 takes a more macro-based view and evaluates the role of foreign slack for domestic inflation in the euro area and whether and how integration in GVCs has affected this role.

4.1 Network effects in the transmission of cost shocks[64]

4.1.1 Introduction and stylised facts

The transmission of foreign cost shocks to euro area inflation rates through GVCs is motivated by the findings in the literature on production networks. Rather than averaging out, for example, idiosyncratic cost shocks to firms or sectors in integrated production networks could propagate through supply and use relationships and cause volatility in macroeconomic aggregates.[65] This means that national inflation figures could be strongly influenced by changes at the microeconomic – or "granular" – level and by international supply chains.

Integration in GVCs influences domestic price setting through imported intermediate inputs. The prices of these intermediate inputs depend on foreign material costs, wages and price formation in the global economy. The more extensive the cross-border dimension of the production networks, the greater the influence of external factors will tend to ultimately be on the costs of domestic firms and in turn on national inflation rates.

The purpose of this study is to assess the relative importance of supply chain spillovers for euro area inflation rates. To answer this question, the contribution of each sector to final consumption is traced through the input-output tables. Second, we employ a regression framework based on the theoretical price setting equation in Amiti, Itskhoki and Konings (2014), which is modified in order to explicitly model the limited pass-through of input costs for inflation spillovers in euro area countries. The novelty of this approach is that it provides estimates of the importance of supply chains for each sector's final price for consumption (the private consumption deflator) in a specific (euro area) destination market. This allows us to capture the full extent of supply chain spillovers for domestic private consumption deflators in the euro area.[66]

The section is structured as follows: Section 4.1.2 provides a brief overview of the data and some stylised facts that support the notion of increasing foreign influence on euro area domestic prices. Section 4.1.3 estimates the impact of inflation spillovers through sectoral supply chains, while controlling for other determinants of sectoral prices. It also distinguishes between foreign and domestic impacts through the supply chain. Section 4.1.4 concludes.

4.1.2 Mapping global supply chains

Production linkages between sectors in different countries are constructed from global input-output tables. While national input-output tables have a

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64 By Erik Frohm, Vanessa Gunnella and Derry O'Brien.

65 For a quantification of the importance of "hub" sectors in transmitting economic disturbances in the global economy, see Frohm and Gunnella (2017).

66 The private consumption deflator and the HICP are closely related. The main difference is that "imputed rents" are taken into account in the private consumption deflator but not in the HICP.

long-standing tradition in national accounting, starting with Leontief (1936), it is only recently that efforts have been made to consistently map these tables with international trade flows.[67] Such global input-output tables have many advantages. They enable the tracing of value added (and not only gross flows) through supply and use linkages between sectors and across borders, thus making it possible to, among many other purposes, assess the relative importance of developments in a sector in one country for another country's GDP or prices.

The latest vintage of the WIOD[68] is used for simulations in the global input-output network. This provides an updated picture (to 2014) of how producer price spillovers have evolved since the Great Recession. The earlier vintage, which is available in current and previous years' prices up to 2009, is used to derive bilateral input prices across sectors and countries, as well as prices for final demand in all euro area countries. The older vintage is accompanied by Socio-Economic Accounts (SEAs), comprising wages and capital costs at the sector level. These data enable us to clearly distinguish between supply chain spillovers to private consumption deflators in euro area countries and at the same time control for the effect of other factors influencing a sector's prices. But first, we use the global input-output tables to take a closer look at the foreign influence on euro area prices.

Domestic inflation rates can be influenced by foreign developments both via the direct effects of increasing final goods imports and the indirect effects of imported inputs in euro area production.

A steadily increasing share of euro area private consumption is of foreign origin (see Chart 28a). By utilising the global input-output tables, we can compute the contribution of each country sector to private consumption in each euro area country. That way, we are also able to distinguish between domestic and foreign contributions. The extra-euro area content in consumption has been increasing generally across the euro area since the 2000s; the median impact increased from around 7% in 2000 to 13% in 2014 (after losing momentum temporarily in 2009). In the four largest euro area economies in 2014, foreign influence accounted for more than 9% in Germany, 7% in France and 6% in Italy and Spain.[69] As expected, the foreign content of consumption in small, open economies (e.g. Ireland, Slovakia and Slovenia) is significantly larger (up to 23% in Ireland) (see Chart 28b).

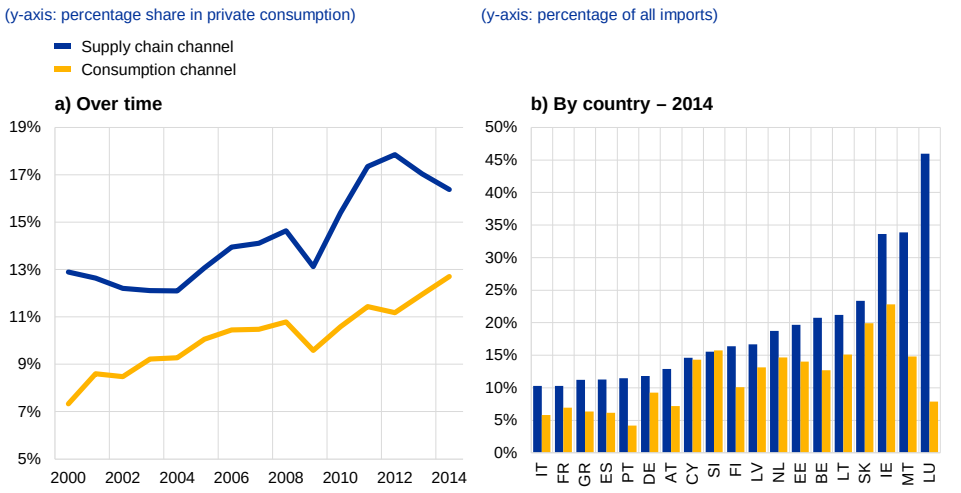
67 Examples are the World Input-Output Tables, OECD Trade in Value Added (TiVA), EORA and JDE-Jetro.

68 See Box 2 for a description of the database.

69 No comparison is drawn with 2009 because of the Great Recession, which brought down the shares significantly but was in all likelihood a temporary decline.

Chart 28

Foreign influence on private consumption in the euro area



Source: World Input-Output Tables (2016 release).
Notes: The interquartile range shows the foreign share of private consumption in euro area countries between the 75th and 25th percentile. It excludes intra-euro area trade flows. The median is calculated across all 19 euro area countries. Latest data: 2014.

Outside of the euro area, other countries in Europe account for an important share of importsWI, which tends to confirm the role of standard, gravity-type trading relationships, i.e. countries that are physically closer to each other, share common characteristics (language, borders, currency and culture) and large markets will tend to trade more intensively. Apart from Europe, China's influence has increased substantially from 2000, although its share in euro area private consumption remains relatively small (around 1% median impact). This shows that the direct influence of foreign imports on euro area prices has increased in line with globalisation trends.

As for indirect effects, the impact of global cost shocks on euro area producer prices has increased (Box 7).

Box 7

Estimating the indirect effects of global cost shocks on producer prices in the euro area

In a first-pass assessment of how shocks impact euro area producer prices via input-output linkages, synthetic cost shocks are applied to all country sectors except for those in the euro area. These shocks are then transmitted to euro area producer prices using the Leontief inverse (see Auer, Levchenko and Sauré, 2017):

$$\widehat{PPI} = (1 - \Gamma')^{-1} \mathrm{D} \hat{C}$$

where $\widehat{PPI}$ is a vector containing the producer prices for each country sector, Γ is the global input-output matrix, D is a diagonal matrix where the diagonal elements are the value added as a share of total output for each country sector and $\hat{C}$ is a vector containing the cost shock scenario.

Applying the methodology to the WIOD (2016 release), the estimated impact for 2014 is noticeably higher than in the early 2000s; for a cost shock that produces a 1% change in global (excluding euro area) producer prices, the median impact on producer prices across euro area countries increases from 0.13% in 2000 to a peak of 0.18% in 2012, before falling back to 0.16% in 2014. This

phenomenon is relatively broadly based across euro area countries, reflecting the proliferation of globally integrated production chains, but the increases are particularly strong for Luxembourg, Belgium and Lithuania.

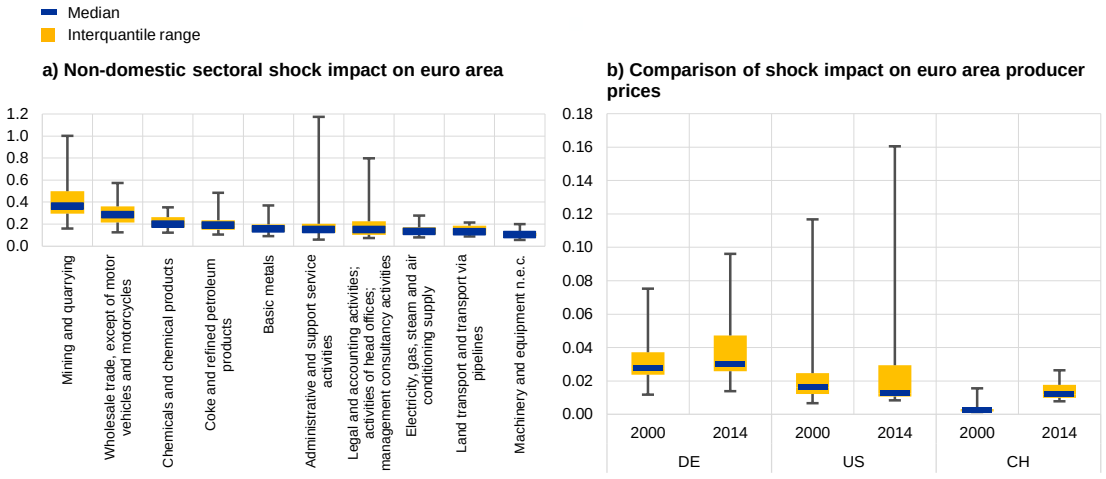
Small, open economies, such as Luxembourg, Malta and Ireland, tend to be most exposed to global cost shocks. By contrast, the impact is relatively modest for large economies (e.g. Italy and France) and small but relatively less open economies (e.g. Greece and Portugal). Notably, shocks originating in all non-domestic mining and quarrying, wholesale trade and chemical products sectors tend to have the largest median impact on aggregate producer prices (Chart Aa). Conversely, for shocks originating in euro area countries' domestic sectors, the real estate, wholesale trade and construction sectors tend to have the largest median impact on aggregate producer prices.

While there is some heterogeneity in the relative importance of the sources of the shocks, key changes have also occurred since the early 2000s, with developing economies generally becoming more influential. For example, the impact of a cost shock originating in China has increased considerably; for a cost shock that produces a 1% change in producer prices across all sectors in China, the median impact across euro area countries has increased six-fold from 0.002% in 2000 to 0.012% in 2014 (see ChartAb). By way of contrast, the corresponding impact from the United States has declined slightly from 0.016% to 0.013% over the same period.

Chart A

Impact of global cost shocks on euro area producer prices

(percentage impact)



Source: ECB projections database.
Notes: The long-run coefficients are computed over various percentiles. The elasticities are obtained from a panel error correction model and estimated with various definitions of the REER (HICP, GDP deflator and export deflator). The chart shows the average elasticities of the three models. Whereas unit labour costs are also significant for the demand elasticities they are not for price elasticities but not prices and are hence excluded from the chart.

Overall, the results support the notion of the rising influence of global cost shocks on euro area producer prices via input-output linkages. The analysis assumes full pass-through and does not control for other factors influencing a sector's price formation. Movements in exchange rates are also not taken into account[70]. In this sense, the estimated impact may be broadly interpreted as upper bounds.

[70] The analysis also does not take into consideration the extent to which foreign sectors use euro area sectors as suppliers to produce goods for euro area consumption.

4.1.3 The importance of foreign price spillovers through supply chains

Domestic sectors account for the bulk of the supply chain effect on euro area inflation rates, although foreign sectors have become more important over time. The estimates in the following suggest that the supply chain effect is statistically and economically significant for prices in the euro area. However, the lion's share of the supply chain effect continues to stem from domestic suppliers. Only a small part can be attributed to foreign countries (intra- and extra-euro area), although their importance has increased over time – especially for inflation rates in some smaller euro area economies. The next section will elaborate on the method employed to derive these results.

Our empirical specification relates domestic private consumption deflators in the euro area to the prices of all suppliers (both domestic and foreign) and accounts for limited pass-through. Building on a general equilibrium model for the determination of export prices with variable mark-ups and imported inputs (Amiti, Itskhoki and Konings, 2014), we specify an equation, which relates a sector's price (of a destination market's private consumption deflator) to changes in input prices of both foreign and domestic suppliers, movements in the exchange rate and other capital and labour costs[71]:

$$\Delta p_{idt} = \beta_{mc}\Delta mc_{it} + \beta_{mc\varphi}\Delta mc_{it}\,\varphi_{id,t-1} + \beta_e \Delta e_{idt} + \beta_l \Delta l_{it} + \beta_k \Delta k_{it} + \varepsilon_{idt}$$

The unit of observation i is a country sector setting prices for destination d at time t. p_{idt} is the price expressed in the producer's currency for final consumption in market d (similar to the private consumption deflator in the national accounts), φ_{idt} is the share of d's intermediate goods in sector i's production for destination d[72], e_{idt} is the nominal exchange rate between i's country and country d[73], l_{it} is the labour compensation of sector i, k_{it} is the capital compensation of sector i and mc_{it} is the marginal cost of sector i. The marginal cost measure includes inputs from both domestic and foreign sectors as well as sector-specific labour costs, weighted by the respective shares, i.e.:

$$\Delta mc_{it} = \sum_{j=1}^{NI}\sum_{c=1}^{NC} w_{ijct}\,\Delta\log(e_{ict}U_{ijct})$$

where U_{ijct} is the price of intermediate inputs produced by sector j in country c and the weight w_{ijct} takes into account all direct and indirect contributions of j to the production of i.[74]

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71 Unlike Amiti, Itskhoki and Konings (2014), the empirical specification is used to focus on the pass-through of input costs rather than on the exchange rate pass-through.

72 φ_{idt} is equivalent to the total imported input value from destination d over total variable costs (intermediate inputs + wages). φ_{idt} is set to zero when sector i's country shares the same currency as country *d*, since there are no currency effects on marginal costs.

73 The exchange rate is expressed in terms of the units of i's currency per one unit of country d's currency, i.e. an increase in e_{idt} corresponds to a depreciation of i's currency.

74 Sector-level final consumption deflators and sector-bilateral intermediate input deflators are calculated using the world input-output tables in current and in previous years' prices.

The marginal cost measure captures the links to domestic and foreign suppliers. This allows us to trace the effect of a change in prices by suppliers in any country sector on domestic inflation in country d. This effect will be dampened if sector i employs a significant share of inputs produced in destination country d. Accordingly, an increase in marginal costs originating from d due to a depreciation of i's currency will be offset by a decrease in prices expressed in d's currency.

While there is a strong theoretical case to include mark-ups in a firm-level regression, reliable proxies for mark-ups are hard to come by at the sector level. Nonetheless, we experiment with two different sets of proxies for mark-ups to check the robustness of the results: (i) the average mark-up (inverse of wage bill/value of sales to destination d[75] and (ii) the sector-level market share of destination d's private consumption.[76] The main results reported below are robust to the inclusion of both measures of mark-ups, although the statistical significance of the mark-up variable depends on the empirical measure.

Supply chain trade is one important determinant of domestic inflation rates. The results point to the strong significance (statistical and economical) of the marginal cost coefficient β_{mc} for price setting in all euro area economies (see Table 15). A standard deviation in the marginal cost variable translates into around 0.2 standard deviations in a sector's price for euro area private consumption. The supply chain effect on a sector's price is as large as the sum of the effects of domestic labour and capital costs. Smaller euro area countries typically exhibit a larger pass-through of costs into final prices. Moreover, sectors with higher import intensities from the euro area destination country tend to have a lower pass-through into prices.

National inflation rates are mostly affected by domestic supply chain spillovers. Using the estimates in Table 15, it is possible to derive the impact of the domestic and foreign part of the global supply chain on each euro area country's private consumption deflator. The estimates take into account limited pass-through and consider the weight of each other sector's intermediate input in producer i's costs. The effects on the private consumption deflator are weighted by the respective share of total private consumption in the destination country. Chart 29 shows the relevance of domestic suppliers and foreign (intra-euro area and extra-euro area) suppliers for inflation rates in each euro area country.[77] Clearly, the bulk of the supply chain impact stems from domestic suppliers in all euro area countries. The influence of foreign supplier sectors ranges from 32% in Ireland to 5% in Italy. From 1996 to 2008, the influence of foreign suppliers increased across almost all euro area countries. This is again particularly the case for smaller, open euro area economies such as Ireland, Malta and Lithuania.

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75 In a Cobb-Douglas production setting and under standard assumptions, with no overhead labour costs, the mark-up is inversely proportional to the labour share.

76 This measure captures sector i's sales as a share of euro area private consumption and is thus a sector-level measure of market power, but does not address the degree of competition within a sector across countries.

77 Given the large drop both in trade and use of imported intermediate inputs in 2009, the chart outlines the domestic and foreign spillovers in 2008.

Table 15

Regression results

(standardised coefficient)

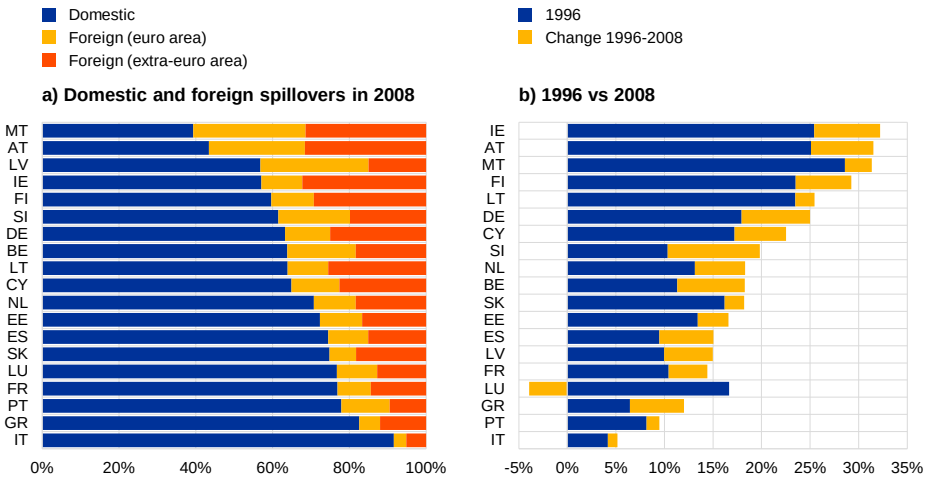
Country	β_{mc}		$\beta_{mc\varphi}$		β_e		β_l		β_k		R^2
AT	0.229***	-0.085	0.125**	-0.055	0.514***	-0.081	0.108***	-0.025	0.091***	-0.01	0.66
BE	0.219**	-0.101	0.297	-0.203	0.521***	-0.088	0.104***	-0.025	0.087***	-0.01	0.65
CY	0.262***	-0.08	1.779	-3.616	0.534***	-0.075	0.089***	-0.024	0.085***	-0.01	0.65
DE	0.197**	-0.092	0.077***	-0.021	0.492***	-0.074	0.096***	-0.023	0.086***	-0.01	0.65
ES	0.187**	-0.082	0.508***	-0.132	0.606***	-0.068	0.093***	-0.021	0.078***	-0.009	0.68
EE	0.278***	-0.101	-0.328	-0.314	0.553***	-0.095	0.088***	-0.025	0.080***	-0.01	0.69
FI	0.237***	-0.086	0.014	-0.019	0.589***	-0.065	0.097***	-0.022	0.080***	-0.009	0.67
FR	0.200**	-0.081	0.165***	-0.063	0.567***	-0.055	0.094***	-0.022	0.083***	-0.01	0.68
GR	0.241***	-0.085	0.321***	-0.107	0.511***	-0.067	0.093***	-0.022	0.085***	-0.01	0.67
IE	0.223***	-0.082	0.185	-0.175	0.635***	-0.056	0.087***	-0.02	0.077***	-0.009	0.69
IT	0.200**	-0.081	0.171***	-0.054	0.482***	-0.088	0.104***	-0.026	0.088***	-0.01	0.67
LT	0.254***	-0.096	-0.19	-0.278	0.619***	-0.075	0.068***	-0.021	0.071***	-0.01	0.73
LU	0.227***	-0.08	0.241	-0.535	0.629***	-0.052	0.089***	-0.021	0.077***	-0.009	0.68
LV	0.193**	-0.078	1.161***	-0.29	0.655***	-0.076	0.071***	-0.021	0.069***	-0.009	0.72
MT	0.203***	-0.07	3.938	-2.81	0.650***	-0.053	0.073***	-0.02	0.068***	-0.008	0.69
NL	0.219**	-0.087	0.173***	-0.039	0.554***	-0.058	0.093***	-0.021	0.089***	-0.01	0.67
PT	0.230***	-0.079	0.642***	-0.132	0.594***	-0.054	0.096***	-0.021	0.082***	-0.009	0.69
SK	0.258***	-0.097	0.438	-0.427	0.515***	-0.084	0.094***	-0.024	0.088***	-0.01	0.65
SI	0.222**	-0.093	2.668**	-1.052	0.555***	-0.074	0.093***	-0.022	0.083***	-0.01	0.66

Notes: The table shows the estimated coefficients from the regression in Section 4.1.3 with sector-country of origin fixed effects, time dummies and errors clustered at the origin year level. To make it possible to compare coefficients, variables are standardised and the coefficients reported measure the effect of a standard deviation in the independent variables. Standard errors are reported in brackets. F and p-value refer to the test of hypothesis $\beta_{mc} + \beta_{mc\varphi}\bar{\varphi}_d = \beta_l + \beta_k$, where $\bar{\varphi}_d$ is the average import intensity from destination d for the estimation sample.

Chart 29

Supply chain spillovers to euro area inflation

(% share of total supply chain effect)



Sources: World Input-Output Tables (2013 edition) and ECB calculations. Latest data: 2008.

How have euro area supply chains developed more recently? While we must await the release of theWIOD tables in previous year' prices to estimate whether the pass-through of foreign cost shocks has changed since the Great Recession, we can indirectly infer whether a change is likely. Although data do suggest that production fragmentation increased after the Great Recession up to 2011, the consensus in the literature, on the basis of a range of updated indicators, is that GVC participation has been quite stable since then (see Timmer, Los, Stehrer and de Vries, 2016; Haugh, Kopoin, Rusticelli, Turner and Dutu, 2016 and IRC Trade Task Force, 2016).

4.1.4 Conclusions

The analysis in this note suggests that while foreign influence on euro area inflation rates increased over the 2000s, domestic factors continue to play a dominant role. The foreign content of euro area consumption has increased steadily over time and suggests a greater "direct impact" on euro area inflation. At the same time, "indirect effects" stemming from global cost shocks through supply chains of euro area producers has also increased. However, regression estimates suggest that although foreign influence through global supply chains on euro area inflation rates has increased, it remains relatively limited when also controlling for other determinants of prices. Instead, spillovers emanating from domestic sectors account for the bulk of the supply chain impact on euro area inflation rates.

Although the estimates suggest a relatively minor quantitative importance overall, foreign producer prices could potentially exert a strong indirect influence on euro area inflation rates at certain times. To the extent that such developments may not be adequately captured in standard foreign variables included in forecasting models, such as import prices, this could potentially lead to forecasting errors. This note offers a toolkit that can help to deepen the understanding of the potential impact of foreign sectoral cost shocks. For example, it allows sectors with potentially large cost spillovers to be identified. In addition, scenario analysis can be used to assess the potential impact of foreign cost shocks in specific countries or sectors on euro area producer prices.

4.2 The role of foreign slack and GVCs in the dynamics of euro area inflation[78]

In traditional Phillips curve approaches, global slack affects domestic inflation only indirectly. The Phillips curve is broadly understood as the relationship between inflation and economic slack, where economic slack is traditionally only defined in domestic terms. In such a framework, global slack nevertheless has considerable influence on commodity prices, which then affect domestic inflation via import prices for commodities. Furthermore, foreign output gaps matter for short-run inflation dynamics by affecting import prices for these goods. And finally, global cyclical

[78] By Alex Tagliabracci, Chiara Osbat, Gerrit Koester and Christiane Nickel.

conditions affect the domestic output gap indirectly, since stronger global demand for goods and services supports domestic income via the net exports channel.

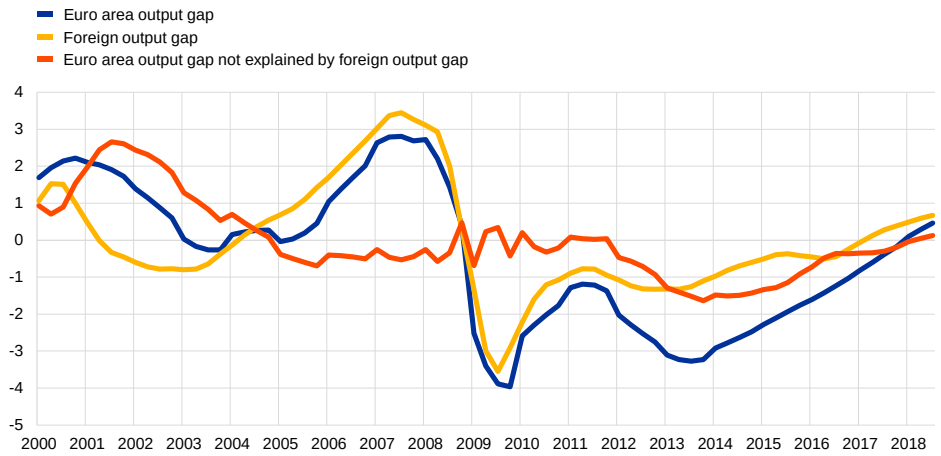
These traditional approaches have been challenged by arguing that globalisation has made national inflation responsive to global slack as well as domestic slack. In this literature (see e.g. Borio and Filardo, 2007), one argument is that any sudden increase in domestic demand for goods and services could translate into higher imports rather than higher domestic prices. The degree to which this dampens domestic prices then depends on global tightness or slack. Another argument is that globalisation constrains domestic wage or price increases in industries open to global competition. This lowers the sensitivity of wages to domestic demand pressures, meaning foreign slack has a direct influence on domestic inflation. In this context, the role of GVCs in increasing the global contestability of factor and labour markets (see Auer, Levchenko and Sauré, 2017) has received a lot of attention (for a more in-depth discussion of global versus domestic drivers of inflation, see ECB, 2017b and Nickel, 2017).

Some of the channels through which global slack could affect domestic inflation may already be captured (at least implicitly) in traditional Phillips curves. In particular, global slack affects import price inflation, which is usually included in Phillips curve models (see also the discussion in Section 4.1). Measures of domestic slack also incorporate indirectly some information about global conditions, since global demand for goods and services is reflected in net trade. Expectations of foreign demand affect investment decisions quite strongly. At the same time, the above-mentioned channels of globalisation are not explicitly captured in the standard Phillips curve framework (ECB, 2017b).

One way of assessing the role of such global influences in domestic inflation is to augment the traditional Phillips curve in a thick modelling approach with measures of foreign slack. A thick modelling approach addresses the uncertainty about the most appropriate specification of the Phillips curve by estimating a large set of specifications that include several different measures of (domestic and foreign) economic slack and inflation expectations (see Ciccarelli and Osbat, 2017). Including foreign slack is complicated by the fact that domestic and foreign slack are highly correlated. To tackle the problem of multicollinearity, an auxiliary regression is run to obtain the part of domestic slack that is not explained by foreign slack. These residuals are then used as a measure of domestic slack. Chart 30 shows the development of foreign and domestic slack (in terms of the respective output gaps) as well as the series with the residual resulting from the auxiliary domestic slack regression.

Chart 30

Foreign and euro area output gap



Source: ECB calculations.
Notes: The euro area output gap is based on data from the European Commission. The foreign output gap (data/projection) is trade-weighted and based on the latest IMF WEO data. The euro area output gap not explained by the foreign output gap is derived from an auxiliary regression (regressing the domestic on the global output gap).

Overall evidence supporting the importance of the role of global slack in determining domestic inflation based on Phillips curve analyses is mixed. The literature offers only limited support for including a measure of foreign slack in traditional Phillips curve analyses. On the one hand, Borio and Filardo (2007) find that proxies for global economic slack add considerable explanatory power to traditional benchmark Phillips curve approaches in advanced economies and that the role of global factors has grown over time. The relevance of the global output gap is also supported by Milani (2009) in the case of the United States after 1985. On the other hand, other studies such as Calza (2008), Gerlach et al. (2008), Ihrig et al. (2010), Martínez-García and Wynne (2010) or Eickmeier and Pijnenburg (2013) find conflicting evidence and suggest that the results of Borio and Filardo are likely to be specific to the estimation sample or particular measurement of the global output. More recently, Mikolajun and Lodge (2016) detect no appreciable direct effects of global economic slack on domestic inflation for the majority of advanced economies.

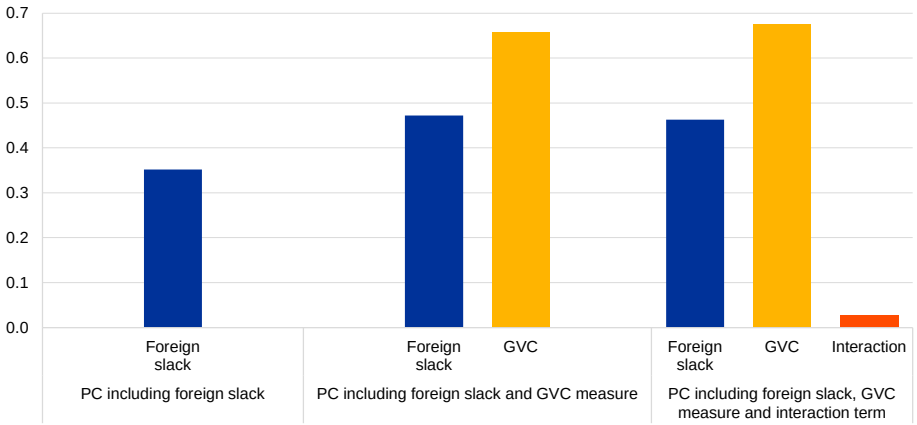
Foreign slack and GVC integration appear to be relevant for a euro area Phillips curve, but not their interaction. A thick modelling approach for the euro area finds that including a measure of global slack in the Phillips curve for the HICP, excluding food and energy inflation, establishes a significant role of foreign slack only in around one-third of the specifications. If indicators for integration in GVCs and foreign slack are included simultaneously, they are significant in around 50% to 60% of the specifications (see Chart 31).The upward trending GVC measure captures a downward sloping trend in inflation, which in some specifications is significant if included in addition to the weighted foreign slack measure. However, the GVC measure is almost never significant when interacted with global slack, implying that integration in GVCs does not have an amplifying effect on the role of foreign slack. Against the background of these findings, we will in the following discuss whether augmenting the Phillips curve with foreign slack actually improves the reliability of

Phillips curve approaches in explaining the recent period of low inflation in the euro area.

Chart 31

Significance of foreign slack and GVC integration measures in euro area Phillips curve specifications for the HICP excluding food and energy

(share of specifications in which the respective variables are significant as a percentage of the total specifications analysed; sample period: 2000-16)

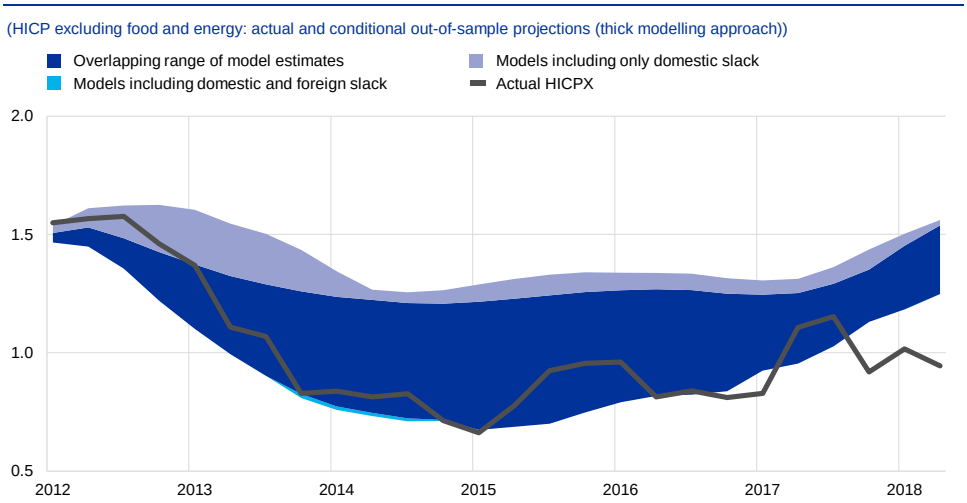


Source: ECB calculations.
Notes: The euro area output gap is based on data from the European Commission. The foreign output gap (data/projection) is trade-weighted and based on the latest IMF WEO data. The results are based on a thick modelling approach including a broad range of fixed-coefficient specifications of the Phillips curve, domestic and foreign slack, a GVC measure and its interaction with the foreign slack.

Augmenting traditional Phillips curve approaches in a thick modelling approach with measures of foreign slack would have slightly improved Phillips curve-based forecasts for HICP inflation excluding energy and food (HICPX) in recent years. Chart 32 illustrates that after 2012, actual HICPX developments were at the lower bound of forecasts based on a broad range of fixed-coefficient Phillips curve specifications conditioned on the outturns for different measures of domestic slack. Including foreign slack shifts the range of forecasts down slightly, putting actual developments somewhat more in the middle of the range of estimates.

Chart 32

HICP excluding food and energy: actual and conditional out-of-sample projections (thick modelling approach)



Notes: The results are based on a thick modelling approach including a broad range of fixed-coefficient specifications of the Phillips curve and either only domestic or domestic and foreign slack. The parameters are estimated for the sample period from Q1 1995 to Q2 2018. The conditional out-of-sample forecast is produced for Q2 2012 to Q2 2018. The range depicts forecasts for the HICP excl. energy and food originating from differently specified Phillips curves. The specifications include permutations of expectations (backward- or forward-looking) and variables representing economic activity or slack. For more details on the thick modelling approach, see Ciccarelli and Osbat (2017) or the speech by B. Cœuré "Scars or scratches – hysteresis in the euro area" (Geneva, 19 May 2017).

Summing up, there is some tentative evidence that augmenting Phillips curve approaches with measures of foreign slack could help to slightly better explain past developments in underlying inflation. However, these results must be interpreted with some caution. First, they are driven only by a small share of specifications at the upper and lower bound of the range of estimates of a thick modelling approach, while a majority of specifications with and without foreign slack yields very similar results (as reflected in the overlapping range of model estimates). Furthermore, even for a period when developments of domestic slack differed substantially from developments of foreign slack, the effects seem to be rather small. Looking ahead, further analysis is needed for a solid assessment of the potential role of foreign slack and GVC integration in domestic inflation in the euro area but also on a country level.

5 Labour markets

5.1 Labour market impact of GVCs[79]

5.1.1 Introduction

Trade in GVCs changes the scope of tasks being performed in each industry, possibly affecting the skill mix within sectors and compensation. The increase in international production segmentation in past decades has been documented by a number of existing studies.[80] The related changes to production processes and input choices could have affected the level of employment and compensation per hour for different types of workers. Therefore, there is a need to assess the relationship between recent labour market developments and different measures of GVC participation across different sectors and for different skill groups. In the following, we first show aggregate developments in value added for skilled and unskilled labour in both gross output and exports in Section 5.1.2. In Section 5.1.3, we then trace employment dynamics (hours worked and compensation) at the sector level by analysing the specific impact of different types of GVC participation. Section 5.1.4 concludes.

5.1.2 Developments I labour value added for skilled and unskilled labour

To trace aggregate trends in labour value added in both gross output and exports, we use the World Bank database developed by Calì et al. (2016).[81] The World Bank's Labor Content of Exports (LACEX) database was developed by Calì et al. (2016) on the basis of a panel of global input-output tables and exports from the Global Trade Analysis Project (GTAP) and national employment data. The database is a panel comprising 24 sectors and 150 countries and quantifies the contribution of labour to a given country's exports – measured as employees compensation (LACEX) or the number of jobs (JOCEX). It also uses gross output in place of exports to construct the labour and jobs content of domestic production. In addition, it disentangles "backward" and "forward" linkages in GVCs. This allows for tracing aggregate trends in labour value added in both gross output and exports.[82]

Between 1997 and 2011, labour usage both in the euro area and in the global economy more generally has shifted away from unskilled workers in favour of high-skilled ones. Aggregating sectoral data at the country level helps to trace the evolution of the labour value added share for different skill groups within the euro area,

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79 By François de Soyres and Elena Pavlova.

80 See for example Koopman et al. (2014) and Hummels et al. (2016).

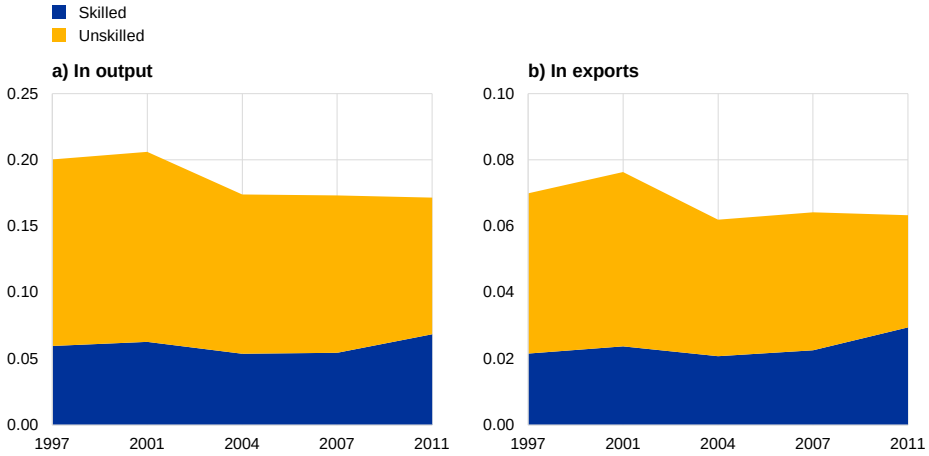
81 See the World Bank Labor Content of Exports (LACEX) database.

82 Data are presented for the following years: 1995, 1997, 2001, 2004, 2007 and 2011. While there are only 687 observations in 1995, this number rises to 1,440 in 1997 and 2,567 in 2011. To avoid selection bias in the first year, our analysis is based on 1997 onwards.

as well as for the world in general.[83] Chart 33 yields three insights: first, the share of domestic labour value added in gross output is significantly higher than that relative to exports. This implies that gross exports encompass a larger share for either capital or imported inputs. Second, the importance of labour in both output and exports decreased slightly from 1997 to 2011. Finally, focusing on the share of unskilled vs skilled value added, skilled labour has captured an increasingly large part of the labour value added at the expense of unskilled labour. Comparing the labour value added in gross output and in exports, exports contain significantly less labour value added than gross output, revealing that exporting firms rely more heavily on imported inputs and/or capital.[84]

Chart 33

Average domestic labour value added share in the euro area



Sources: Labor Content of Exports database (World Bank) and ECB staff calculations.
Note: The findings are very similar when using all 150 countries in the panel.

While many euro area countries have experienced a significant shift towards high-skilled labour, developments have been heterogeneous. Taking a country perspective, we compute the cumulative growth of the ratio of skilled labour value added to unskilled labour value added for all euro area countries (see Chart 34). From 1997 to 2011, the majority of euro area economies experienced a shift towards high-skilled at the expense of unskilled labour value added (notably Austria, Slovakia, Malta and Italy).

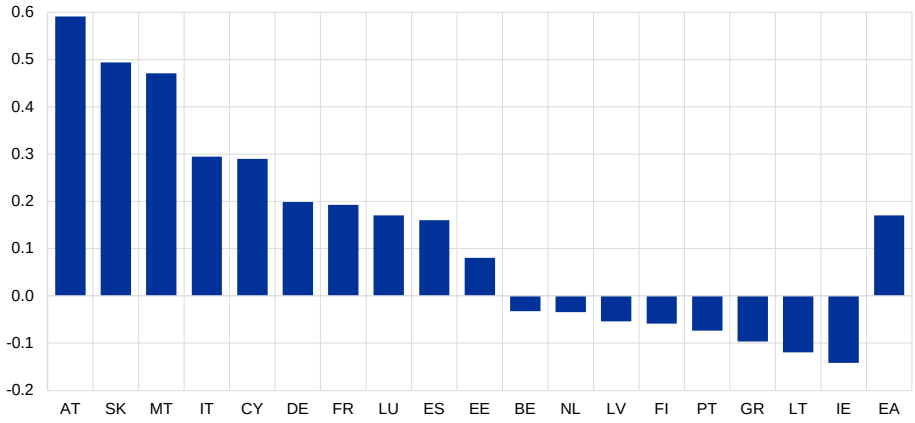
83 Labour value added in any sector is equal to total labour payment, which can be decomposed as the product of hours worked and hourly compensation. Total value added is the difference between sales and the cost of intermediate inputs, which is also equal to factor payment (labour and capital), including profits. The labour value added share of output is then defined as the share of labour value added in total sales.

84 This finding is consistent with previous studies, such as Muuls and Pisu (2009) or Amiti, Itskhoki and Konings (2014). Using data for Belgium, Muuls and Pisu (2009) show that both imports and exports appear to be highly concentrated among a small number of firms and seem to have become more so over time. In a similar vein, Amiti, Itskhoki and Konings (2014) find that the distribution of import intensity among exporters is highly skewed, with the import-intensive firms being among the largest exporters, accounting for a major share of international trade.

Chart 34

Cumulative growth of the ratio of high-skilled to low-skilled labour value added

(cumulative percentage growth, 1997-2011)



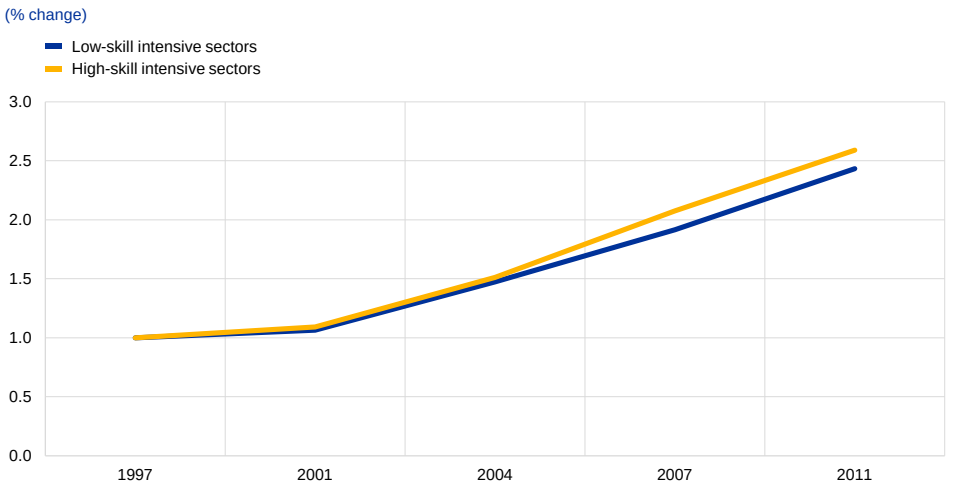
Sources: Labor Content of Exports database (World Bank) and ECB staff calculations.
Note: Due to missing data, Slovenia is not included in the computations.

To better understand the shift towards high-skilled value added, it is important to investigate the role of sectoral compositional effects and within-sector changes. As a first step, to investigate the origin of the observed aggregate change in the skill mix, we compute the cumulative growth rate of gross output and exports for all sectors and compare the evolution of low-skill-intensive and high-skill-intensive ones. In each country, sectors are labelled as low-skill-intensive if the value added share of unskilled labour is above the country average in the first year of the panel (1997). The classification takes into account only the first year, so that categories are fixed for each sector within a given country and clear differences in sector growth rates can be analysed without being biased by changes to the composition of groups. The results in Charts 35 and 36 reveal that both types of sectors experienced a very similar growth rate of output, with a cumulative increase of around 250% in total. For exports, high-skill-intensive sectors saw much larger increases (300% by the end of 2011, whereas low-skill-intensive sectors increased by less than 250%). This different evolution means that the composition of exports changed from 1997 to 2011, which partly explains the change in the composition of domestic labour value added embedded in exports.[85]

[85] Interestingly, the findings are very similar when focusing on the euro area, with sectors using relatively more high-skilled labour and exhibiting a stronger growth rate of exports and a slightly higher growth rate of output.

Chart 35

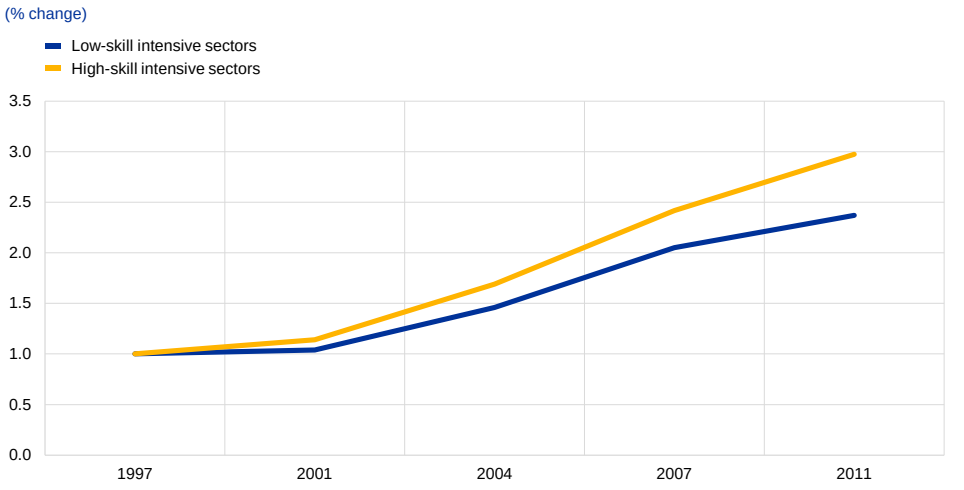
Evolution of gross output for high and low-skill-intensive sectors



Sources: Labor Content of Exports database (World Bank) and ECB staff calculations.
Notes: All variables are normalised to be equal to one in 1997. We used all 150 countries in the panel. Similar results hold when we focus on the euro area.

Chart 36

Evolution of exports for high and low-skill-intensive sectors



Sources: See Chart 35.

The comparable growth rates in gross output for both types of sectors imply that an important part of the skill change must also come from within-sector changes. In order to investigate changes in labour usage within sectors, unskilled value added as a share of total labour value added is computed for each sector. Such an analysis allows us to control for changes in the total labour value added and focus on the skill mix used by different sectors.

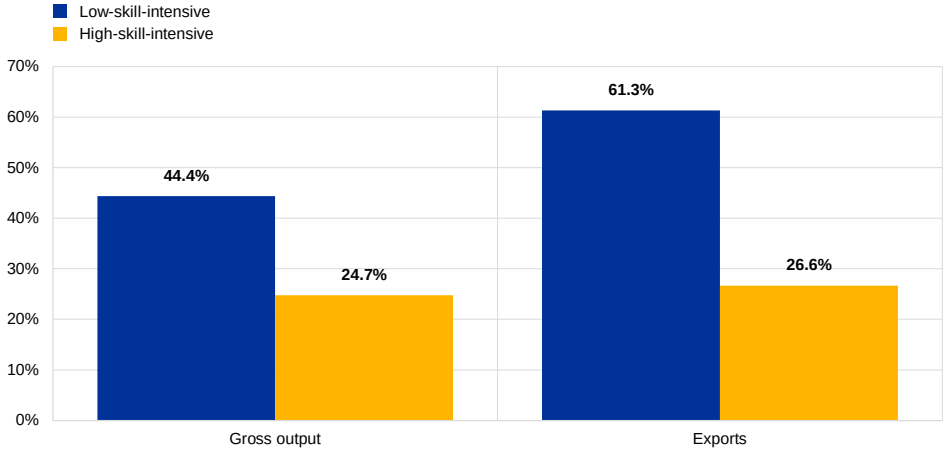
Sectors using a large share of unskilled labour in 1997 have experienced a larger shift towards high-skilled labour than those starting with a skilled labour force. Chart 37 reveals several findings. First, for all sectors and for both gross output and exports, unskilled labour as a share of labour value added decreased significantly

from 1997 to 2011. Second, on average, sectors using a large share of unskilled labour in 1997 have experienced a larger shift towards high-skilled labour than those starting with a skilled labour force. This suggests that an important share of the aggregate change in the skill composition is driven by within-sector changes and not only by the evolution of sectoral composition in the aggregate. The next section therefore analyses the specific impact of GVC participation on within-sector changes in several variables related to labour market dynamics, including skill-specific compensation and hours worked.

Chart 37

Evolution of ratio of skilled to unskilled value added in gross output and exports by sector skill intensity

(cumulative percentage growth, 1997-2011)



Sources: Labor Content of Exports database (World Bank) and ECB staff calculations.
Notes: The blue bars represent the growth rate between 1997 and 2011 of the ratio of high-skill value added to low-skill value added in sectors that are relatively low-skill-intensive in the first year of the panel. The yellow bars represent the growth rate between 1997 and 2011 of the ratio of high-skill value added to low-skill value added in sectors that are relatively high-skill-intensive in the first year of the panel.

5.1.3 Panel estimation results

Based on the SEAs from the WIOD, this section uses within-sector variations to assess the relationship between participation in GVCs and several labour market variables. The SEAs contain annual data (1995-2009) for 35 industries in 40 countries on gross output and value added at current and constant prices as well as compensation and employment by skill type (low-, medium- and high-skilled). The World Input-Output Tables then allow the construction at the sectoral level and for each year of all indices described in the previous section. Exploiting the panel dimensions of the data, we can assess the statistical relationship between hours worked and compensation for different skill groups on the one hand and both forward and backward GVC participation on the other hand. In all the analyses presented in this section, regressions include sector-country fixed effects (a total of 1,400, each appearing over a period of 15 years). The results presented here do not provide evidence for causality, but are designed to assess the correlation between different GVC participation indices and labour market outcomes.

As a first step, we study the impact of GVCs on the skill composition of the labour force within sectors. The main variable of interest is the share of high-skilled workers' hours in total hours worked for each industry, which is informative of the actual relative skill intensity in production.[86]

Our econometric specification is defined as:

$$\log \mathrm{HS\ share}_{i,c,t} = \gamma_0 + \gamma_1 * \log \mathrm{IV}_{i,c,t} + \gamma_2 * \log \mathrm{FV}_{i,c,t} + \mathrm{FE}_{i,c} + \mathrm{FE}_{c,t} + \epsilon_{i,c,t}$$

where $\mathrm{HS\ share}_{i,c,t}$ is the share of high-skilled workers' hours in total hours worked for industry i in country c at time t and the indices $\mathrm{IV}_{i,c,t}$ and $\mathrm{FV}_{i,c,t}$ represent forward and backward GVC participation and are defined following Koopman et al. (2012) as described in Box 1. A range of unobserved country- and sector-specific determinants, such as, for instance, labour market reforms or technology shocks, as well as time-invariant technology differences across countries and industries, are captured by two fixed effects: country-sector and country-year. In particular, country-sector fixed effects control for time-invariant differences of skill intensity across industries and country-year fixed effects control for aggregate changes in skill usage that are country-specific for each given year and that might be due to changes in the relative supply of skills within countries.[87]

The estimation results show a significant impact of foreign value added in exports on sectoral skill mix (Table 16). Relative to average skill usage in the country at a given date and controlling for time-invariant differences of skill usage across sectors, we find that an increase in foreign value added embedded in exports is associated with a shift towards high-skilled labour.

Table 16

Panel fixed effect analysis: share of high-skilled hours worked in total hours and GVC participation

	Dependent variable: log share of high-skilled hours in total hours
Log IV Index	-0.016
t-stat	-1.17
Log FV Index	0.024**
t-stat	2.18
Country-sector FE	Yes
Country-time FE	Yes
R2	0.671
Number of observations	19,882

Sources: WIOD and SEAs data and ECB staff calculations.
Note: *** means p < 0.01, ** means p < 0.05 and * means p < 0.1.

86 The SEAs dataset does not include the number of employees per sector disaggregated by skill group. Hence, the analysis performed in this section using hours worked cannot be extended by using total headcount.

87 The inclusion of the 1,400 sector-country fixed effects implies that any time-invariant differences across sectors are controlled for and cannot bias our estimates. Time-country fixed effects control for aggregate fluctuations that are common to all sectors within a country. The set of fixed effects used in to control for omitted variable bias is a common approach in the trade literature; see for example the recent papers by Di Giovanni, Levchenko and Méjean (2016), Baier, Bergstrand and Feng (2014) or Constantinescu, Mattoo and Ruta (2017).

It has been argued by several authors that the impact of GVCs on labour market outcomes may depend on each sector's characteristics and in particular its position in the value chain.[88] To take this into account, we disentangle sectors according to their position in the GVC and create two categories: we label as upstream sectors that have a positive position index in the first year of the panel, while all other sectors are categorised as downstream.[89] Applying the previously described econometric strategy separately for upstream and downstream sectors uncovers an especially strong role for downstream sectors. As shown in Table 17, the aggregate shift towards high-skilled employees associated with backward GVC participation is present for all sectors, but it is particularly pronounced for downstream sectors.[90] Intuitively, sectors that are located towards the end of the production process have a better ability to switch to high-skilled workers when they use imported inputs in their production.

Table 1

Panel fixed effect analysis: share of high-skilled hours by position in the supply chain

	Dependent variable: log share of high-skilled hours in total hours	
	Downstream sectors	Upstream sectors
Log IV Index	-0.010	-0.026
t-stat	-1.10	-0.80
Log FV Index	0.056**	0.027*
t-stat	2.19	1.76
Country-sector FE	Yes	Yes
Country-time FE	Yes	Yes
R2	0.707	0.649
Number of observations	11,586	8,296

Sources: WIOD and SEAs data and ECB staff calculations.
Note: *** means p < 0.01, ** means p < 0.05 and * means p < 0.1.

To further understand the driver of value added behaviour uncovered in Section 5.1.2, it is also interesting to analyse the relationship between integration in GVCs and the behaviour of average compensation. Labour value added in any sector is equal to the wage bill, which is the product of hours worked and the (hourly) compensation for each skill category. The estimation equation in this section relies on the assumption that wages are related to the marginal productivity of workers. With a production function for value added that relies on capital and labour in a Cobb-Douglas way, we have for each industry/country at date t:

$$F(K, L) = A(GVC) * K^{\alpha} * L^{1-\alpha}$$

where α is the capital share in value added and the TFP A(GVC) is a function of sectors' decisions to participate in GVCs and hence a function of the different indices of GVC participation, in particular the FV (backward) and IV (forward) indices defined above. In this setup, the marginal productivity of labour is given by:

88 See for example Ottaviano (2015) or Hummels, Munch and Xiang (2016).

89 In total, 59% of all observations are labelled as downstream, the rest being upstream.

90 Looking at aggregate hours worked (not separating skill groups) and/or focusing on the index of total participation in GVC yields the same results: most of the positive association between GVC and hours worked comes from downstream sectors.

$$w = F_L(K, L) = A(GVC) * \left(\frac{K}{L}\right)^{\alpha}$$

Taking the log of this expression and adding fixed effects leads to the following reduced estimation specification:

$$\log w_{i,c,t} = \gamma_0 + \alpha * \log\left(\frac{K}{L}\right)_{i,c,t} + \gamma_1 * \log IV_{i,c,t} + \gamma_2 * \log FV_{i,c,t} + FE_{i,c} + FE_{c,t} + \epsilon_{i,c,t}$$

For simplicity, we assume here that the production function is additively separable in the different skills, so that the wage for a given skill does not depend on the relative share of skills in the total labour force.

The results of this analysis show that both high and low-skilled workers experience an increase in their hourly compensation when the sector they are working in increases the foreign value added embedded in its exports (Table 18). Those findings are consistent with findings in other studies such as Koren and Csillag (2016), which show that machine operators exposed to imported machines earn higher wages than similar workers at similar firms. Moreover, imported inputs have been shown to generate important productivity effects, through channels involving learning, variety or quality aspects (Amiti and Konings, 2007, Goldberg, Khandelwal and Topalova, 2008, Halpern, Korag and Szeidl, 2009, Constantinescu, Mattoo and Ruta, 2017). We should also note that the observed increase in average compensation could well also be due to a change of worker distribution within each skill group: for example, compensation could go up for low-skilled workers on average without any individual worker-level change if the less qualified workers within the low-skilled group are dismissed. In order to assess the strength of such a mechanism, more disaggregated data with worker-level observations or a more detailed categorisation of skill groups are required.

Table 18

Panel fixed effect analysis: compensation and GVC participation

	Dependent variable: log share of high-skilled hours in total hours	
	Downstream sectors	Upstream sectors
Log IV Index	-0.010	-0.026
t-stat	-1.10	-0.80
Log FV Index	0.056**	0.027*
t-stat	2.19	1.76
Country-sector FE	Yes	Yes
Country-time FE	Yes	Yes
R2	0.707	0.649
Number of observations	11,586	8,296

Sources: WIOD and SEAs data and ECB staff calculations.
Note: *** means p < 0.01, ** means p < 0.05 and * means p < 0.1.

Finally, to refine the analysis above, we perform the estimation separately for downstream and upstream sectors. Similar to the results for compensation, the role of backward participation in GVCs is found to be more pronounced for downstream sectors.

Table 19

Panel fixed effect analysis: compensation and GVC participation disentangled by position in the supply chain

	Dependent variable: log compensation			
	Downstream sectors		Upstream sectors	
	High-skilled	Low-skilled	High-skilled	Low-skilled
Log IV Index	0.002	0.000	-0.004	-0.022
t-stat	0.14	-0.01	-0.15	-0.80
Log FV Index	0.096*	0.121**	0.074	0.041
t-stat	1.80	2.50	1.34	0.74
Log capital-labour ratio	0.357***	0.361***	0.282***	0.287***
t-stat	6.20	6.27	6.01	6.08
Country-sector FE	Yes	Yes	Yes	Yes
Country-time FE	Yes	Yes	Yes	Yes
R2	0.794	0.796	0.813	0.818
Number of observations	10,999	10,999	7,870	7,870

Sources: WIOD and SEAs data and ECB staff calculations.
Note: *** means p < 0.01, ** means p < 0.05 and * means p < 0.1.

5.1.4 Conclusions

The analysis suggests that it is advisable to monitor carefully future participation in GVCs by euro area countries and their relative position in the supply chain. As such, both participation and position in GVCs are likely to be important for labour market outcomes.

As to the skill mix, sectors increasing their involvement in GVCs tend to hire high-skilled labour disproportionately, especially when these sectors are located downstream in the supply chain. GVC participation is also associated with an increase in compensation per hour, both for high and low-skilled workers, with a stronger impact in sectors located downstream. This effect is in line with studies documenting an increase in productivity and/or quality for firms with a high share of imported inputs in production.

The impact of GVCs on labour market dynamics could be further analysed from a sectoral perspective. As an example, one useful approach might be to estimate the elasticity of substitution between material inputs on the one hand and differently skilled labour on the other, across several industries. With this information, predictions of the consequences of increasing the imported input share on labour demand and compensation per hour could be improved.

5.1.5 Appendix: Robustness checks: panel estimation results for the euro area

Table A.1

Panel fixed effect analysis: share of high-skilled hours worked in total hours and GVC participation – euro area

	Dependent variable: log share of high-skilled hours in total hours
Log IV Index	-0.030
t-stat	-1.64
Log FV Index	0.058*
t-stat	1.81
Country-sector FE	Yes
Country-time FE	Yes
R2	0.609
Number of observations	9,457

Sources: WIOD and SEAs data and ECB staff calculations.
Note: *** means p < 0.01, ** means p < 0.05 and * means p < 0.1.

Table A.2

Panel fixed effect analysis: share of high-skilled hours disentangled by position in the supply chain – euro area

	Dependent variable: log share of high-skilled hours in total hours	
	Downstream sectors	**Upstream sectors**
Log IV Index	-0.009	-0.096
t-stat	-0.46	-0.59
Log FV Index	0.113***	0.038***
t-stat	3.10	2.62
Country-sector FE	Yes	Yes
Country-time FE	Yes	Yes
R2	0.630	0.613
Number of observations	6,240	3,217

Sources: WIOD and SEAs data and ECB staff calculations.
Note: *** means p < 0.01, ** means p < 0.05 and * means p < 0.1.

Table A.3

Panel fixed effect analysis: compensation and GVC participation – euro area

	Dependent variable: log compensation	
	High-skilled	Low-skilled
Log IV Index	-0.006	-0.006
t-stat	-0.25	-0.25
Log FV Index	0.112**	0.080*
t-stat	2.35	1.72
Log capital-labour ratio	0.276***	0.276***
t-stat	4.54	4.55
Country-sector FE	Yes	Yes
Country-time FE	Yes	Yes
R2	0.606	0.686
Number of observations	8,851	8,851

Sources: WIOD and SEAs data and ECB staff calculations.
Note: *** means p < 0.01, ** means p < 0.05 and * means p < 0.1.

Table A.4

Panel fixed effect analysis: compensation and GVC participation disentangled by position in the supply chain – EURO AREA

	Dependent variable: log compensation			
	Downstream sectors		Upstream sectors	
	High-skilled	Low-skilled	High-skilled	Low-skilled
Log IV Index	-0.009	-0.006	-0.031	-0.031
t-stat	-0.33	-0.19	-0.86	-0.80
Log FV Index	0.119*	0.109	0.082	0.026
t-stat	1.68	1.53	1.40	0.46
Log capital-labour ratio	0.293***	0.299***	0.178***	0.161***
t-stat	4.01	4.05	2.85	2.43
Country-sector FE	Yes	Yes	Yes	Yes
Country-time FE	Yes	Yes	Yes	Yes
R2	0.616	0.682	0.664	0.756
Number of observations	5,898	5,898	2,953	2,953

Sources: WIOD and SEAs data and ECB staff calculations.
Note: *** means p < 0.01, ** means p < 0.05 and * means p < 0.1.

References

Acemoglu, D., Akcigit, U. and Kerr, W. (2015), "Networks and the macroeconomy: An empirical exploration", *NBER Working Paper Series*, No 21344, National Bureau of Economic Research.

Acemoglu, D., Carvalho, V.M., Ozdaglar, A. and Tahbaz-Salehi, A. (2012), "The network origins of aggregate fluctuations", *Econometrica*, Vol. 80(5), pp. 1977-2016.

Ackerberg, D., Caves, K. and Frazer, G. (2006), "Structural Identification of Production Functions", *MPRA Paper* No. 38349.

Aghion, P., & Howitt, P. (2006), "Appropriate growth policy: a unifying framework", *Journal of the European Economic Association*, Vol. 4(2-3), pp. 269-314.

Alessandria, G., Kaboski, J.P. and Midrigan, V. (2010), *The Great Trade Collapse of 2008-09: An Inventory Adjustment*?, Research Department, Federal Reserve Bank of Philadelphia.

Altomonte, C., di Mauro, F., Ottaviano, G., Rungi, A. and Vicard, V. (2012), "GVCs during the Great Trade Collapse: A Bullwhip Effect?", *Working Paper Series*, No 364, Banque de France.

Amador, J. and di Mauro, F. (eds.) (2015), *The Age of Global Value Chains*, CEPR Press and VoxEU.org book.

Amiti, M. and Davis, D.R. (2012), "Trade, Firms, and Wages: Theory and Evidence", *The Review of Economic Studies*, Vol. 79 (1), pp. 1-36.

Amiti, M., Itskhoki, O. and Konings, J. (2014), "Importers, exporters, and exchange rate disconnect", *American Economic Review*, Vol. 104(7), pp. 1942-1978.

Amiti, M. and Konings, J. (2007), "Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia", *American Economic Review*, Vol. 97(5), pp. 1611-1638.

Anderton, R., Baltagi, B.H., Skudelny, F. and Sousa, N. (2007), "Intra- and Extra- Euro Area Import Demand for Manufacturers", *Applied Economics Quarterly*, Vol. 53(3).

Antràs, P. and Chor, D. (2013), "Organizing the global value chain", *Econometrica*, Vol. 81(6), pp. 2127-2204.

Arellano, M. and Bond, S. (1991), "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations", *Review of Economic Studies*, Vol. 58, pp. 277-297.

Arellano, M. and Bover, O. (1995), "Another look at the instrumental variable estimation of error-components models", *Journal of Econometrics*, Vol. 68, pp. 29-51.

Arkolakis, C. and Ramanarayanan, A. (2009), “Vertical specialization and international business cycle synchronization”, *The Scandinavian Journal of Economics*, Vol. 111 (4), pp. 655-680.

Atoyan, R., Manning, J. and Rahman, J. (2013), “Rebalancing: Evidence from Current Account Adjustment in Europe”, *Working Paper Series*, No 13/74, IMF.

Atalay, E. (2014),, “How important are sectoral shocks?”, *Working Paper Series,* No CES-WP-14-31, US Census Bureau Center for Economic Studies.

Auer, R., Borio, C. and Filardo, A. (2017), “The globalisation of inflation: the growing importance of global value chains”, *Working Paper Series*, No 602, BIS.

Auer, R.A., Levchenko, A. and Sauré, P. (2017), “International Inflation Spillovers Through Input Linkages”, *NBER Working Paper Series*, No 23246, National Bureau of Economic Research.

Autor, D.H. and Dorn, D. (2013), “The Growth of Low-Skill Service Jobs and the Polarization of the US Labor Market”, *American Economic Review*, Vol. 103, No 5, pp. 1553-1597(45), August.

Autor, D.H., Dorn, D. and Hanson, G. (2013), “The China Syndrome: Local Labor Market Effects of Import Competition in the United States”, *American Economic Review*, Vol. 103, No 6, pp. 2121-2168(48), October.

Backus, D., Kehoe, P.J. and Kydland, F.E., (1993), “International business cycles: theory and evidence", *NBER Working Paper Series*, No 4493, National Bureau of Economic Research.

Baldwin, R. (2006), Globalisation: the great unbundling(s). Economic Council of Finland, No 20(3), pp. 5-47.

Baldwin, R. (2016), *The Great Convergence*, Harvard University Press.

Bartelsman, E.J., Haltiwanger J. and Scarpetta, S. (2004), “Microeconomic Evidence of Creative Destruction in Industrial and Developing Countries”, *World Bank Policy Research Paper*, No. 3464.

Bartelsman, E.J., Haltiwanger J. and Scarpetta, S. (2013), “Cross-Country Differences in Productivity: The Role of Allocation and Selection”, *American Economic Review*, Vol. 103(1), pp. 305-334.

Baxter, M. and Kouparitsas, M.A. (2005), “Determinants of business cycle comovement: a robust analysis”, *Journal of Monetary Economics*, Vol. 52(1), pp. 113-157.

Baier, S., Bergstrand, J. and Feng, M. (2014), “Economic Integration Agreements and the Margins of International Trade”, *Journal of International Economics*, Vol. 93(2), pp. 339-350.

Bedoya, S. F. (2018), *Essays on the Trade and Macroeconomic dimensions of Global Value Chains*, Economies and finances, Université Paris-Saclay.

Bems, R. and Johnson, R.C. (2012), "Value-Added Exchange Rates", *NBER Working Paper Series*, No 18498, National Bureau of Economic Research.

Bems, R. and Johnson, R.C. (2015), "Demand for Value Added and Value-Added Exchange Rates", *NBER Working Paper Series,* No 21070, National Bureau of Economic Research.

Bems, R., Johnson, R.C. and Yi, K.-M. (2011), "Vertical Linkages and the Collapse of Global Trade", *American Economic Review,* Vol. 101(3), pp. 308-312.

Benedetto, J. (2012), "Implications and interpretation of value-added trade balances", *Journal of International Commerce and Economics,* Vol. 4(2).

Benkovskis, K. and Wörz, J. (2014), "Made in China': How does it affect our understanding of global market shares?", *Working Paper Series*, No 1787, ECB, Frankfurt am Main, April.

Bhatia, K., Evenett S. J., and Hufbauer, G. C. (2016), "Why General Electric is localising production", Voxeu.org, August 28.

Blundell, R. and Bond, S. (1998), "Initial conditions and moment restrictions in dynamic panel data models", *Journal of Econometrics*, Vol. 87, pp. 115-143.

Borin, A. and Mancini, M. (2015), "Follow the value added: bilateral gross export accounting," *Working Paper Series*, No 1026, Bank of Italy.

Borio, C. and Filardo, A. (2007), "Globalisation and inflation: New cross-country evidence on the global determinants of domestic inflation", *Working Paper Series*, No 227, BIS.

Broda, C., Greenfield, J. and Weinstein, D., (2006), "From groundnuts to globalization: A structural estimate of trade and growth", *NBER Working Paper Series*, No 12512, National Bureau of Economic Research.

Buelens, C. and Tirpak, M. (2017), "Reading the footprints: how foreign investors shape participation in GVCs", *Working Paper Series*, No 2060, ECB, Frankfurt am Main, May.

Boehm, C., Flaaen, A. and Pandalai-Nayar, N. (2014), *Complementarities in Multinational Production and Business Cycle Dynamics*, working paper, University of Michigan.

Burstein, A., Kurz, C. and Tesar, L. (2008), Trade, production sharing, and the international transmission of business cycles. *Journal of Monetary Economics*, Vol. 55(4), pp. 775-795.

Calì, M., Francois, J., Hollweg, C.H., Manchin, M., Oberdabernig, D.A., Rojas Romagosa, H.A., Rubinova, S. and Tomberger, P. (2016), “The labor content of exports database”, *Policy Research Working Paper Series*, No 7615, World Bank.

Calza, A. (2008), “Globalisation, domestic inflation and global output gaps: Evidence from the euro area”, *Working Paper Series*, No 13, Federal Reserve Bank of Dallas.

Carvalho, V. (2010), “Aggregate Fluctuations and the Network Structure of Intersectoral Trade”, *Economics Working Papers*, No 1206, Department of Economics and Business, Universitat Pompeu Fabra.

Carvalho, V.M. (2014), “From micro to macro via production networks”, *The Journal of Economic Perspectives*, Vol. 28(4), pp. 23-47.

Cerina, F., Zhu, Z., Chessa, A. and Riccaboni, M. (2015), World input-output network, *PLOS ONE*, Vol. 10(7), Ref. e0134025.

Chang, W., Ethier. W. and Kemp, M. (1980), “The theorems of international trade with joint production”, *Journal of International Economics*, Vol. 10, issue 3, pp. 377-394.

Chiacchio, F., Gradeva, K. and Lopez-Garcia, P. (2018), “The post-crisis TFP growth slowdown in CEE countries: exploring the role of Global Value Chains”, *Working Paper Series*, No 2143, ECB, Frankfurt am Main, April.

Ciccarelli, M. and Osbat, C. (2017), “Low inflation in the euro area: Causes and consequences”, *Occasional Paper Series*, No 181, ECB, Frankfurt am Main, January.

Comin, D. and Gertler, M. (2006), “Medium-term business cycles”, *American Economic Review*, Vol. 96(3), pp. 523-551.

Constantinescu, C., Mattoo, A. and Ruta, M. (2015), “The Global Trade Slowdown: Cyclical or Structural?”, *Working Paper Series*, No WP/15/6, IMF.

Daudin, G., Rifflart, C. and Schweisguth, D. (2011), “Who produces for whom in the world economy?”, *Canadian Journal of Economics*, Vol. 44(4), pp. 1403-1437.

De Backer, K. and Miroudot, S. (2014), “Mapping global value chains”, *Working Paper Series*, No 1677, ECB, Frankfurt am Main, May.

de Soyres, F. (2016), *Value Added and Productivity Linkages Across Countries*, working paper.

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”, *Working Paper Series*, No WPS8535, World Bank.

Dietzenbacher, E., Los, B., Stehrer, R., Timmer, M. and de Vries, G. (2013), “The construction of world input–output tables in the WIOD project”, *Economic Systems Research*, Vol. 25(1), pp. 71-98.

di Giovanni, J. and Levchenko, A.A. (2010), “Putting the parts together: trade, vertical linkages, and business cycle comovement”, *American Economic Journal: Macroeconomics*, Vol. 2(2), pp. 95-124.

di Giovanni, J., Levchenko, A.A. and Méjean, I. (2014), “Firms, destinations, and aggregate fluctuations”, *Econometrica*, Vol. 82(4), pp. 1303-1340.

di Giovanni, J., Levchenko, A. and Méjean. I. (2015), “The Micro Origins of International Business Cycle Comovement”, *Working Paper Series*, Research Seminar in International Economics, University of Michigan.

Dix-Carneiro, R. (2014), “Trade Liberalization and Labor Market Dynamics”, *Econometrica*, Vol. 82(3), pp. 825-885.

Drozd, L.A., Kolbin, S. and Nosal, J., (2018), *Long-Run Price Elasticity of Trade and the Trade-Comovement Puzzle*, mimeo.

ECB (2017a), “The impact of global value chains on the macroeconomic analysis of the euro area”, *Economic Bulletin*, Issue No 8, 28 December.

ECB (2017b), “Domestic and global drivers of inflation in the euro area”, *Economic Bulletin,* Issue 4.

Eaton, J., Kortum, S., Neiman, B. and Romalis, J. (2011), “Trade and the Global Recession”, *NBER Working Paper Series*, No 16666, National Bureau of Economic Research.

Eickmeier, S. and Pijnenburg, K. (2013), “The global dimension of inflation – Evidence from factor-augmented Phillips curves”, *Oxford Bulletin of Economics and Statistics*, Vol. 75(1), pp. 103-122.

Frohm, E. and Gunnella, V. (2017), “Sectoral interlinkages in global value chains: spillovers and network effects”, *Working Paper Series*, No 2064, ECB, Frankfurt am Main, May.

Foerster, A.T., Sarte, P.-D.G. and Watson, M.W. (2011), “Sectoral versus Aggregate Shocks: A Structural Factor Analysis of Industrial Production”, *Journal of Political Economy*, Vol. 119(1), pp. 1-38.

Frankel, J.A. and Rose, A.K. (1998), “The endogeneity of the optimum currency area criteria”, *The Economic Journal*, Vol. 108(449), pp. 1009-1025.

Gabaix, X. (2011), “The granular origins of aggregate fluctuations”, *Econometrica*, Vol. 79(3), pp. 733-772.

Galuščák, K. and Lízal, L. (2011), “The Impact of Capital Measurement Error Correction on Firm-Level Production Function Estimation”, *Czech National Bank Working Paper*, No. 9.

Gangnes, B.S., Ma, A.C. and Assche, A.V. (2014), “GVCs and Trade Elasticities”, *Working Paper Series*, University of Hawaii at Mānoa Department of Economics.

Gereffi, G. (2014), “GVCs in a Post-Washington Consensus world”, *Review of International Political Economy*.

Gereffi, G., Humphrey, J. and Sturgeon, T. (2005), “The governance of GVCs”, *Review of International Political Economy*, Vol. 12(1), pp. 78-104.

Gerlach, S., Giovannini, A., Tille, C. and Viñals, J. (2008), “Testing times for central banks”, *10th Geneva Report on the World Economy*.

Goldberg P.K., Khandelwal, A.K., Pavcnik, N. and Topalova, P. (2010), “Imported Intermediate Inputs and Domestic Product Growth: Evidence from India”, *The Quarterly Journal of Economics*, Vol. 125(4), pp. 1727-1767.

Goos, M., Manning, A. and Salomons, A. (2014), “Explaining Job Polarization: Routine-Biased Technological Change and Offshoring”, *American Economic Review*, Vol. 104 (8), pp. 2509-2526.

Halpern, L., Koren, M. and Szeidl, A. (2015), “Imported Inputs and Productivity”, *American Economic Review*, Vol. 105(12), pp. 3660-3703.

Haltmeyer, J. (2015), “Have GVCs contributed to global imbalances?”, *International Finance Discussion Paper Series*, No 1154.

Hansen, B.E. (1999), “Threshold effects in non-dynamic panels: Estimation, testing, and inference”, *Journal of Econometrics*, Vol. 93(2), pp. 345-368.

Haugh, D., Kopoin, A., Rusticelli, E., Turner, D. and Dutu, R., (2016), “Cardiac arrest or dizzy spell: why is world trade so weak and what can policy do about it?, *OECD Economic Policy Papers*, No. 18.

Horvath, M. (1998), “Cyclicality and sectoral linkages: Aggregate fluctuations from independent sectoral shocks”, *Review of Economic Dynamics*, Vol. 1(4), pp. 781-808.

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

Hummels D., Munch, J.R. and Xiang, C. (2016), “Offshoring and Labor Markets”, *NBER Working Paper Series*, No 22041, National Bureau of Economic Research.

Iacovone, L. and Crespi, G. (2010), “Catching Up with the Technological Frontier: Micro-level Evidence on Growth and Convergence”, *Industrial and Corporate Change*, Vol. 19(6), pp. 2073-2096.

Ihrig, J., Kamin, S., Lindner, D. and Marquez, J. (2010), “Some simple tests of the globalization and inflation hypothesis”, *International Finance*, Vol. 13(3), pp. 343-375.

Imbs, J. (2004), “Trade, finance, specialization, and synchronisation”, *Review of Economics and Statistics*, Vol. 86(3), pp. 723-734.

IMF (2011), *Changing Patterns of Global Trade*, International Monetary Fund: Strategy, Policy, and Review Department.

IMF (2015), “Reaping the benefits from GVCs”, *Regional Economic Outlook Asia and Pacific*.

IRC Trade Task Force (2016), “Understanding the weakness in global trade – What is the new normal?”, *Occasional Paper Series,* No 178, ECB, Frankfurt am Main, September.

Ito, T. and Vezina, P.-L. (2016), “Production fragmentation, upstreamness and value added: Evidence from Factory Asia 1990-2005”, *Journal of The Japanese and International Economies*.

Johnson, R.C. (2014), “Trade in intermediate inputs and business cycle comovement”, *American Economic Journal: Macroeconomics*, Vol. 6(4), pp. 39-83.

Johnson, R.C. and Noguera, G. (2012), “Accounting for intermediates: Production sharing and trade in value added”. *Journal of international Economics*, Vol. 86(2), pp. 224-236.

Jones, C.I. (2011), “Intermediate goods and weak links in the theory of economic development”, *American Economic Journal: Macroeconomics*, Vol. 3(2), pp. 1-28.

Kalemli-Ozcan, S., Papaioannou, E. and Peydro, J.L., (2013), “Financial regulation, financial globalization, and the synchronization of economic activity”, *The Journal of Finance*, Vol. 68(3), pp. 1179-1228.

Kapetanios, G., Mitchell, J. and Shin, Y. (2014), “A nonlinear panel data model of cross-sectional dependence” *Journal of Econometrics*, Vol. 179(2), pp. 134-157.

Koopman, R., Powers, W., Wang, Z. and Wei, S.-J. (2010), “Give credit where credit is due: Tracing value added in global production chains”, *NBER Working Paper Series*, No w16426, National Bureau of Economic Research.

Koopman, R., Wang, Z. and Wei, S.-J. (2014), “Tracing Value-Added and Double Counting”. *American Economic Review*, Vol. 104(2), pp. 459-494.

Koren, M. and Csillag, M. (2011), “Machines and machinists: Capital-skill complementarity from an international trade perspective”, *CEPR Discussion Paper Series*, No 8317.

Kose, M.A. and Yi, K.M., (2001), “International trade and business cycles: Is vertical specialization the missing link?”, *American Economic Review*, Vol.91(2), pp. 371-375.

Kose, A. and Yi, K.-M. (2006), “Can the standard international business cycle model explain the relation between trade and comovement?”, *Journal of International Economics*, Vol. 68(2), pp. 267-295.

Kummritz, V., Taglioni, D. and Winkler, D. (2015). “Economic upgrading through global value chain participation – which policies increase the value added gains?”, *Policy Research Working Paper Series*, No 8007, World Bank Group.

Lane, P., and Shambaugh, J. C. (2007), “Financial exchange rates and international currency exposures”, *NBER Working Paper Series*, No w13433, National Bureau of Economic Research.

Leamer, E.E., (1998), “Let's Take the Con Out of Econometrics”, *American Economic Review*, Vol. 73(1), 31-43.

Levinson, J. and Petrin, A. (2003), “Estimating Production Functions Using Inputs to Control for Unobservables”, *The Review of Economic Studies*, Vol. 70(2), pp. 317-341.

Liao, W. and Santacreu, A.M., (2015), “The trade comovement puzzle and the margins of international trade”, *Journal of International Economics*, Vol. 96(2), pp. 266-288.

Long, J.B. Jr. and Plosser, C.I. (1983), “Real business cycles”, *The Journal of Political Economy*, pp. 39-69.

Lu, Y. (2017), “China’s electrical equipment manufacturing in the Global Value Chain: A GVC income analysis based on World Input-Output Database (WIOD)”, *International Review of Economics & Finance*, Vol. 52, pp. 289-301.

Lucas, R.E., Jr. (1977), “Understanding Business Cycles”, in Brunner, K. and Meltzer, A.H. (eds.), *Stabilization of the Domestic and International Economy*, Carnegie-Rochester Conference Series on Public Policy 5, Amsterdam.

Marel, E. van der (2015), “Positioning on the global value chain map – Where do you want to be?”, *Occasional Paper Series*, No 1/2015, ECIPE.

Mariscal, A. and Taglioni, D. (2017), *GVCs as Source of Firm Capabilities*, mimeo.

Martínez-García, E. and Wynne, M. (2010), “The global slack hypothesis”, *Staff Papers*, No 10, Federal Reserve Bank of Dallas.

McKinsey (2014), *Global flows in a digital age: How trade, finance, people, and data connect the world economy*, McKinsey Global Institute, April.

Michaels, G., Natraj, A. and Van Reenen, J. (2014), “Has ICT Polarized Skill Demand? Evidence from Eleven Countries over 25 Years”, *The Review of Economics and Statistics*, Vol. 96, No 1, pp. 60-77.

Mikolajun, I. and Lodge, D. (2016), “Advanced economy inflation: The role of global factors”, *Working Paper Series*, No 1948, ECB, Frankfurt am Main, August.

Milani, F. (2009), “Global slack and domestic inflation rates: A structural investigation for G-7 countries”, *Working Paper Series*, No 33, Federal Reserve Bank of Dallas.

Mishkin, F.S. (2009), “Globalization, macroeconomic performance, and monetary policy”, *Journal of Money, Credit and Banking*, Vol. 41, pp. 187-196.

Monacelli, T. and Sala, L. (2009), “The international dimension of inflation: evidence from disaggregated consumer price data”, *Journal of Money, Credit and Banking*, Vol. 41, pp. 101-120.

Moran, P.A. (1950), “Notes on continuous stochastic phenomena”, *Biometrika*, Vol. 37(1/2), pp. 17-23.

Muûls, M. and Pisu, M. (2009), “Imports and Exports at the Level of the Firm: Evidence from Belgium”, *The World Economy*, Wiley-Blackwell, Vol. 32(5), pp. 692-734.

Nickell, S. (1981), “Biases in dynamic models with fixed effects”*, Econometrica*: *Journal of the Econometric Society*, pp. 1417-1426.

Nickel, C. (2017), *The role of foreign slack in domestic inflation in the Eurozone*, VoxEU.

OECD (2013), *Science, Technology and Industry Scoreboard 2013*, Chapter 7.

OECD (2013), “Interconnected Economies: Benefiting from GVCs”, OECD Publishing.

OECD (2015), *TIVA 2015 Indicators – Definitions*.

Olley, G. S. and Pakes, A. (1996), “The Dynamics of Productivity in the Telecommunications Equipment Industry”, *Econometrica*, Vol. 64(6), pp. 1263-1297.

Ottaviano, G. (2015), “Offshoring and the migration of jobs”, *IZA World of Labor*, pp. 170.

Patel, N., Wang, Z. and Wie, S-J. (2014), “GVCs and Effective Exchange Rates at the Country-Sector Level”, *NBER Working Paper Series*, No 20236, National Bureau of Economic Research.

Pesaran, M.H. (2006), “Estimation and inference in large heterogeneous panels with a multifactor error structure”, *Econometrica*, Vol. 74(4), pp. 967-1012.

Pesaran, M.H. and Yang, C.F. (2016), *Econometric Analysis of Production Networks with Dominant Units*, mimeo.

Powers, W. and Riker, D. (2013), *The Effect of Exchange Rates on the Costs of Exporters when Inputs are Denominated in Foreign Currencies*, US International Trade Commission.

Prades, E. and Villanueva, P. (2017), “España en las cadenas globales de valor”, *Banco de España Boletin Economico*, Vol. 3/2017.

Reijnders, L.S.M., Timmer, M.P. and Ye, X. (2016), “Offshoring, Biased Technical Change and Labour Demand: New Evidence from GVCs”, *GGDC Research Memorandum Series*, No 164.

Saia, A., Andrews, D., & Albrizio, S. (2015), “Productivity Spillovers from the Global Frontier and Public Policy: industry-level evidence”, *OECD Economic Department Working Papers*, No. 1238.

Saito, M., (2004), “Armington elasticities in intermediate inputs trade: a problem in using multilateral trade data”, *Canadian Journal of Economics*, Vol. 37(4), pp. 1097-1117.

Saito, Y., Nirei, M. and Carvalho, V. (2014), “Supply chain disruptions: Evidence from Great East Japan Earthquake”, *2014 Meeting Papers*, No 595, Society for Economic Dynamics.

Schmitz, M., De Clercq, M., Fidora, M., Lauro, B. and Pinheiro, C. (2012), “Revisiting the effective exchange rates of the euro”, *Occasional Paper Series*, No 134, ECB, Frankfurt am Main, June.

Stehrer et al. (2012), “GVCs and the EU industry”, *WIIW Research Report*, No 383.

Stehrer, R. (2012), “Trade in value added and the value added in trade”, *WIIW Working Paper Series*, No 81, The Vienna Institute for International Economic Studies.

Tagliabracci, A., Osbat, C. and Koester, G. (forthcoming), *The role of foreign slack and global integration for domestic inflation*.

Timmer, M.P., Dietzenbacher, E., Los, B., Stehrer, R. and de Vries, G.J. (2015), “An Illustrated User Guide to the World Input–Output Database: the Case of Global Automotive Production”, *Review of International Economics*, Vol. 23(3), pp. 575-605.

Timmer, M.P., Los, B., Stehrer, R. and de Vries, G.J. (2016), “An Anatomy of the Global Trade Slowdown based on the WIOD 2016 Release”, *Research Memorandum Series*, No GD-162), Groningen Growth and Development Centre, University of Groningen.

Tóth, P. (2014), “To What Extent Can Czech Exporters Cushion Exchange Rate Shocks Through Imported Inputs?”, *Focus on European Economic Integration Q3-2014*, Oesterreichische Nationalbank, pp. 74-93.

Van der Wiel, H., Creusen, H., van Leeuwen, G. and van der Pijll, E. (2008): "Cross Your Border and Look Around", *DEGIT Conference Papers*.

Wagner, J. (2013), “Exports, imports and firm survival: first evidence for manufacturing enterprises in Germany”, *Review of World Economics*, 2013(1), pp. 113-130.

Wang, Z. et al. (2016). *Characterizing Global Value Chains*, paper presented at the 19th Annual Conference on Global Economic Analysis, Washington DC.

Wang, Z., Wei, S. and Zhu, K. (2013), “Quantifying international production sharing at the bilateral and sector levels”, *NBER Working Paper Series*, No 19677, National Bureau of Economic Research.

Wooldridge, J. M. (2009), “On Estimating Firm-level Production Functions Using Proxy Variables to Control for Unobservables”, *Economics Letters*, Vol. 104(3), pp. 112-114.

World Trade Organization (2013), *World Trade Report – Factors shaping the future of world trade*.

Yi, K.-M. (2001), *Can Vertical Specialization Explain The Growth of World Trade?*, International Research, Federal Reserve Bank of New York.

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