2 The impact of global value chains on the macroeconomic analysis of the euro area

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With the decline in transportation costs and the reduction of barriers to trade in the last decades, production processes have become more fragmented as firms locate their production and source their inputs across national borders. This has significantly increased trade in intermediate goods and services. Euro area countries, in particular, have been increasingly participating in cross-border production chains, both within the currency area and outside.

This article analyses how global value chains affect the euro area economy. In particular, accounting for the presence of global value chains has an impact on some key economic indicators. The rise in importance of the value-added concept as opposed to conventional gross trade and the increase in intermediate trade change the way macroeconomic indices are computed and interpreted. Moreover, firms' and sectors' participation in global value chains creates or strengthens cross-country linkages via trade in intermediate inputs, which has consequences for macroeconomic analysis, namely for real activity spillovers and the skill mix and compensation of the labour force.

1 Introduction

The last few decades have witnessed a rapid expansion of global value chains (GVCs). Firms have been locating their production and sourcing their inputs across national borders. As a result, production has been increasingly organised in several stages across different countries, implying that exports have a significant amount of imported inputs incorporated into them (the "import content of exports"). As a result, production processes have become internationally fragmented, trade in intermediate goods and services has substantially increased (around 60% of world trade is estimated to be in intermediate goods), and the gross value of exports has become much higher than the value added originating in each exporting country. Multilateral free trade negotiations and the subsequent reduction of tariffs and non-tariff barriers, the opening-up of emerging market economies (EMEs) to global trade, financial liberalisation, the internationalisation of business services and technological improvements are the most prominent factors that contributed to the expansion of cross-country supply chains until recently.
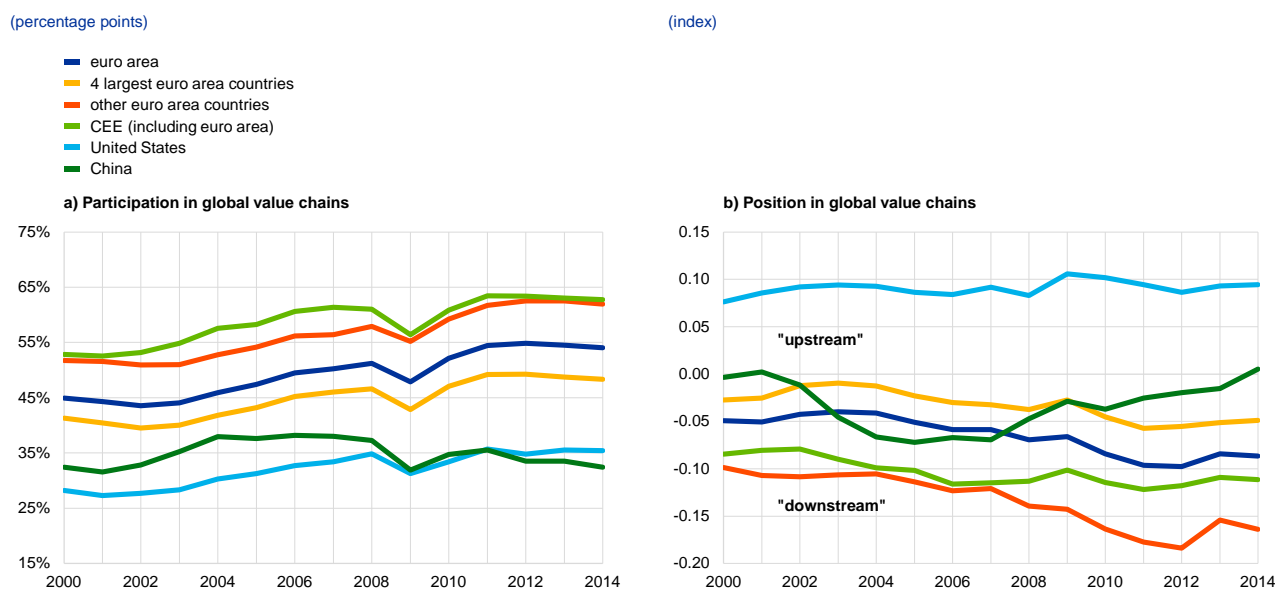
Euro area countries, in particular, have been increasingly participating in cross-border production chains, stimulated by a harmonised regulatory framework within the European Union (EU) and integration in a common currency area. As a result, the establishment of a regional production chain and trade in intermediate products with the rest of the world have been fostered. A comparison of countries' GVC participation indices[49] (Chart 1, panel a) shows that the euro area[50] is more

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[49] See Box 1 for details of the various measures of GVC integration.

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involved in global production chains than other large economies, such as the United States and China.

Chart 1

Participation and position in global value chains between 2000 and 2014

(percentage points)   (index)

- euro area
- 4 largest euro area countries
- other euro area countries
- CEE (including euro area)
- United States
- China

a) Participation in global value chains   **b) Position in global value chains**

Sources: World Input-Output Database (WIOD) (2016 release) and authors' calculations.
Notes: See Box 1 for details of the measures. The "4 largest euro area countries" are Germany, France, Italy and Spain. The "other euro area countries" are all of the other euro area countries, excluding CEE countries. "CEE" refers to all of the countries in central and eastern Europe that are EU members, five of which are in the euro area and six of which are outside the euro area.

In the years following the Great Recession, which occurred in the period 2008-09, the pace of supply chain expansion slowed substantially. Panel a of Chart 1 shows that the halt in the expansion of global value chains has been a global phenomenon. It has been partly due to increasing labour costs in emerging markets, as well as the onshoring[51] of multinational activities towards export markets (the "shortening of global value chains", in which production is brought closer to demand markets). In addition, the introduction of protectionist non-tariff barriers (for instance through local content requirements and other regulations) has increased trade costs, thus weighing on the expansion of global value chains. Other contributing factors may have been a global demand shift towards services, which are less trade intensive than goods, as well as robotisation, which is encouraging renewed localisation of production in the advanced economies.[52]

Euro area countries, however, have been less affected by GVC shortening than other countries (Chart 1, panel a). The process of shortening was particularly

[50]   The euro area aggregates in Chart 1 include intra-euro area trade in global value chains. Excluding intra-euro area trade would deliver a lower participation in global value chains in the euro area. This highlights the relevance of regional production chains.

[51]   Onshoring consists in transferring parts of the intermediate production processes close to the customers' location. For instance, in the production of a car model which is sold in Asia, the production of components and parts of the vehicles would be relocated in the Asian region.

[52]   For an account of the factors behind the global trade slowdown in general, see IRC Trade Task Force, "Understanding the weakness in global trade: what is the new normal?", *Occasional Paper Series*, No 178, ECB, September 2016.

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pronounced in China. While in 2014 (the last year for which data are available) the degree of participation of the United States in global value chains was comparable to that in 2008, in the euro area it was significantly higher and was driven by intra-euro area trade.

Since the beginning of the 21st century, euro area countries have also recorded a rise in the foreign value added embedded in their exports, that is, they have been increasingly using imported inputs in the production of their exports. In panel b of Chart 1, the evolution over time of the position of selected economies in the global value chain is plotted. The position index[53] of the euro area has fallen further below zero in recent years, meaning that euro area firms are using more foreign inputs and supplying fewer intermediate products to other countries. Hence, they are located more "downstream" in global value chains. Large euro area countries are, in turn, located "upstream" with respect to both small euro area countries and central and eastern European (CEE) countries[54]. This means that the last two country groupings use a relatively higher share of imported inputs in the production of their exports, often as a result of final assembly activities as part of the pan-European contribution to global value chains. Conversely, the United States is comparatively upstream as it provides intermediate products related to R&D, the financial sector and the commodity sectors to the rest of the world. Also, China[55] has been moving significantly upstream when comparing 2007 with 2014.

Global value chains have an impact on some key economic indicators. The rise in importance of the value-added concept, as opposed to conventional gross trade, and the increase in intermediate trade have brought about some challenges with regard to the way macroeconomic indices are computed and interpreted. In Section 2, the implications of global value chains for the measurement and interpretation of three key indicators – real effective exchange rates, export market shares and the global demand elasticity of trade – will be analysed.

Firms' and sectors' participation in global value chains also creates or strengthens cross-country linkages via trade in intermediate inputs. This has important consequences for macroeconomic analysis. Specifically, in Section 3 the focus is on real spillovers, as well as the skill mix and compensation of the labour force.

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[53]   See Box 1 for a definition.

[54]   The CEE countries considered in this analysis are: Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

[55]   See the article entitled "China's economic growth and rebalancing and the implications for the global economy", *Economic Bulletin*, Issue 7, ECB, 2017.

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Box 1

The measurement of global value chain integration

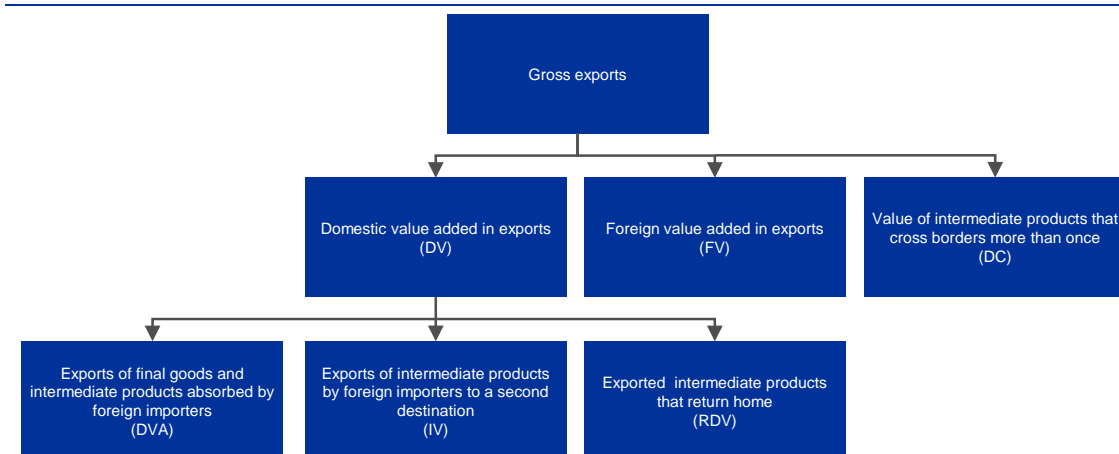Prepared by Benedetta di Lupidio and Joachim Schroth

Recent strands of the GVC literature have made use of global input-output tables in order to trace value-added flows through the various stages of production.[56] 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).[57] Figure A 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 the genuine contribution of exports to GDP. Foreign value added refers to the use of foreign inputs in the process of export production. Finally, 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).
Note: The value of intermediate products that cross borders more than once is the value incorporated in all those intermediate inputs that are produced in a country A, which are exported to country B (and are hence counted as an export of country A) to produce products for another country (either A itself or a third country C) and 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.[58] 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 allows the involvement in cross-border production chains of a given country or sector to be gauged. Backward (or downstream) participation in global value

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[56] See Koopman, R., Wang, Z. and Wei, S. J., "Tracing value added and double counting in gross exports", *American Economic Review*, Vol. 104(2), 2014, pp. 459-494, and Wang, Z., Wei, S. J. and Zhu, K., "Quantifying international production sharing at the bilateral and sector levels", NBER Working Paper No 19677, National Bureau of Economic Research, 2013.

[57] Double-counting arises when an intermediate input crosses a border more than once.

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

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chains 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, on the other hand, 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 a sector's involvement in global value chains can be defined as the sum of GVC-related components divided by gross exports (E_{ijt}), i.e.:

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

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 relatively higher share of foreign value added from upstream input providers would indicate a downstream position and hence lead to a negative value of the index. 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.

Global input-output tables are needed in order to decompose gross trade into its value-added components. In most of the analyses in this article, the World Input-Output Database (WIOD)[59] 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 2000-2014.

2 Implications of global value chains for the measurement and interpretation of macroeconomic indicators

2.1 Global value chain-based real effective exchange rates

Real effective exchange rates (REERs) are a measure of the international price and cost competitiveness of a country. REERs are computed as a trade-weighted average of a country's bilateral exchange rates vis-à-vis its most important trading partners, adjusted for price levels.[60] As such, they are used in aggregate export and

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[59]   See www.wiod.org.

[60]   See also "Revised trade weights for the effective exchange rates of the euro reflect the increasing importance of emerging market economies", *Economic Bulletin*, Issue 6, ECB, 2015.

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import flow models and as a synthetic indicator for the analysis of trade performance and balance of payments adjustments.

A challenge to the interpretation of conventional REERs is posed by the fact that imports are pervasively used to produce exports in today's global economy. As a result, countries often compete against each other in specific stages of the value-added chain (e.g. two emerging economies may compete in the assembly of an iPhone). The conventional REER measures, however, assume that countries compete to sell products that they produce entirely at home, using only domestic inputs.

In particular, bilateral value-added trade patterns may differ significantly from gross trade patterns, which implies that gross value trade weights may over- or understate the degree of bilateral competition for value-added exports. To account for this effect, value-added real effective exchange rates (VAREERs) based on bilateral value-added trade data can be constructed. VAREERs thus take into account that gross trade flows of intermediate goods, for instance between neighbouring countries, may distort the extent to which value added in terms of final goods is traded between countries.

Moreover, as countries trade intermediate inputs intensively, this affects the impact of exchange rate changes on trade. An appreciation vis-à-vis a trading partner from which a country largely imports intermediate goods (e.g. components imported by China from Japan for iPhone assembly) may actually 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) can be constructed. IOREERs identify an additional channel through which exchange rate movements affect price competitiveness. An appreciation not only increases the relative price of domestic goods and therefore worsens the country's price competitiveness, it also has a counteracting effect on competitiveness as it reduces the cost of foreign inputs used in production.

REERs based on GVC weights therefore offer a complementary measure that enriches the interpretation of more traditional measures based on gross trade and used in the computation of the REERs disseminated by the ECB.[61] VAREERs are calculated by replacing conventional bilateral total gross trade weights with value-added weights. IOREERs, instead, take into account bilateral trade in intermediates and attach a lower weight to partners that provide a sizeable share of inputs in a country's production in order to account for the fact that an appreciation vis-à-vis such trading partners may actually be beneficial to the competitiveness of the importing country as it reduces the cost of production.[62]

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[61] See Bems, R. and Johnson, R. C., "Demand for Value Added and Value-Added Exchange Rates", NBER Working Paper No 21070, National Bureau of Economic Research, 2015.

[62] In order to ensure full consistency, GVC REERs are computed following the ECB method for the computation of its published REERs, namely by using three-year non-overlapping averages as weights. Standard REERs are in turn recalculated by deflating nominal exchange rates with relative GDP deflators and by considering a basket of only 40 (instead of 57) currencies because of data availability limitations for input-output data.
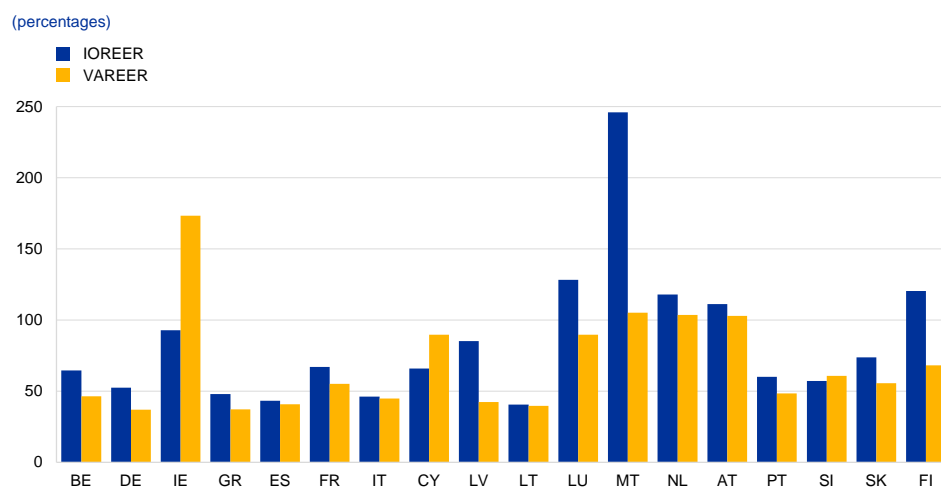
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Although GVC weights are highly correlated with gross trade weights, their absolute differences are non-negligible. Table 1 reports the correlation coefficients between GVC-based trade weights (i.e. the share of each trading partner in the total trade of any given country) and conventional trade weights. On first inspection, the different weights look highly correlated for the majority of countries, with the exception of some small countries (Lithuania, Luxembourg and Slovakia), which have a correlation coefficient below 0.8. However, despite the high degree of correlation, absolute differences between GVC weights and conventional trade weights are substantial. In order to illustrate this, Chart 2 shows for each country the average of the absolute percentage deviations of its trading partners' value-added and input-output-based trade weights from conventional trade weights. It turns out that in most cases value-added and input-output-based trade weights on average deviate by around 50% from the conventional trade weights and, in some cases, the average absolute percentage deviation is even higher than 100%.

Table 1

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

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

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

Chart 2

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

(percentages)

Sources: Bems and Johnson (2015), op. cit., ECB and ECB staff calculations.
Note: The average absolute percentage deviation of GVC-based trade weights from conventional trade weights is calculated as follows for any given country. In a first step, for each of the given country's trading partners, the percentage deviation of its GVC-based trade weight from its conventional trade weight is calculated. In a second step, the arithmetic average of the absolute values of these percentage deviations is calculated in order to obtain the average absolute percentage deviation.
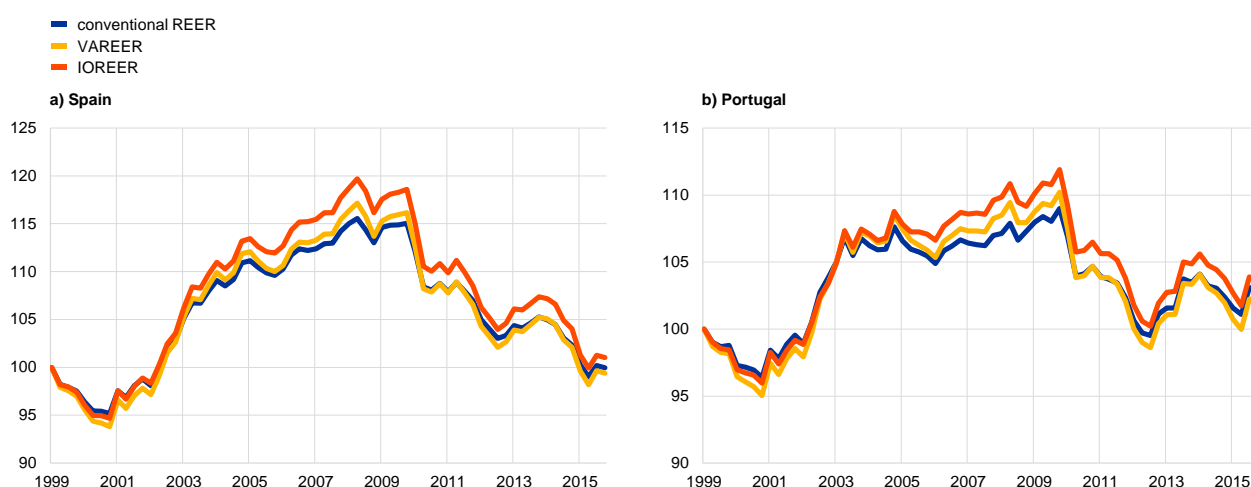
An interesting finding is that the GVC REERs show larger changes in price competitiveness for the euro area countries that were most affected by the crisis, thus suggesting that they might have been useful in the detection of pre-crisis country vulnerabilities. Across euro area countries, a comparison of the dynamics of GVC REERs with conventional REERs delivers broadly consistent

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messages. In the case of the euro area countries most affected by the crisis, however, the evolution of REERs (see the examples of Spain and Portugal in Chart 3) shows that both the VAREER and, to a larger extent, the IOREER measures point to stronger losses in competitiveness in the years preceding the crisis and, correspondingly, larger gains in the post-crisis period. In macroeconomic analysis it would thus be beneficial to look at GVC REERs, which could provide useful complementary insights into competitiveness developments.

Chart 3
Comparison of VAREER, IOREER and conventional REER indices

(index: Q1 1999 = 100)

conventional REER
VAREER
IOREER

a) Spain

b) Portugal

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

2.2   Global value chains and export market shares

With GVC integration, gross exports might not gauge a country's international contribution to trade in terms of value added. As intermediate inputs cross borders several times within production chains, tracing value-added flows can be crucial for the assessment of the effective contribution of a country to the world market. Input-output data can be used in order to gather information on countries' value-added structures[63] and can be complemented with trade price data in order to investigate the price and non-price factors behind the evolution of market shares.

Value-added and gross trade shares broadly deliver the same trends in market shares for the period 2000-14. Chart 4 compares changes in market shares of value added in exports of goods (called "value-added market shares" for simplicity) with conventional global market shares based on gross exports of goods.[64] Both measures point to substantial gains in market shares for CEE euro area countries and corresponding losses for most non-CEE euro area countries. Less pronounced
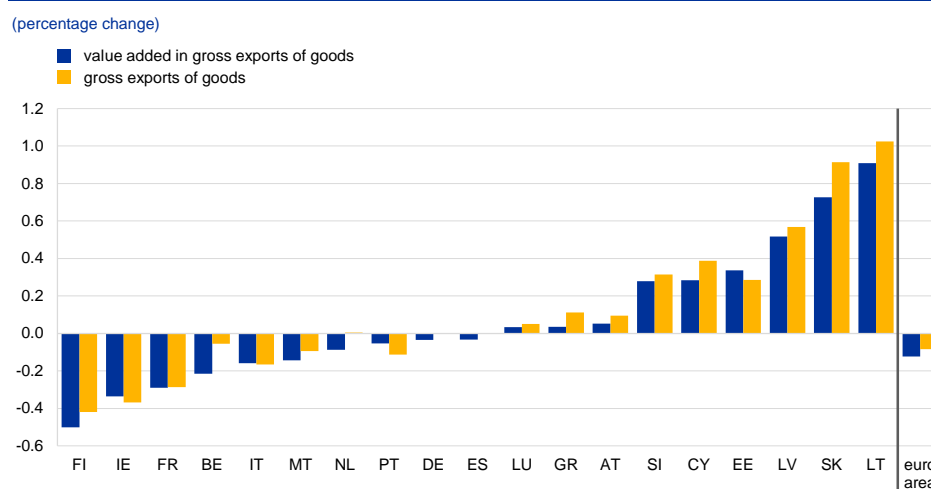
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[63]   See Box 1.

[64]   Market shares are computed using bilateral trade and price information from the UN Comtrade database and input-output data from the WIOD (2016 release).

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gains in terms of value added compared with gross trade in Slovenia and Slovakia can be explained by the outsourcing to these countries of the final assembly of motor vehicles by Germany, France and Italy. A similar trend is observed in the manufacturing of food products, chemical products and wood products outsourced from Finland, Sweden and Germany to Lithuania and Latvia. Estonia shares the above-mentioned tendencies of the other Baltic countries, while larger gains in terms of value added are driven by the reduced outsourcing of electronic production from Finland.[65]

Chart 4

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

(percentage change)

Sources: WIOD, UN Comtrade, Latvijas Banka and Oesterreichische Nationalbank staff calculations.
Notes: Cumulative log changes of global market shares are shown. Figures for the euro area are calculated as a weighted average for individual euro area countries (using gross exports and value added in gross exports as weights).

The decomposition of the determinants of the changes in global market shares suggests that the international fragmentation of production plays a non-negligible role in the shifts of market shares (Chart 5). Changes in global value-added market shares can be decomposed into shifts in production chains, the variation of price factors and the change of residual non-price factors which can be thought of as being related to product quality and consumers' tastes.[66] The decomposition is done at the very detailed product level which makes it possible to control for differences in market conditions. First, the elasticity of real trade flows to changes in relative prices is estimated for every product on every geographical market. Taken together with the information on the changes in unit values, it provides the contribution of price and cost factors at a disaggregated level. Then, the aggregate contribution of price competitiveness is obtained. To account for the fact that each product contains value added from various countries, the aggregation uses weights calculated from trade in value added (rather than gross trade, as in the conventional REER). Moreover, a specific term accounting for shifts in global value
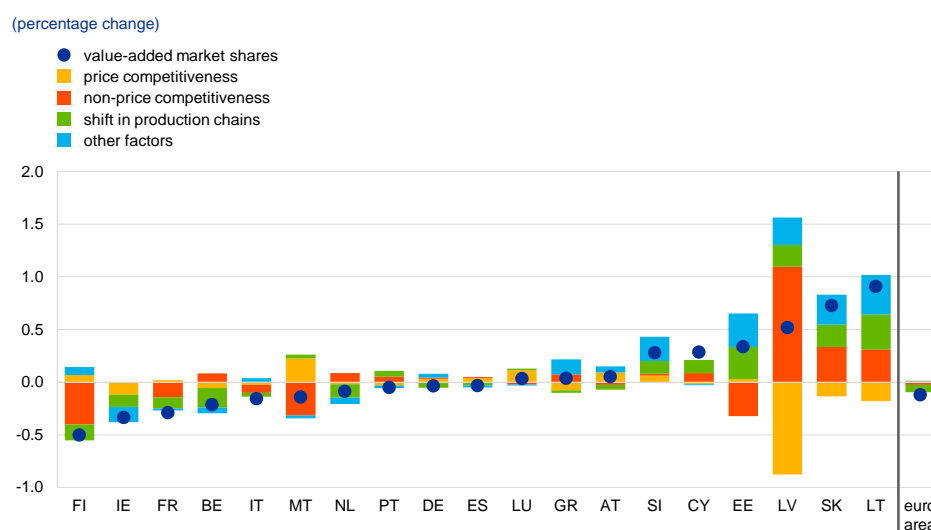
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[65] This was related to the manufacturing process of Elcoteq in Estonia, which started in the late 1990s and was later reduced substantially.

[66] The decomposition also includes "other factors" such as shifts in demand or changes in the set of competitors. The empirical importance of other factors is found to be minor, but they are still needed for a theoretically sound decomposition.

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chains is introduced into the decomposition; it is calculated as the weighted growth in a country's share in the production of all goods exported by all countries. The positive shift in production chains can be achieved either by a higher domestic content in a country's own gross exports, or by a higher value-added share in third countries' gross exports. Finally, the non-price competitiveness is measured as a residual term that is not explained by the above-mentioned factors.[67]

Chart 5
Decomposition of value-added market shares between 2000 and 2014

(percentage change)

Sources: WIOD, UN Comtrade, Latvijas Banka and Oesterreichische Nationalbank staff calculations.
Notes: Other factors include the extensive margin, the set of competitors and shifts in the demand structure. The chart shows cumulative log changes of global market shares. Figures for the euro area are calculated as a weighted average for individual euro area countries (using value added in gross exports as a weight). For details of the methodology, see Benkovskis and Wörz (2015).

Changes in GVC participation and outsourcing resulted in market share losses for non-CEE euro area countries (except for Portugal, Luxembourg, Malta and Cyprus) and gains for CEE euro area countries between 2000 and 2014 (Chart 5). At the same time, increases in quality and consumers' preferences for CEE euro area countries' products overcompensated for the losses in price competitiveness. Compared with gross export market shares, the decomposition considering value-added shares downplays the role of non-price competitiveness, since some part of quality gains and losses of the gross exports can be attributed to the outsourcing process.[68] Thus, the analysis based on value-added shares enhances the role of cost and price factors.

In conclusion, using value-added flows instead of gross exports for the computation of global market shares improves the understanding of the drivers behind the external performances of euro area countries. Although both market shares follow similar trends, the decomposition of the value-added shares reveals the role of production outsourcing and provides a more precise contribution of price and non-price factors.

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[67] For details of the methodology, see Benkovskis, K. and Wörz, J., "'Made in China' – How does it affect our understanding of global market shares?", *Working Paper Series*, No 1787, ECB, 2015.

[68] For more empirical results, see Benkovskis and Wörz (2015), op. cit.

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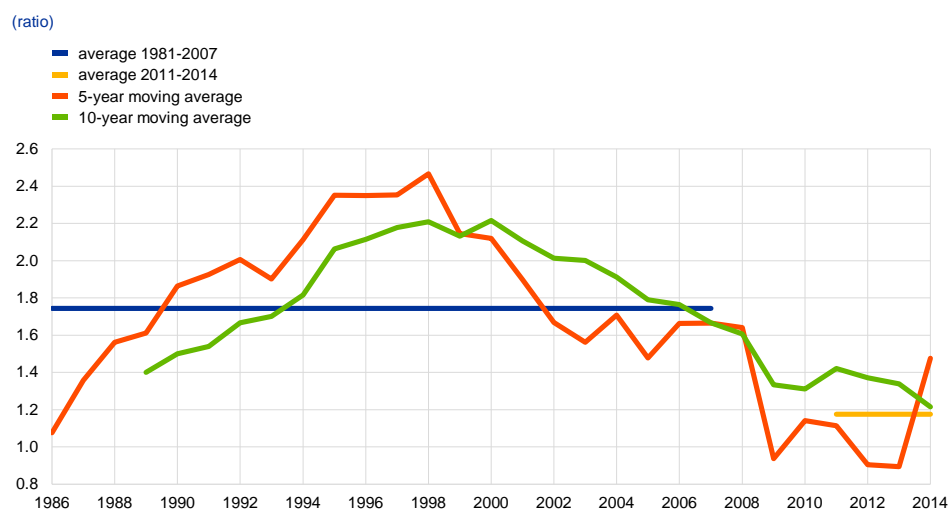
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2.3   Global income elasticities of trade

While trade grew by twice as much as income over the period 1981-2007, the trade-to-GDP growth ratio fell to about unity in the period 2011-2014 (Chart 6). In particular, the drop in the ratio was driven by a collapse in trade flows following the Great Recession that was significantly stronger than the decline in global income.

Chart 6
Ratio of global import growth to GDP growth
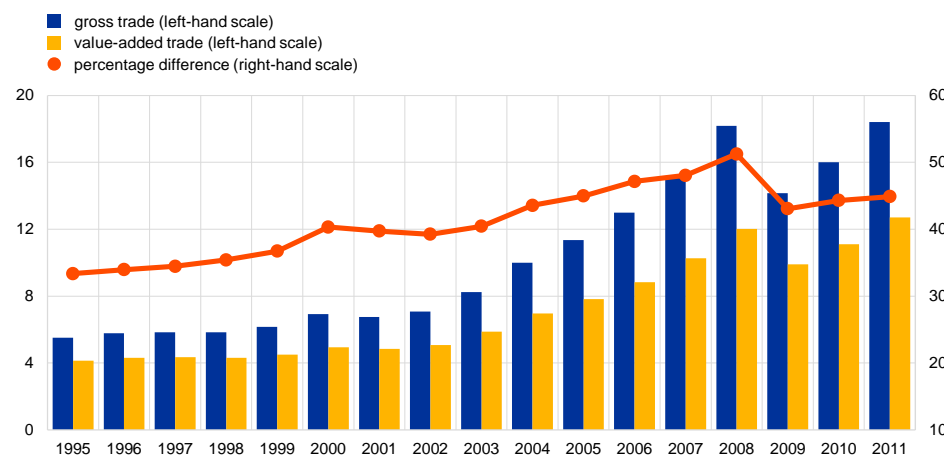
(ratio)

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

The changing international fragmentation of production is one of the drivers of the trade growth dynamics in relation to income growth. Although (tariff and non-tariff-related) trade costs, trade openness and financial liberalisation have been important determinants of trade growth, the intensity of engagement in global value chains plays a key role in explaining the disproportionate growth of trade compared with income at the end of the last century and the unexpectedly sharp drop after the crisis. First, from a merely statistical point of view, the organisation of production chains implies that goods and services cross borders several times during the production process and are hence partly double-counted in customs trade flow statistics (see Figure A in Box 1). As a result, registered gross trade flows exceed the effective value added of trade flows (Chart 7). Second, trade in global value chains is mainly in durable goods, which are known to have a high income elasticity, explaining the steepness of the trade reaction in the global crisis. Third, supply chain effects might intensify negative demand shocks, as downstream firms would initially cut inventories, affecting input providers.

Chart 7

Global gross trade versus value-added trade

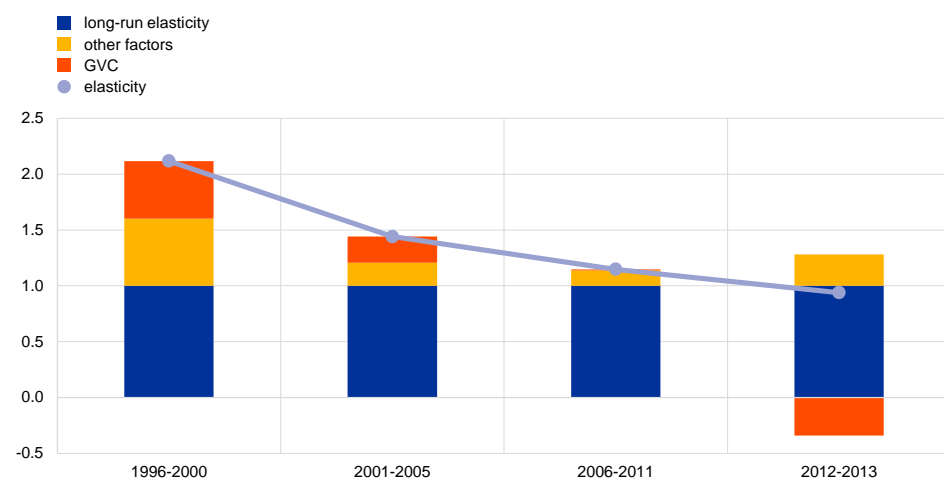(left-hand scale: USD trillions; right-hand scale: percentages)

- gross trade (left-hand scale)
- value-added trade (left-hand scale)
- percentage difference (right-hand scale)

Sources: WIOD and ECB calculations.

Chart 8

Contributions to the global income elasticity of trade

(trade-income elasticity and contributions)

- long-run elasticity
- other factors
- GVC
- elasticity

Source: IRC Trade Task Force, "Understanding the weakness in global trade: what is the new normal?", Occasional Paper Series, No 178, ECB, 2016, Section 3.
Notes: The calculations follow Borin and Mancini (2015), op. cit. Other factors refer to the income elasticity of the non-GVC-related import content of final demand.

GVC participation helps to explain significant variations in the global trade-income elasticity. Regression results based on a standard import demand model[69] augmented by a GVC participation index show that global value chains have a significant impact on import elasticities. Moreover, the decomposition of the income elasticity of trade for the period 1995-2011 shows that the contribution of global value

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[69] See Anderton, R., Baltagi, B. H., Skudelny, F. and Sousa, N., "Intra- and Extra-Euro Area Import Demand for Manufactures", *Applied Economics Quarterly*, Vol. 53(3), 2007, pp. 221-241.

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chains has been about 40% on average.[70] However, recent data on GVC integration indicate a flattening trend in recent years[71] and this translates into a negative contribution of global value chains to the global income elasticity of trade for the period 2012-13 (Chart 8).

The results of this analysis suggest that GVC dynamics are relevant for medium-term trade projections. From a euro area policy perspective, the decline in GVC participation was one of the factors explaining recent downward revisions to the global income elasticity of trade.[72] Going forward, a close monitoring of GVC dynamics is warranted to ensure consistent trade projections.

3 Other implications of cross-country production linkages for macroeconomic analysis

3.1 Sectoral spillovers via global production linkages

Production linkages are a potential channel for real economic activity spillovers.[73] Firms and sectors are increasingly sourcing or selling their inputs across borders and production processes are broken down in such a way that value is added in each step. This section utilises the World Input-Output Database to investigate empirically how production linkages give rise to real activity spillovers and to establish which characteristics of the network are relevant for the transmission of spillovers. Chart 9 reports correlation coefficients of sectors' growth in real value added at a given distance[74] in the input-output network. It shows that because sectors are more closely connected with each other through trade in intermediate inputs, their value-added growth is more correlated. As a recent strand of literature[75] has shown, shocks to specific firms or sectors transmit through production networks and might potentially translate into aggregate macroeconomic disturbances.

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[70] See Borin, A. and Mancini, M., "Follow the value added: bilateral gross export accounting", Banca d'Italia Working Paper No 1026, 2015, for methodological details.

[71] See Chart 1.

[72] See IRC Trade Task Force, "Understanding the weakness in global trade: what is the new normal?", *Occasional Paper Series*, No 178, ECB, 2016.

[73] International input-output linkages may have also contributed to synchronising inflation rates by intensifying the spillovers from foreign cost shocks; see Auer, R. A., Borio, C. and Filardo, A., "The globalisation of inflation: the growing importance of global value chains", BIS Working Paper No 602, Bank for International Settlements, 2017, and Auer, R. A., Levchenko, A. A., and Sauré, P., "International inflation spillovers through input linkages", NBER Working Paper No 23246, National Bureau of Economic Research, 2017.
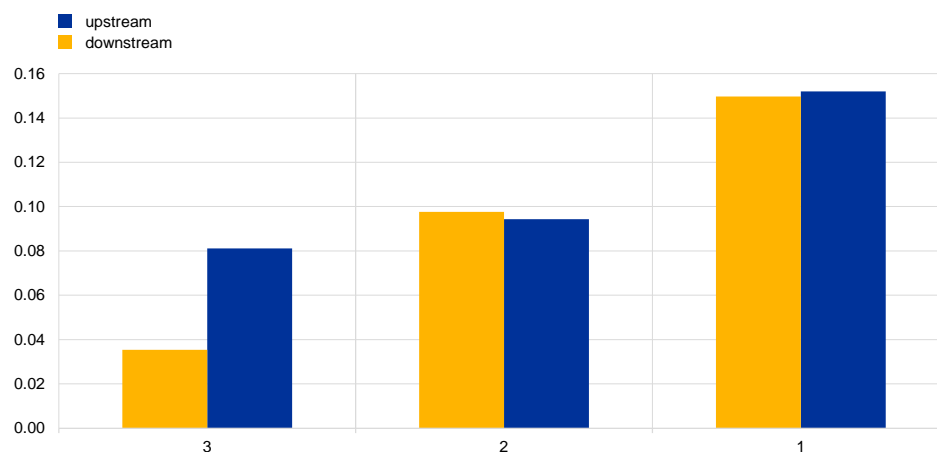
[74] Distance measures the shortest path between any two sectors in the network, that is, how many times inputs from one sector are sold in order to reach another sector. It is computed with the Dijkstra algorithm.

[75] See Gabaix, X., "The granular origins of aggregate fluctuations", *Econometrica*, Vol. 79(3), 2011, pp. 733-772, and Acemoglu, D., Carvalho, V. M., Ozdaglar, A. and Tahbaz-Salehi, A., "The network origins of aggregate fluctuations", *Econometrica*, Vol. 80(5), 2012, pp. 1977-2016.

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Chart 9

Real value-added synchronisation and distance between sectors

(correlation coefficients for value added in interrelated sectors)

- upstream
- downstream

Sources: WIOD (2013 release) and ECB calculations.
Notes: The chart shows the average (1996-2009) pairwise correlation between sectors' value added at a given distance to upstream and downstream sectors. The distance is equal to one when two sectors trade directly, two when two sectors trade through another sector and three when two sectors trade through two other sectors.

The presence of hub sectors is relevant for the transmission of economic shocks as they connect otherwise unrelated entities through input-output linkages and could act as a conductor of shocks. In the World Input-Output Database[76] the upstream hubs (i.e. sectors that supply inputs to other sectors) are mostly located in the United States, the United Kingdom, Germany and Russia, and operate in sectors such as computer activity, headquarter activity, R&D, finance and raw materials. As regards the downstream part of the value chain (i.e. sectors that purchase inputs from other sectors), the hubs are transport equipment, electronics, construction and basic metals in Germany, the United States and more recently China. Box 2 focuses on the spillover effects originating in some of these sectors.

Activity spills over via these sectors to many other trading partners. A panel econometric analysis of the WIOD data confirms that, on average, spillovers to a sector stemming from other upstream and downstream sectors involved in its production chains are significant.[77]

Box 2

Identification of sectoral spillovers in the global economy

Prepared by Erik Frohm and Vanessa Gunnella

To investigate the transmission of shocks through global supply chains, a non-linear panel model is estimated. In the model, the change in real value added of sector *i* is related to its past values and to the previous period's change in value added of a set of direct and indirect upstream

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76   See Box 1 for a description of the database.

77   See Box 2 for further details.

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and downstream sectors.[78] The estimation controls for other observed factors determining the activity of sector i, x_{it}, as well as common unobserved time factors in the error term ε_{it}:

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

$\tilde{y}_{i,t-1}^{up}$ and $\tilde{y}_{i,t-1}^{down}$ are weighted averages of the value added of a selected group of upstream and downstream sectors:

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

where * stands for "up" and "down" and the weight $w_{ij,t-1}^*$ measures the bilateral importance of the value-added contribution and is inversely proportional to the bilateral distance. The aggregate $\tilde{y}_{i,t-1}^*$ is constructed such that only sectors with a weight above a certain level r are included in the average. The threshold is endogenously determined by the model and allows the identification of the most important sectors for spillover transmission.[79]

The regressions confirm that upstream and downstream spillovers through supply chains are significant. The spillover effects are positive and of sizeable magnitude and their significance is not lost when including other determinants of sector i's activity (employment and capital), the country's activity and global factors (agriculture, fuel and metal prices and US interest rates). This means that the change in activity of a sector is related to the change in activity of both its input providers and its customers.

The impact of a change in real value added in any sector can be traced and quantified by using the estimated coefficients from the model. This exercise identifies spillovers that stem solely from a change in real value added in the affected sectors. For example, the transport equipment sector (i.e. the car industry) in Germany and the electronics and optical equipment sector in China illustrate how changes in real value added propagate to other domestic sectors, the euro area and the rest of the world (Chart A). Obviously, the supply chain impact is the greatest in the domestic economy, affecting 27 and 30 sectors respectively (blue bars), but it also affects many other sectors in the euro area (yellow bars) and even spills over to other countries and involves a total of 236 and 172 sectors respectively (red bars). When these and other hub sectors' ties to the rest of the value chains are severed, spillovers gradually diminish and become statistically insignificant.[80]
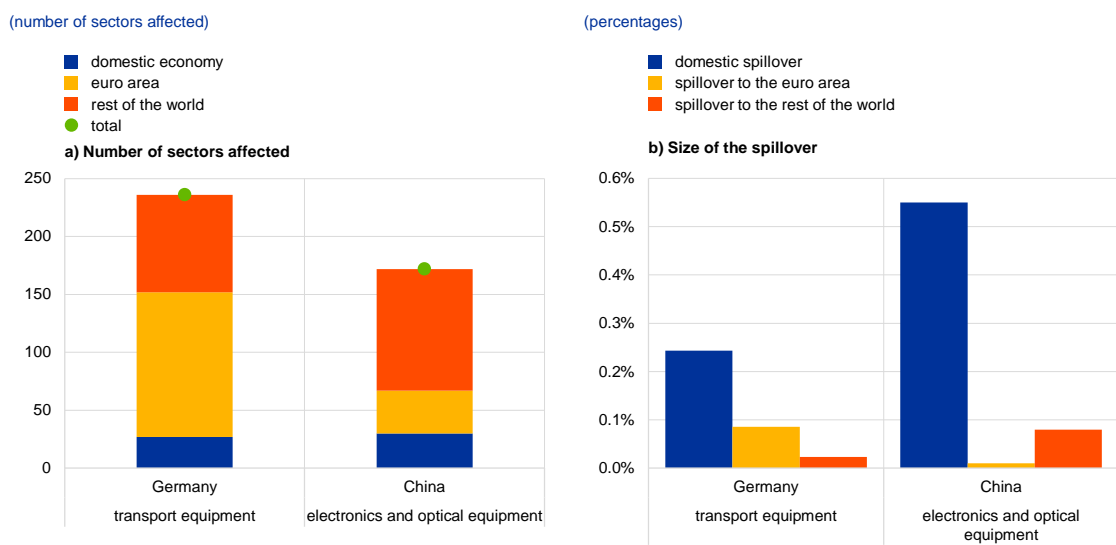
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[78] The analysis in this box does not attempt to investigate the nature of the shock. In a Cobb-Douglas setting, demand-side shocks transmit upstream in the value chain, whereas supply shocks propagate to downstream sectors; see Acemoglu, D., Akcigit, U. and Kerr, W., "Networks and the macroeconomy: An empirical exploration", *NBER Macroeconomics Annual*, Vol. 30(1), 2016, pp. 273-335. For a further investigation of the impact of demand and supply shocks in this analysis, see Frohm, E. and Gunnella, V., "Sectoral interlinkages in global value chains: spillovers and network effects", *Working Paper Series*, No 2064, ECB, 2017.

[79] For further details of the methodology, see Frohm and Gunnella (2017), op. cit.

[80] See Figure 5 of Frohm and Gunnella (2017), op. cit.

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Chart A

Spillovers from specific sectors

(number of sectors affected)   (percentages)

- domestic economy   - domestic spillover
- euro area   - spillover to the euro area
- rest of the world   - spillover to the rest of the world
- total

a) Number of sectors affected   **b) Size of the spillover**

Sources: WIOD (2013 release) and ECB calculations.
Notes: In panel b, the impact of the sector reported on each other sector i is computed as $\hat{\rho}^{*} w_{ij,t}^{*}$ and the overall impact as $\hat{\rho}^{*} \sum_{i \neq j} 1 \left(w_{ij,t}^{*} \geq \hat{r}^{*} \right) w_{ij,t}^{*}$, with domestic (same-country) effects, euro area effects and effects on the rest of the countries in the sample (rest of the world) being calculated by considering the affected sectors. Spillovers are aggregated by using the sectors' respective GDP weights in total GDP of the aggregate considered.

Overall, this analysis suggests that there is significant scope for propagation of sectoral shocks through global supply chains. As hub sectors could potentially be the channel of transmission across countries and sectors, particular attention should be paid to their developments and their links with other sectors in the global economy.

3.2 The impact of global value chains on labour value added, hours worked and compensation

Between 1997 and 2011 unskilled labour's value-added share in the euro area has substantially declined, whereas skilled labour's share has increased.
Aggregating sectoral data at the country level helps to disentangle the evolution of the labour value-added contribution for different skill groups within the euro area.[81] The overall importance of labour in both euro area output and exports decreased slightly from 1997 to 2011. Among the five largest euro area economies, Germany is characterised by the highest shares of labour value added. Euro area exports contain significantly less labour value added than gross output, revealing that exporting firms rely more heavily on imported inputs and/or capital (Chart 10). With
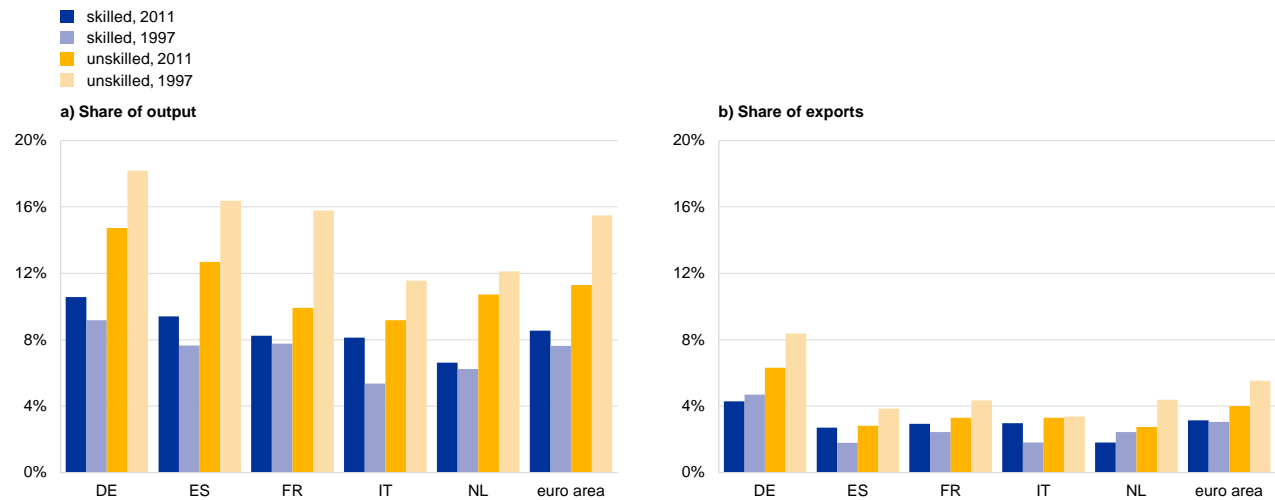
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[81]   For this purpose, use is made of the World Bank's Labor Content of Exports (LACEX) Database developed by Calì et al. in 2016 on the basis of a panel of global input-output tables, exports from the Global Trade Analysis Project and national employment data. The database is a panel covering 24 sectors and 150 countries and measures the contribution of labour to a given country's exports – measured as employees' compensation (LACEX dataset) or the number of jobs (JOCEX dataset).

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regard to the skill mix, skilled labour has captured a growing part of labour value added at the expense of unskilled labour.

Chart 10

Average domestic labour value-added share in the euro area and its five largest economies

(percentage share)

- ■ skilled, 2011
- ■ skilled, 1997
- ■ unskilled, 2011
- ■ unskilled, 1997

a) Share of output

b) Share of exports

Sources: Labor Content of Exports Database (World Bank) and ECB staff calculations.
Notes: The shares for the euro area are computed as a weighted average of all available euro area countries, with gross output as a weight. Due to missing data, Slovenia is not included in the computations.

Trade in global value chains changes the scope of tasks being performed in each industry, possibly affecting the skill mix and compensation within sectors. The changes to production processes and input choices related to international production segmentation in the past decades 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.

Box 3

Employment, labour compensation and global value chains

Prepared by François de Soyres and Elena Pavlova

This box presents the analysis of the relationship between hours worked and compensation for different skill groups, on the one hand, and GVC participation, on the other hand, in a panel of euro area sectors over the period 1995-2009. The estimating regression is:

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

where the unit of observation is a sector *i* in country *c* at time *t*, $y_{i,c,t}$ is either the log of the share of high-skilled hours in total hours or the log of compensation of high-skilled and low-skilled workers, and $IV_{i,c,t}$ and $FV_{i,c,t}$ are backward and forward GVC indices, respectively.[82] Sector-country

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[82] See Box 1 for a description of the GVC participation indices.

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($FE_{i,c}$) and country-time ($FE_{c,t}$) fixed effects are included in order to control for unobserved time-invariant differences across industries and aggregate country-level changes in each year.[83]

The estimation results confirm that there is a significant effect of foreign value added on the skill mix and on the compensation of both high and low-skilled workers.

Estimation results using within-sector changes show that participation in global value chains may be associated with a shift towards high-skilled labour.[84] A panel fixed-effects estimation shows that participation in global value chains is associated with a change in the skill composition within sectors characterised by a shift towards high-skilled workers (Chart 11, panel a).[85] When disentangling the effect between backward and forward-looking participation indices, this effect is mainly driven by an increased usage of imported inputs.[86] Such a job polarisation might be related to a combination of both offshoring and skill-biased technical change at the sectoral level.

Turning to wages, panel analysis shows that backward participation in global value chains is associated with an increase in hourly compensation for all skill groups (Chart 11, panel b). Both high and low-skilled workers experience an increase in their hourly compensation when the sector they are working in sees an increase in the foreign value added embedded in its exports (backward participation).[87] This result is supported by existing studies that show that imported inputs generate important productivity effects, through channels involving learning, innovation, and variety or quality aspects.[88] While an increased share of imported inputs in the production process might benefit total factor productivity and hence potential output,[89] competitiveness would improve only when productivity increases faster than input costs (wages and the rental rate of capital). A number of firm-level studies find a positive net effect of imported inputs on external competitiveness, hence enabling entry into new export markets.[90] Moreover, the strengthening of global value chains has the potential to weaken the elasticity of exports to the exchange rate, for example if exports are increasingly made of inputs bought in foreign currencies.[91]

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[83]   The wage regressions also include the capital-to-labour ratio as a determinant of the marginal productivity of labour in a Cobb-Douglas production function setting.

[84]   The results presented here do not provide evidence of causality, but are designed to assess correlation between different GVC participation indices and labour market outcomes.

[85]   For more details of the methodology, see Box 3.

[86]   See Box 1 for a description of the GVC participation indices.

[87]   This is consistent with firm-level studies such as Bas, M. and Strauss-Kahn, V., "Does importing more inputs raise exports? Firm-level evidence from France", *Review of World Economics*, Vol. 150, 2014, pp. 241-275.

[88]   See, for example, Halpern, L., Koren, M. and Szeidl, A., "Imported Inputs and Productivity", *American Economic Review*, Vol. 105(12), 2015, pp. 3660-3703.

[89]   See Box 4 for an analysis of technology transmission through production linkages in the CEE countries.
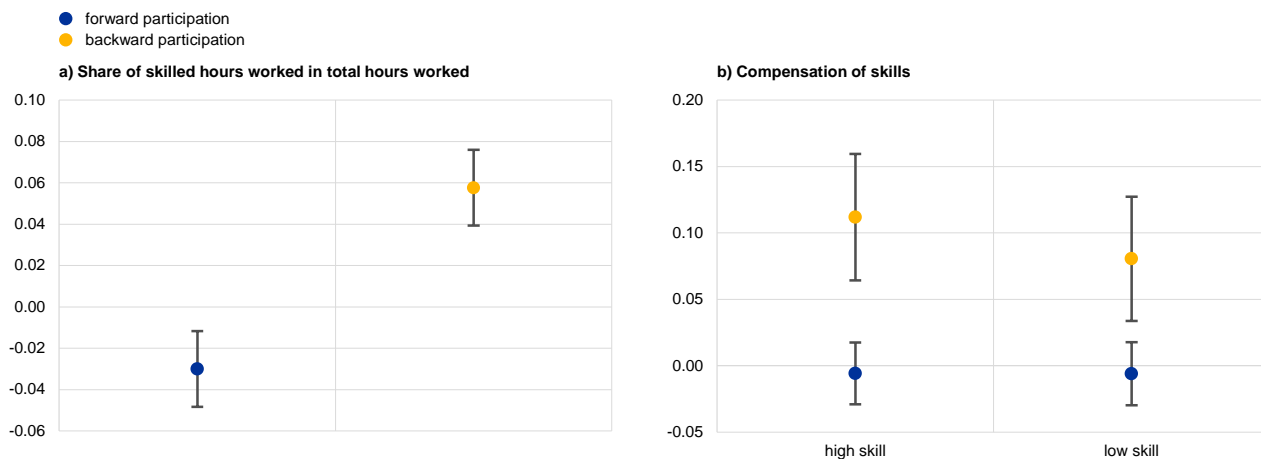
[90]   See, for example, Kasahara, H. and Lapham, B., "Productivity and the decision to import and export: Theory and evidence", *Journal of International Economics*, Vol. 89(2), 2013, pp. 297-316.

[91]   See Section 2.1 of this article for an account of the effects of the use of imported inputs in production on countries' price competitiveness.

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Chart 11

GVC participation correlations with skill composition and compensation of high and low-skilled employees

(percentage change corresponding to a 1% increase in the GVC participation index)

● forward participation
● backward participation

a) Share of skilled hours worked in total hours worked

b) Compensation of skills

Sources: World Input-Output Database (2013 release) and ECB staff calculations.

This analysis suggests that global value chains have an impact on labour market outcomes. A greater share of imported inputs in production may be associated with a shift towards high-skilled labour. Foreign inputs could raise wages for all skill groups. At the same time, global value chains may have positive welfare implications for the participating economies, namely technological advancement following the more efficient allocation of workers to high-skilled tasks which also implies higher wages in advanced economies, on the one hand, and increased salaries for workers in emerging economies, on the other.[92]

Box 4

Technology transfer through global value chains and productivity growth in central and eastern European countries

Prepared by Katerina Gradeva and Paloma Lopez-Garcia

Supply chain linkages are an important channel for technology transmission from parent to host firms. Firms involved in production chains can benefit from being related to more technologically advanced parent firms as they can learn and absorb their technology. According to the literature, there are two main transmission channels. On the one hand, firms utilising parent companies' intermediate products in their production – i.e. firms with backward supply linkages – can have access to new technology embedded in those products and to a wide variety of inputs. On the other hand, firms providing intermediate products to their parent companies – i.e. firms with forward supply linkages – are subject to quality checks which improve their products. This, in turn, would enhance their productivity and allow them to upgrade capital.

Given the high integration of CEE countries in global value chains, productivity developments of firms in these countries depend heavily on these technology spillovers. As

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[92]   Welfare gains for advanced economies only materialise when resources are efficiently and rapidly reallocated across skill groups. See Rodriguez-Clare, A., "Offshoring in a Ricardian World", *American Economic Journal: Macroeconomics*, Vol. 2(2), 2010, pp. 227-258.

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shown in panel a of Chart 1, CEE countries are integrated in GVCs to a much larger extent than the euro area on average, even after the general slowdown in GVC participation growth after 2011. For this reason, this box uses the CEE region as a case study to analyse to what extent and how technology spills from parent to host firms in GVCs.

According to the literature, new technology diffuses across countries in two stages: first from global frontier firms to national frontier firms, and second from national frontier firms to national non-frontier firms. This framework is adapted to GVCs and it is assumed that the relevant global frontier firms are parent firms and that only national frontier firms in the host country participate directly in GVCs. Accordingly, in a first stage, the most productive firms in the host country absorb technology from parent firms. In a second stage, the new technology spills from firms participating in GVCs to non-frontier firms in the host economy, which operate in domestic production chains and interact with national frontier firms. Moreover, transmission depends on the exposure to and learning from the relevant frontier firms ("pass-through" effect), as well as the ability to catch up with the frontier ("catch-up" effect).

Table A

TFP growth of national frontier and non-frontier firms

	First stage of technology diffusion		Second stage of technology diffusion	
	GVC forward participation (exports)	GVC backward participation (imports)	GVC forward participation (exports)	GVC backward participation (imports)
TFP growth of GVC frontier	0.156***	0.430***	0.060*	0.151***
	(0.044)	(0.058)	(0.036)	(0.041)
Lagged TFP gap between GVC frontier and national frontier	0.281***	0.364***	0.041	0.010
	(0.044)	(0.054)	(0.026)	(0.024)
TFP growth of national frontier			0.947***	0.920***
			(0.051)	(0.049)
Lagged TFP gap between national frontier and non-frontier firms			0.560***	0.569***
			(0.077)	(0.080)
GVC participation growth	0.079**	0.199**	0.068**	0.203**
	(0.036)	(0.079)	(0.032)	(0.079)
Observations	642	642	642	642
Adjusted R-squared	0.224	0.334	0.727	0.736

Sources: CompNet, WIOD (2016 release) and ECB calculations.
Notes: Robust standard errors in parentheses, clustered at the country-sector level. Country-sector fixed effects, a constant and dummies for crisis and post-crisis periods are included.
*** p<0.01, ** p<0.05, * p<0.10

Parametric analysis using data from the Competitiveness Research Network (CompNet) and the latest WIOD release for nine CEE countries and ten years (2003-12) provides evidence in support of the importance of technology transfer for total factor productivity (TFP) growth in CEE economies. First, TFP growth of the most productive firms in CEE countries, assumed to be directly participating in GVCs, is associated positively and significantly with TFP growth of non-CEE EU frontier firms operating in sectors involved in the same production chain (the "GVC frontier"). The first two columns of Table A confirm the importance not only of the pass-through effect, but also of the catch-up effect (proxied by the lagged TFP gap to the GVC frontier). Second, TFP growth of non-frontier firms in CEE countries is related fundamentally to TFP growth of the most productive domestic firms participating in GVCs, rather than to the GVC frontier (the last two columns of Table A). Thus, non-frontier firms benefit only indirectly from the technology transfer through GVCs. These results confirm the two-stage technology diffusion process proposed by the literature. Moreover,

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Table A shows that backward linkages are more important for technology transfer than forward linkages, as higher-quality inputs are made available to host firms and generate positive externalities.

In conclusion, technology transfer through GVCs, particularly via backward linkages, is a key factor behind productivity developments in CEE countries.

Note: This box is based on Chiacchio, F., Gradeva, K. and Lopez-Garcia, P., "The post-crisis TFP growth slowdown in CEE countries: exploring the role of global value chains", *Working Paper Series*, ECB (forthcoming).

4 Conclusions

Euro area countries are heavily involved in global production chains. This has an impact on some key macroeconomic indicators. It is therefore essential to consider global value chains when dealing with certain macroeconomic concepts. More specifically:

- Measures of competitiveness which account for the presence of global value chains, such as value-added and input-output REERs, portray different pictures regarding episodes of currency appreciation/depreciation compared with conventional REERs.

- Although shifts in production chains are not a major determinant of the change in global market shares of euro area countries, taking into account global value chains helps to understand the drivers of competitiveness.

- Developments in global value chains have played a role in the accelerating and then decelerating dynamics of the elasticity of trade to global demand over the past decades. To the extent that the high responsiveness of trade to income – which was observed before the crisis also as a result of the expansion of global value chains – is no longer observed in the future, a lower elasticity of trade to income could be regarded as the "new normal".

Firms' and sectors' involvement in production chains creates cross-country interlinkages. This has a bearing on the analysis of macroeconomic spillovers:

- Real spillovers via input-output linkages occur and certain sectors may play a key role in their transmission. Moreover, production chains are a channel for foreign and domestic technological transfer to non-frontier firms, which takes place through the technology that is embedded in imported intermediate products.

- Finally, sectors increasing their involvement in global value chains tend to hire a higher share of high-skilled workers and show systematically higher wages for any given skill level. In particular, sectors located downstream in the value chain see a positive effect on wages from using more foreign inputs.

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