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The transmission of productivity through global value chains: formal concept and application to recent developments in the EU27

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Contents

Abstract

Inspired by the ideas developed in Timmer (2017), this paper proposes a measure of Global Value Chain – Total Factor Productivity (GVC-TFP) and a decomposition of its changes into three informative factors: changes in factor requirements associated with efficiency gains/losses in the use of capital and labour, shifts in the distribution of value added due to changes in factor shares, and shifts in the composition of the value chain, which are mainly due to geographical relocation of production stages. Based on the World Input-Output Database (WIOD), we use this methodology to analyse the evolution of GVC-TFP in different sectors across EU27 Member States between 2000 and 2014. Comparing the periods before and after the Great Recession, we find a sharp contrast between the intensity, the sectoral composition, geographical contributions and the nature of the driving forces of GVC-TFP developments. In the context of the economic crisis following the COVID-19 pandemic, in which import dependency and supply security mark the debate on the future of the EU Single Market, we find that our methodology could contribute to a comprehensive assessment of strategic restructuring of value chains.

JEL classification: E24, F14, F23, L16

Keywords: Productivity, value chain, sectoral heterogeneity, convergence, European Union.

1 Introduction

In the context of the economic crisis following the COVID-19 pandemic, import dependency and supply security mark the debate on the future of global trade, adding to pre-existing factors transforming global value chains. It might be the case that production networks turn less global and hence productivity dynamics within the EU Single Market become more critical. In principle, a potential reshoring of production capacities could exert positive effects on EU productivity, directly due to the relocation of resources to more efficient production units compared to foreign suppliers and a higher share of tradable activities in the total economy, and indirectly by improving the resilience of EU value chains and lowering vulnerabilities to global shocks.

In this paper we propose a methodological framework for the quantification and analysis of these forces. First, inspired by the methodology in Timmer (2017) and relying on multi-country input-output data from WIOD, we introduce the concept of Global Value Chain - Total Factor Productivity (GVC-TFP) and describe how to estimate it. Second, based on the decomposition of changes in the GVC-TFP, it will be assessed how productivity across EU27 Member States has been driven by productivity changes in upstream value chain stages, as well as by structural shifts in the composition of value chains.

The results of our analysis show a sharp contrast between the intensity, composition and driving forces of GVC-TFP developments in two considered sub-periods, namely 2000-2007 and 2007-2014. Before the Great Recession, we observe a general but uneven process of productivity growth, characterized by convergence among EU Member States, the positive impact of imported efficiency gains, the leading role of manufacturing, and the – not always successful - shift of value added to production units in the value chain that are less efficient but show fast-growing productivity. After the Great Recession, we observe a productivity slowdown, including significant GVC-TFP losses in non-manufacturing activities for some EU countries, the slowdown (or even halt) of the convergence process among Member States, and the reversal of the value added reshuffling, shifting in this sub-period production to more efficient units in the value chain.

In policy terms, our analysis provides an insightful approach on how efficiency gains are transmitted through the different country-sector production stages in value chains. In addition, we are able to differentiate a number of underlying forces driving productivity developments, which need to be considered for a comprehensive assessment of strategic restructuring of value chains, either from a country or sector perspective. In the current context, in which import dependency and supply security characterize the debate on the future of the EU Single Market, we believe that these criteria need to be taken into account to secure a satisfactory outcome in terms of productivity and welfare for economic agents.

The remainder of the document is organized as follows. Section 2 describes the methodology to estimate the GVC-TFP and its decomposition into informative factors, including a toy-model for illustrative purposes. Section 3 provides the results for EU27 countries and broad sectors comparing the two aforementioned sub-periods in the sample and including different analytical dimensions. Section 4 concludes and provides the main takeaways from the policy perspective.

2 Data and methods

Studying the global macro-economy with its country and cross-sectoral linkages by using global input-output data has become a widely used approach since the pioneering work of Hummels et al. (2001). Broadly speaking, the input-output accounting structure comprises all economic transactions between the possible combinations of producing sectors and countries, differentiating between production used for further processing (intermediate demand) and production used for final consumption or investment (final demand).

In this study we rely on the well-known World Input Output Database (WIOD), in its year 2016 version([1]), complemented by the so-called Socio-Economic Accounts (SEA) and the tables in previous year prices released in 2019.([2]) With annual frequency and encompassing the years between 2000 and 2014, WIOD covers 56 economic activities in 43 individual countries – including all EU member states – and an aggregate region representing the rest of the world (see Annex 1 for details).

Based on this framework and inspired by the work of Timmer (2017), in sub-section 2.1 we introduce the concept and use of GVC-TFP. More formally, in sub-section 2.2 we present the methodology to estimate the GVC-TFP for the output of each country-sector pair, and in sub-section 2.3 we propose a structural decomposition of changes in GVC-TFP accounting for different types of factors, including shifts in the composition of the value chains. Finally, in sub-section 2.4 we illustrate the interpretation of the factors in the decomposition with a simplified input-output structure – a sort of toy-model - with two countries and two sectors.

2.1 The concept and use of GVC-TFP

The traditional approach to measure Total Factor Productivity (TFP) evaluates the efficiency of a particular sector to develop its production process combining labour and capital factors, as well as material and service inputs (such as the methodology developed in EU KLEMS and described in Stehrer et al., 2019). These inputs are themselves the result of the combination of factors and inputs in previous production stages (upstream activities), so they incorporate a certain degree of efficiency to the sectors where they are used (downstream activities).

Following a broad definition, the bundle of upstream and downstream activities that are necessary worldwide to elaborate a certain product is called a Global Value Chain (GVC). Since the value added generated in each of the activities integrating a GVC is eventually distributed to the owners of labour and capital factors, we can think of a GVC as the outcome of international, regional and national fragmentation of production into labour and capital units distributed around the world (Timmer, 2017). Accordingly, the combined efficiency of use of these labour and capital units in different sectors and countries makes up the overall level of efficiency of a GVC, which we call GVC-TFP.

A positive (negative) change of GVC-TFP in a particular country-sector pair describes an overall efficiency net gain (loss) along the full value chain up to the production stage in which the country-sector pair participates. Changes in GVC-TFP can be decomposed into the individual or aggregate contributions of the different participating production units (e.g. the contribution of business services to the change of overall efficiency in manufacturing value chains).

Furthermore, we propose a decomposition of these contributions into informative drivers explaining changes in GVC-TFP: changes in factor requirements associated with efficiency gains/losses in the use of capital and labour (FRQ), shifts in the distribution of value added due to

([1]) Timmer et al. (2016). Data and methodology available at http://www.wiod.org/release16.
([2]) Some minor adjustments have been made to the original dataset, mainly to correct methodological breaks stemming from the use of different national account systems over the sample period.

changes in the factor shares over output (FSH) and shifts due to changes in the composition of the value chain (VCC), which mainly correspond to the geographical relocation of production stages.

First, a change of capital or labour units needed for the same amount of output (what we call factor requirements) corresponds to a shift in the efficiency level for a particular country-sector pair and is commonly associated with technological progress. The impact of these efficiency changes on the overall GVC-TFP depends on the degree of participation of this activity in the value chain, defined in terms of the share of value added (e.g. if business services account for a 10% of value added in manufacturing value chains, a reduction of 10% in their factor requirements would imply a positive contribution of 1 percentage point to overall efficiency gains for manufacturing value chains).

Second, a change in the composition of the value added generated along a value chain has also an important effect on GVC-TFP changes due to production units showing different levels of efficiency in the use of labour and capital factors. If a certain share of the value added in a value chain moves to a production unit with lower (higher) factor requirements per unit of output, this will generate a positive (negative) impact on the overall efficiency.

Under our framework, a change in the composition of the value added has two possible sources. On the one hand, capital or/and labour units of a certain activity can change the fraction of the value added that they retain relative to the amount of output (what we call factor shares). This could be result of a number of reasons, including the fragmentation of the production process (outsourcing, offshoring), as well as the evolution of output-inputs relative prices, mark-ups, education and capital returns, workers bargaining power, etc. And on the other hand, keeping the factor shares constant, the participation in value added could change as a result of a shift in the composition of value chains, i.e. a change in the country-sector pair as producing unit in a particular stage. Most of the shifts correspond to the geographical level, consisting of a sector in a country increasing its participation in a value chain to the detriment of the same sector in a different country. These changes are the result of competitive forces at some stage in a GVC, but associated shifts in upstream activities could be just reflecting the prevalence of regional or domestic networks (e.g. if a producer of machinery changes its main supplier of components to a different continent it´s likely that services used by the component producer are also displaced to a large extent to the new location). On the sectoral level, technological developments or outsourcing could also generate relevant shifts in the composition of value chains, as shown for the case of electronics in Marschinski and Martínez-Turégano (2020a, 2020b).

2.2 A formal definition of GVC-TFP

Approaches to measure TFP that consider both factor and material and service inputs, such as the methodology developed in EU KLEMS (Stehrer et al., 2019), evaluate total productivity at the single last stage of production. Instead, following Timmer (2017), we formulate the production function in terms of the factor inputs that are used along the full value chain, capturing productivity developments in each of the stages.

For this purpose, we assume that the value chain production function of sector *j* in country *c* follows a standard Cobb-Douglas form with constant returns to scale in production factors, i.e. labour and capital used along all production stages, sectors and countries involved in the value chain [3]:

$$Y_{c,j} = A_{c,j} \times \prod_{b,i} \left(L_{(b,i),(c,j)}^{\alpha_{(b,i),(c,j)}} \times K_{(b,i),(c,j)}^{\beta_{(b,i),(c,j)}} \right) \quad (1)$$

[3] Further research would need to consider alternative specifications and assess the limitations imposed by this assumption. For EU countries, Bauer et al. (2020) find that at the micro level there is an evidence for increasing returns to scale, while estimates at the sectoral level suggest decreasing returns to scale.

where $A_{c,j}$ is the estimated GVC-TFP of sector *j* in country *c*, $L_{(b,i),(c,j)}$ and $K_{(b,i),(c,j)}$ are the total amount of labour and capital factors used by sector *i* in country *b* along the whole value chain, and $\alpha_{(b,i),(d,j)}$ and $\beta_{(b,i),(d,j)}$ are their respective value added shares, which we use as estimators of the elasticity of output to factors.

We assume that the total value added generated by one unit of output in any country-sector pair is equal to one and so is the sum of the factor shares: ([4])

$$\sum_{b,i}\left(\alpha_{(b,i),(c,j)} + \beta_{(b,i),(c,j)}\right) = 1 \quad (2)$$

We make use of this property to reformulate Equation 1 by dividing both sides by $Y_{c,j}$, taking logs and moving the GVC-TFP component to the left-side:

$$log(A_{c,j}) = -\sum_{b,i} \alpha_{(b,i),(c,j)} \times log\left(l_{(b,i),(c,j)}\right) - \sum_{b,i} \beta_{(b,i),(c,j)} \times log\left(k_{(b,i),(c,j)}\right) \quad (3)$$

where the production factors, $l_{(b,i),(c,j)}$ and $k_{(b,i),(c,j)}$, are now expressed intensively, i.e. in terms of the labour and capital requirements along the whole value chain implied by one unit of output of sector *j* in country *c*.

All the elements in Equation 3 could be further decomposed into an idiosyncratic characteristic of each country-sector pair and its specific output participation in the value chain (i.e. the corresponding backward-looking output multiplier from the Leontief (1966) inverse matrix) (see Annex 2 for details on the input-output framework):

$$\alpha_{(b,i),(c,j)} = lsh_{b,i} \times m_{(b,i),(c,j)} \quad (4)$$

$$\beta_{(b,i),(c,j)} = ksh_{b,i} \times m_{(b,i),(c,j)} \quad (5)$$

$$l_{(b,i),(c,j)} = l_{b,i} \times m_{(b,i),(c,j)} \quad (6)$$

$$k_{(b,i),(c,j)} = k_{b,i} \times m_{(b,i),(c,j)} \quad (7)$$

where $m_{(b,i),(c,j)}$ is the output multiplier of one unit of production in sector *j* of country *c* on the production of sector *i* in country *b*, $lsh_{b,i}$ and $ksh_{b,i}$ are the labour and capital value added shares in one unit of output of sector *i* in country *b*, and $l_{b,i}$ and $k_{b,i}$ are the labour and capital requirements per unit of output of sector *i* in country *b*.

Before moving into the structural decomposition, two important methodological clarifications related to the output multipliers are needed.

First, while the Leontief inverse is derived from the so-called technical coefficient matrix, the value added share of production factors also plays a role. We illustrate this for the technical coefficient representing the share of inputs of sector *i* in country *b* used for one unit of output of sector *j* in country *c*. We can reformulate the standard initial expression in order to differentiate genuine changes in technical coefficients from shifts in the share of output that is attributed to production factors:

$$a_{(b,i)(c,j)} = \frac{Y_{(b,i),(c,j)}}{Y_{c,j}} = \frac{Y_{(b,i),(c,j)}}{\sum_{b,i} Y_{(b,i),(c,j)}} \times \frac{Y_{c,j} - VA_{c,j}}{Y_{c,j}} = \tilde{a}_{(b,i)(c,j)} \times \left(1 - vay_{c,j}\right) \quad (8)$$

where $\tilde{a}_{(b,i)(c,j)}$ corresponds to the share of inputs of sector *i* in country *b* relative to the total inputs used for one unit of output of sector *j* in country *c*, and $vay_{c,j}$ is the ratio of value added to output of sector *j* in country *c*, which is the sum of the labour share ($lsh_{c,j}$) and the capital share ($ksh_{c,j}$).

Therefore, when assessing the impact of changes in output multipliers, we need to use different specifications of the Leontief inverse to differentiate the contribution of the components in Equation 8.

([4]) Net taxes on products and international transport margins explain marginal deviations in observed data.

The second methodological clarification is related to the functional form of the value chain production function. The estimated TFP using a Cobb-Douglas form is very sensitive to changes of production fragmentation and the associated relocation of production factors, particularly for those stages with an initial small participation along the value chain.

A simple example illustrates these effects. Let´s consider two sectors, *i* and *j*. While sector *i* produces output from the use of labour, sector *j* combines inputs from sector *i* and labour. Since there is no capital, all the value added generated in a sector is attributed to labour. We follow Equation 3 to estimate the corresponding GVC-TFP in each case (we omit the country notation):

$$log(A_i) = -log(l_i) \tag{9}$$

$$log(A_j) = -\gamma \times log(l_i \times \gamma) - (1-\gamma) \times log(l_j) \tag{10}$$

where γ is the share of inputs from sector *i* per unit of output of sector *j*.

Assuming that total labour requirements per unit of final output are the same for the value chain of both sectors ($l_j = (1-\gamma) \times l_i$), the difference of GVC-TFP is given by:

$$log(A_j/A_i) = -log(\gamma^{\gamma} \times (1-\gamma)^{1-\gamma}) > 0 \; for \; \gamma \in (0,1) \tag{11}$$

This difference is always positive to the benefit of the sector with a fragmented value chain, and could reach a maximum of 0.69 if the share of inputs and labour used in the production process is the same ($\gamma = 0.5$).

Since the accounting of these effects could be then showing spurious changes in GVC-TFP, we let them aside in the decomposition analysis we present in the following subsection – opening a field for future research on how to tackle this issue.

2.3 A decomposition of GVC-TFP changes

Having detailed each of the components of the estimated GVC-TFP in Equation 3, we now turn to the decomposition of its changes over time. We identify three factors moving productivity along value chains:

$$\Delta log(A_{c,j}) = \Delta^{FRQ} log(A_{c,j}) + \Delta^{FSH} log(A_{c,j}) + \Delta^{VCC} log(A_{c,j}) \tag{12}$$

The first factor captures the changes in the labour and capital requirements across all country-sector pairs participating in the value chain[5]:

$$\Delta^{FRQ} log(A_{c,j}) = -\sum_{b,i} \alpha_{(b,i),(c,j)} \times \Delta log\left(l_{b,i}\right) - \sum_{b,i} \beta_{(b,i),(c,j)} \times \Delta log\left(k_{(b,i)}\right) \tag{13}$$

where FRQ stands for factor requirements. This component is basically equivalent to the value chain TFP accounting proposed in Timmer (2017), keeping constant both the factor shares and the technical coefficients. Value added shares are expressed in nominal terms, labour factor requirements as employment (number of persons employed) over output in constant-prices terms and capital factor requirements as the nominal capital-to-output ratio[6].

The second factor accounts for changes in the labour and capital shares of output across all country-sector pairs participating in the value chain:

$$\Delta^{FSH} log(A_{c,j}) = -\sum_{b,i} \Delta\hat{\alpha}_{(b,i),(c,j)} \times log\left(\frac{l_{b,i}}{l_i}\right) - \sum_{b,i} \Delta\hat{\beta}_{(b,i),(c,j)} \times log\left(\frac{k_{b,i}}{k_i}\right) \tag{14}$$

[5] We omit time notation for the sake of clarity. In all cases, the variables with differential operator refer to the change between two years and those in levels correspond to the average value of the two years in order to account for interaction terms.

[6] We unfortunately did not find a satisfactory solution to account for changes in relative prices of the capital stock and output within sectors for all countries in the WIOD dataset.

where FSH stands for factor shares, $\Delta\hat{\alpha}_{(b,i),(c,j)}$ and $\Delta\hat{\beta}_{(b,i),(c,j)}$ are the changes in factor shares keeping constant the technical composition of the value chain, and l_i and k_i are the output-weighed cross-country average of the factor requirements in sector *i*.

Finally, the third factor in the decomposition corresponds to changes in the composition of the value chain due to the relocation of production stages to countries with a higher or lower level of productivity:

$$\Delta^{VCC} log(A_{c,j}) = -\sum_{b,i} \Delta\tilde{\alpha}_{(b,i),(c,j)} \times log\left(\frac{l_{b,i}}{l_i}\right) - \sum_{b,i} \Delta\tilde{\beta}_{(b,i),(c,j)} \times log\left(\frac{k_{b,i}}{k_i}\right) \quad (15)$$

where VCC stands for value chain composition, and $\Delta\tilde{\alpha}_{(b,i),(c,j)}$ and $\Delta\tilde{\beta}_{(b,i),(c,j)}$ are the changes in value chain factor shares due to genuine changes in technical coefficients (i.e. $\tilde{a}_{(b,i)(c,j)}$.in Equation 8).

Using the relative level of factor requirements in the second and third components allows us, on the one hand, to solve potential biases coming from the measurement units of factors in Equation 3, and, on the other hand, present the net effect on GVC-TFP of the redistribution in factor shares along the value chain[7].

In addition to quantifying and decomposing GVC-TFP changes over time, we are interested in comparing the intensity and the nature of these changes between periods. The level and dimension of disaggregation depend on the purpose of the analysis, making it possible, e.g., to differentiate changes in the contributions by the position in the value chain (upstream vs. downstream activities), by sector (e.g. services used in manufacturing value chains) or geographical location (domestic compared with 'imported' productivity).

From a methodological point view, when comparing productivity changes between two periods we need to take into account the interaction between the underlying factors driving the contributions to GVC-TFP. Without getting into additional algebra, in Equation 13 this interaction is represented by the effects of shifting value added shares to countries with higher or lower productivity growth, while in Equations 14 and 15 capture the effects of convergence in factor requirements and hence the more limited productivity impact from shifting production stages to a different country.

2.4 Interpreting the decomposition: an illustration

For an intuitive understanding of the decomposition, we now discuss a toy-model example based on a simplified input-output structure consisting of two countries (A and B) and two sectors (1 and 2). The starting point is an economic structure, which analogously to the WIOD dataset is represented by an input-output table and socio-economic accounts. We assume that both countries share the same sectoral and geographical composition of inputs for both sectors, but differ in the factor shares and factor requirements in a way that is reminiscent of existing gaps between high- and middle-income countries (Table 1). On the other hand, Sector 1, which could be associated with the manufacturing sector, differs from Sector 2 – representing service activities - by having a more fragmented value chain, captured by a lower ratio of value added to output in both countries.

[7] More formally, Timmer and Ye (2020) recently explored "factor substitution bias in measuring GVC TFP" stemming from the invalidity of assuming that each input is paid globally its marginal product.

Input-output table			Intermediate demand					
			Country A		Country B		Total final demand	Total output
			Sector 1	Sector 2	Sector 1	Sector 2		
Supply	Country A	Sector 1	15	12	5	4	26	62
		Sector 2	15	30	5	10	80	140
	Country B	Sector 1	5	4	15	12	21	57
		Sector 2	5	10	15	30	52	112
Total intermediate consumption			40	56	40	56		
Value added			22	84	17	56		
Total output			62	140	57	112		

Socio-economic accounts

Factor shares

Value Added (VA) per unit of output	0.35	0.60	0.30	0.50
Labour compensation, %VA	65%	65%	50%	60%
Capital compensation, %VA	35%	35%	50%	40%

Factor requirements

Employment per unit of output	50	50	150	150
Capital stock per unit of output	50	50	100	100

Table 1: Initial economic structure

Based on this initial economic structure, we introduce a number of changes in the structural characterization of sectors and countries over two consecutive periods (Table 2). The first period is characterized by a decrease and convergence of labour factor requirements (number of persons engaged per unit of output), a higher degree of value chain fragmentation in Sector 1 (accounted by lower value added per unit of output) and an increasing share of foreign inputs, which is more intense for Country A. In contrast, these trends become softer – and even come to a halt in a number of cases - during the second period. In the sample covered by WIOD (2000-2014), these two periods proxy very roughly developments before and after the Great Recession.

		Value chain			
		Country A		Country B	
	% change	Sector 1	Sector 2	Sector 1	Sector 2
Employment per unit of output	*Period 1*	-5%	-5%	-15%	-15%
	Period 2	0%	0%	-5%	-5%
Value Added per unit of output	*Period 1*	-10%	0%	-10%	0%
	Period 2	0%	0%	0%	0%
Share of foreign inputs	*Period 1*	+15%	+15%	+5%	+5%
	Period 2	+5%	+5%	0%	0%

Table 2: Change of structural parameters, by period

We now compute, following Equations 13 to 15, the contribution of these structural shifts to the change in the estimated GVC-TFP. In Table 3, we show the decomposition by period and type of factor. Contributions from factor requirements correspond exclusively to labour as capital per output remains constant over time. We detail these contributions by country-sector pair to illustrate how productivity developments are transmitted through value chains. However, the contribution of changes in factor shares and in the composition of value chains are shown in aggregate terms. In this case we are interested in the net result of shifting value added to production in which the factor requirements are different.

A couple of observations are quite intuitive and mainly related to developments in labour factor requirements. First, GVC-TFP growth slows down between periods in both countries and sectors, and, second, GVC-TFP growth is higher in Country B in both sectors and periods.

There are however a number of less straightforward readings. First, lower labour factor requirements in Sector 2 contribute as much as the decline of those in Sector 1 to TFP growth in

Sector 1 value chains, illustrating how productivity developments in upstream activities are transmitted. Second, lower labour factor requirements in Country B account for a significant positive contribution to TFP growth in Country A value chains, being this 'imported' component the only source of productivity growth in the second period. Third, the contribution of changes in factor shares and in the composition of value chains are negative for Country A and positive for Country B in both periods. This is the combined result of strong country heterogeneity in factor requirements and the generalized increase in the share of foreign value added in value chains. For instance, in the value chain for Sector 1 in Country A, the positive contribution from lower labour factor requirements is to large extent compensated in productivity terms by the shift of production to Country B in which factor requirements (both labour and capital) are higher.

			Value chain			
			Country A		Country B	
			Sector 1	Sector 2	Sector 1	Sector 2
Period 1	**GVC-TFP, % change**		**0.66**	**2.22**	**7.82**	**7.68**
	Contributions, percentage points					
	a. Labour factor requirements		4.26	3.82	6.37	7.32
	Country A	*Sector 1*	*1.50*	*0.18*	*0.26*	*0.13*
		Sector 2	*0.95*	*2.57*	*0.60*	*0.46*
	Country B	*Sector 1*	*0.48*	*0.21*	*2.98*	*0.48*
		Sector 2	*1.32*	*0.85*	*2.53*	*6.25*
	b. Factor shares		-1.13	-0.07	1.16	0.11
	c. Value chain composition		-2.48	-1.52	0.29	0.25
Period 2	**GVC-TFP, % change**		**0.06**	**0.01**	**2.63**	**2.85**
	Contributions, percentage points					
	a. Labour factor requirements		0.70	0.40	1.90	2.34
	Country A	*Sector 1*	*0.00*	*0.00*	*0.00*	*0.00*
		Sector 2	*0.00*	*0.00*	*0.00*	*0.00*
	Country B	*Sector 1*	*0.18*	*0.08*	*1.00*	*0.16*
		Sector 2	*0.52*	*0.32*	*0.90*	*2.18*
	b. Factor shares		0.00	0.00	0.00	0.00
	c. Value chain composition		-0.64	-0.39	0.73	0.52

Table 3: Contributions to changes in GVC-TFP, by period and type of factor

3 Recent developments of GVC-TFP in EU27 countries

Based on the methodology explained in the previous section we have estimated the GVC-TFP annual changes and factor decomposition for all country-sector pairs in WIOD over the 2000-2014 period. In this section we summarize the results for developments in EU27 Member States, first from an aggregate perspective and then accounting for sectoral heterogeneity, dividing the sample into two sub-periods for analytical purposes, 2000-2007 and 2007-2014.

We start by providing a cross-country perspective using as a reference the output-weighted average across sectors (we discuss later other aggregations). Figure 1 shows the average annual change of country output GVC-TFP over the 2000-2007 period and the contribution of the three factors explained in the decomposition methodology.

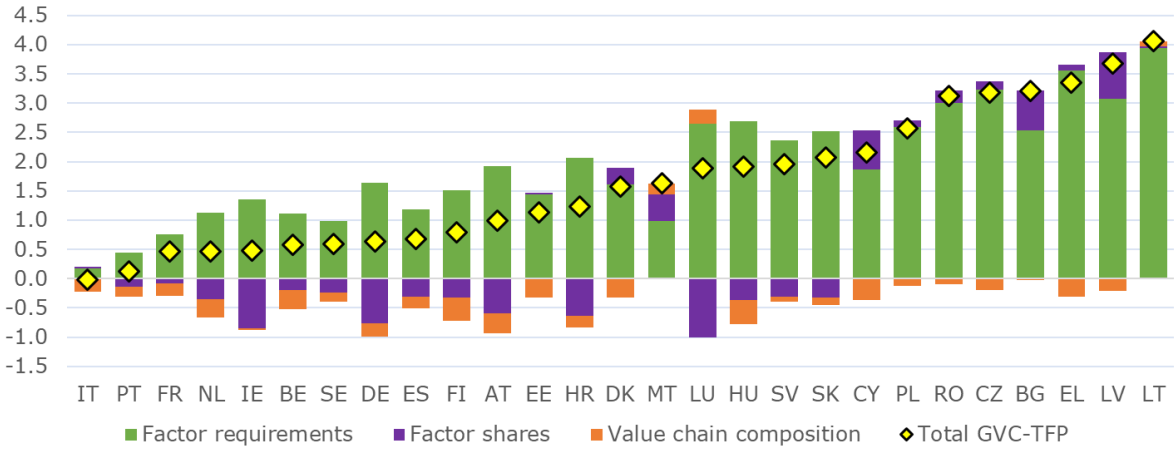

Figure 1. Average annual change of total production GVC-TFP (%) in the 2000-2007 period, contribution by component (percentage points)

First, we observe strong heterogeneity across Member States, with top performers reaching 3-4% average growth and low performers showing rates of 1% or below. This characterization corresponds to a period of productivity convergence between 2000 and 2007. The 13 Member States that joined the EU in successive enlargements starting in 2004 (EU13 countries) –with a lower initial level of productivity - averaged an annual increase of 2.6% in GVC-TFP compared to 0.9% in the EU15* (EU15 excluding the UK).

Second, efficiency gains represented by the reduction of factor requirements is the main force explaining changes of GVC-TFP across the board. The contribution of changes in factor shares and the value chain composition – what we broadly call "value added reshuffling" - are more limited but still non-negligible, having on average a negative effect on GVC-TFP changes. In this respect, within the group of countries with higher initial levels of productivity, we find that negative effects coming from the shift of value added to producers with higher factor requirements are generally faced with limited efficiency gains. In other words, what might be rational from a cost-profitability perspective might have a milder positive impact in productivity terms.

We further investigate the efficiency gains due to reductions in factor requirements by decomposing the contributions by the origin of value added. For this purpose, we simplify the 2464 country-sector pairs (44 countries x 56 sectors) into four categories that we consider to capture the essence of these processes, differentiating two domestic contributors – the own producing sector and other sectors providing inputs – and two foreign ones – other EU and nonEU countries. Figure 2 shows this decomposition for the 2000-2007 period keeping the ranking of countries as in Figure 1.

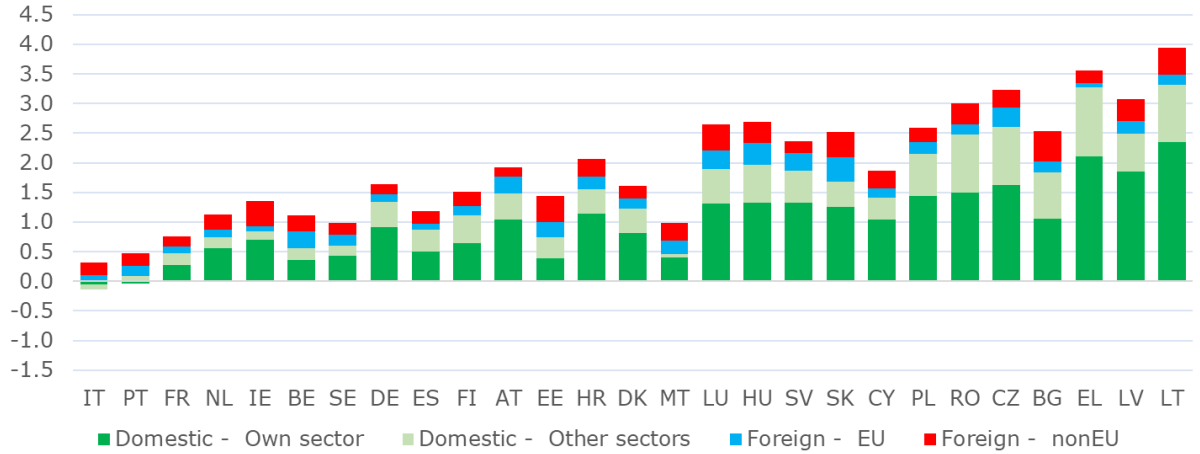

Figure 2. Contribution of changes in factor requirements (percentage points) to the average annual change of total production GVC-TFP in the 2000-2007 period, by origin of value added

First, we observe that domestic developments dominate heterogeneity in the overall contribution of changes in factor requirements. Second, within the domestic component, productivity developments in sectors other than the producing one accounts for around a third of the contribution, reinforcing or dragging efficiency gains throughout the domestic supply network. Third, the contribution of foreign efficiency gains is more homogeneous, adding on average 0.5 percentage points (pp) to GVC-TFP annual growth, 0.2pp of which comes from other EU Member States and 0.3pp are imported from nonEU countries. Considering the high degree of integration among EU Member States, this result shows that the reduction of factor requirements was much more intense in global input suppliers than regional ones.

Analogously, Figures 3 and 4 show the estimation of the GVC-TFP change and decomposition for the 2007-2014 period. There is indeed a strong contrast in many aspects when comparing results with the corresponding figures of the 2000-2007 period.

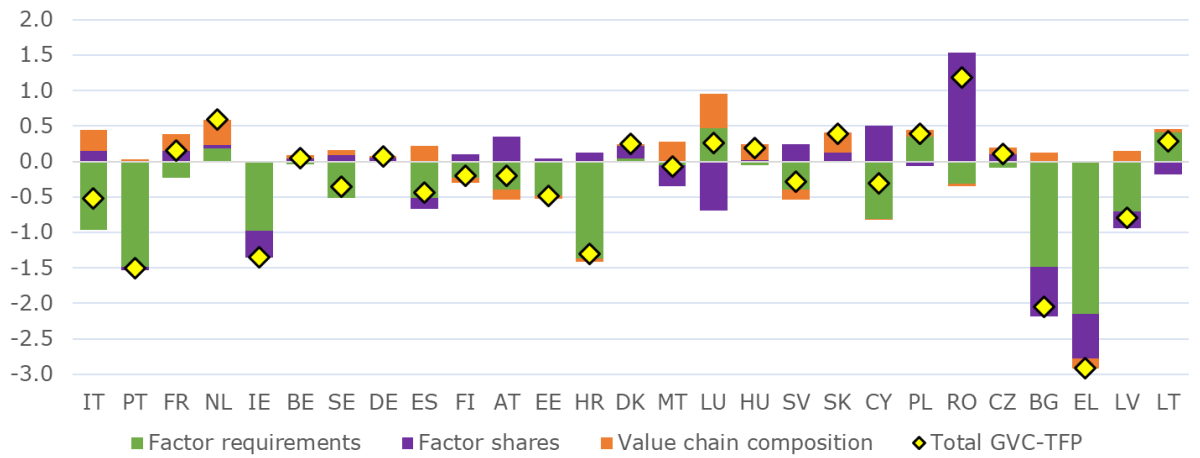

Figure 3. Average annual change of total production GVC-TFP (%) in the 2007-2014 period, contribution by component (percentage points)

First, GVC-TFP gains are no longer the norm across countries but rather exceptional, with a number of countries posting significant declines. Second, changes in factor requirements are again the main driver of productivity developments, but to a lesser extent and accounting for generalized efficiency losses along the full value chain, including nonEU input suppliers. Third, the contribution of value added reshuffling has turned positive in many countries, suggesting in the

case of the value chain composition component a relocation of production stages to countries with lower factor requirements.

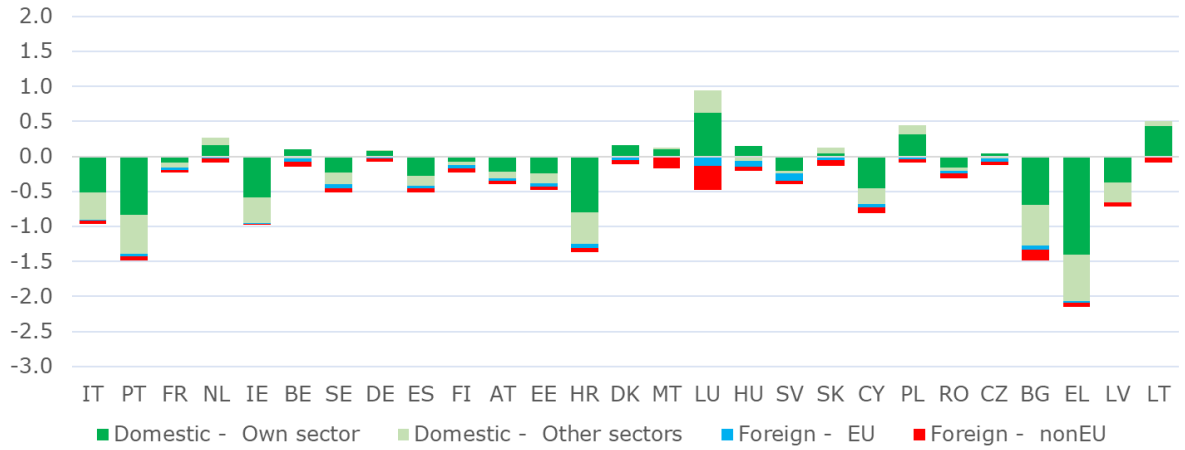

Figure 4. Contribution of changes in factor requirements (percentage points) to the average annual change of total production GVC-TFP in the 2007-2008 period, by origin of value added

3.1 Sectoral heterogeneity

Following the overall picture for recent developments in GVC-TFP at country level, we now turn to the sectoral perspective. For this purpose, we group economic activities into three broad sectors, manufacturing, business services and other activities (see Annex 1 for details).

Figures 5 and 6 respectively show the average annual change of the sectoral output GVC-TFP over 2000-2007 and 2007-2014, with countries ranked by the manufacturing performance in the first period.

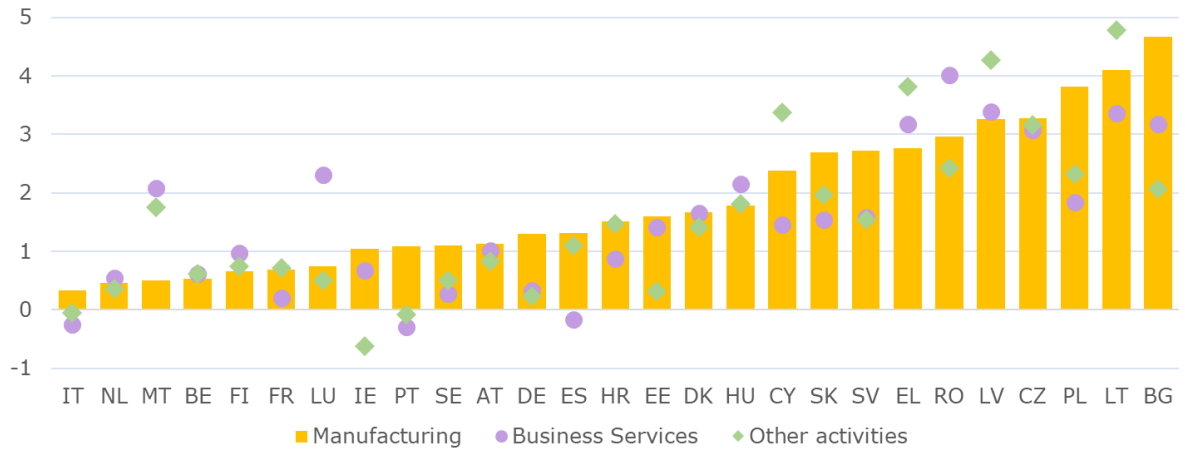

Figure 5. Average annual change of sectoral production GVC-TFP (%) in the 2000-2007 period

First, we observe that before the Great Recession productivity along the value chain increased faster in the manufacturing sector (1.9% on average across EU countries) than in business services or other activities (1.5% in both cases). Second, co-movement of sectoral productivity was stronger among the top performers, whereas a few underperforming countries even showed a decline of GVC-TFP in business services or/and other activities. Beyond the overall decline of productivity, the sectoral characterization didn´t change much in the 2007-2014 period, with a smaller average reduction of productivity in manufacturing than in the other sectors (-0.1pp vs. -0.4pp). This was more pronounced in this period among the top performers, for which the

manufacturing output GVC-TFP even slightly increased on average, in contrast with a larger decline than in the underperforming countries in the rest of activities.

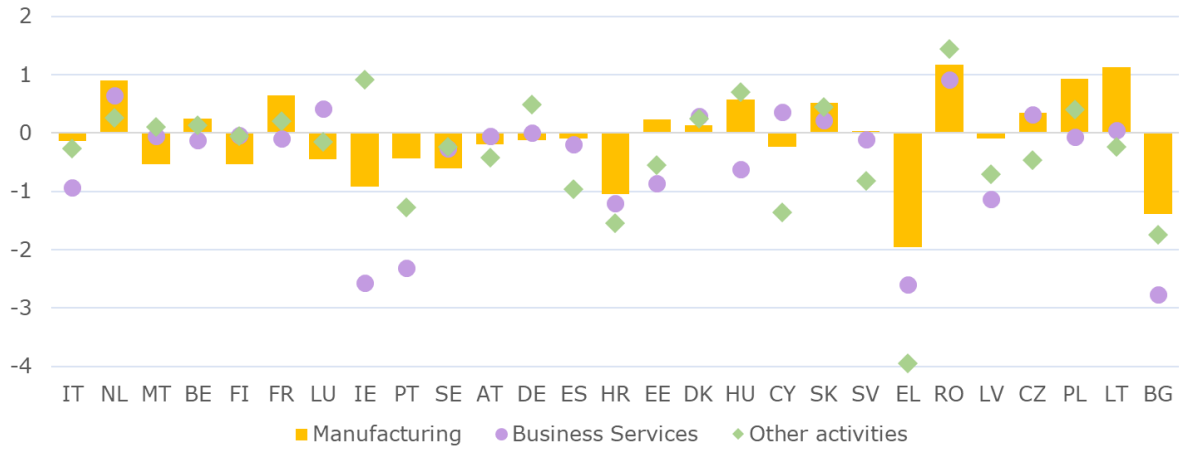

Figure 6. Average annual change of sectoral production GVC-TFP (%) in the 2007-2014 period

Now we turn to the decomposition factors behind changes in sectoral production GVC-TFP. In particular, we analyse the interaction between different components on three dimensions. First, we look into how the contribution of shifts in the value chain composition relates to changes in factor requirements of foreign-sourced inputs. We would expect that a negative effect from shifting input supply to less productive units is compensated by stronger efficiency gains. Second, in the same line, we use the broader concept of value added reshuffling (i.e. changes in factor shares and value chain composition) to compare its developments with the overall change in factor requirements different from the own producing sector, what we call "upstream factor requirements". And third, we compare the contribution from changes in factor requirements of the own producing sector (i.e. the traditional value added TFP measure) relative to the rest of components.

The panels in Figure 7 show these three analytical dimensions for the two periods in the sample and for the three broad sectors. The diagonal line identifies a zero net result from summing up the contributions of the corresponding two components in the x- and y-axis.

Regarding the first dimension (panels A and B), during the 2000-2007 period, the value chain shifted to sector-country pairs with higher factor requirements than the sectoral average, hence making a negative contribution to GVC-TFP change, which was however more than compensated by the positive contribution of the reduction in factor requirements over time in foreign input production. This was particularly intense for the manufacturing sector (on average -0.35pp vs +0.84pp respectively), but also true for business services and other economic activities in the majority of countries. In the 2007-2014 period, these trends came to a halt and even reversed somewhat. On the one hand, the shift of the value chain composition showed a slightly positive contribution as stages in a number of value chains were moved to sector-country pairs with lower factor requirements than the sectoral average. And on the other hand, foreign factor requirements increased on average and had a negative contribution to GVC-TFP changes across the EU, with the manufacturing sector being the most affected.

Second (panels C and D), we consider now a broader measure of value added reshuffling along the value chain, not only considering changes in the technical coefficients but also taking into account shifts in how much value added out of one unit of output is distributed to production factors. These latter changes can be due to aspects of very different nature, stemming from the evolution of relative prices (output vs inputs), mark-ups, education and capital returns, workers bargaining power, outsourcing, etc. We assess the intensity of the overall reshuffling of value

added compared to developments of factor requirements in upstream stages, both domestic and foreign, i.e. whether there was a net TFP gain or loss coming from the dynamics and shifting structure of the supply chain. In the 2000-2007 period, the reshuffling of value added along the value chain had a predominant negative contribution on GVC-TFP changes, although less homogeneous than when only value chain composition is considered, including a larger number of activities showing a negative net effect due to an insufficient reduction in factor requirements along the supply chain. In the 2007-2014 period, in contrast with a generalized negative contribution from factor requirements in upstream stages, the impact of the value added reshuffling on GVC-TFP was quite disperse across sector-country pairs.

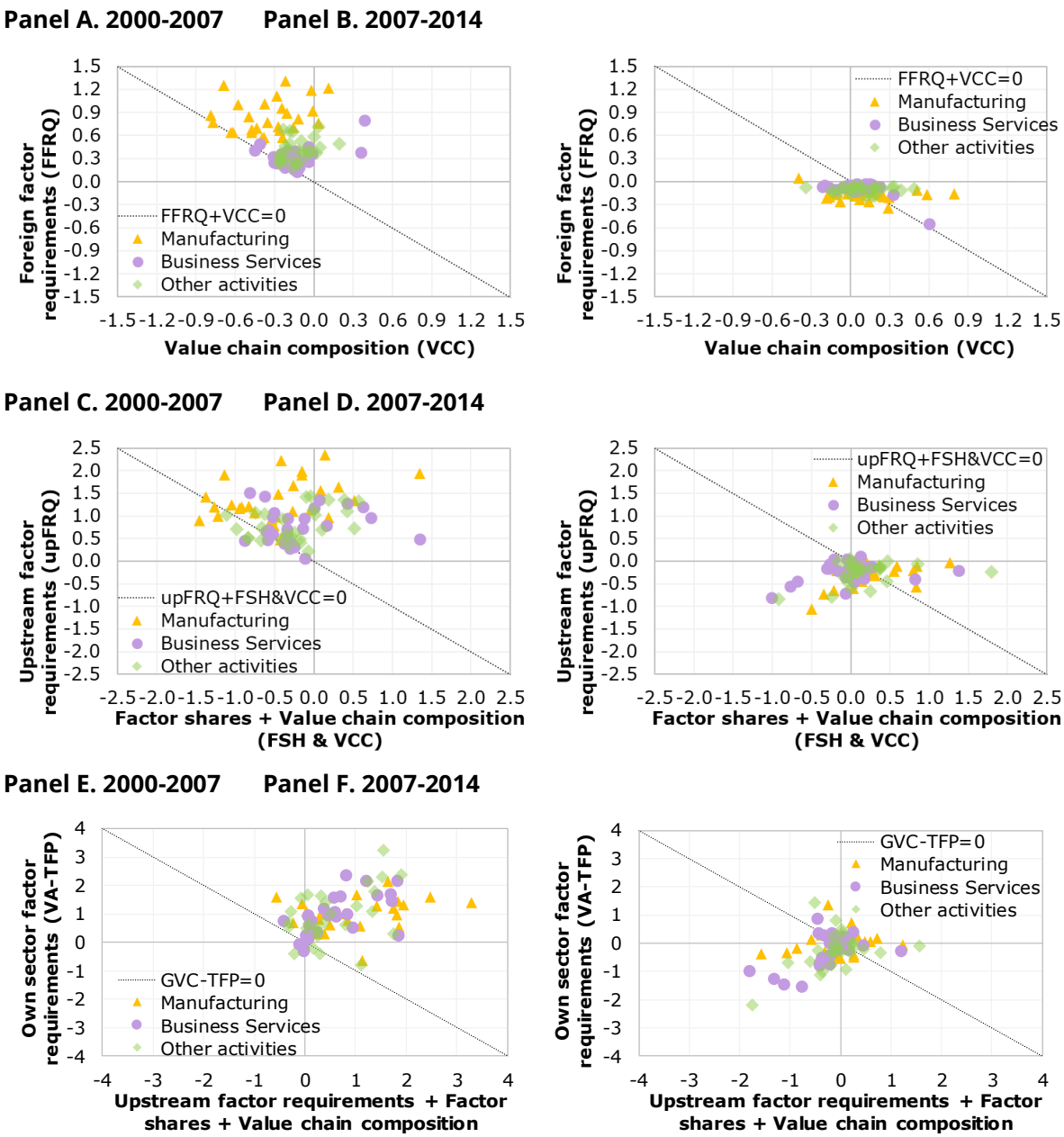

Figure 7. Average annual change of sectoral production GVC-TFP, contribution by selected components (percentage points) in the 2000-2007 and 2007-2014 periods

Third (panels E and F), we compare the contribution of changes in factor requirements of the own production sector, i.e. the traditional value added TFP approach (VA-TFP), relative to the rest of the components of the GVC-TFP, i.e. the sum of contributions from changes in upstream factor requirements and the value added reshuffling. In the 2000-2007 period, both measures moved

the same way in the majority of country-sector pairs, with a stronger correlation for business service activities, suggesting that for this sector the positive contribution coming from the dynamics and shifting structure of the supply chain could have exerted a positive impact on the VA-TFP at the (final) production stage. In contrast, a significant number of activities showed no improvement in VA-TFP despite the positive contribution from the supply chain, suggesting that upstream efficiency gains might have been not channelled to own TFP gains but to profitability in the best case. This characterization was mirrored but with the opposite sign in the 2007-2014 period, in which GVC-TFP declined for the majority of country-sector pairs.

3.2 GVC-TFP in exports and final demand

Sectoral heterogeneity in GVC-TFP changes combines with sectoral structure to generate composition effects into GVC-TFP at the aggregate level. So far, we have focused on the production perspective when analyzing productivity developments, but there are other aggregations that are interesting for analysis. Here we compare the production perspective with the export side and the domestic final demand, differentiating in the latter case between domestic and imported final products.

In the 2000-2007 period (Figure 8), the contribution of each of the three broad sectors was relatively balanced from the production perspective. In contrast, given its sectoral structure, growth in the export GVC-TFP was mainly driven by the contribution of manufacturing (two thirds on average), followed by business services (a fourth). An opposite picture holds for domestic final demand of domestic production, in which other economic activities (mostly non-tradables such as construction or public services) contributed the most to GVC-TFP changes, closely followed by business services (both representing together three quarters on average). Finally, when restricting to imported final products, the situation was pretty homogeneous across EU countries, both in total and sectoral contribution terms. Imported final products recorded an average annual growth of GVC-TFP above 1.5% (and in a narrow 1-2% range), of which the bulk corresponds to the contribution of the manufacturing sector.

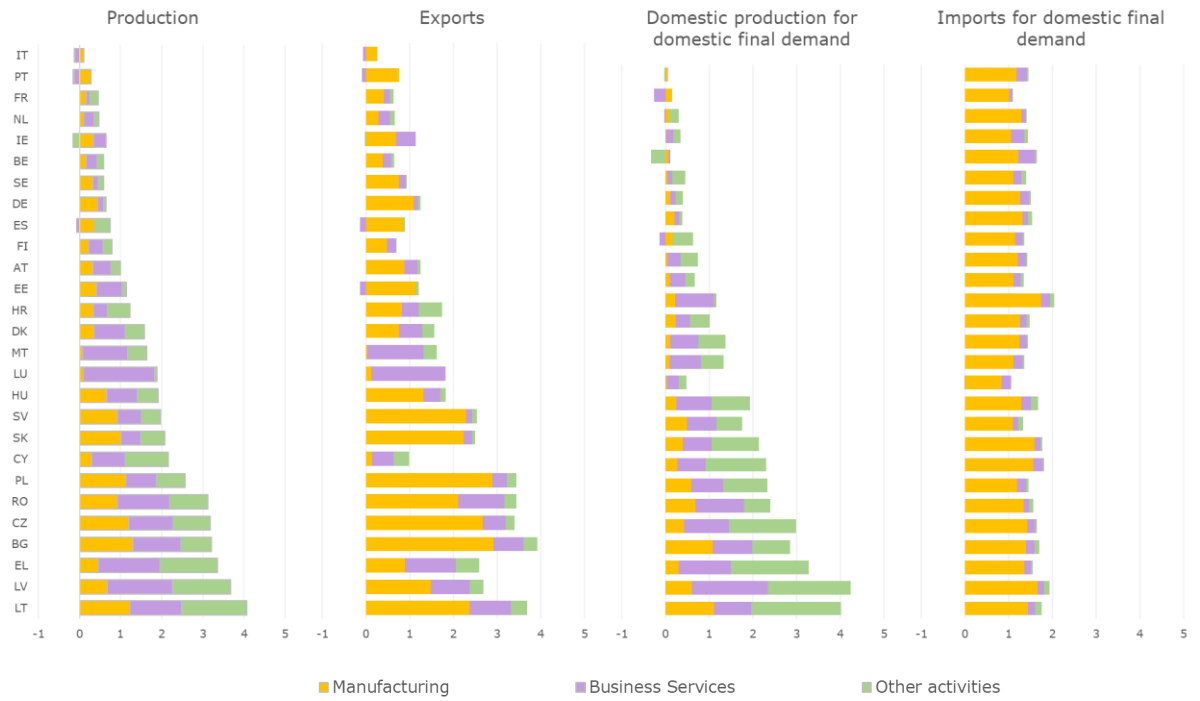

Figure 8. Average annual change of GVC-TFP by aggregate, contribution by sector (percentage points) in the 2000-2007 period

In the 2007-2014 period (Figure 9), the situation became more homogenous – albeit to the worse in the majority of countries. This was the result of manufacturing contributing very little to GVC-TFP changes across all aggregates and of significant negative contributions to production GVC-TFP of either (or both) business services or other economic activities in a number of countries, affecting both products for exports and domestic demand. On the other hand, imported GVC-TFP through final products remained almost flat.

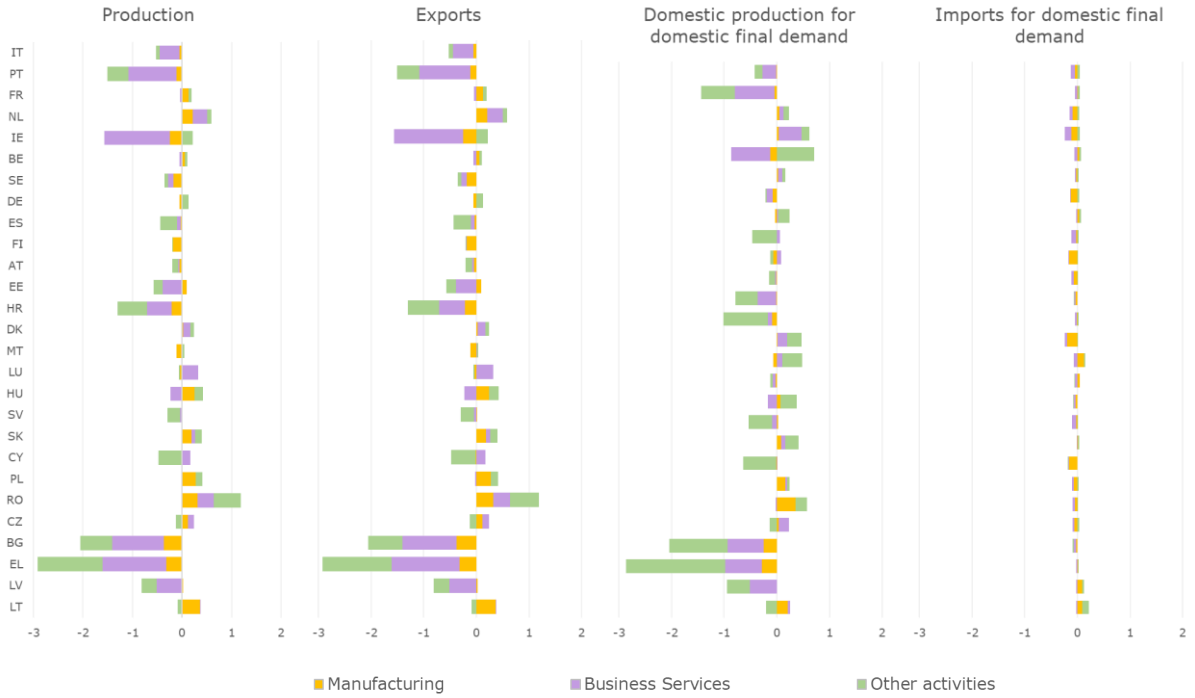

Figure 9. Average annual change of GVC-TFP by aggregate, contribution by sector (percentage points) in the 2007-2014 period

4 Main findings and policy readings

Inspired by the methodology in Timmer (2017), this paper proposes a measure to estimate changes of TFP along the different stages of a value chain – what we call GVC-TFP, as well as a decomposition into three informative factors: changes in factor requirements associated with efficiency gains/losses in the use of capital and labour, shifts in the distribution of value added due to changes in factor shares, and shifts in the composition of the value chain, which are mainly due to geographical relocation of production stages.

Based on this framework and the 2016 release of the World Input-Output Database (WIOD), we assess the performance of GVC-TFP across EU27 Member States between 2000 and 2014, both at aggregate and sectoral level, with particular focus on the role of efficiency gains in upstream value chain stages and structural shifts in the composition of value chains. The results of our analysis show a sharp contrast between the intensity, composition and driving forces of GVC-TFP developments before and after the Great Recession.

In the first sub-period (2000-2007), we observe a generalized growth of productivity, although the increase of GVC-TFP across countries showed a high degree of heterogeneity, with Member States that started to join the EU in 2004 (EU13) over-performing relative to the EU15* (EU15 excluding the UK). Structural transformation and technological convergence in EU13 countries supported generalized efficiency gains across sectors that were transmitted to the whole economy through domestic supply chains (around a third of the domestic contribution corresponds to other sectors than the producing one).

The positive contribution of imported efficiency gains (i.e. a reduction of factor requirements in foreign input suppliers) was also larger on average for EU13 countries, benefiting from both a higher degree of trade openness and a higher share of manufacturing activities. For both groups of countries, the largest contribution of imported efficiency gains corresponded to nonEU suppliers (a 60% on average), particularly reflecting the catching-up process of China and other Asian developing countries.

Finally, the net effect of shifts in the composition of value added on changes in GVC-TFP was particularly negative for EU15* countries, as a result of less efficient production units increasing their relative participation along value chains. This was the result of an increasing fragmentation of production processes, reflected in lower retention of value added per unit of output (negative contribution of the factor shares component), and its international nature, captured by the geographical relocation of production to less developed countries (negative contribution of the value chain composition component).

On a sectoral basis, TFP increased at a higher rate in manufacturing value chains for most countries in this sub-period, benefiting from the relocation of upstream supply stages to production units that showed a significant reduction in factor requirements. The degree of (international) fragmentation in production processes, which was already higher for manufacturing than other activities, further increased during this sub-period. However, a detailed analysis shows that, in some cases, the positive effect of higher efficiency gains in new production units was substantially (or fully) compensated by the negative difference relative to previous efficiency levels (as illustrated by the example in Box 3); or, in other cases, efficiency gains in upstream activities, although likely contributing to improve profitability, did not translate into TFP gains for downstream producers. These developments took place also in non-manufacturing activities, but they were less intense and showed, particularly in the case of business services, a closer relation between TFP gains from the supply chain and own TFP gains.

The second sub-period (2007-2014) presents a clear contrast with the first one in a number of aspects. First, GVC-TFP gains turned to be the exception instead of the norm due to the stop and

even reversal of efficiency gains from factor requirements, including, in a context of a global productivity slowdown (Eichengreen et al., 2017), nonEU economies. Second, on a sectoral basis, developments in non-manufacturing activities explained a larger share of the dispersion of productivity performance across countries; some Member States even recorded significant drops of TFP in business services, which eventually had a negative effect on efficiency of downstream activities through value chains, including exports of manufactures. And third, the shift of value added distribution went in most cases to the opposite direction after the Great Recession, increasing the share of those production units that are more efficient (i.e. with lower factor requirements), reflecting both the stop in international fragmentation (Timmer et al., 2016) and reshoring decisions (Eurofound, 2016).

In policy terms, our analysis provides an insightful approach on how productivity developments are transmitted from upstream to downstream activities, as well as on the factors driving changes of overall efficiency in value chains (i.e. changes in factor requirements and shifts in the composition of value added). In the context of the economic crisis following the COVID-19 pandemic, import dependency and supply security loom in the debate on the future of global trade, adding to pre-existing factors transforming global value chains (UNCTAD, 2020). It might be the case that production networks turn less global and hence productivity dynamics within the EU Single Market become more critical. In principle, a potential reshoring of production capacities could exert positive effects on EU productivity, directly due to the relocation of resources to more efficient production units compared to foreign suppliers and a higher share of tradable activities in the total economy, and indirectly by improving the resilience of EU value chains and lowering vulnerabilities to global shocks (García-Herrero and Martínez Turégano, 2020).

However, this poses important challenges in light of the significant loss of EU competitiveness against manufacturing global competitors since 2000, including both downstream and upstream activities and those with high-technological content (Marschinski and Martínez-Turégano, 2019, 2020a, 2020b). This has been particularly the case of electronics, in which the EU's global share has fallen even more than in total manufacturing, without evidence that specialisation in other segments of this value chain – such as scientific R&D, software development, or IT services – could significantly mitigate the trend. On top of that, were the relocation eventually to take the place, a sustained path of productivity gains would still be needed beyond the one-off effect of reshoring production to more efficient production units. In this sense, the EU Single Market would indeed benefit from a push to competition and efficiency in business services, which would spread to the rest of the economy through value chains, and the building of capacities in critical activities for overall productivity growth, such as electronic hardware, robotics, digitalisation and software development.

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Annex 1. Tables

Table A1. Economic activities in WIOD, 2016 Release

NACE code	Broad sector	Name of economic activity
A01	Other activities	Crop and animal production, hunting and related service activities
A02	Other activities	Forestry and logging
A03	Other activities	Fishing and aquaculture
B	Other activities	Mining and quarrying
C10-C12	Manufacturing	Manufacture of food products, beverages and tobacco products
C13-C15	Manufacturing	Manufacture of textiles, wearing apparel and leather products
C16	Manufacturing	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
C17	Manufacturing	Manufacture of paper and paper products
C18	Manufacturing	Printing and reproduction of recorded media
C19	Manufacturing	Manufacture of coke and refined petroleum products
C20	Manufacturing	Manufacture of chemicals and chemical products
C21	Manufacturing	Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22	Manufacturing	Manufacture of rubber and plastic products
C23	Manufacturing	Manufacture of other non-metallic mineral products
C24	Manufacturing	Manufacture of basic metals
C25	Manufacturing	Manufacture of fabricated metal products, except machinery and equipment
C26	Manufacturing	Manufacture of computer, electronic and optical products
C27	Manufacturing	Manufacture of electrical equipment
C28	Manufacturing	Manufacture of machinery and equipment n.e.c.
C29	Manufacturing	Manufacture of motor vehicles, trailers and semi-trailers
C30	Manufacturing	Manufacture of other transport equipment
C31_C32	Manufacturing	Manufacture of furniture; other manufacturing
C33	Manufacturing	Repair and installation of machinery and equipment
D35	Other activities	Electricity, gas, steam and air conditioning supply
E36	Other activities	Water collection, treatment and supply
E37-E39	Other activities	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services
F	Other activities	Construction
G45	Business Services	Wholesale and retail trade and repair of motor vehicles and motorcycles
G46	Business Services	Wholesale trade, except of motor vehicles and motorcycles
G47	Business Services	Retail trade, except of motor vehicles and motorcycles
H49	Business Services	Land transport and transport via pipelines
H50	Business Services	Water transport
H51	Business Services	Air transport
H52	Business Services	Warehousing and support activities for transportation
H53	Business Services	Postal and courier activities
I	Business Services	Accommodation and food service activities
J58	Business Services	Publishing activities
J59_J60	Business Services	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities
J61	Business Services	Telecommunications
J62_J63	Business Services	Computer programming, consultancy and related activities; information service activities
K64	Business Services	Financial service activities, except insurance and pension funding
K65	Business Services	Insurance, reinsurance and pension funding, except compulsory social security
K66	Business Services	Activities auxiliary to financial services and insurance activities
L68	Business Services	Real estate activities
M69_M70	Business Services	Legal and accounting activities; activities of head offices; management consultancy activities
M71	Business Services	Architectural and engineering activities; technical testing and analysis
M72	Business Services	Scientific research and development
M73	Business Services	Advertising and market research
M74_M75	Business Services	Other professional, scientific and technical activities; veterinary activities
N	Business Services	Administrative and support service activities
O84	Other activities	Public administration and defence; compulsory social security
P85	Other activities	Education
Q	Other activities	Human health and social work activities
R_S	Other activities	Other service activities
T	Other activities	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
U	Other activities	Activities of extraterritorial organizations and bodies

Table A2. Countries in WIOD, 2016 Release

Area	Country	Code	Area	Country
EU	Austria	AT	nonEU	Australia
EU	Belgium	BE	nonEU	Brazil
EU	Bulgaria	BG	nonEU	Canada
EU	Croatia	HR	nonEU	China
EU	Cyprus	CY	nonEU	India
EU	Czech Republic	CZ	nonEU	Indonesia
EU	Denmark	DK	nonEU	Japan
EU	Estonia	EE	nonEU	Korea
EU	Finland	FI	nonEU	Mexico
EU	France	FR	nonEU	Norway
EU	Germany	DE	nonEU	Russia
EU	Greece	EL	nonEU	Switzerland
EU	Hungary	HU	nonEU	Taiwan
EU	Ireland	IE	nonEU	Turkey
EU	Italy	IT	nonEU	UK
EU	Latvia	LV	nonEU	USA
EU	Lithuania	LT		
EU	Luxembourg	LU	nonEU	Rest-of-World
EU	Malta	MT		
EU	Netherlands	NL		
EU	Poland	PL		
EU	Portugal	PT		
EU	Romania	RO		
EU	Slovakia	SK		
EU	Slovenia	SV		
EU	Spain	ES		
EU	Sweden	SE		

Annex 2. Input-output framework

For a given sector j (j∈J) in country c (c∈C) we can write its total production as the sum of intermediate demand (ID) and final demand (FD) for its output in all countries:

$$\mathrm{Y_{c,j}} = \sum_{\mathrm{b,i}} \mathrm{ID_{(c,j),(b,i)}} + \sum_{\mathrm{d}} \mathrm{FD_{(c,j),b}} \quad \text{(A1)}$$

where $\mathrm{ID_{(c,j),(b,i)}}$ is the intermediate demand of products from sector *j* in country *c* by sector *i* in country *b*, and $\mathrm{FD_{(c,j),b}}$ is the final demand of products from sector *j* in country *c* by country *d*.

Each element of the first term, the intermediate demand, can be represented as a share of total production in sector *i* in country *b*:

$$\mathrm{ID_{(c,j),(b,i)}} = \mathrm{a_{(c,j),(b,i)}} \times \mathrm{Y_{b,i}} \quad \text{(A2)}$$

where $\mathrm{a_{(c,j),(b,i)}}$ is referred to as a technical coefficient.

In matrix terms, we can then express the full world input-output framework as follows:

$$\mathrm{Y} = ID + FD = A \times \mathrm{Y} + \mathrm{FD} \quad \text{(A3)}$$

where *Y* and *FD* are column vectors with *C x J* rows representing the production of each country-sector pair of the economy and the final demand of products from each country-sector pair, respectively; *ID* and *A* are square matrices accounting for all intermediate demand transactions between the *C x J* country-sector pairs and the corresponding technical coefficients, respectively.

Finally, solving Equation A3 for production, we get to the following expression:

$$\mathrm{Y} = (\mathrm{I} - \mathrm{A})^{-1} \times \mathrm{FD} = \mathrm{M} \times \mathrm{FD} \quad \text{(A4)}$$

where *M* represents the country-sector interlinkages through the structure of intermediate demand. This square matrix has *C x J* rows and columns and is known as the Leontief inverse.

Each element $m_{(b,i),(c,j)}$ of matrix *M* is known as the backward-looking output multiplier of one unit of production of sector *i* in country *b* on sector *j* in country *c*:

$$m_{(b,i),(c,j)} = \frac{\mathrm{Y_{(b,i),(c,j)}}}{\mathrm{Y_{c,j}}} \quad \text{(A5)}$$

From the perspective of value added, one unit of output in a country-sector pair generates one unit of value added that is distributed to owners of production factors across all sectors and countries in the world participating in the value chain:

$$\mathrm{Y_{c,j}} = \sum_{\mathrm{b,i}} \mathrm{VA_{(b,i),(c,j)}} \quad \text{(A6)}$$

where $\mathrm{VA_{(b,i),(c,j)}}$ is the value added generated in sector *i* of county *b* by one unit of output in sector *j* of country *c*.

Since value added distributed to labour and capital owners in each country-sector pair is a fraction of their output, the previous element can be expressed as:

$$\mathrm{VA_{(b,i),(c,j)}} = lsh_{b,i} \times \mathrm{Y_{(b,i),(c,j)}} + ksh_{b,i} \times \mathrm{Y_{(b,i),(c,j)}} \quad \text{(A7)}$$

where $lsh_{b,i}$ and $ksh_{b,i}$ correspond to the share of value added that is distributed to labour and capital in sector *i* of country *b*.

Finally, the value added participation in the value chain for production in sector *j* of country *c* is obtained combining equations A5 and A7:

$$\frac{\mathrm{VA_{(b,i),(c,j)}}}{Y_{c,j}} = lsh_{b,i} \times \frac{\mathrm{Y_{(b,i),(c,j)}}}{Y_{c,j}} + ksh_{b,i} \times \frac{\mathrm{Y_{(b,i),(c,j)}}}{Y_{c,j}} = lsh_{b,i} \times m_{(b,i),(c,j)} + ksh_{b,i} \times m_{(b,i),(c,j)} \quad \text{(A8)}$$

An analogous derivation is followed for factor requirements per unit of output to get to Equations 6 and 7 in sub-section 2.2.

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