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Francesco Chiacchio, Katerina Gradeva,
Paloma Lopez-Garcia

The post-crisis TFP growth slowdown in CEE countries: exploring the role of Global Value Chains

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1) Productivity growth drivers and efficiency of resource allocation
2) International trade, euro area rebalancing and global value chains

Abstract

Using micro-aggregated firm information for nine Central and Eastern European (CEE) countries and data from input-output tables, we examine the role of Global Value Chains (GVCs) for technology diffusion across EU countries. Our empirical results provide support for a two-stage diffusion process of technology across countries. In the first stage, the most productive firms in the host economy benefit from their direct exposure to new technology created in parent firms as a result of their GVC participation. In the second stage, technology spills over to the rest of firms in the host economy via domestic production networks. In addition, we show that the import of intermediate inputs –i.e. backward linkages- is the main channel of technology diffusion within GVCs. We use these results to explain the pronounced post-crisis drop in Total Factor Productivity (TFP) growth in CEE countries. We show that due to their deep integration in GVCs, CEE countries have been exposed to two recent developments highly correlated with their TFP performance: (i) a slowdown in TFP growth of parent firms located in non-CEE EU countries; and (ii) a global slowdown in the growth rate of GVC participation, which is evident also for CEE countries from 2011 onwards. Moreover, we find that the capacity of host firms in CEE countries to absorb and understand new knowledge has decreased since the crisis. We argue that this is related to the drop in R&D investment in the CEE region during the post-crisis period.

Keywords: TFP growth, Global Value Chains, technology diffusion, Central and Eastern Europe

JEL codes: O33, O47, O57, C33

Non-technical executive summary

Trade in general and Global Value Chains (GVCs) in particular have been shown to be important channels for technology transfer across countries. Firms' engagements in GVCs combine "arm's length transactions", which are normal commercial transactions between a supplier and a consumer (of inputs), and typical features of intragroup investments. This means that even if there are no proper or formal ownership links in GVCs, the opportunities for transferring know-how, technology and process innovation are vast. Indeed, firms can access the new technology embedded in imported inputs and benefit from new varieties of intermediate goods by expanding the set of inputs used in production and reaching a better complementary between them. Participation in GVCs also fosters collaboration in research and development (R&D), enables product diversification and forces upstream firms to invest more to meet the quality standards of parent companies.

This paper contributes to this literature by exploring the role of openness and GVCs for technology diffusion in Europe. The paper also adds value to the more recent literature exploring the sources of the global productivity growth slowdown, visible particularly since the financial crisis. A number of papers have highlighted the role played by (the lack of) technology diffusion from global frontier firms to the rest of firms in explaining the slowdown (OECD, 2015). In this line, this paper explores whether the disproportionate productivity slowdown in Central and Eastern European (CEE) countries, which are deeply integrated in GVCs, can be partially attributed to a change in the cross-country transmission of technology within GVCs.

The framework of the analysis follows a Neo-Schumpeterian growth model where firms' TFP growth in a catching-up economy depends on their exposure to the global technological frontier and their distance to the frontier. We adapt this model to include the particular characteristics of GVCs. More precisely, we assume that the relevant global technology frontier firms are the parent firms operating in non-CEE EU countries and that only firms participating in GVCs in the host economy, the most productive ones, benefit directly from direct exposure to the frontier. The rest of firms in the host economy benefit indirectly from exposure to firms engaged in GVCs.

We test this model using CompNet data and WIOD tables to compute bilateral country-sector GVC links for nine CEE countries, nine non-CEE countries, nine macro-sectors and 10 years (2003-2012). Our results show that technology diffuses first from parent firms to the most productive firms in the host economy via GVCs and in a second step to the rest of firms. The main channel of technology diffusion is the import of intermediate inputs by host firms, rather than the export of inputs to parent firms. Finally, we find that the pronounced slowdown in TFP growth in CEE countries is related to a drop in the technology creation in parent firms as well as to a fall in the absorptive capacity of host firms. We show that the latter could be related to the drop in R&D investment in the CEE region after the crisis.

1 Introduction

One of the long acknowledged sources of learning, technology transfer and productivity growth is related to openness to trade and production chains (Grossman and Helpman, 1991). On the one hand, exporting provides exposure to new ideas and incentives to upgrade. On the other hand, import activity allows exploiting complementarities between domestic and foreign capabilities and might increase access to technology and its embedded know-how.

The productivity gains from trade can be even larger in the presence of foreign direct investment (FDI) given that the cost of transferring technology is reduced within integrated companies. Global Value Chains (GVCs), which combine typical features of intragroup investments with "arm's length" transactions - normal commercial transactions between a supplier and a consumer- might also provide support for rapid knowledge spillovers. The reason is that GVCs offer a high degree of exposure to, and learning from, the fast-evolving, technology-enabled, business models that characterize fragmented production chains, even without the need for participating firms to engage in ownership arrangements.

This paper contributes to the literature exploring the role of openness and GVCs for technology diffusion in Europe. The analysis of trade, and especially of international production chains, as a channel for cross-country knowledge transfer and, therefore, productivity growth, is particularly relevant in Europe given its deep trade integration and tight firm-to-firm connectivity. The paper also adds value to the more recent literature examining the sources of the global productivity growth slowdown, visible since the financial crisis. A number of papers have highlighted the role played by (the lack of) technology diffusion from global frontier firms to the rest of firms in explaining the slowdown (e.g. OECD, 2015). In this line, this paper explores whether the productivity slowdown in Central and Eastern European (CEE) countries can be partially attributed to a change in the cross-country diffusion of technology within GVCs.

Measuring technology transmission is a challenging task. Hence, in this paper we adopt the distance-to-frontier approach (e.g. Griffith at al., 1996) and assume that knowledge created at the firm can be measured by its Total Factor Productivity (TFP) growth rate, while learning from the frontier can be approximated by the correlation between TFP growth at the firm and at a nominated frontier firm or set of firms. This indirect method of measuring knowledge flows has the advantage of implicitly looking at non-patentable innovations, which are the prevalent ones within GVCs.

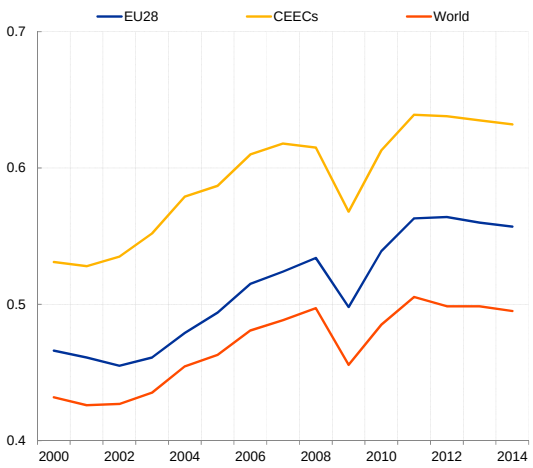
To explore these issues the paper focuses on CEE countries. The reasoning behind this choice is twofold. First, total GVC participation measured as the share in gross exports of the sum of two items, domestic value added in third country exports (forward GVC participation) and foreign value added in own exports (backward GVC participation), in CEE countries has been persistently above the EU28-average since 2000 (Figure 1).[1] Second, CEE countries have experienced a sharper drop in annual labour productivity growth than other EU countries since the onset of the crisis, driven fundamentally by very weak TFP performance (Figure 2). Thus, in the following we argue that due to their deep

[1] See Koopman et al. (2014) for details on the decomposition of value added flows at the country level.

integration in GVCs, CEE countries have been particularly exposed to two recent developments, which are highly correlated with their TFP growth performance: (i) weaker TFP growth of parent firms, which has reduced the new knowledge generated in parent firms and transmitted to host firms through GVCs; and (ii) a global slowdown in the growth rate of GVC participation which has decreased the opportunities for technology transfer. This slowdown is evident for CEE countries from 2011 onwards, even after controlling for country-sector and time-specific shocks (Figure 3).[2]

Figure 1: GVC participation

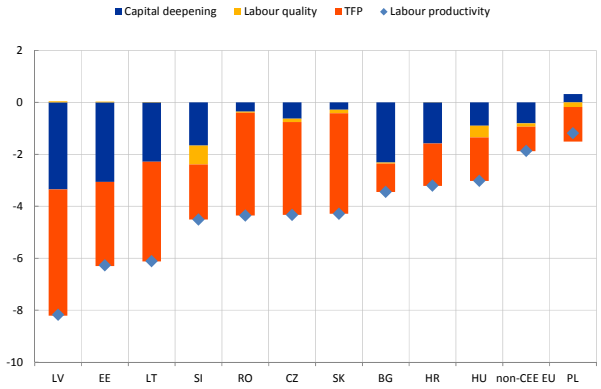
(share in gross exports)



Source: Authors' calculations based on WIOD (2016).
Note: GVC participation measured as the share in gross exports of the sum of: (i) domestic value added in third country exports (forward GVC participation); and (ii) the foreign value added in own exports (backward GVC participation).

Figure 2: Difference in annual labour productivity growth and its contributors between the crisis and post-crisis (2008-2015) period and pre-crisis period (2000-2007)

(in percentage points)



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

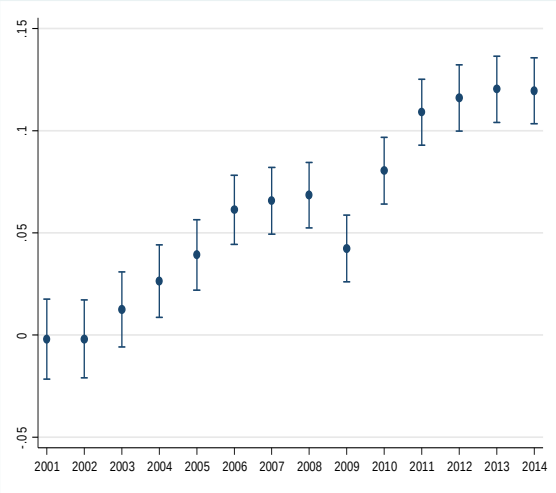
In our empirical framework, we depart from a Neo-Schumpeterian model, assuming that a country's productivity growth depends on the exposure to the global technological frontier and distance to the frontier, and expand it to accommodate the specific characteristics of GVCs. More precisely, we assume that only the most productive firms in each sector of the host economy are directly related to parent firms through GVCs, and therefore are exposed to the technology created at the frontier. In turn, those top productive host firms outsource part of their non-core activities to other local firms. This second stage is crucial for the technology diffusion to the rest of non-frontier firms in the host

[2] Note that Figure 3 refers to the import intensity of production, rather than to the backward and forward linkages of firms, as shown in Figure 2.

economy and is consistent with the evidence of a two-stage technology diffusion process put forward by Bartelsman et al. (2013), Van der Wiel et al. (2008), and Iacovone and Crespi (2010).

We test these links using CompNet data and the recent release of the World Input-Output Database (WIOD) for a set of nine CEE countries, nine macro-sectors and 10 years (2003-2012) and find that GVC participation plays a key role in explaining the TFP performance of host firms in these countries. Moreover, we provide evidence supporting that technology diffuses from parent companies to host economies in two stages. In addition, we show that firms in host economies benefit more, in terms of TFP growth, from importing inputs from parent firms than from exporting intermediate inputs.

Figure 3: CEE countries' import intensity



Source: Authors' calculations based on WIOD (2016) following Timmer et al. (2016).
Note: The figure plots estimated coefficients and 95% confidence intervals on year dummies after regressing CEE countries' import intensity on country-sector and year fixed effects. Coefficients are relative to 2000.

The next section reviews briefly the interconnection between trade and technology transfer to highlight the possible channels at play. Section 3 presents the framework for the analysis, while Section 4 introduces the empirical strategy and describes the data. Section 5 discusses the econometric results and several robustness exercises. Section 6 applies the results to explore the factors behind the productivity growth slowdown in the CEE region after the crisis and, finally, Section 7 concludes.

2 Technology transfer through trade linkages: main channels[3]

Several studies suggest that TFP growth is influenced by the ability of firms to take advantage of new and existing technology created at the global frontier. In the Neo-Schumpeterian models (e.g. Aghion and Howitt, 2006; Saia et al., 2015), a country's productivity growth depends on two elements. The first one is the "pass-through" effect which is defined as the exposure to, and learning from, new technology created at the frontier. It depends on the frontier's rate of technology creation, which is often proxied by the average TFP growth of frontier firms. The second element is the so-called "catch-up" effect or distance to the global productivity frontier. It represents the ability of firms to take advantage of existing technologies and it is generally proxied by the lagged gap in the productivity level between the global frontier and the country under study. The larger the gap, the larger the role of the catch-up effect for TFP growth. Comin and Hobijn (2010) provide theoretical and empirical evidence for the importance of technology diffusion for TFP growth, in particular for emerging countries. Success stories such as the ones of the "East Asian Tigers" have coincided with a

[3] This section relies heavily on the literature review by Lopez-Garcia and Taglioni (2018).

fast catch-up in terms of technology with respect to OECD countries through substantial reduction of technology adoption lags. The aggregate implications of technology diffusion are far reaching: cross-country adoption lags seem to explain at least one quarter of income per capita differentials.

The possibility to learn from the global frontier depends among other factors on the existence of trade linkages. Amiti and Konings (2007) find that the largest productivity gains from trade are due to lower tariffs on inputs rather than to a competition effect. Interestingly, a main channel for the gains is the access to a more differentiated variety of inputs, which seems to matter more than the direct benefits from lower prices or higher quality foreign inputs (Goldberg et al., 2010; Halpern et al., 2015). Similar results are found by Bas and Strauss-Kahn (2014), who show that an increase in the share of imported inputs used in production boosts firm-level productivity and exports in France by expanding the set of inputs used in production and reaching a better complementarity between them. Importing gives also rise to transfer of tacit knowledge (Csillag and Koren, 2011; MacGarvie, 2006). The reason is that the newly imported sophisticated machinery and capital goods require highly trained operators. Importing better inputs also leads to upgrading for other firms indirectly connected via supply chains. Kee (2015) shows, for example, that after EU firms expanded FDI in Bangladesh, domestic firms that shared the same suppliers with the foreign investors expanded their product scope by 25 percent and enjoyed productivity gains by 33 percent. Çagatay and de Haas (2015) provide evidence that in an emerging country context (Russia in their analysis) technological advances are mostly made through cooperation with others, in particular suppliers, highlighting imports as an important channel of technology diffusion.

Exporting, on the other hand, is associated with skills upgrading, particularly for domestic frontier firms. Bustos (2011), for example, finds an increased demand for skills after the creation of MERCOSUR. Furthermore, as firms become larger and start exporting, they expand their organizational capital inducing a greater need for more complex management structures, which in turn brings more skills (Bloom et al., 2016). Exporting also generates opportunities for learning by exporting for firms and their workers (De Loecker, 2013). Demand factors play as well an important role in inducing positive knowledge spillovers from exporting given that it enables firms to learn about more sophisticated consumers and competitive markets. Accordingly, one explanation of the success of China in international markets is that Chinese firms invested in capability building to improve their product appeal and demand (Sutton, 2007; Brandt et al., 2008; Schott, 2008). Also, Brambilla et al. (2012) show that firms exporting predominantly to high-income countries use relatively higher levels of skills and pay higher wages than domestic firms or exporters to middle- or low-income countries.

Technology tends to flow faster and more easily as a result of the interconnections established in GVCs. Such production arrangements link together multiple firms, usually located in different countries, in ways similar to intra-group investment and trade. This type of engagement is based on deep relationships that involve ownership or licensing, franchising, joint ventures, strategic alliances, or other forms of non-equity modes of investment. It is the deep nature of engagement that allows the faster, more sizeable, and knowledge-intensive transfer of capabilities between countries (Mariscal

and Taglioni, 2017). The capacity of GVCs to act as a channel of technology transfer is shown, for example, by Baldwin and Yan (2014), who controlling for self-selection estimate that Canadian firms witnessed a 5% increase in their productivity level after only one year from the start of their participation into a GVC. Moreover, Acemoglu et al. (2015) show that the existence of pronounced industry interlinkages might amplify significantly the macroeconomic impact of a shock. Supply-side shocks in productivity such as a TFP shock or changes in patented technology frontiers propagate mostly downstream from supplier to customer industries, while demand-side shocks have predominantly upstream effects.

3 Framework of the analysis

In line with Neo-Schumpeterian models and models of technology diffusion in multiple stages (Bartelsman et al. 2013; Van der Wiel et al. 2008; Iacovone and Crespi, 2010), we assume that technology diffuses in two stages across countries linked through trade. In the first stage technology is diffused from the global frontier firms to the national frontier firms. Global frontier firms learn predominantly through own radical innovation, research and development (R&D), patenting activity, and from addressing untapped needs of sophisticated customers. They are the most advanced and productive firms in a given sector at a global scale. These firms usually engage in international production and trade through establishing linkages with the most productive firms in a target country, what we call the national frontier firms. Direct collaboration of national frontier firms with global frontier firms results in acquisition of new technology, learning new processes, and enabling technological upgrading. In a second stage, the technology flows to the rest of firms in the host economy, predominantly through domestic networks.

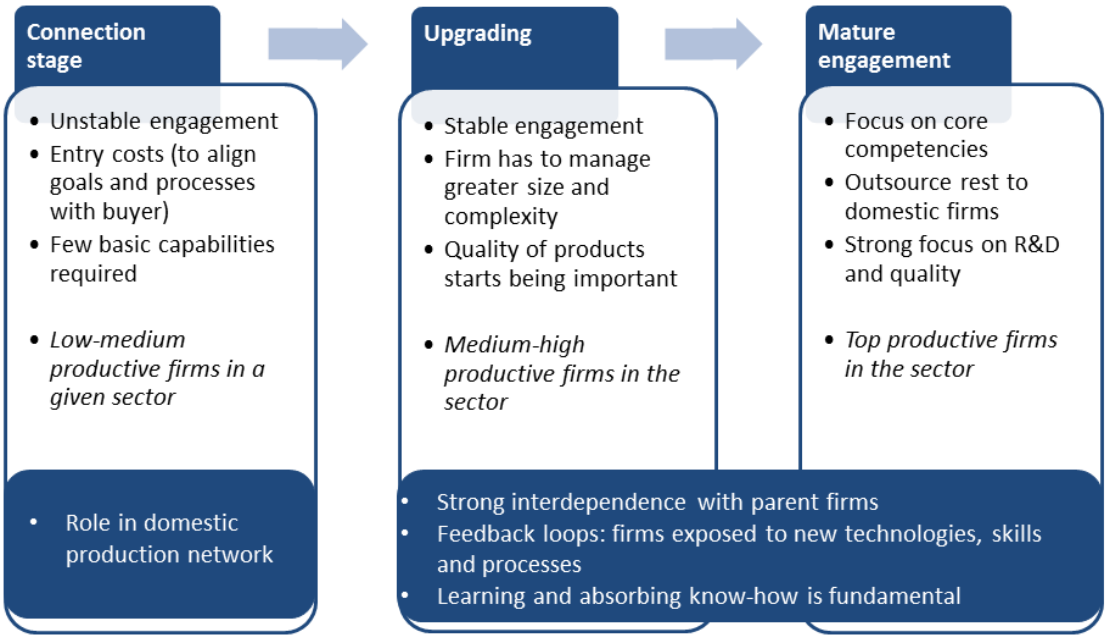
To adapt this set-up to the GVC framework, we assume that in countries with very large participation in GVCs the relevant global frontier, that is, the source of new technology, is what we call the "GVC frontier". Firms at the GVC frontier are the most productive firms in country-sectors with tight GVC links with host firms.

Further, we consider three distinct types of firms in the host economies: national frontier firms, mid-productivity firms, and laggards. The national frontier firms are those at the top 20 percent of the TFP distribution in the host country/macro-sector. The mid-productive firms are those between the 30th and the 70th percentiles of the productivity distribution, while laggards refer to the bottom 20 percent firms in terms of TFP. The reason for this distinction is that the role and integration in GVCs of firms in host economies depends on their capabilities. Initial entry into a GVC, what Mariscal and Taglioni (2017) call *connection stage*, implies unstable engagement in GVCs and involves firms with basic capabilities (the low-middle productive firms in a given sector). These firms will eventually enter a process of *upgrading*, conditioned on the firm being able to manage larger size and complexity, in which there is a more stable relationship with the parent firms. Lastly, *mature engagement* in GVCs implies that host firms focus on core competencies and outsource other tasks to local firms. At this stage, there is a strong focus on R&D, quality and direct connection with parent firms. Only the most

productive firms in a given sector of the host country, what we call the national frontier firms, have the capabilities required to play this role.

It is important to note that in the last two stages of the GVC participation (upgrading and mature engagement), there are feedback loops between parent and host firms. Firms are exposed directly to new technology, skills and processes, and they can benefit and adapt as much technology as possible via enhancement of their absorptive capacity. These firms are also forming their own stable network of domestic suppliers (Figure 4).

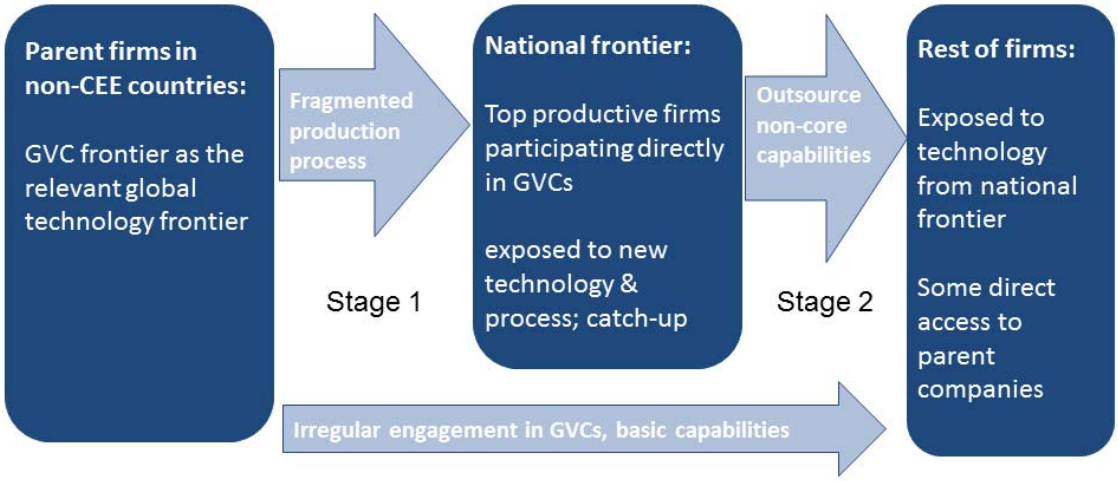
Figure 4: Integration in GVCs and host firms' capabilities



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

Hence, in a GVC framework knowledge flows in the first place from the GVC frontier firms to the national frontier firms in host economies and in a second stage from the national frontier firms to the rest of the domestic firms, predominantly through domestic firm-to-firm and firm-to-worker linkages. Domestic networks are fuelled by the outsourcing of non-core activities of the value chain. There is also a direct channel from foreign companies to the medium-low productivity firms in peripheral economies, which however grants lower technology transfer; the engagement involves most likely non-core functions, requires capabilities that are basic in nature, and it is based on "arm's length" trade relationships (Figure 5).

Figure 5: Technology diffuses from the GVC frontier to host economies in two stages



Source: Authors' elaboration based on Mariscal and Taglioni (2017).

4 Empirical specification and data

4.1 The GVC frontier

The GVC frontier is unique to host firms operating in a given country/macro-sector because it depends on their exposure to different firms at the global frontier. The exposure to the GVC frontier depends on the GVC links between a "parent" country/macro-sector and a "host" country/macro-sector measured either by the backward (downstream) position of firms in GVCs, which depends on their imports of intermediate inputs, or by their forward (upstream) position based on their exports of intermediates. As described in the previous section, the concrete channels of technology transfer vary depending on the type of GVC links established between parent and host firms.

Our baseline measures of GVC links follow a "gross" definition and are based either on the imports or the exports of intermediates of a given host country/macro-sector:

$$GVC\ participation_{z,j,t} = \frac{Imports\ of\ intermediates_{z,j,t}}{Domestic\ supply\ of intermediates_{z,j,t}} \quad (1)$$

$$GVC\ participation_{z,j,t} = \frac{Exports\ of\ intermediates_{z,j,t}}{Domestic\ supply\ of\ intermediates_{z,j,t}} \quad (2)$$

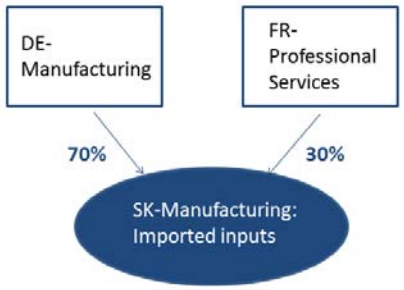
where z is the host country, j is the sector of activity and t is the year. In addition, we use as robustness check the definitions of GVC links based on the value added concept following Wang et al. (2014).[4] For our baseline specifications we opt, however, for the GVC measures based on the gross

[4] We thank an anonymous referee for this suggestion.

concept in order to be consistent with the definition of the GVC frontier, for which, as explained below, we use bilateral sector-to-sector trade flows to compute the weights.[5]

In Figure 6 we explain the construction of the GVC frontier on the basis of a simplified example of the manufacturing sector in Slovakia, which imports inputs from two non-CEE EU countries, Germany and France. More concretely, Slovakian manufacturing firms import 70% of their imported inputs from manufacturing firms in Germany and 30% from firms in the professional service sector in France. This means that the GVC frontier of Slovakian manufacturing firms is a weighted average of the most productive firms in Germany-manufacturing and France-professional services. The weights depend on the particular exposure of the Slovakian-manufacturing firms to the two countries, which in this example is 70-30. If technology creation at global frontier firms is approximated, as specified in the introduction, by their TFP growth, then the technology creation at the GVC frontier of Slovakian-manufacturing firms is going to be a weighted average (with weights being 70-30) of the TFP growth of frontier firms in Germany-manufacturing and France-professional services.

Figure 6: Constructing the GVC frontier



Thus, technology creation at the GVC frontier based on Equation 1 (imports of intermediate inputs) is specified as follows:[6]

$$TFP\ growth\ at\ GVC\ frontier_{z,j,t} = \sum_{p \in P} TFPgrowth_{p,i=top\ 20\%,t} \cdot \frac{Imports\ of\ intermediates_{p \to z,j,t}}{\sum_{p \in P} Imports\ of\ intermediates_{p \to z,j,t}} \quad (3)$$

where z is the host country (Slovakia in the example), j is the macro-sector (manufacturing in the example) and t is time. p is a pair of parent country/macro-sector (e.g., manufacturing of Germany) from the set of all parent countries/macro-sectors, which we denote by P (Germany/manufacturing and France/professional services in the example above); and $p \to z,j,t$ is the flow of intermediate imports from parent country/macro-sector p to country z, macro-sector j, at time t. Finally, i is the productivity percentile of a given firm. The most productive firms in a given sector are assumed to belong to the top 20% of the productivity distribution in the country/macro-sector. Hence,

[5] The decomposition proposed by Wang et al. (2014) provides unfortunately only information on value added flows from/to a sector in the host country to/from a parent country, with no information on the sector of origin/destination in the parent country.

[6] For details on the computation of TFP and other variables, please refer to Annex 1.

$TFPgrowth_{p,j,i=top\ 20\%,t}$ is the TFP growth of the most productive firms in the parent country/macro-sector p.

In order to investigate whether the most relevant channel of technology transfer is the import or export of inputs, we compute an alternative GVC frontier using as weights the ratio of exported intermediate inputs to total intermediate exports by a given host country/macro-sector (based on Equation 2):

$$TFP\ growth\ at\ GVC\ frontier_{z,j,t} = \sum_{p \in P} TFPgrowth_{p,i=top\ 20\%,t} \cdot \frac{Exports\ of\ intermediates_{z,j,t \to p}}{\sum_{p \in P} Exports\ of\ intermediates_{z,j,t \to p}} \quad (4)$$

4.2 TFP growth of national frontier firms in host economies

According to Neo-Schumpeterian models (Aghion and Howitt, 2006; Saia et al., 2015), TFP growth of (host) firms depends on their direct exposure to technology creation at the global (GVC) frontier, measured by the correlation of their own TFP growth with that of the global (GVC) frontier firms, as well as on their distance to the frontier, measured by the lagged gap in TFP levels.

Hence, TFP growth of the national frontier, i.e. the most productive firms in a given sector in the host economy, is estimated through the following equation:

$$TFP\ growth_{z,j,i=top\ 20\%,t} = \alpha_{zj} + \beta_1\ TFP\ growthGVCfrontier_{z,j,t} + \beta_2 ln\left(tfp\ level\ GVCfrontier_{z,j,t-1}/tfp\ level_{z,j,i=top\ 20\%,t-1}\right) + \beta_3 GVC\ growth_{z,j,t} + \delta_1 crisis_t + \delta_2 postcrisis_t + u_{z,j,t} \quad (5)$$

where the term $TFP\ growthGVCfrontier$ captures the TFP growth of the GVC frontier of macro-sector j in host country z at time t (see Equations 3 and 4). The term $ln\left(tfp\ level\ GVCfrontier_{z,j,t-1}/tfp\ level\ _{z,j,i=top\ 20\%,t-1}\right)$ measures the lagged distance from host frontier firms to the GVC frontier. The crisis and post-crisis variables equal one from 2008 to 2010 and from 2011 onwards, respectively, and capture cross-country common developments during the two periods which might explain a change in TFP growth relative to the pre-crisis period (results are robust to the use of year dummies). In addition, we also control for the sector's involvement in GVCs, measured by the sector–specific growth of GVC participation (or by the sector–specific level of GVC participation) as defined by Equations 1 and 2. The underlying assumption is that if many firms in a given sector are already participating in GVCs, or are joining in because GVCs are expanding, there might be a positive externality beyond the one captured by the exposure to the frontier and the catch-up. This effect is due to the fact that workers are more skilled in this sector, and inputs are of better quality than in sectors less involved in GVCs (Kee, 2015).

4.3 TFP growth of mid-productive and laggard firms in the host economy

According to the theoretical framework presented in the previous section, in a second stage technology diffuses from the national frontier firms, involved in GVCs, to the rest of local firms through domestic production networks. Hence, non-frontier firms learn not directly from the global frontier but rather from the national frontier firms. So, TFP growth of laggards and mid-productive firms in a given sector depends on their exposure to the technology already adopted by the national frontier and on the distance to the national frontier. As mentioned earlier, laggard and mid-productive firms might also, in the initial stages of their GVC engagement, have sporadic contact with parent companies in non-CEE EU countries. Therefore, we control also for the GVC frontier TFP growth and their distance to the GVC frontier:

$$TFP\ growth_{z,j,i,t} = \alpha_{zj} + \beta_1 TFP\ growthNational\ frontier_{\ z,j,t} + \beta_2 ln\left(tfp\ levelNational\ frontier_{\ z,j,t-1}/ tfp\ level_{z,j,i,t-1}\right) + \beta_3\ TFP\ growthGVCfrontier_{z,j,t} + \beta_4 ln\left(tfp\ level\ GVC\ frontier_{z,j,t-1}/ tfp\ level_{z,j,i,t-1}\right) + \beta_5 GVC\ growth_{z,j,t} + \delta_1 crisis_t + \delta_2 postcrisis_t + u_{z,j,t} \quad (6)$$

where *i* is equal to the bottom 20 percent of the TFP distribution in a given macro-sector *j* and host country *z* in year *t* in the case of the laggard firms, and between the 30th and 70th deciles of the distribution when considering TFP growth of mid-productive firms. The term $TFPgrowthNational\ frontier_{\ z,j,t}$ proxies for the technology creation at the national level, while the term $ln\left(tfp\ levelNational\ frontier_{\ z,j,t-1}/tfp\ level_{z,j,i,t-1}\right)$ proxies for the catch-up to the national frontier. As before, $GVC\ growth_{z,j,t}$ represents GVC participation growth of a given macro-sector, $TFPgrowthGVC\ frontier_{\ z,j,t}$ is technology creation at the GVC frontier and $ln\left(tfp\ level\ GVC_{z,j,t-1}/tfp\ level_{z,j,i,t-1}\right)$ is the lagged distance to the GVC frontier. Equations 5 and 6 are the baseline specifications for the evolution of TFP growth of the national frontier firms and the other (non-frontier) firms in each sector of the host economies, respectively. To explore whether the basic links changed over the crisis and post-crisis periods, relative to the pre-crisis one, in a later stage we interact our proxies for technology creation and absorption as well as GVC participation growth with the crisis dummies.

The proposed specifications (Equations 5 and 6) are estimated using fixed-effects, thus, exploiting the within country/macro-sector time variation of the variables. Standard errors are clustered at the country/macro-sector level to adjust for common group effects. Our estimation strategy suffers potentially from an endogeneity bias because we cannot rule out the case that more productive sectors are participating more intensively in GVCs in the first place. An omitted variable could also be responsible for the changes in TFP growth and GVC participation. Hence, we do not claim causality but rather correlation. Nevertheless, we still believe that investigating the relationship between the dynamics of the GVC-related variables and TFP growth of host firms is informative and offers interesting and important insights.

4.4 Data

Given the specific country case which we analyse in this paper, we assume that CEE countries are the host economies and that parent firms are located in non-CEE EU countries.[7]

Data on TFP growth of the frontier and non-frontier firms in parent and host countries are taken from the CompNet micro-aggregated database. CompNet is a research network created in 2012 within the European System of Central Banks and devoted to the analysis of competitiveness from a multidimensional prospective. The CompNet database is based mainly on administrative data from the firm registries and constructed following a micro-distributed approach due to the confidential nature of firm-level information in most countries (Bartelsman et al., 2004). The database provides harmonised cross-country information on all deciles of the distribution of a number of variables related to firm performance and competitiveness, including productivity, in a given country, macro-sector and year. In total, CompNet covers about 18 EU countries, nine macro-sectors, including manufacturing, construction and seven service sectors[8], for the time period 2001-2013. Lopez-Garcia et al. (2015) provides further information on the dataset and coverage.

CompNet data used in this paper refer to non-financial corporations with at least one employee (20 employees in Poland, Romania and Slovakia). Our final sample includes nine CEE countries[9], nine non-CEE EU countries[10] (used for constructing the GVC frontier), nine macro-sectors and 10 years, 2003-2012, in order to achieve the most consistent coverage across countries, sectors and time. The final dataset is an unbalanced panel and covers, on average, around half of the employment and value added in each country (see Table A1 in Annex 1).

Regarding the GVC-related variables, both the weights to compute the GVC frontier and the participation in GVCs are computed using data from the recent release of the WIOD (2016). The WIOD combines national supply and uses tables with bilateral international trade data so that it provides information on the final consumption and inter/intra-country intermediate supply and usage of goods and services. The sample covers 43 countries in total, including all EU28 countries (as well as a model for the rest of the world), and 56 mainly two-digits sectors[11] for the time period 2000-2014. Based on these data we construct the relative importance (weight) of each non-CEE EU country in total intermediate imports/exports of CEE countries by macro-sector and year according to Equations 3 and 4. In addition to the GVC participation measures defined in Equations 1 and 2, we use as well GVC participation indicators based on the value added concept following Wang et al. (2014). These capture either sector's backward linkages, depending on the foreign value added incorporated in the host country-sector's gross exports, or its forward linkages, which depend on the

[7] This assumption seems reasonable given that on average, during the period 2003-2012, CEE imports of intermediate inputs amounted to 43% of their domestic intermediate input usage with half of them (about 22%) originating from other non-CEE EU countries.

[8] Wholesale and retail trade; transportation and storage; accommodation and food service activities; information and communication; real estate activities; professional, scientific and technical services; and administrative and support service activities.

[9] Croatia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

[10] Austria, Belgium, Denmark, Finland, France (sample 20+ employees), Germany, Italy, Portugal and Spain.

[11] Including three agricultural sectors, mining, 19 manufacturing sectors, construction, three utilities sectors, and 27 services sectors.

domestic value added in third countries' gross exports (for details refer to Annex 1). Unless otherwise indicated, in the following we refer to the GVC measures based on the gross definition as our baseline indicators.

Table 1 presents the descriptive statistics of our main variables, namely, growth of TFP of all different sets of host firms, as well as of the GVC frontier and participation in GVCs, for the pre- and crisis/post-crisis periods separately. In general, as expected, in the post-2008 period TFP growth rates have been significantly lower for all types of firms compared to their pre-crisis dynamics, while the slowdown of GVC participation in the post-crisis is evident if we include data up to 2014.

Table 1: Descriptive statistics

	2003-2007	2008-2010	2011-2012	2003-2012	Bonferroni comparison of means by period		
					2008-2010 minus 2003-2007	2011-2012 minus 2003-2007	2011-2012 minus 2008-2010
TFP growth GVC frontier	3.0	-0.4	-1.5	0.9	-3.346***	-4.473***	-1.127
TFP growth sector	4.7	-3.2	2.8	1.3	-7.883***	-1.865	6.017***
TFP growth national frontier	3.9	-2.9	2.8	1.1	-6.829***	-1.118	5.711***
TFP growth mid-prod.	3.8	-3.1	2.5	0.9	-6.88***	-1.313	5.567***
TFP growth laggards	4.0	-5.0	3.1	0.4	-8.986***	-0.915	8.071***
GVC participation growth	1.4	-0.0	2.0	1.1	-1.405***	0.639	2.044***
GVC participation growth up to 2014	1.4	-0.0	1.0				

Note: Averages across periods. Last three columns show the pairwise period mean difference for each variable. All TFP growth variables are defined as: growth(x)=$\ln(x)_t$-$\ln(x)_{t-1}$ and refer to TFP growth of the respective set of firms. GVC participation based on imported inputs as a share of domestic intermediate usage.
Bonferroni mean pairwise comparison test: *** p<0.01, ** p<0.05, * p<0.10.

5 Results

5.1. TFP growth of a host country/macro-sector

We start off by exploring TFP growth of firms in a given host country/macro-sector, without distinguishing between national frontier firms and laggards.[12] Then, we move on to analyse TFP growth of different types of firms in the host economy.

According to our results, during the crisis and post-crisis periods sectoral TFP growth in the CEE countries has been significantly lower compared to its pre-crisis level: during the crisis period (2008-2010) TFP growth was 8.2pp lower than in pre-2008 average, while after 2010 (post-crisis) it recovered slightly to be only 2.3pp below the pre-crisis period (Table 2, column 1). Interestingly, when we control for the dynamics of the GVC-related variables, the crisis period is associated with a smaller drop in TFP growth and the post-crisis dummy is not significant anymore.

[12] Sector TFP growth is defined as the weighted average of TFP growth of the frontier, mid-productive and laggard firms in the sector, where weights depend on their respective employment share.

Table 2: TFP growth of the host country/macro-sector

	Only crisis dummies	GVC participation based on gross imports	GVC participation based on gross exports	GVC participation based on gross imports and exports	GVC participation based on value added (backward)	GVC participation based on value added (forward)
	(1)	(2)	(3)	(4)	(5)	(6)
2008-2010 dummy	-0.082***	-0.051***	-0.048***	-0.044***	-0.053***	-0.056***
	(0.011)	(0.014)	(0.015)	(0.013)	(0.014)	(0.012)
Post-2010 dummy	-0.023**	-0.001	-0.003	0.002	-0.003	-0.003
	(0.010)	(0.014)	(0.013)	(0.013)	(0.014)	(0.013)
TFP growth GVC frontier based on imports (backward linkages)		0.483***		0.438***	0.462***	
		(0.063)		(0.065)	(0.068)	
Lagged TFP gap GVC frontier based on imports (backward linkages)		0.521***		0.402***	0.515***	
		(0.136)		(0.120)	(0.137)	
TFP growth GVC frontier based on exports (forward linkages)			0.167***	-0.020		0.208***
			(0.054)	(0.053)		(0.062)
Lagged TFP gap GVC frontier based on exports (forward linkages)			0.426***	0.133**		0.421***
			(0.103)	(0.055)		(0.095)
GVC participation growth - based on imports (backward linkages)		0.182*		0.294**	0.543**	
		(0.105)		(0.126)	(0.214)	
GVC participation growth - based on exports (forward linkages)			0.057	-0.082		-1.539
			(0.058)	(0.055)		(0.977)
Constant	0.049***	-1.662***	-1.252***	-1.678***	-1.638***	-1.231***
	(0.006)	(0.439)	(0.315)	(0.441)	(0.444)	(0.286)
Observations	613	613	613	613	613	613
Adjusted R-squared	0.062	0.345	0.267	0.353	0.350	0.299

Note: *** p<0.01, ** p<0.05, * p<0.10.
Robust standard errors in parentheses, clustered at the country-sector level. Country-sector FE included.

Regarding our variables of interest, we find that both technology creation at the GVC frontier as well as the distance to the frontier are significantly correlated with sectoral TFP growth in CEE countries (Table 2, columns 2-3). Interestingly, the definition of GVC participation, based either on import content of inputs (column 2) or on exports of inputs (column 3), matters. First, the correlation between sectoral TFP growth and technology creation at the GVC frontier is *higher* when the definition of the GVC frontier is based on CEE countries' imports of intermediate products rather than on exports. Second, while sectors which engage more in importing intermediate products grow faster than other sectors in terms of TFP, this is not the case for sectors which display higher growth of exporting

intermediate inputs. This result points towards the existence of positive externalities for firms operating in a sector with a growing participation in GVCs through importing intermediate inputs, rather than exporting inputs. Column 4 (Table 2) confirms this finding by regressing sectoral TFP growth on both measures of GVC participation simultaneously: only the linkages through importing intermediate inputs remain significant.

Finally, columns 5 and 6 (Table 2) use the alternative definitions of GVC participation based on the foreign value added incorporated in the host country's exports (backward) or on the domestic value added included in a third countries' exports (forward). Results are consistent and show the same picture.[13]

Table 3 provides further evidence for the robustness of the results. Columns 1 and 2 include as an additional control variable the R&D intensity of the host country/macro-sector, as spending in R&D is fundamental for TFP growth. Results do not change, and the R&D intensity variable is not significantly different from zero. Next, we substitute the GVC frontier by the EU frontier or add it as an additional control variable (columns 3 to 6). The EU frontier is defined as the unweighted TFP growth of frontier firms in non-CEE EU firms and proxies technology creation in non-CEE EU countries independently of their GVC links with the host economies. In columns 3 and 4 the GVC frontier and distance to the frontier are substituted by the EU frontier[14], whereas in columns 5 and 6 both the GVC and EU frontiers (and distances to the respective frontier) are included.

We find that when the GVC frontier is substituted by the EU frontier, TFP growth of the EU frontier and distance to the EU frontier still matter for TFP growth of the host economy, though the correlation is of a lower magnitude. Clearly, there are trade links between CEE and non-CEE EU countries which facilitate technology transfer but they are not as tight as the ones established under the umbrella of GVCs, as predicted by the literature. When both the GVC and the EU frontier are included together, we find that GVC linkages through importing inputs are the only ones which are important for technology transfer (EU frontier is not significant in column 5). Interestingly, in the case of forward linkages, i.e. exports of intermediates, what matters is the EU frontier rather than the GVC frontier (column 6). We read this result as support for the fact that the impact of exports on productivity growth comes via the degree of sophistication of destination markets rather than via participation in GVCs (Brambilla et al. 2012). This result is further supported by the fact that, when distinguishing between different types of host firms, this result holds only for the most productive host firms –the ones exporting-, rather than for host non-frontier ones (see below).

[13] Note, however, that only the GVC participation indicators differ in this specification, relative to the one including GVC measures based on gross exports and imports. The GVC frontier has to be measured using gross flows due to the unavailability of data on value added flows from host country-sector to parent country-sector.

[14] The EU frontier is the same in columns 3 and 4 but column 3 includes the growth in GVC participation of the country/sector using the gross import definition and column 4 using the gross export one.

Table 3: Sectoral TFP growth - robustness

	GVC participation based on gross imports	GVC participation based on gross exports	GVC participation based on gross imports with EU frontier	GVC participation based on gross exports with EU frontier	GVC participation based on gross imports and EU frontier	GVC participation based on gross exports and EU frontier
	(1)	(2)	(3)	(4)	(5)	(6)
2008-2010 dummy	-0.045**	-0.045**	-0.031*	-0.033*	-0.039**	-0.033*
	(0.020)	(0.020)	(0.018)	(0.019)	(0.015)	(0.018)
Post-2010 dummy	0.022	0.009	0.032*	0.036**	0.018	0.027
	(0.019)	(0.020)	(0.019)	(0.018)	(0.015)	(0.017)
TFP growth GVC frontier based on imports (backward linkages)	0.547***				0.404***	
	(0.081)				(0.070)	
Lagged TFP gap GVC frontier based on imports (backward linkages)	0.572***				0.361**	
	(0.090)				(0.137)	
TFP growth GVC frontier based on exports (forward linkages)		0.183***				0.051
		(0.066)				(0.058)
Lagged TFP gap GVC frontier based on exports (forward linkages)		0.472***				0.192**
		(0.075)				(0.073)
GVC participation growth - based on imports (backward linkages)	0.212*		0.330***		0.179	
	(0.114)		(0.122)		(0.112)	
GVC participation growth - based on exports (forward linkages)		0.136**		0.049		0.044
		(0.053)		(0.054)		(0.058)
R&D intensity	-0.473	-0.152				
	(0.566)	(0.638)				
TFP growth EU frontier			0.327**	0.365***	0.136	0.261**
			(0.134)	(0.126)	(0.099)	(0.107)
Lagged TFP gap EU frontier to sector			0.482***	0.490***	0.182**	0.335***
			(0.118)	(0.115)	(0.074)	(0.093)
Constant	-1.861***	-1.418***	-1.842***	-1.872***	-1.853***	-1.849***
	(0.300)	(0.232)	(0.463)	(0.452)	(0.459)	(0.435)
Observations	350	350	613	613	613	613
Adjusted R-squared	0.410	0.337	0.306	0.297	0.352	0.313

Note: *** p<0.01, ** p<0.05, * p<0.10.
Robust standard errors in parentheses, clustered at the country-sector level. Country-sector FE included. R&D intensity measured as fixed capital formation out of value added.

5.2 TFP growth of host national frontier firms

Turning to the analysis of different types of firms in the host economy, Table 4 shows the results for the TFP growth of the most productive firms in the sector – the national frontier firms (Equation 5).

The baseline results in Table 4, columns 2 and 4, are consistent with the ones for the sectoral TFP growth (Table 2) and confirm the importance of GVCs: both technology creation by the parent companies as well as the catching-up process are strongly correlated with the TFP growth of the national frontier firms in the host economy. Also, similar to Table 2, the effect of the crisis dummy drops by a third when including the rest of GVC-related explanatory variables. The findings are robust to the definition of GVC participation in terms of backward or forward linkages. Again, the correlation between the GVC-related variables and the TFP growth of the CEE frontier firms is lower when considering the exports of intermediate inputs, rather than the imports. The results are also robust to the definition of GVC linkages using value added trade flows (Table A3.1 in Annex 3).

In Annex 3 we show the estimation of Equation 5 including also the EU frontier. Similar to the case of sectoral TFP growth, we find that importing inputs is the main channel of technology transfer within GVCs. However, the GVC frontier loses significance in favour of the EU frontier when trade links are measured by the exports of intermediate inputs. This result confirms that for firms exporting intermediate inputs what matters is the export destination market rather than having direct linkages to the frontier firms in the parent countries.

Columns 3 and 5 of Table 4 interact all explanatory variables with the crisis and post-crisis period dummies. The purpose is to explore whether the capacity to learn from direct exposure to new technology and to catch-up have changed over the crisis and post-crisis period relative to the pre-crisis period (reference category). The results suggest that the absorptive capacity of CEE frontier firms dropped significantly in the post-2008 period relative to the pre-crisis one. The results disclose as well that sectors with relatively high backward linkages were actually more resilient than the rest of sectors to the crisis (and post-crisis) TFP slowdown. Interestingly, this result does not hold for sectors involved in exporting of intermediates.

Table 4: TFP growth of national frontier firms

		GVC participation based on gross imports		GVC participation based on gross exports	
	(1)	(2)	(3)	(4)	(5)
2008-2010 dummy	-0.069***	-0.046***	0.033	-0.049***	0.010
	(0.010)	(0.010)	(0.032)	(0.010)	(0.029)
Post-2010 dummy	-0.012	0.004	0.073*	0.001	0.052
	(0.009)	(0.011)	(0.039)	(0.010)	(0.034)
TFP growth GVC frontier		0.430***	0.445***	0.156***	0.182***
		(0.058)	(0.118)	(0.044)	(0.062)
TFP growth GVC frontier *2008-2010 dummy			0.045		0.031
			(0.145)		(0.108)
TFP growth GVC frontier *post-2010 dummy			-0.245*		-0.232**
			(0.143)		(0.089)
Lagged gap TFP GVC frontier to national frontier		0.364***	0.386***	0.281***	0.294***
		(0.054)	(0.052)	(0.044)	(0.041)
Lagged gap*2008-2010 dummy			-0.030***		-0.024**
			(0.010)		(0.010)
Lagged gap*post-2010 dummy			-0.028**		-0.020
			(0.012)		(0.013)
GVC participation growth		0.199**	-0.080	0.079**	0.027
		(0.079)	(0.107)	(0.036)	(0.069)
GVC participation growth *2008-2010 dummy			0.358***		0.094
			(0.134)		(0.089)
GVC participation growth *post-2010 dummy			0.317*		-0.003
			(0.181)		(0.082)
Constant	0.040***	-0.991***	-1.048***	-0.691***	-0.721***
	(0.005)	(0.148)	(0.145)	(0.112)	(0.106)
Observations	642	642	642	642	642
Adjusted R-squared	0.087	0.334	0.355	0.224	0.235

Note: *** p<0.01, ** p<0.05, * p<0.10.
Robust standard errors in parentheses, clustered at the country-sector level. Country-sector FE included.

5.3 TFP growth of host laggard firms

The next step in the empirical analysis is to investigate the determinants of TFP growth of non-frontier CEE firms (Equation 6) considering firms at the bottom percentiles of the productivity distribution. Following the crisis, TFP growth of the laggard firms has been about 9pp lower relative to the pre-crisis period (Column 1, Table 5), though, this effect drops considerably once including the GVC-related variables in the regression.

Two key messages emerge from Table 5. First, technology creation at the GVC frontier is substantially less important for TFP growth of laggards than technology creation at the national

frontier in the host economy, confirming the two-step diffusion process put forward by Bartelsman et al. (2013). Second, firms at the bottom of the productivity distribution also display higher TFP growth rates when they operate in sectors with high GVC participation growth rates (relative to laggard firms in sectors with low GVC participation). Hence, the larger the integration of sectors in GVCs, the higher the exposure of laggard firms to the frontier technology.

Table A3.2 in Annex 3 shows the results of interacting all explanatory variables with the crisis and post-crisis dummies in order to explore whether the basic relations changed during the post-2008 period. Differently from what we found for frontier firms in host economies, the interactions are not significant while the main results still hold. Thus, the basic correlation did not change during and after the crisis relative to the pre-crisis period for the laggard firms.

Table 5: TFP growth of host laggard firms

		GVC participation based on gross imports	GVC participation based on gross exports
	(1)	(2)	(3)
2008-2010 dummy	-0.090***	-0.025***	-0.029***
	(0.011)	(0.008)	(0.008)
Post-2010 dummy	-0.009	-0.022**	-0.027***
	(0.012)	(0.008)	(0.008)
TFP growth national frontier		0.920***	0.947***
		(0.049)	(0.051)
Lagged gap TFP national frontier to laggards		0.569***	0.560***
		(0.080)	(0.077)
TFP growth GVC frontier		0.151***	0.060*
		(0.041)	(0.036)
Lagged gap TFP GVC frontier to laggards		0.010	0.041
		(0.024)	(0.026)
GVC participation growth		0.203**	0.068**
		(0.079)	(0.032)
Constant	0.040***	-1.054***	-1.168***
	(0.005)	(0.113)	(0.111)
Observations	642	642	642
Adjusted R-squared	0.092	0.736	0.727

Note: *** p<0.01, ** p<0.05, * p<0.10.
Robust standard errors in parentheses, clustered at the country-sector level. Country-sector FE included.

Table A3.3 in Annex 3 presents the results for laggard firms in the host economy: (i) including at the same time backward and forward linkages; (ii) including value-added-based indicators of GVC

participation; and (iii) including the EU frontier in addition to the GVC frontier. None of the robustness checks changes our main findings. Differently from the results for the national frontier firms, all variables related to the EU frontier are not significant. An explanation for this finding might be the fact that laggard firms are probably engaged to a lesser extent in trade with frontier firms in non-CEE EU countries.

The results for mid-productive firms in the host economy are very similar to the laggard ones and are shown in Table A3.4 of Annex 3. Annex 3 shows also several other robustness exercises. Table A3.5 includes the results from estimating the baseline specification for each set of firms (sector, frontier, laggard and mid-productive) including country- and sector-fixed effects separately as well as year-fixed effects instead of controlling for country-sector fixed effects and the three time periods (pre-, post- and crisis). This specification, which also corrects for the cyclicality of TFP growth, provides very similar findings to our baseline. In Table A3.6 we include as a control the level of GVC participation in the host country/macro-sector instead of its growth rate. The findings provide evidence that not only operating in sectors with growing participation in GVCs results in higher TFP growth, but also in sectors with a higher level of GVC integration.

6 Drivers of the post-crisis TFP growth slowdown in CEE countries

6.1 Shift-share analysis

In this section, we use the results of our parametric exercise to explore the sources of the TFP growth slowdown in CEE economies in the post-crisis period relative to the pre-crisis one. In order to assess which are the main contributing factors – a decrease in the value of the regressor between the pre- and post-crisis period or a change in the estimated elasticities - we carry out a shift-share exercise. The shift-share analysis decomposes the aggregate growth rate of a given variable, in this case the change in TFP growth from the pre- to the post-crisis period, in the following components: (i) change in the value of the given determinant holding its coefficient constant at the pre-crisis level; (ii) change in the elasticity of each determinant, holding its value constant at the pre-crisis level; and finally (iii) a covariance term between the change in the determinant and the coefficient. We depart from Equation 5, the TFP growth specification for the national frontier firms, and expand it to include all interactions with the period dummies considered in Table 4, columns 3 and 5. The predicted change in TFP growth of national frontier firms in host country *z* from the pre-crisis period *t-1* to the post-crisis period *t* can be expressed then as follows[15]:

$$\Delta TFPgrowth^{E}_{z,t} = \sum_{v \in V} \Delta d^{v}_{z,t} \times w^{v}_{t-1} + \sum_{v \in V} d^{v}_{z,t-1} \times \Delta w^{v}_{t} + \Delta d^{v}_{z,t} \times \Delta w^{v}_{t} + \Delta r_{t} \quad (7)$$

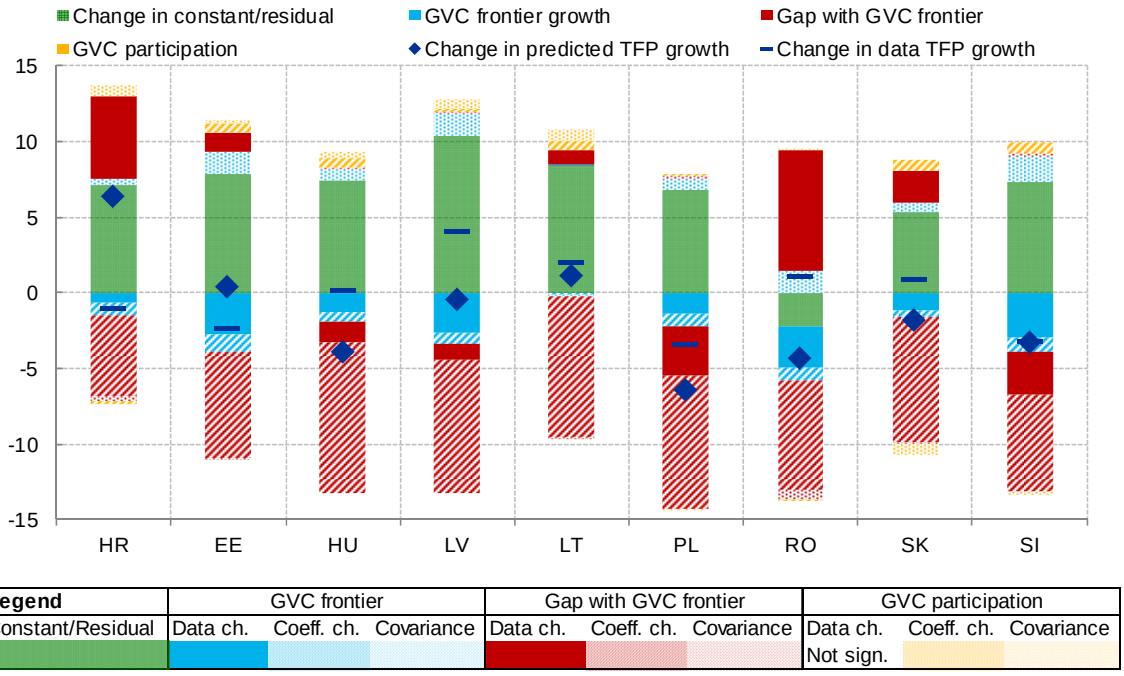
Change in predicted TFP growth of national frontier firms from the pre-crisis to the post-crisis period	Change in value of the regressor, holding its coefficient at the pre-crisis level	Change in the coefficient of the regressor, holding its value at the pre-crisis level	Covariance between value of regressor and coefficients	Residual

[15] The predicted TFP change is first estimated for each macro-sector *j* and then aggregated to the country level using the sectoral value added as weights.

where V is the set of regressors, $d_{z,t}^{v}$ represents the aggregated value of the variable v at time t in country z, w_t^v is the estimated coefficient of v at time t, r is the residual and Δ is the change between the pre-crisis and the post-crisis period.

We find that the main contributor to the decline in predicted TFP growth of the host national frontier firms is the decrease in absorptive capacity of host firms, captured by the decrease in the coefficient of the TFP gap to the GVC frontier (red bars with diagonal pattern in Figure 7). The TFP growth slowdown in non-CEE EU parent companies (solid light blue bars) also has played an important role.

Figure 7: Shift-share analysis of national frontier predicted TFP growth, 2011-2012 vs. 2003-2007
(in percentage points)



Note: Changes in contributions can be split into (i) a change in the period data averages, times the previous coefficient; (ii) a change in the coefficient, times the previous period data average; (iii) a covariance term.

6.2 The role of research and development

Given the relevant role played by the drop in absorptive capacity of national frontier firms in explaining CEE countries' slowdown in TFP growth, this sub-section explores possible factors behind that development. The seminal work of Cohen and Levinthal (1989) shows that firms' absorptive capacity depends crucially on their investment in human capital and intangibles, particularly R&D (Cohen and Levinthal, 1989; Griffith et al., 2004). According to the descriptive evidence, shown in Annex 2 (Figures A2.1 and A2.2), R&D spending as a share of GDP (or of population) has decreased or flattened in CEE countries during the 2011-2015 period. This development might have hindered the

absorptive capacity of national frontier firms in CEE countries, thus, amplifying their post-crisis TFP growth slowdown.

In order to investigate the role of R&D for TFP growth of frontier firms, we follow the approach suggested by Rajan and Zingales (1998) given the lack of firm-level information on R&D. The idea is that the drop in R&D investment by firms in the host economy will affect relatively more the absorptive capacity of firms operating in sectors which are more R&D-intensive. In other sectors, less dependent on R&D, the absorptive capacity of firms might not suffer as much due to the lower investment in intangibles. Therefore, we split sectors in a given host country-year according to their R&D intensity (defined as fixed capital formation in R&D as a share of sectoral value added). Sectors with R&D intensity above the country-year median are labelled R&D-intensive sectors, while the sectors below the median are less R&D-intensive.[16]

Table 6 shows the results of re-estimating Equation 5 considering separately R&D-intensive and less intensive sectors. Because we do not have data on R&D investment for all countries, sectors and years used in the previous analysis, we first show in column 1 the baseline results of Table 4 (pooling all sectors together) but using the sub-sample of country-sector-years with R&D data. Baseline results in this sub-sample are confirmed providing confidence that the results do not suffer from a sample bias. We find that the drop in absorptive capacity of host firms in the post-crisis period is significant only in R&D-intensive sectors, while there is no evidence of a change in elasticities for firms operating in less R&D-intensive sectors (columns 2 and 3). Furthermore, the results referring to the pre-crisis period are quite similar for R&D-intensive and less intensive sectors. Table 6 provides, thus, suggestive evidence that the observed drop in absorptive capacity of host frontier firms during the post-crisis period might be the result of their reduction in R&D investment.[17]

As a robustness check, Table A3.7 in Annex 3 uses the intellectual property products (IPP) as a different measure of investment in intangibles. Although less significant, we still find that the drop in absorptive capacity of frontier firms during the crisis period is relatively more pronounced in IPP-intensive sectors.

[16] The results are robust to using different measures of R&D intensity such as the level of gross fixed capital formation in R&D or its share of sectoral output.

[17] Another possible explanation, provided by Acemoglu et al. (2006), is that economies closer to the frontier switch to more R&D-intensive activities, while at the early stages of development they follow a rather investment-based strategy.

Table 6: TFP growth of national frontier firms, sectors split by R&D intensity (as % of value added)

	Baseline for R&D sample (pooled sectors)	R&D-intensive sectors	Less R&D-intensive sectors
	(1)	(2)	(3)
2008-2010 dummy	-0.045***	0.027	0.013
	(0.014)	(0.038)	(0.084)
Post-2010 dummy	0.016	0.088*	0.084
	(0.015)	(0.043)	(0.087)
TFP growth GVC frontier	0.464***	0.677**	0.416
	(0.065)	(0.255)	(0.265)
TFP growth GVC frontier*2008-2010 dummy		-0.320	0.005
		(0.250)	(0.347)
TFP growth GVC frontier*Post-2010 dummy		-0.494**	0.028
		(0.212)	(0.274)
Lagged gap TFP GVC frontier to national frontier	0.481***	0.530***	0.511***
	(0.063)	(0.090)	(0.108)
Lagged gap*2008-2010 dummy		-0.024*	-0.027
		(0.014)	(0.023)
Lagged gap*2011-2012 dummy		-0.023*	-0.036
		(0.012)	(0.029)
GVC participation growth	0.204**	-0.183	-0.538
	(0.096)	(0.148)	(0.444)
GVC participation growth*2008-2010 dummy		0.618**	1.217*
		(0.250)	(0.631)
GVC participation growth*2011-2012 dummy		0.344*	1.069+
		(0.191)	(0.713)
Constant	-1.361***	-1.447***	-1.480***
	(0.183)	(0.258)	(0.327)
Observations	369	184	185
Adjusted R-squared	0.413	0.461	0.408

Note: *** p<0.01, ** p<0.05, * p<0.10.
Robust standard errors in parentheses, clustered at the country-sector level. Country-sector FE included.

7 Conclusion

The literature has long emphasized the role of GVCs for spurring productivity growth. However, less is known about the mechanisms through which GVCs contribute to the development process.

In this paper, we focus on the role of GVCs as a channel of technology transfer from parent firms to host economies. In particular, we explore the case of CEE countries, which are deeply integrated in GVCs and, therefore, depend to a large extent on technology creation at the parent firms, what we call the GVC frontier. We show that the main channel of technology diffusion between parent and host firms is backward linkages, that is, the import of intermediate inputs, rather than the forward linkages. According to the literature, host firms importing inputs are exposed to more variety and better complementarities as well as better technology embedded in the imported inputs. Moreover, in order

to include foreign, more complex, inputs in the production function host firms might need to hire skilled workers which increase their productivity. We find as well that firms exporting inputs to non-CEE EU countries, independently of their GVC links with host economies, also feature higher TFP growth. This second result is in line with the findings of Brambilla et al. (2012) on the importance for productivity of the technological sophistication of export destinations.

Our results confirm the idea that technology created at the global level is diffused to the rest of the economies via a two-stage process. In particular, frontier firms are directly involved in GVCs and exposed to new technology, while non-frontier firms mainly benefit from their participation in domestic production networks, as well as, to a lesser extent, from direct contact with parent companies.

We use these results to explain the slowdown in TFP growth of CEE countries in the post-crisis period. We find that the main contributor to this decline is the decrease in host firms' absorptive capacity of new knowledge, possibly caused by a drop in R&D investment, as well as the slowdown in technology creation of parent firms.

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Annex 1

Table A1.1: Data coverage

Country	Sample period	Missing sectors	Exclusion rule	Coverage vis-à-vis National Accounts [1]	
				Employment	VA
Croatia	2003-2012	none	none	56%	75%
Estonia	2003-2012	none	none	58%	34%
Hungary	2004-2012	none	none	56%	49%
Latvia	2006-2012	none	none	59%	43%
Lithuania	2003-2011	none	none	59%	36%
Poland	2005-2012	Accommodation and food service activities	>19 employees	38%	29%
Romania	2004-2012	none	>19 employees	41%	47%
Slovakia	2003-2012	none	>19 employees	38%	67%
Slovenia	2003-2012	none	none	55%	44%

[1] Source: Eurostat – National Accounts Series.

Note: CompNet data for Poland, Romania and Slovakia refer to firms with 20 employees or more. Average coverage over the respective sample period.

Variable definitions

a. Sector TFP growth:

$TFP\ growth_{z,j,t} \cong \sum_{i=p10-20,p30-70,p80-90} w_{z,j,i,t} tfp\ growth_{z,j,i,t}$

where *z* stands for country, *j* for sector, *t* for year and *i* for the set of firms belonging to either the average of the 10th and 20th percentiles (laggard firms), the average of the 30th to 70thpercentiles (mid-productive firms), or the average of the 80th and 90th percentiles of the TFP distribution (frontier firms).[18] *w* captures the (time-varying) share of employment of each set of firms.[19]

b. TFP level and growth:

TFP is computed as the difference between observed and expected firm-level output, given the industry-specific coefficients of labour and capital estimated using a semi-parametric approach. More concretely, we depart from a Cobb-Douglas production function:

$RVA_{it} = A_{it} K_{it}^{\alpha} L_{it}^{1-\alpha}$

where *RVA* is real value added of firm *i* at time *t* operating in a given two-digit industry (according to the NACE rev.2 sector classification), K is its real book value of net capital and L its total employment. The above production function is estimated in logs building on the approach developed by Olley and Pakes (1996), Levinshon and Petrin (2003), Ackerberg et al (2006) and using an alteration of Wooldridge (2009) proposed by Galuščák and Lízal (2011). The approach uses (lagged value of) inputs to control for unobserved productivity shocks to address the simultaneity bias

[18] Results are robust to different definitions of frontier firms, e.g. including 99th percentile as well.

[19] Results are robust to a time-invariant definition of *w*.

stemming from the fact that the firm knows its productivity when choosing inputs for production.[20] Because labour and TFP are simultaneously determined, while capital takes time to build, labour is instrumented by its first lag. In addition, several higher order and interaction terms between capital and materials are included in order to control for non-linearities. A full set of year dummies is included to control for sector-specific trends. Standard errors are clustered at the firm-level. Following the estimation, firm-level TFP is retrieved as the difference between (log) real value added and the fitted values for (log) real capital, (log) labour and a year trend:

$$TFP_{it} = RVA_{it} - \left(\hat{\beta}_0 + \hat{\beta}_1 k_{it} + \hat{\gamma} Year_t + \hat{\omega} L_{i(t-1)}\right)$$

c. GVC participation: value added concept (robustness)

Wang et al. (2014) develop a bilateral trade accounting framework in order to decompose gross exports flows at the sectoral level into their value added components, taking into account the direct and indirect trade partners along the value chain as well as double-counting of trade flows. In this framework, two possible indicators for sectoral GVC participation emerge:

$$Backward\ GVC\ participation_{z,j,t} = \frac{Foreign\ value\ added\ in\ exports_{z,j,t}}{Gross\ exports_{z,j,t}}$$

$$Forward\ GVC\ participation_{z,j,t} = \frac{Own\ value\ added\ in\ third\ countries'\ exports_{z,j,t}}{Gross\ exports_{z,j,t}}$$

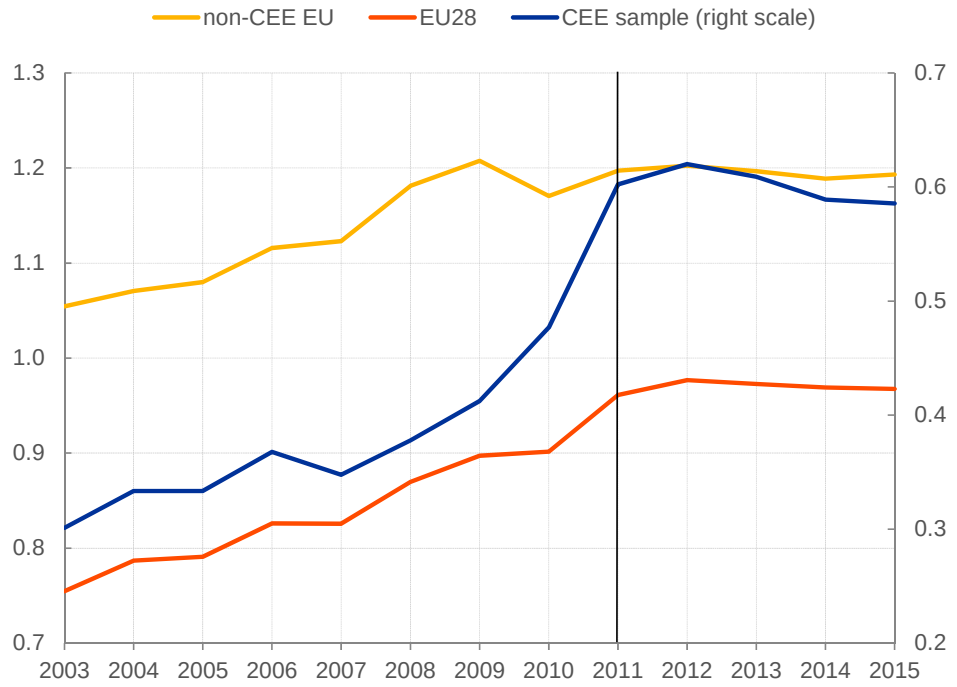
where *z* is the given country, *j* the sector and *t* the year. The forward GVC participation captures also the own value added, which is exported and then returns back to the country as third countries' exports, excluding this component does not change the results.

[20] For more information on TFP estimation in CompNet, please refer to the CompNet taskforce (2014) reference paper as well as Lopez-Garcia et al. (2015). See also Olley and Pakes (1996), Levinsohn and Petrin (2003), and Wooldridge (2009).

Annex 2: R&D in host economies

Figure A2.1: R&D as a share of GDP

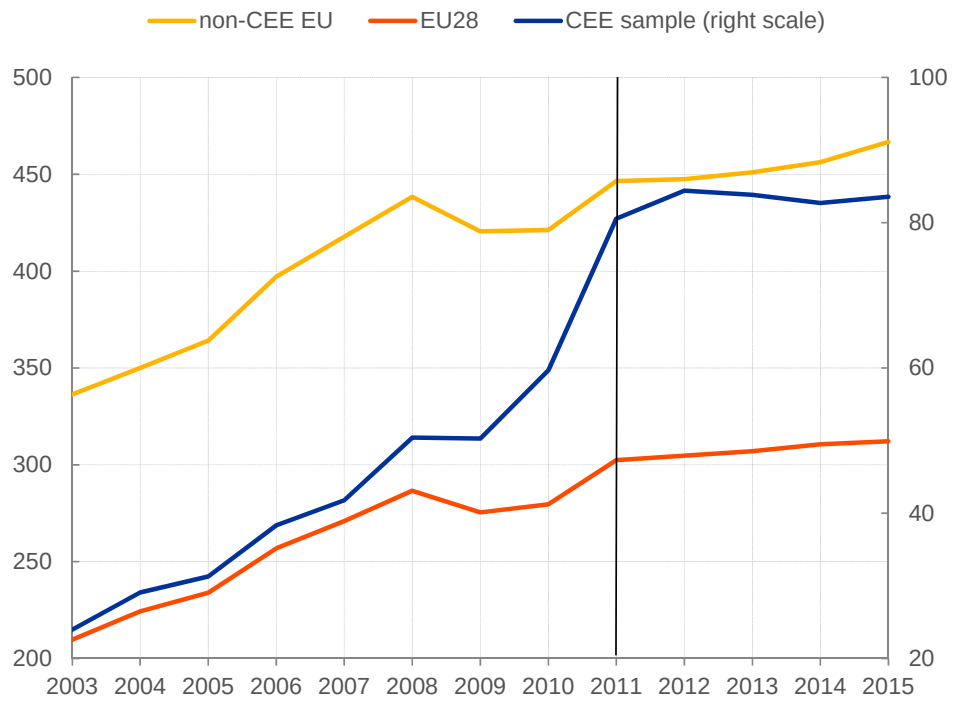
(in percentage points)



Source: Authors' calculations based on Eurostat.
Note: R&D captures R&D expenditure of the business enterprise sector. Non-CEE EU refers to the unweighted average of Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. CEE sample: Croatia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

Figure A2.2: R&D as a share of population

(in percentage points)



Source: Authors' calculations based on Eurostat.

Note: R&D captures R&D expenditure of the business enterprise sector. Non-CEE EU refers to the unweighted average of Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. CEE sample: Croatia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

Annex 3: Robustness of econometric results

Table A3.1: TFP growth of host frontier firms - robustness

	GVC participation imports/ exports	Backward GVC participation	Forward GVC participation	GVC participation based on imports and EU frontier	GVC participation based on exports and EU frontier
	(1)	(2)	(3)	(4)	(5)
2008-2010 dummy	-0.043***	-0.050***	-0.051***	-0.038***	-0.037***
	(0.010)	(0.010)	(0.010)	(0.011)	(0.011)
Post-2010 dummy	0.007	0.002	0.002	0.019	0.025**
	(0.010)	(0.010)	(0.010)	(0.012)	(0.010)
TFP growth GVC frontier imports/backward	0.404***	0.392***		0.376***	
	(0.057)	(0.060)		(0.065)	
Lagged TFP gap GVC frontier imports/backward to national frontier	0.308***	0.352***		0.253***	
	(0.049)	(0.055)		(0.077)	
TFP growth GVC frontier exports/forward	0.006		0.170***		0.072
	(0.042)		(0.045)		(0.048)
Lagged TFP gap GVC frontier exports/forward to national frontier	0.070*		0.285***		0.115**
	(0.039)		(0.044)		(0.054)
GVC participation growth - imports/backward	0.259**	0.733***		0.192**	
	(0.101)	(0.174)		(0.081)	
GVC participation growth - exports/forward	-0.052		-0.448		0.065*
	(0.037)		(0.291)		(0.034)
TFP growth EU frontier				0.102	0.206***
				(0.072)	(0.066)
Lagged TFP gap EU frontier to national frontier				0.127**	0.249***
				(0.054)	(0.049)
Constant	-1.013***	-0.955***	-0.696***	-1.118***	-1.116***
	(0.158)	(0.154)	(0.114)	(0.149)	(0.146)
Observations	642	642	642	642	642
Adjusted R-squared	0.337	0.355	0.225	0.341	0.271

Note: *** p<0.01, ** p<0.05, * p<0.10.
Robust standard errors in parentheses, clustered at the country-sector level. Country-sector FE included.

Table A3.2: TFP growth of host laggard firms – interaction with period dummies

		GVC participation based on imports		GVC participation based on exports	
	(1)	(2)	(3)	(4)	(5)
2008-2010 dummy	-0.090***	-0.025***	-0.009	-0.029***	-0.032
	(0.011)	(0.008)	(0.042)	(0.008)	(0.038)
Post-2010 dummy	-0.009	-0.022**	-0.016	-0.027***	-0.004
	(0.012)	(0.008)	(0.038)	(0.008)	(0.036)
TFP growth national frontier		0.920***	0.905***	0.947***	0.886***
		(0.049)	(0.074)	(0.051)	(0.073)
TFP growth national frontier *2008-2010 dummy			0.063		0.149
			(0.099)		(0.101)
TFP growth national frontier *post-2010 dummy			-0.127		-0.137
			(0.110)		(0.107)
Lagged gap TFP national frontier to laggards		0.569***	0.587***	0.560***	0.564***
		(0.080)	(0.079)	(0.077)	(0.078)
Lagged gap TFP national frontier to laggards *2008-2010 dummy			-0.009		-0.012
			(0.021)		(0.020)
Lagged gap TFP national frontier to laggards *post-2010 dummy			-0.027		-0.022
			(0.023)		(0.024)
TFP growth GVC frontier		0.151***	0.074	0.060*	0.029
		(0.041)	(0.091)	(0.036)	(0.041)
TFP growth GVC frontier *2008-2010 dummy			0.147		0.084
			(0.103)		(0.064)
TFP growth GVC frontier *post-2010 dummy			-0.100		-0.061
			(0.140)		(0.098)
Lagged gap TFP GVC frontier to laggards		0.010	0.001	0.041	0.039
		(0.024)	(0.028)	(0.026)	(0.030)
Lagged gap TFP GVC frontier to laggards *2008-2010 dummy			-0.000		0.006
			(0.010)		(0.010)
Lagged gap TFP GVC frontier to laggards *post-2010 dummy			0.010		0.004
			(0.012)		(0.012)
GVC participation growth		0.203**	0.191**	0.068**	0.048
		(0.079)	(0.096)	(0.032)	(0.060)
GVC participation growth *2008-2010 dummy			-0.051		-0.005
			(0.089)		(0.055)
GVC participation growth *post-2010 dummy			-0.143		0.013
			(0.159)		(0.069)
Constant	0.040***	-1.054***	-1.044***	-1.168***	-1.165***
	(0.005)	(0.113)	(0.109)	(0.111)	(0.106)
Observations	642	642	642	642	642
Adjusted R-squared	0.092	0.736	0.740	0.727	0.732

Note: *** p<0.01, ** p<0.05, * p<0.10.
Robust standard errors in parentheses, clustered at the country-sector level. Country-sector FE included.

Table A3.3: TFP growth of host laggard firms - robustness

	GVC participation imports/ exports	Backward GVC participation	Forward GVC participation	GVC participation based on imports and EU frontier	GVC participation based on exports and EU frontier
	(1)	(2)	(3)	(4)	(5)
2008-2010 dummy	-0.023***	-0.027***	-0.028***	-0.023**	-0.029***
	(0.008)	(0.008)	(0.008)	(0.009)	(0.008)
Post-2010 dummy	-0.020**	-0.020**	-0.026***	-0.017	-0.028***
	(0.009)	(0.008)	(0.008)	(0.010)	(0.009)
TFP growth GVC frontier imports/backward	0.130***	0.166***		0.131***	
	(0.044)	(0.040)		(0.047)	
Lagged TFP gap GVC frontier imports/backward to laggards	-0.034	0.012		-0.036	
	(0.042)	(0.025)		(0.055)	
TFP growth GVC frontier exports/forward	0.031		0.051		0.062
	(0.034)		(0.036)		(0.040)
Lagged TFP gap GVC frontier exports/forward to laggards	0.057		0.038		0.042
	(0.042)		(0.025)		(0.045)
TFP growth national frontier	0.916***	0.918***	0.954***	0.915***	0.947***
	(0.049)	(0.049)	(0.050)	(0.049)	(0.051)
Lagged TFP gap national frontier to laggards	0.566***	0.569***	0.564***	0.561***	0.560***
	(0.080)	(0.081)	(0.077)	(0.079)	(0.074)
GVC participation growth - imports/backward	0.190*	0.210*		0.211**	
	(0.110)	(0.121)		(0.081)	
GVC participation growth - exports/forward	0.006		0.207		0.070**
	(0.058)		(0.221)		(0.032)
TFP growth EU frontier				0.003	-0.015
				(0.045)	(0.048)
Lagged TFP gap EU frontier to laggards				0.055	-0.001
				(0.056)	(0.048)
Constant	-1.150***	-1.064***	-1.162***	-1.117***	-1.166***
	(0.217)	(0.118)	(0.112)	(0.146)	(0.139)
Observations	642	642	642	642	642
Adjusted R-squared	0.737	0.734	0.726	0.737	0.727

Note: *** p<0.01, ** p<0.05, * p<0.10.
Robust standard errors in parentheses, clustered at the country-sector level. Country-sector FE included.

Table A3.4: TFP growth of mid-productive firms –robustness

		GVC participation based on imports		GVC participation based on exports	
	(1)	(2)	(3)	(4)	(5)
2008-2010 dummy	-0.069***	-0.004	-0.019	-0.004	-0.033
	(0.009)	(0.005)	(0.022)	(0.004)	(0.021)
Post-2010 dummy	-0.014	-0.004	-0.032	-0.006	-0.030
	(0.009)	(0.005)	(0.029)	(0.005)	(0.028)
TFP growth national frontier		0.862***	0.782***	0.884***	0.792***
		(0.028)	(0.034)	(0.029)	(0.037)
TFP growth national frontier *2008-2010 dummy			0.142***		0.161***
			(0.046)		(0.045)
TFP growth national frontier *post-2010 dummy			-0.008		-0.027
			(0.060)		(0.060)
Lagged gap TFP national frontier to middle		0.593***	0.549***	0.610***	0.560***
		(0.072)	(0.068)	(0.072)	(0.068)
Lagged gap TFP national frontier to middle*2008-2010 dummy			0.022		0.024
			(0.018)		(0.016)
Lagged gap TFP national frontier to middle*post-2010 dummy			0.014		0.018
			(0.021)		(0.019)
TFP growth GVC frontier		0.095***	0.077	0.024	0.029
		(0.019)	(0.047)	(0.018)	(0.025)
TFP growth GVC frontier *2008-2010 dummy			0.020		0.013
			(0.053)		(0.036)
TFP growth GVC frontier *post-2010 dummy			-0.009		-0.059
			(0.067)		(0.051)
Lagged gap TFP GVC frontier to middle		0.032*	0.036*	0.035**	0.040**
		(0.018)	(0.020)	(0.017)	(0.017)
Lagged gap TFP GVC frontier to middle*2008-2010 dummy			-0.001		0.002
			(0.005)		(0.005)
Lagged gap TFP GVC frontier to middle*post-2010 dummy			0.004		0.003
			(0.006)		(0.007)
GVC participation growth		0.065*	0.057	0.019	0.020
		(0.037)	(0.064)	(0.016)	(0.033)
GVC participation growth *2008-2010 dummy			-0.021		-0.011
			(0.062)		(0.034)
GVC participation growth *post-2010 dummy			0.027		-0.004
			(0.111)		(0.032)
Constant	0.038***	-0.608***	-0.585***	-0.626***	-0.597***
	(0.004)	(0.064)	(0.069)	(0.063)	(0.062)
Observations	642	642	642	642	642
Adjusted R-squared	0.093	0.861	0.865	0.857	0.863

Note: *** p<0.01, ** p<0.05, * p<0.10.
Robust standard errors in parentheses, clustered at the country-sector level. Country-sector FE included.

Table A3.5: Baseline with country, sector, and year dummies

	Sector	Frontier	Mid-productive	Laggards
	(1)	(2)	(3)	(4)
TFP growth national frontier			0.816***	0.878***
			(0.033)	(0.052)
Lagged gap TFP national frontier to middle			0.054***	
			(0.017)	
Lagged gap TFP national frontier to laggards				0.015*
				(0.008)
TFP growth GVC frontier	0.161*	0.095	0.043	0.050
	(0.090)	(0.083)	(0.027)	(0.053)
Lagged gap TFP GVC frontier to sector	0.018			
	(0.016)			
Lagged gap TFP GVC frontier to national frontier		0.002		
		(0.008)		
Lagged gap TFP GVC frontier to middle			0.009***	
			(0.003)	
Lagged gap TFP GVC frontier to laggards				0.024***
				(0.006)
GVC participation growth	0.287***	0.155**	0.084**	0.247**
	(0.086)	(0.063)	(0.042)	(0.094)
Constant	-0.055	-0.001	-0.082***	-0.147***
	(0.042)	(0.023)	(0.020)	(0.030)
Observations	613	642	642	642
Adjusted R-squared	0.101	0.199	0.812	0.636

Note: *** p<0.01, ** p<0.05, * p<0.10.
Robust standard errors in parentheses, clustered at the country-sector level. Country, sector, and year FE included.

Table A3.6: Baseline with level of GVC participation instead of growth in GVC participation

	Sector	Frontier	Mid-productive	Laggards
	(1)	(2)	(3)	(4)
2008-2010 dummy	-0.054***	-0.049***	-0.005	-0.028***
	(0.014)	(0.011)	(0.005)	(0.009)
Post-2010 dummy	-0.014	-0.002	-0.007	-0.026**
	(0.017)	(0.012)	(0.006)	(0.010)
TFP growth national frontier			0.859***	0.921***
			(0.029)	(0.050)
Lagged gap TFP national frontier to middle			0.597***	
			(0.070)	
Lagged gap TFP national frontier to laggards				0.572***
				(0.080)
TFP growth GVC frontier	0.493***	0.452***	0.101***	0.176***
	(0.057)	(0.056)	(0.018)	(0.039)
Lagged gap TFP GVC frontier to sector	0.542***			
	(0.137)			
Lagged gap TFP GVC frontier to national frontier		0.380***		
		(0.056)		
Lagged gap TFP GVC frontier to middle			0.040**	
			(0.019)	
Lagged gap TFP GVC frontier to laggards				0.023
				(0.026)
GVC participation	0.270***	0.169***	0.086**	0.122**
	(0.089)	(0.060)	(0.039)	(0.054)
Constant	-1.815***	-1.089***	-0.671***	-1.157***
	(0.461)	(0.164)	(0.065)	(0.114)
Observations	613	642	642	642
Adjusted R-squared	0.354	0.336	0.863	0.735

Note: *** p<0.01, ** p<0.05, * p<0.10.
Robust standard errors in parentheses, clustered at the country-sector level. Country-sector FE included.

Table A3.7: TFP growth of national frontier firms, sectors split by IPP intensity

	IPP intensive sectors	Less IPP intensive sectors
	(1)	(2)
2008-2010 dummy	0.046	-0.046
	(0.041)	(0.067)
Post-2010 dummy	0.074*	0.054
	(0.044)	(0.080)
TFP growth GVC frontier	0.931**	0.453*
	(0.358)	(0.233)
TFP growth GVC frontier*2008-2010 dummy	-0.476	-0.043
	(0.320)	(0.308)
TFP growth GVC frontier*Post-2010 dummy	-0.731**	0.016
	(0.320)	(0.240)
Lagged gap TFP GVC frontier to national frontier	0.535***	0.466***
	(0.092)	(0.094)
Lagged gap*2008-2010 dummy	-0.024*	-0.004
	(0.014)	(0.020)
Lagged gap*2011-2012 dummy	-0.018	-0.022
	(0.011)	(0.025)
GVC participation growth	-0.142	-0.397
	(0.116)	(0.364)
GVC participation growth*2008-2010 dummy	0.504***	1.225**
	(0.180)	(0.514)
GVC participation growth*2011-2012 dummy	0.359**	0.986
	(0.142)	(0.625)
Constant	-1.455***	-1.378***
	(0.263)	(0.289)
Observations	188	229
Adjusted R-squared	0.447	0.417

Note: *** p<0.01, ** p<0.05, * p<0.10.
Robust standard errors in parentheses, clustered at the country-sector level. Country-sector FE included.

Table A3.8: TFP growth of national frontier firms, sectors split by R&D intensity and GVC participation based on exports

	Baseline for R&D sample	R&D intensive sectors	R&D less intensive sectors
	(1)	(2)	(3)
2008-2010 dummy	-0.044***	0.018	0.038
	(0.013)	(0.030)	(0.067)
Post-2010 dummy	0.013	0.073*	0.071
	(0.015)	(0.040)	(0.101)
TFP growth GVC frontier	0.170***	0.138	0.230**
	(0.058)	(0.221)	(0.105)
TFP growth GVC frontier*2008-2010 dummy		0.369	-0.130
		(0.278)	(0.171)
TFP growth GVC frontier*Post-2010 dummy		-0.180	-0.389**
		(0.279)	(0.160)
Lagged gap TFP GVC frontier to national frontier	0.365***	0.329***	0.362***
	(0.053)	(0.064)	(0.071)
Lagged gap*2008-2010 dummy		-0.029***	-0.030+
		(0.010)	(0.019)
Lagged gap*2011-2012 dummy		-0.024*	-0.024
		(0.012)	(0.038)
GVC participation growth	0.120***	-0.018	-0.044
	(0.033)	(0.044)	(0.263)
GVC participation growth*2008-2010 dummy		0.247***	-0.168
		(0.070)	(0.466)
GVC participation growth*2011-2012 dummy		0.078	0.069
		(0.103)	(0.266)
Constant	-0.938***	-0.802***	-0.967***
	(0.141)	(0.164)	(0.195)
Observations	369	184	185
Adjusted R-squared	0.290	0.371	0.241

Note: *** p<0.01, ** p<0.05, * p<0.10.
Robust standard errors in parentheses, clustered at the country-sector level. Country-sector FE included.

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Francesco Chiacchio
Bruegel, Brussels, Belgium; email: francesco.chiacchio@bruegel.org

Katerina Gradeva
European Central Bank, Frankfurt am Main, Germany; email: katerina.gradeva@ecb.europa.eu

Paloma Lopez-Garcia
European Central Bank, Frankfurt am Main, Germany; email: paloma.lopez-garcia@ecb.europa.eu

Postal address	60640 Frankfurt am Main, Germany
Telephone	+49 69 1344 0
Website	www.ecb.europa.eu

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