GVC spillovers on total factor productivity of local firms: evidence from the Russian Federation*

Igor Drapkin,[a] Anna Fedyunina[b] and Yuri Simachev[b]

Abstract

Global value chains (GVCs) generate significant effects on participating firms. But can GVCs affect other companies in the host economies? We propose a conceptual framework for GVC spillovers and test it using data for Russian manufacturing firms in 2009–2015. Using a panel estimation technique with random and fixed effects, we find that firms in industries that are intensively integrated into GVCs, on average, have higher total factor productivity (TFP), controlling for firm heterogeneity, industry and region fixed effects. TFP gains in GVCs are unequally distributed and depend on (i) the industry's position in the GVC, (ii) the industry's technological intensity and (iii) the firm's TFP level. We relate the findings to the evidence of the "optimal" technological gap that maximizes productivity spillovers for national companies. The results are highly relevant for policymakers as they prove that trade policy and foreign direct investment attraction policy should not go hand in hand but should be incorporated into GVC-oriented policy to encourage the full range of TFP improvements in local (non-GVC-included) firms. To fully benefit from GVC-oriented policy, State policy should encourage the development of inter-firm links. In addition, our results support the importance of evolutionary structural changes in economic upgrading in GVCs and the strength of the role of policies oriented towards medium-technology industries as drivers of technological development.

Keywords: GVC spillovers, forward and backward linkages, TFP, Russian manufacturing

JEL classification codes: C67, F10, F23, O12,

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[a] Corresponding author. National Research University Higher School of Economics, Moscow, Russian Federation; Ural Federal University, Yekaterinburg, Russian Federation (i.m.drapkin@mail.ru)

[b] National Research University Higher School of Economics, Moscow, Russian Federation

1. Introduction

Contemporary production processes are usually divided by different stages and locations and require coordination through arm's-length transactions or within a vertically integrated firm (Baldwin and Yan, 2017). This determined the emergence of the phenomenon of global value chains (GVCs), where production processes are subdivided into fine slices and each firm specializes in a particular set of activities (Globerman, 2011; WTO, 2019). The growing role of GVCs in world production has provoked an explosion in the number of publications devoted to the phenomenon of GVCs and, particularly, the effects of vertical specialization on productivity at the macro level (Constantinescu et al., 2019; Formai and Caffarelli, 2016; Kummritz, 2016; Taglioni and Winkler, 2016). Empirical evidence confirms the existence of productivity premia for exporting and importing firms (see, for instance, well-known extensive surveys of relevant literature (Singh, 2010; Wagner, 2007 and 2012) and recent theoretical (Geishecke et al., 2017) and empirical studies (Brambilla, 2017)). It has been shown that countries with lower income, lower export participation rates and worse regulatory quality have, on average, higher productivity premia for exports (ISGEP, 2008) and that intercountry exporter premia can be accounted for by countries' average productivity and variation in productivity and trade costs dispersion (Kiyota et al., 2018; Geishecke et al., 2017). This emphasizes the expanding role of GVCs in productivity growth in developing economies – in particular, the Russian economy – that are trapped in a lack of or slow technological progress (Simachev et al., 2019) and steadily falling productivity for the last 10–15 years (Blöchliger and Wildnerova, 2020; Voskoboynikov, 2020).

In this paper, we investigate spillover effects from GVCs on the productivity of Russian manufacturing firms. The participation of the Russian economy in GVCs is rather limited and based predominantly on low value added activities and supply of raw materials and simple intermediates (Fedyunina et al., 2020; Meshkova and Moiseichev, 2016). There is evidence of positive effects of FDI inflows on the quality and productivity of Russian exporters (Kadochnikov and Fedyunina, 2017; Poupakis, 2022). Yet, GVC spillovers come not only from local affiliates of multinational companies, but also from global buyers and sellers.[1]

The purpose of this study is to empirically estimate the spillover effects of participation in GVCs on the productivity of Russian manufacturing companies. Our approach is based on two strands of the literature. We combine theoretical and empirical results on the relationship between firms' participation in international trade and productivity spillovers with the growing literature on the effects on firms of

[1] See, for instance, Murakami and Otsuka (2020) who provide an extensive survey of FDI and GVC spillovers literature.

participation in global value chains (GVCs). To build an empirical model, we use the now-standard spillover equation specification following Smarzynska and Javorcik (2004) and augment it with measures of GVC participation at the industry level, which is in line with Hagemejer (2015) and Montalbano et al. (2016). Measures of GVC participation, in turn, are in line with two approaches. The first approach comes from Hummels et al. (2001) and Johnson and Noguera (2012), who introduced the term "vertical specialization" to describe the increasingly sequential nature of world production and defined the foreign content of a country's exports as a measure of international production sharing. Our measures of participation in GVCs at the industry level comes from the UIBE (University of International Business and Economics) GVC database, which is a secondary (derived) database based on the publicly released ICIO tables and in accordance with methods developed by Wang et al. (2017a and 2017b).

This study extends the literature by making the following contributions. It extends the narrow, micro-level, empirical evidence on the effects of GVC spillovers on firm productivity on the basis of data on Russian manufacturing firms and estimates firms' productivity gains from their position in GVCs. The empirical evidence shows that channels for positive TFP spillovers are wider than just direct GVC effects for GVC-included firms and also include indirect spillovers for non-GVC firms. This opens up a discussion about the exact channels through which GVC spillovers are transmitted to local firms.

The findings of this paper are relevant for policymakers not only in the Russian Federation, but in other economies oriented towards increases in productivity and upgrading in GVCs. The findings call for a GVC-oriented policy as an integrated approach to FDI and international trade policies to ensure positive TFP spillovers. In addition to the need to synchronize trade and FDI policy measures, we discuss a number of other issues that policymakers should consider when they design GVC-oriented policy. Our findings strongly suggest that special attention should be paid to measures oriented towards the expansion of inter-firm links in GVC-upgrading economies in particular, between foreign and domestic firms, and between exporting and non-exporting firms, including indirect exporters. In addition, our results support the evolutionary approach to economic development and prove that medium-tech industries, but not high-tech industries may benefit more in terms of total factor productivity (TFP) from participation in GVCs.

The study is organized as follows: Section 2 discusses theoretical and empirical evidence on GVC spillovers and develops testable hypotheses. Section 3 introduces the conceptual model. In section 4 we discuss the patterns of Russian participation in GVCs with particular reference to major changes in the trade policy of the Russian Federation. Data and methodology are presented in section 5. Section 6 deals with estimation results, and section 7 discusses the conclusions and presents policy implications.

2. Literature review and hypothesis development

Empirical literature on external effects from GVC participation is significantly scarce. GVC studies are largely conceptual and use mainly the case-study approach.[2] This approach allows researchers to discuss the relationships between foreign and local firms in GVCs and exact mechanisms of spillover translation within horizontal (intra-industry) and vertical (inter-industry) links that are reflected in higher productivity of local firms. However, this approach does not allow for the aggregation of results and the synthesis of accumulated evidence, as in the literature on FDI spillovers. Thus, studies of FDI spillovers are extremely helpful for summarizing and explaining GVC spillovers to local firms (Murakami and Otsuka, 2020; Taglioni and Winkler, 2016) given that FDI remains the main driver of GVCs (WTO, 2019).

Based on the literature review, we distinguish a number of spillovers to local firms from GVC participation, as follows:

Demand effect. Lead firms in GVCs usually require specific intermediate products or quality and/or variety improvements of local supply. This leads to performance improvements in local GVC participants and, through market adjustment mechanisms, to improvements in non-participants. Demand effect is similar to what is usually called *export effect* in international trade literature. It argues that access to larger foreign markets allows exporting firms to exploit scale economies and learn about new technologies and products, and it increases their incentives to invest and innovate (Baldwin and Yan, 2017; Bontadini and Saha, 2021; Winkler and Farole, 2015). Export effects have been introduced by seminal theoretical papers (Bernard et al., 1995; Melitz, 2003) and have been documented in a large number of empirical papers.[3] In line with other studies, evidence from Russian data suggests that Russian exporters are larger, are more productive and have higher innovation intensity (Wilhelmsson and Kozlov, 2007). Based on this discussion, it is expected that

H1. Firms in export-oriented industries (industries with higher domestic value added in exports) are more productive.

Supply effect. Local GVC participants can improve the quality of exported goods through access to a greater variety of inputs available for them in GVCs or through the opportunity to use advanced technologies embedded in the imported intermediates (Xu and Mao, 2018). Improving the quality of locally produced goods through networks affects the upgrading of quality of other local firms. The supply effect is similar to what is called the import effect in international trade literature.

[2] See, for instance, recent review of GVC studies by Murakami and Otsuka (2020).

[3] Including extensive surveys by Greenaway and Kneller (2007); López (2005), Singh (2010) and Wagner (2007 and 2012).

It states that a firm's productivity increases when the firm has access to foreign inputs and to technologies not available at home (Baldwin and Yan, 2017; Bontadini and Saha, 2021; Winkler and Farole, 2015). The effect has been theoretically shown by Grossman and Rossi-Hansberg (2008) and confirmed by empirical studies in Canada, Chile, Hungary, India and Indonesia (Goldberg et al., 2010; Gu and Yan, 2014; Halpern et al., 2015; Kasahara and Lapham, 2013; Kasahara and Rodrigue, 2008; Topalova and Khandelwal, 2011). Thus, it is proposed that

H2. Firms in import-intensive industries (industries with higher shares of foreign value added in the final product) are more productive.

We believe that firms also benefit not only from direct backward and forward linkages in GVCs, but also through other types of relations with lead firms in GVCs:

- *Assistance effect.* Lead firms can transfer knowledge, technological and managerial capabilities to local suppliers to ensure that their quality requirements and standards are met. This also may lead to quality improvements in non-participants through market adjustment mechanisms, given that they built their absorptive capacity.
- *Training effect.* Lead firms can organize training for local firms that through labour market turnover will improve human capital also in non-GVC participants, resulting in overall improvements.
- *Demonstration effect.* Local firms among the GVC and non-GVC participants can introduce organizational, process and production innovations through imitation and reverse engineering based on GVC practices.

These effects are what is discussed in international trade literature as the *complementary export and import causal effect* benefiting firms from both developing (e.g. Chile, Namibia and South Africa) (Kasahara and Lapham, 2013; Winkler and Farole, 2015) and developed countries (e.g. Belgium, Canada, France, Germany, Italy, Spain, Sweden and the United States) (Baldwin and Yan, 2017; Bas and Strauss-Khan, 2014; Bernard et al., 2009; Castellani and Fassio, 2019; Fariñas and Martin-Markos, 2010; Muuls and Pisu, 2009; Turco and Maggioni, 2013; Vogel and Wagner, 2010). Empirical evidence for the Russian Federation confirms that manufacturing firms that import high-tech intermediates have higher export intensity (Fedyunina and Averyanova, 2018). Thus, it is expected that

H3. Firms in industries with a greater degree of forward and backward participation in GVCs are more productive.

The GVC position of an industry may differ considerably across countries, which reflects differences in the location of each country along a particular production network. For example, in the textile and apparel industry, China, India and Turkey are located at the late stages of the GVC since they produce the final products,

whereas the Russian Federation is positioned at the early stages of the GVC since it provides natural resource–based intermediate inputs. A relatively limited but increasing number of studies capture the "length" of linkages between countries and industries or between producers and consumers.[4] With regard to relative position in GVCs, it has been shown that value added gains differ significantly not only between sectors, but also for manufacturing industries (Meng et al., 2020; Wang et al., 2017b). Several reasons likely explain this phenomenon. First, increasing processing trade leads to higher specialization in manufacturing industries. Thus, for some industry we can find high value added production activities of more complex intermediate goods in one country and low value added production activities such as assembling final products or producing homogeneous intermediates in other countries. Second, assembling becomes a lower value added activity as a labour-intensive process under increasing wages and increasing usage of intermediate imports. Third, the value added of a country's industry depends on its industrial organization. As in the case of the Russian Federation and other developing economies, the predominance of vertically integrated groups leads to contractual imperfections, market foreclosure (i.e. prevents the entry of new firms), and helps to reduce fixed costs and coordinate prices (Brown et al., 1999; Iwasaki and Mizobata, 2020). The existence of vertical integration increases competitive advantages by disrupting the traditional distribution of value added between industries and re-distributing value added from upstream to downstream industries (Harrigan, 1984; Jacobides and Billinger, 2006; Meyer and Hitt, 2003; Uhlenbruck et al., 2003). Based on the existing evidence it is proposed that

H4. Firms in industries that specialize in the early and late stages of GVCs feature higher TFP than firms in the middle part of GVCs, hence forming a U-shaped TFP curve.

The evidence is unclear about the size of the "optimal" technological gap between national companies and foreign companies operating within a GVC that maximizes productivity spillovers for the national companies. On the one hand, the larger is the gap the larger are the potential spillovers. On the other hand, in the case of very large gaps national companies are unable to assimilate advanced technologies. Following the literature on FDI spillovers, we assume that a certain gap should exist but should not be very large (Zukowska-Gagelman, 2000). We suggest that medium-productivity companies as well as companies in the medium-tech industries seem to be the recipients of the positive productivity spillovers of participating in the GVCs. Thus, it is expected that

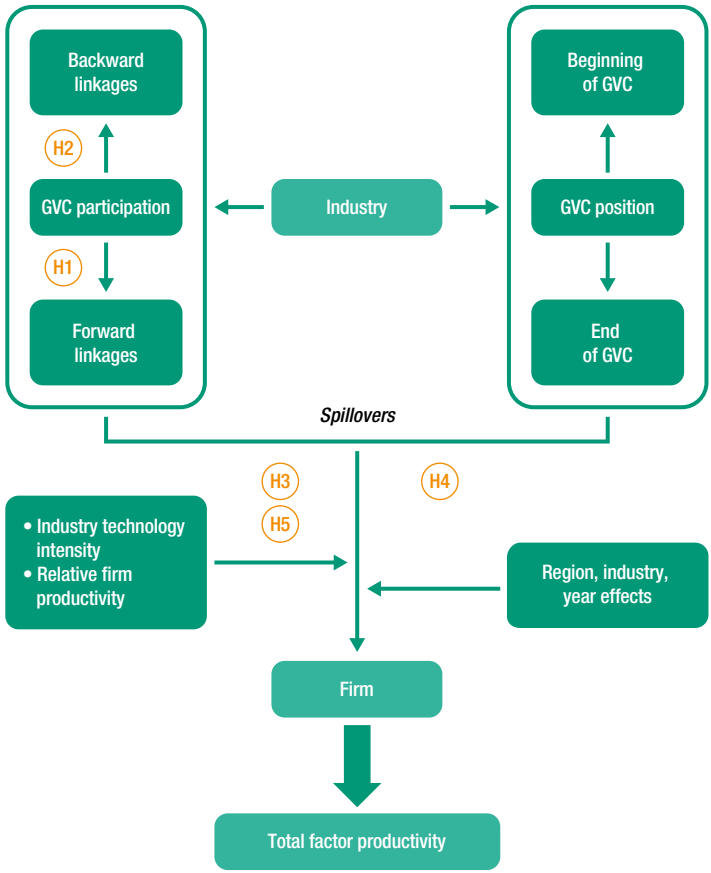
H5. Medium-productivity firms and firms in medium-tech industries have larger GVC productivity gains.

[4] They include early studies (Dietzenbacher et al., 2005; Dietzenbacher and Romero, 2007; Inomata, 2008) and recent ones (Ito and Vézina, 2016; Meng et al., 2020).

3. Conceptual model

Taking into consideration the literature and hypotheses, the following conceptual model summarizes our approach to estimating GVC spillovers on firm productivity. Figure 1 lays out a schematic diagram showing the general structure of the model. The approach assesses effects of GVC participation through backward and forward linkages and effects of GVC position on productivity. The model takes into account year and meso-level unobserved heterogeneity that might potentially affect GVC spillovers on firms' productivity and control for year-, region- and industry-specific effects. In addition, we account for firm heterogeneity and use firm-specific controls.

Figure 1. Conceptual framework for GVC spillovers



Source: Authors' elaboration.

To test for the "optimal" technological gap, we introduce, first, industry technology intensity and distinguish between low, medium and high technology-intensive industries and, second, measure productivity relative to the industry's average and distinguish between firms with different productivity levels. On the basis of the empirical literature, we choose TFP as a measure of firms' productivity.

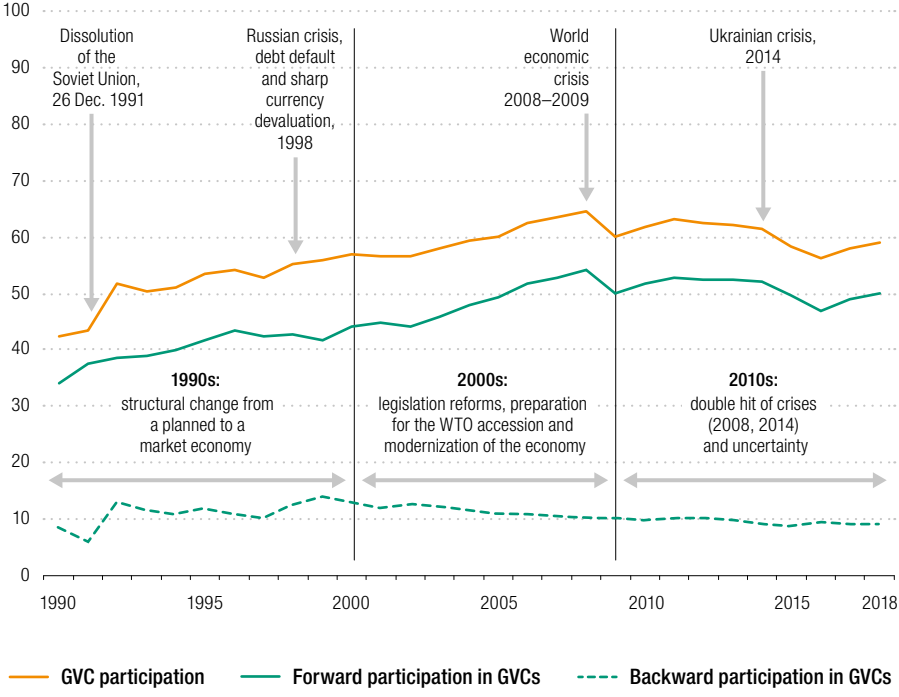
4. Russian economy in GVCs and major shifts

Figure 2 presents the evolution of GVC participation and its components – backward and forward linkages. Russian participation in GVCs might be considered in the context of three periods in the country's external policy. During the first two periods – the 1990s and the 2000s – participation in GVCs by Russian firms increased from 43 per cent of gross exports (1993) to a maximum of 65 per cent (2008). This increase was largely due to significant changes in Russian foreign trade policy and in regulation of trade and foreign direct investment, which in fact was reformulated from the ground up (Isachenko, 2013; Sutyrin et al., 2019). The first key documents aimed at regulation of foreign trade were introduced in the early 1990s. They abolished the state monopoly on foreign economic activities and gave companies and enterprises the right to participate in foreign economic relations. Later they underwent significant revisions, but the strategic shift occurred in the early 2000s when accession to the WTO became one of the major themes. During 2000–2003 many major laws oriented towards conformity with WTO regulations were adopted. In particular, a tax code and a new customs code brought significant changes, helping to reduce the previously massive corruption and long delays in customs (Aslund, 2010). Overall, the expansion of Russian participation in GVCs was significantly supported by the massive inflow of foreign direct investment, some of it export-oriented, which explains the expansion of forward GVC participation in the country during the 2000s.

The world economic crisis of 2008–2009 has brought uncertainty to global trade, slowed growth rates and made firms more cautious about participation in GVCs. As shown in figure 2, Russian participation in GVCs between 2009 and 2014 changed slightly, from 60 per cent in 2009 to 63 per cent in 2011 and 61 per cent in 2014. The Ukrainian crisis of 2014 and the introduction of European and United States sanctions, together with the related depreciation of the rouble, contributed to decreased participation of Russian firms in GVCs. The effect was most pronounced in 2016, when the GVC participation index fell to 56 per cent.

The empirical analysis of the effects of GVCs on firm productivity in the current study is based on the period 2010–2015. We consider this period important as before 2010 the Russian economy already had extended participation in GVCs and did not change it significantly, whereas in our view, a significant change in participation over the period could affect estimates of GVC spillovers.

Figure 2. Russian Federation: GVC participation and specifics of internal and external conditions, 1990-2018 (Per cent)



Source: Authors' elaboration.

5. Description of data, econometric model and methods

5.1 Data and descriptive statistics

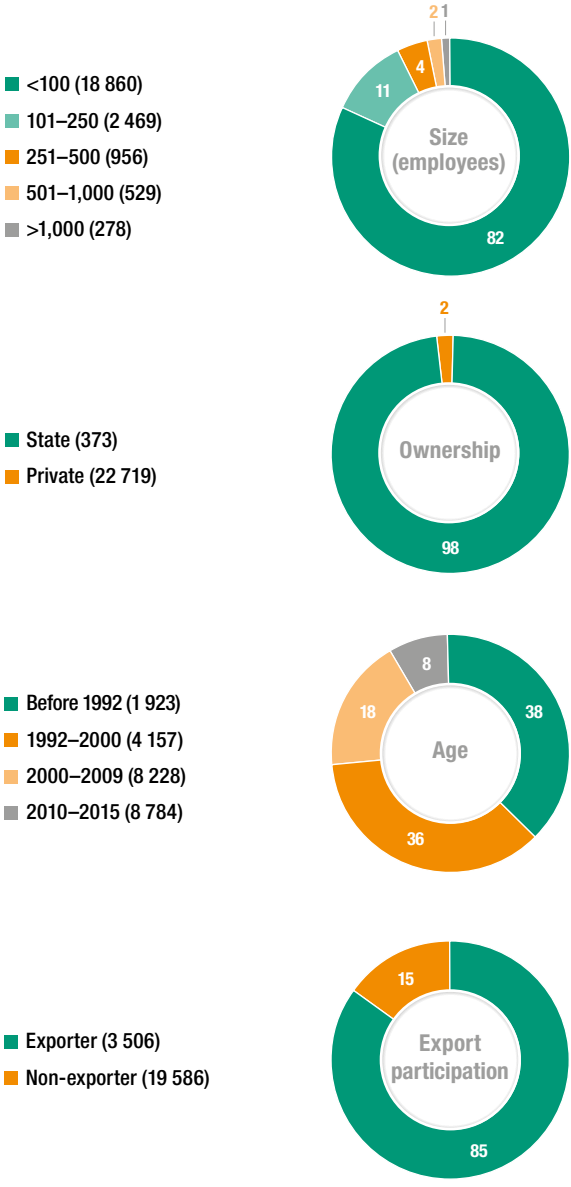
We use the Ruslana Bureau van Dijk database for firm-level data on the Russian companies. The coverage period is 2009–2015, limited by the availability of statistics on GVCs. We consider only companies in the manufacturing sector. The services sector and the agriculture sector, as well as extractive industries, are excluded because of their mutual incomparability. The total number of national companies included in the database is 23,092, with 74,950 observations within the analysed time period, thus providing on average 3.5 observations on each company for the six-year period.

The indicators on GVC participation are derived from the open-access UIBE GVC database, calculated using the World Input-Output Data. It is important to stress that GVC participation data are disaggregated at the industry level, with data on 24 manufacturing industries available. The descriptive statistics for the variables used in this research are summarized in appendix table 1. The list of industries and the distribution of companies across these industries appears in appendix table 2.

The size, age, ownership and export status structure of the companies in the database are presented in figure 3. Eighty-two per cent of companies are small businesses (fewer than 100 employees), nearly 15 per cent are medium-size (10–500 employees) and 3 per cent are very large (more than 1,000 employees). Fifteen per cent of companies in the database are direct exporters, but 85 per cent are not. We have roughly equal distribution for companies founded before 2000, in the 2000s and after 2010. Only 2 per cent of companies in the database have State ownership. That may seem little for the Russian economy, given the large share of the Government in the economy, but the possible explanation is that we consider only the manufacturing sector, where the share of state companies is obviously smaller than in many other sectors (e.g. mining, finance, utility sector). The information in figure 3 allows us to make the conclusion that our sample is representative.

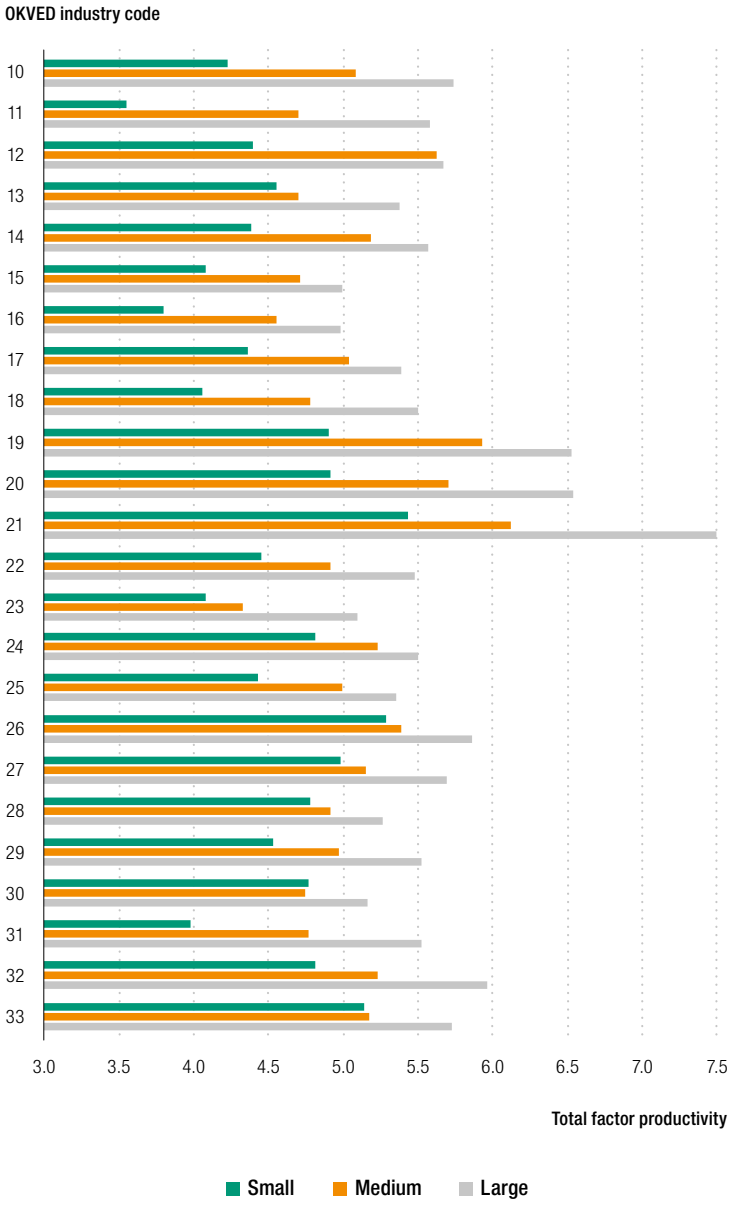
The descriptive statistics of the TFP of the companies in the database deliver standard economic results. Large companies are more productive than medium-size ones, while medium-size companies are more productive than small ones (presented in figure 4). In most industries, private companies are more effective than State-owned ones (figure 5). Besides that, direct exporters have higher TPF than non-exporters (controlling for the industry; not reported for reasons of space). Companies founded since 2010 had the highest productivity, whereas companies founded before 2000 had the lowest productivity (also controlling for the industry, not reported in order to save space). The distribution of companies' TPF in each industry is close to normal.

Figure 3. Distribution of companies in the database according to size, ownership, age and export activities (Per cent)



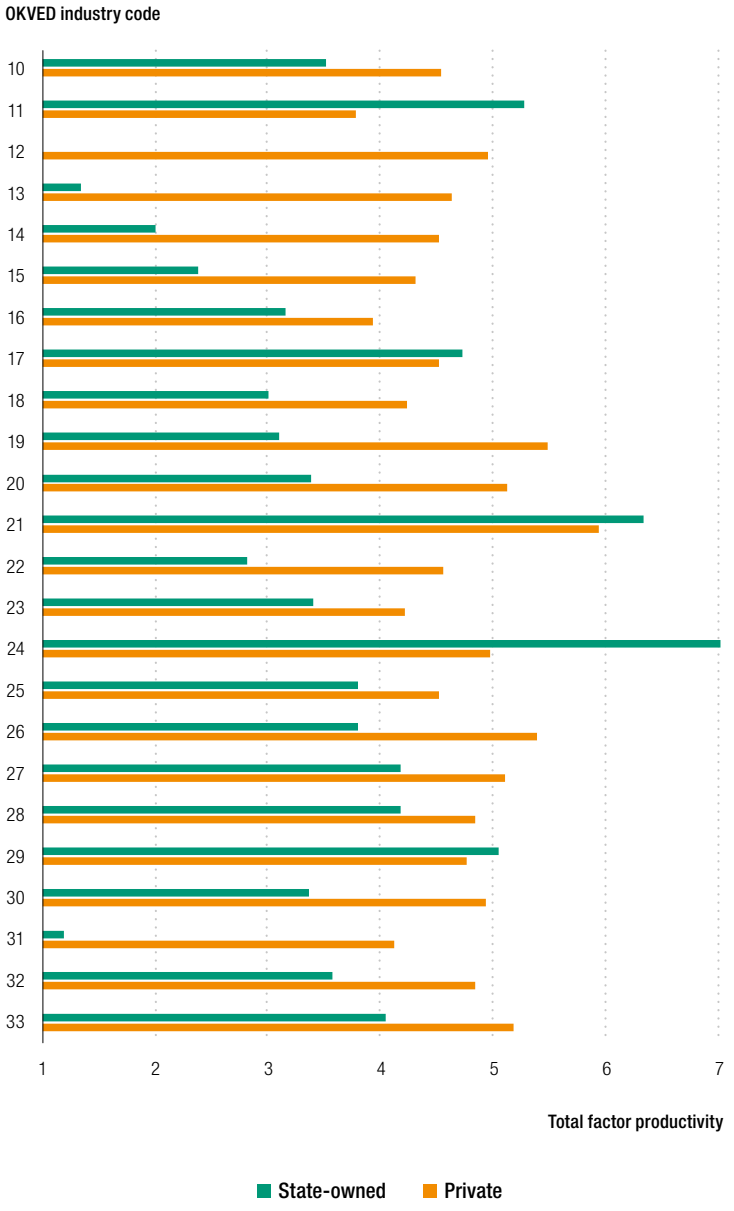
Source: Authors' calculations.

Figure 4. Total factor productivity of companies by size



Source: Authors' calculations.
Note: The correspondence of the OKVED codes to industries appears in table 2.

Figure 5. Total factor productivity of State-owned and private companies



Source: Authors' calculations.
Note: the correspondence of the OKVED codes to the industries can be seen in table 2.

5.2 Econometric model and methods

To check the hypotheses defined in section 2, we construct the following econometric model:

$$TFP_{ijrt} = a_0 + a_1 Age_i + a_2 State_i + a_3 Region_r + a_4 Size_{it} + a_5 Ind_j + a_6 GVCs_{jt} + e_{ijrt},$$

where TFP_{ijrt} is TFP of company i in industry j in region r in year t, calculated according to the Levinson and Petrin (2003) approach, based on revenue, total assets, number of employees and material costs of the particular company in the particular year; Age_i is the age of company i, constructed as a set of four dummy variables depending on the period of registration of the company: before 1990, between 1991 and 1999, between 2000 and 2009, or after 2010; $State_i$ is a dummy variable for the presence of State authorities among the shareholders of company i; $Region_r$ is a dummy for the operating region for company i; $Size_{it}$ is a dummy variable for the size of company i, distinguishing five groups of companies depending on their size: small (fewer than 100 employees), lower middle (101 to 250), upper middle (251 to 500), large (501 to 1,000) and very large (more than 1,001); Ind_j is an industry dummy for company i; GVC_{sjt} is the industry's vector of participation in GVCs in year t; a_0 is the constant, $a_1 - a_6$ are the estimated coefficients before the regressors, and ε_{ijrt} is the error term.

The set of variables for GVC participation include the following indicators: domestic value added in exports as a share of industry gross domestic product (GDP), as a measure of the industry's export orientation (DVA share of foreign value added in final products as a measure of an industry's import dependency (FVA), measures of backward and forward linkages and, finally, measures of the length to the end and starting point of the chain.

Measures of backward and forward linkages in GVCs are based on Wang et al. (2017a) and include (1) a *backward linkage–based GVC participation index (GVC_B)*, measured as the share of domestic and foreign value added in intermediate imports in an industry's value added in final goods production; (2) a *backward linkage–based simple GVC participation index (GVC_BS)*,[5] measured as the share of domestic and foreign value added in intermediate imports directly used in production of domestically consumed products in an industry's value added in final goods production; (3) a *backward linkage–based complex GVC participation index (GVC_BC)*,[6] measured as the share of imported value added directly used in production of exported products in an industry's value added in final

[5] In simple GVCs, the intermediate product crosses the country once, where it is consumed by the trading partner.

[6] In complex GVCs, the product is used by the partner country to produce exports.

goods production; (4) a *forward linkage–based GVC (GVC_F) participation index*, measured as the share of value added embodied in production of intermediate exports in an industry's total value added; (5) a *forward linkage–based simple GVC participation index (GVC_FS)*, measured as the share of value added embodied in intermediate goods exports that is directly absorbed by the importer in an industry's total value added; (6) a *forward linkage–based complex GVC participation index (GVC_FC)*, measured as the share of value added embodied in intermediate goods exports used for production of re-exports that are finally consumed abroad.

Measures of production length are based on Wang et al. (2017b). They include (1) the average production length of GVC activities based on forward linkages (to the end of the chain), which is the ratio of GVC-related domestic value added and its induced gross output (*PLV*); (2) the average production length of GVC activities based on backward linkages (*PLY*); (3) the average production length of complex GVC activities based on forward linkages (to the end of the chain), which is the ratio of complex GVC related domestic value added and its induced gross output; (4) the average production length of complex GVC activities based on backward linkages (to the starting point of the chain), which is the ratio of GVC-related foreign value added and its induced gross output.

The database has a panel structure and thus can be estimated using fixed-effects and random-effects models. We choose a random-effects estimator for the following reasons. First, fixed-effects models cannot estimate the effect of a variable that has no within-group variation because fixed effects subsume all observed and unobserved group-specific variation. In our case such variables as age, size, ownership, region and industry cannot be estimated within a fixed-effects framework. Second, using random effects instead of fixed effects greatly reduces the number of parameters to be estimated and saves a lot of degrees of freedom, equal to the number of firms (23,092) in the estimated model (Greene, 2005). Third, GVC indicators used in the research have small within-group variation because the economies are complicated systems that slowly adapt to changes. In this case, GVCs indicators are correlated with the fixed effects, and fixed-effects estimators will be inefficient (Bartels, 2008). Fourth, because of their construction, random-effects models are preferable to fixed-effects models when the number of time periods (six in the database) is relatively low and the number of groups is relatively high (23,092 in the database).

The estimation is made for only the national companies in the database. We exclude foreign companies because their productivity depends to a large extent on the technology received from the headquarters company and we cannot control this parameter within our econometric model. After the analysis of the distribution of the generated TFP indicator, in order to deal with the normally distributed dependent variable, we consider 1 per cent of left-hand and 5 per cent of right-hand observations as outliers. Some of the GVC indicators in the

constructed model are correlated; the pairwise correlation appears in appendix table 3. To avoid the multicollinearity problem, we estimate highly correlated GVC indicators separately. Because R-squared has some drawbacks when explaining the fitness of the model, adjusted R-squared and F-test (indicating the probability of all the regressor coefficients in the model equal to zero) are also reported for each estimated model.

6. Estimation results

First, we test hypotheses *H1* and *H2* and include the indicators of domestic value added in exports as a share of sector GDP and the share of foreign value added in final products as explanatory variables in the regression. In addition to these benchmark results, we estimate the model using the first lags of the GVC indicators. The reasons to include the first lags are the following. First, we believe that some changes in the GVC position of the industry affect the productivity of national companies with some delay, thus, taking the lags allows us to solve the potential simultaneity problem. Second, as the data on GVC participation is limited, ending in 2014, taking the first lag allows us to extend the database to 2015.

As presented in table 1, we observe positive and statistically significant coefficients for the variable domestic value added in exports (as a share of sector GDP) in the industry and foreign value added in final products. As both variables are measured at the industry level, the results suggest the existence of not only direct effects (for firms in GVCs) but also indirect effects (for firms not included in GVCs) on the productivity of local firms from an industry's export and import orientation. These results are in line with empirical evidence that over 80 per cent of Russian exports are provided by the largest companies, and the total number of exporters is relatively small; thus, SMEs are underrepresented in exports (Simachev et.al., 2019). Our results allow us to confirm hypotheses *H1* and *H2*.

Next, we examine the relationship between the industry's overall integration in GVCs and the productivity of the national companies. We use the indicators of *backward and forward linkage–based GVC participation indexes* to measure the degree of industry integration in GVCs. The UIBE GVC database provides information on participation in the simple and complex value chains, as well as a composite indicator of participation in both types of value chains. The results presented in table 2 indicate that there is statistically significant positive effect on the productivity of national companies in the Russian Federation from GVC participation, which supports hypothesis *H3*. In particular, we find that backward and forward GVC participation overall as well as for simple and complex GVCs in current values and first lags (except for the first lag of backward participation in simple GVCs) are positive and statistically significant determinants of TFP in Russian manufacturing industries.

Table 1. Influence of domestic value added in exports and foreign value added in final products on productivity of national companies (panel random-effects model)

Indicator	Model 1	Model 2	Model 3	Model 4
Domestic value added in exports	0.86*** (0.17)			
Domestic value added in exports (1st lag)		1.50*** (0.16)		
Foreign value added in final products			1.87*** (0.44)	
Foreign value added in final products (1st lag)				1.05** (0.42)
State ownership dummy	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes
Region dummy	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes
Size dummy	Yes	Yes	Yes	Yes
Age dummy	Yes	Yes	Yes	Yes
Number of observations	66 749	74 950	66 749	74 950
R-sq.	0.173	0.174	0.173	0.174
Adj. R-sq.	0.177	0.178	0.177	0.178
F-test	0.000	0.000	0.000	0.000

Source: Authors' calculations.
Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

This means that national firms do not only benefit from GVCs through arm's-length relationships in backward and forward linkages with foreign companies. Our findings allow us to confirm the hypotheses *H3*.

Another important question is how the productivity of companies depends on an industry's position along the GVC. We regress the TFP of national firms on the distance to the early and late stages of GVC, along with the standard control variables (table 3). We find a statistically significant negative relationship between firms' TFP and the distance to both GVC ends. As a robustness check, we repeat the regression for complex GVCs separately, using measures of industry position to both ends and find that the results are unchanged. We follow Wang et al. (2017b) and construct the "backwardness" indicator and divide the industry's distance to the starting point of the GVC into its distance to the end of the GVC. Then we separately estimate the model with two dummies: when backwardness is less than one and when backwardness is greater than or equal to one, which correspond to upsteam and downstream positions in the GVC, respectively.

Table 2. Backward and forward participation in GVCs and productivity of national companies (panel random-effects model)

Indicator	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Backward participation	2.18*** (0.44)					
Forward participation	1.63*** (0.30)					
Backward participation (1st lag)		1.67*** (0.43)				
Forward participation (1st lag)		2.81*** (0.29)				
Backward participation (simple GVCs)			1.31* (0.70)			
Forward participation (simple GVCs)			1.50*** (0.51)			
Backward participation (simple GVCs, 1st lag)				- 1.53** (0.67)		
Forward participation (simple GVCs, 1st lag)				1.27*** (0.48)		
Backward participation (complex GVCs)					3.74*** (0.72)	
Forward participation (complex GVCs)					1.94*** (0.46)	
Backward participation (complex GVCs, 1st lag)						4.46*** (0.70)
Forward participation (complex GVCs, 1st lag)						4.13*** (0.43)
State ownership dummy	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes
Region dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Size dummy	Yes	Yes	Yes	Yes	Yes	Yes
Age dummy	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	66 749	74 950	66 749	74 950	66 749	74 950
R-sq.	0.173	0.174	0.173	0.174	0.173	0.174
Adj. R-sq.	0.178	0.178	0.177	0.178	0.178	0.179
F-test	0.000	0.000	0.000	0.000	0.000	0.000

Source: Authors' calculations.
Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

We find that the longer the distance to the early and late stages of the GVC for an industry, the higher the TFP of firms in that industry (coefficients in models 1–4 in table 6 are negative and statistically significant). In addition, we find that both constructed backwardness indicators are also negative and statistically significant (models 5–6 in table 6). These results suggest that firms in manufacturing industries on both ends of GVCs, i.e. producing simple intermediates and final goods, respectively, have higher TFP than firms in industries involved in interim parts of a GVC. These results are in line with existing evidence for other countries and confirm hypothesis *H4*.

Table 3. Position of industries in GVCs and productivity of national companies (panel random-effects model)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Distance to end of GVC	-0.21*** (0.03)					
Distance to starting point of GVC		-0.58*** (0.08)				
Distance to end of GVC (complex chains)			-0.30*** (0.04)			
Distance to starting point of GVC (complex chains)				-0.19*** (0.03)		
Distance to end of GVC (backwardness < 1)					-0.56*** (0.10)	
Distance to starting point of GVC (backwardness ≥ 1)						-0.70*** (0.10)
State ownership dummy	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes
Region dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Size dummy	Yes	Yes	Yes	Yes	Yes	Yes
Age dummy	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	66 749	66 749	66 749	66 749	23 302	43 447
R-sq.	0.173	0.173	0.173	0.173	0.201	0.161
Adj. R-sq.	0.178	0.178	0.178	0.178	0.207	0.164
F-test	0.000	0.000	0.000	0.000	0.000	0.000

Source: Authors' calculations.
Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Finally, we consider the question of the "optimal" technological gap between national and foreign companies operating in a GVC that maximizes productivity spillovers for national companies. To test whether the effects of GVCs depend on firms' productivity, we separately estimate the model for firms with the lowest productivity (less than 0.7 of the industry average) and the highest productivity (more than 1.3 of the industry average). Firms with middle productivity are separated into lower-middle productive (from 0.7 to 1.0 of the industry average) and upper-middle productive (from 1.0 to 1.3 of the industry average). As shown in table 7, GVC spillovers are positive and statistically significant for firms with different level of productivity with only two exceptions on the ends of the TFP distribution. First, TFP spillovers from forward participation for firms with the lowest productivity are positive but insignificant. Second, TFP spillovers from backward participation for firms with the highest productivity are positive but insignificant. This suggests that only firms with lower- and upper-middle productivity gain GVC spillovers from both backward and forward participation.

To test whether GVC spillovers depend on an industry's technology intensity, we separately estimate regressions for firms in low-tech, middle-tech and high-tech industries. For middle-tech industries, we find that backward and forward participation are positive and statistically significant. For low-tech industries, we find that backward participation is negative and forward participation is positive and statistically significant. Finally, for high-tech industries, we find that both backward and forward participation are positive but insignificant. Summing up the results presented in tables 4 and 5, we conclude that the main recipients of the positive effects of GVC participation in the Russian Federation are national companies with a medium level of productivity and firms in medium-technology industries; thus, we confirm hypothesis *H5*.

Here it is important to notice that R-squared and adjusted R-squared are not very high along all the reported estimates in this section (the value lies within the interval 0.15–0.2 for most regressions). The reason for it is heterogeneity of cross-sections: R-squared (like adjusted R-squared) is low when the number of groups (firms) is high and the number of periods (years) is low. Another reason for low (and adjusted) R-squared in the random-effects model is the large number of observations relative to the number of regressors. When the fixed-effects estimates are presented in the next section (i.e. when group dummies are included), R-squared and adjusted R-squared are boosted to 0.83–0.84.

Table 4. Effects of backward and forward participation in GVCs for national firms with different productivity (panel random-effects model)

	Productivity			
	Lowest	**Lower middle**	**Upper middle**	**Highest**
Backward participation	2.04*** (0.68)	1.69*** (0.32)	1.48*** (0.33)	0.61 (0.73)
Forward participation	0.19 (0.45)	1.25*** (0.21)	2.03*** (0.24)	1.24*** (0.47)
State ownership dummy	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes
Region dummy	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes
Size dummy	Yes	Yes	Yes	Yes
Age dummy	Yes	Yes	Yes	Yes
Number of observations	12 707	22 371	19 272	12 399
R-sq.	0.15	0.41	0.53	0.26
Adj. R-sq.	0.14	0.41	0.53	0.26
F-test	0.000	0.000	0.000	0.000

Source: Authors' calculations.
Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5. Effects of backward and forward participation in GVCs for national firms: low-tech, middle-tech and high-tech industries (panel random-effects model)

	Low-tech	**Mid-tech**	**High-tech**
Backward participation	-4.11** (1.71)	6.83*** (1.26)	0.07 (0.68)
Forward participation	1.73*** (0.43)	1.72** (0.86)	1.51 (1.07)
State ownership dummy	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes
Region dummy	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes
Size dummy	Yes	Yes	Yes
Age dummy	Yes	Yes	Yes
Number of observations	31 714	20 615	14 420
R-sq.	0.181	0.151	0.137
Adj. R-sq.	0.188	0.153	0.137
F-test	0.000	0.000	0.000

Source: Authors' calculations.
Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

7. Robustness checks

The first possible concern about the estimates derived in the previous section may be associated with applying a panel random-effects model. Although the Hausman test shows that fixed effects should be preferred to random-effects estimates, the authors consider the random-effects model as more relevant for the particular econometric model and data used (for reasons discussed in subsection 5.2). As a robustness check, the fixed-effects estimates with year dummies appear in table 6. For brevity we demonstrate only the main GVC indicators in the table and do not include the lagged estimates.

Another issue relates to identification. The explanatory variables in the estimated model are either defined at the industry level and are time specific or defined at the firm level and are time invariant. As we do not have both firm- and time-specific indicators among the regressors, standard errors need to be adjusted (Moulton, 1990). Following seminal works by Javorcik (2004) and Merlevede et al. (2014), in table 9 we show standard errors clustered for all observations in the same industry and year. Although the estimates with robust standard errors are more conservative, the results support those presented in the previous section.

The next concern may be associated with multicollinearity of the GVC variables. Due to construction, all GVC indicators used in this paper are based on the value added concept. In other words, they show how the value added in the industry changes when the industry integrates into GVCs (increasing either backward or forward participation), or how the value added depends on the position of the industry along the GVC. These indicators are interdependent; for example, increasing the share of imported intermediates affects the backward linkage–based GVC participation index, backward linkage-–based simple GVC participation index and the backward linkage–based complex GVC participation index ,as well as foreign value added in final products. Increasing the level of exports in a particular industry, we may expect a change in the forward linkage–based GVC participation index, the forward linkage–based simple GVC participation index and the forward linkage–based complex GVC participation index as domestic value added in exports changes.

The impossibility of simultaneously including all the GVC variables in the regression may seem a limitation of the research because it may be considered as discussion of the partial but not general effects of GVC participation. In this context it should be noted that we consider different indicators of backward and forward participation as a kind of robustness check in the model. Instead of choosing three baseline indicators for GVC participation (for example, GVC_B, GVC_F and PLV), we include a set of indicators to confirm the hypotheses of the research. From our point of view this provides additional proof of the reliability of the derived results.

Table 6. Effects of GVC participation for national firms (panel fixed-effects model with clustered standard errors)

Indicator	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Domestic value added in exports	0.95*** (0.36)					
Foreign value added in final products		2.02 (1.25)				
Backward participation			2.37* (1.27)			
Forward participation			1.84*** (0.66)			
Backward participation (1st lag)				1.76* (1.05)		
Forward participation (1st lag)				3.11*** (0.74)		
Distance to end of GVC					-0.24*** (0.07)	
Distance to starting point of GVC						-0.63*** (0.22)
Hausman test	445***	446***	452***	421***	448***	447***
Number of observations	60 827	60 827	60 827	68 510	60 827	60 827
R-sq.	0.845	0.845	0.845	0.84	0.845	0.845
Adj. R-sq.	0.833	0.833	0.833	0.831	0.833	0.832
F-test	0.000	0.000	0.000	0.000	0.000	0.000

Source: Authors' calculations.
Note: Standard errors clustered over industry and year in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

8. Concluding remarks and policy recommendations

Most empirical papers discuss the external effects of participation in GVCs using a case-study approach. This study is one of the first that uses econometric analysis to estimate GVC spillovers on TFP using the data of Russian manufacturing firms. First, we find that, on average, firms in industries that are intensively integrated into GVCs have higher TFP, after controlling for firm heterogeneity, industry and region fixed effects. This result significantly extends the existing empirical evidence on direct GVC effects on local GVC participants and confirms the existence of indirect GVC spillovers. We interpret these findings as the working of complex GVC-induced spillovers, meaning that backward and forward integration of an industry in GVCs allows local GVC and non-GVC firms to open up access to new

knowledge and intermediates-embodied advanced technologies and through pro-competitive effects increases overall local firm performance. Regarding existing empirical evidence, our results suggest that direct GVC-induced effects for local GVC firms as well as FDI productivity spillovers arising within GVCs cannot explain the whole story of TFP improvements in local (non-GVC) firms.

We test the effects of an industry's positioning in a GVC on the TFP of firms and find robust empirical evidence of unequal distribution of TFP gains, suggesting that Russian firms in manufacturing industries at the early and late stages of GVCs, on average, have higher TFP than those in the middle parts of GVCs, controlling for firm heterogeneity, industry and Russian region fixed effects. These results are consistent with existing empirical evidence in the Russian Federation and other countries. We believe that our findings reinforce the discussion on repositioning in GVCs to increase productivity that is common for most developing countries and some developed countries, in particular, those that have recently joined the group of developed countries. From the perspective of repositioning in GVCs, it is important to consider not only the change in specialization towards industries located near the beginning or end of GVCs, but also to consider the shift of firms' business functions in an industry in favour of those that add more value i.e., from assembly to the production of final products or intermediate products with higher added value.

We estimate the existence of GVC spillovers for firms with different productivity levels and for firms in industries with low, medium, and high technology intensity and control for firm heterogeneity, industry and region fixed effects. We find that only firms with lower-middle and upper-middle TFP gain both backward and forward spillovers in GVCs. We relate these results to the evidence of the "optimal" technological gap between local non-GVC firms and GVC firms that allows gaining the largest spillovers. We find forward GVC spillovers for firms with the lowest productivity insignificant and explain this fact by the existence of a large technological gap that prevents the absorption of advanced technologies and knowledge spillovers by local firms. We find backward spillovers for the most productive firms insignificant. In our view, this corresponds to empirical observations stating that the most productive firms are usually direct importers of intermediate goods so that they are affected by the direct effects of GVC participation, but not spillover effects as estimated by the model.

We find the existence of positive backward and forward GVC spillovers on TFP only for middle-tech industries, which is again in line with our predictions about the "optimal" technological gap that maximizes productivity spillovers for national firms. We find that firms in low-tech industries gain positive spillovers from forward linkages and negative spillovers from backward linkages. A possible explanation for the absence of positive TFP spillovers from backward participation for low-tech industries is that in the Russian Federation most intermediate inputs for low-tech manufacturing industries are produced locally.

Finally, we find that firms in high-tech industries do not experience statistically significant GVC spillovers, which might be caused by political impediments to cooperation between Russian and foreign companies within the GVC that prevent the inter-firm spread of technologies and knowledge. These findings once again raise the issue of the role of absorptive capacity in GVC upgrading. From an industry perspective, the predominance of low-productive firms will hinder upgrading opportunities. Thus, the issues of increasing productivity in Russian manufacturing sectors and decreasing intra-industry productivity gaps should be on the industrial policy agenda.

Our findings have implications for policymakers oriented towards ensuring TFP improvements in local firms using instruments of international trade and FDI attraction policies.

First, channels for positive TFP spillovers are wider than just direct GVC effects and indirect GVC spillovers; they also include indirect spillovers from lead firms in GVCs to local firms. There is a need for an integrated approach to FDI and trade policies to ensure positive TFP spillovers that might be called GVC-oriented policy. Conducting GVC-oriented policy will require efforts to synchronize trade liberalization and foreign direct investment attraction, and expand favourable trade regimes (including preferential import tariffs on intermediates) and investment agreements between countries. Such policies should also require measures oriented towards increasing inter-firm linkages between firms in hosting economies, including measures related to localizing FDI and strengthening domestic value chains and domestic elements of GVCs.

Implementation of GVC-oriented policy will be beneficial for both developed and developing countries but has special importance for economies striving to increase productivity and upgrade in GVCs. Regarding the Russian economy, special attention should be paid to supporting the formation of inter-firm links. Measures aimed at developing the verticalization of Russian industries should be combined with measures supporting the expansion of links between foreign and domestic firms as well as between exporting (GVC-included) and local (non-GVC) firms, including measures supporting indirect exporters.

Second, positive spillovers are more likely to occur in a more transparent environment for both foreign and domestic firms. Indeed, firms in an industry may benefit from links of other firms with lead firms in GVCs through a number of effects discussed in previous empirical studies, including demonstration effects as well as effects induced by market adjustment mechanisms and labour market turnover. From the policymakers' perspective, it is important to monitor positive market improvements and to take the role of the State as a facilitator, assisting with the operation of markets and distribution of positive spillovers by leveraging behavioural incentives for FDI and for firms in GVCs to increase cooperation with local firms in hosting economies.

Third, economies pursuing structural change should not prioritize the development of high-tech industries only. Structural changes should be gradual. Given our results, we can argue that firms in medium-tech industries benefit the most from spillovers in GVCs. This renews the debate about gradual structural change and supports the importance of evolutionary versus revolutionary structural changes in upgrading economies.

We acknowledge that our study has some limitations. In particular, because of data limitations we estimate GVC spillovers in the Russian Federation only in 2010–2015. From the perspective of policy recommendations, it would be important to discuss GVC spillovers at earlier and later stages of GVC integration.

This study provides strong support for the existence of positive GVC spillovers and stresses the importance of participation and upgrading in GVCs for both developing and developed countries. There is a consensus among academic scholars, experts and policymakers that GVCs will continue to play a significant role in the world economy despite greater trade tensions and barriers (UNCTAD, 2020; Zhan, 2021). Since GVCs will undergo substantive transformation in the decade ahead, this is a call to further research and policy analysis on the role and effects of GVCs, which obviously should take into account relevant results and previous experience, in order to address tomorrow's challenges.

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Appendix table 1. Descriptive statistics of variables

Variable, measurement	Mean	Standard deviation	Minimum	Maximum	Source
Revenue (thousands of dollars)	6 706.49	30 317.86	0.018	2 499 701	Ruslana Bureau Van Dijk
Employees	106.5	318.78	1.000	16 766	Ruslana Bureau Van Dijk
Total assets (thousands of dollars)	7 034.641	65 499.830	1.000	5 529 195	Ruslana Bureau Van Dijk
Cost of goods (thousands of dollars)	5 678.827	26 553.120	0.018	2 335 243	Ruslana Bureau Van Dijk
Total factor productivity[a]	4.06	1.41	0.56	7.499	Authors' calculations
Domestic value added in exports as share of sector GDP (fraction)	0.287	0.141	0.012	0.614	The UIBE-GVC-Indicators
Foreign value added share in final products (fraction)	0.111	0.069	0.034	0.356	The UIBE-GVC-Indicators
Backward linkage–based GVC participation index (fraction)	0.114	0.070	0.035	0.362	The UIBE-GVC-Indicators
Forward linkage–based GVC participation index (fraction)	0.230	0.137	0.011	0.578	The UIBE-GVC-Indicators
Backward linkage–based simple GVC participation index (fraction)	0.068	0.044	0.018	0.221	The UIBE-GVC-Indicators
Forward linkage–based simple GVC participation index (fraction)	0.132	0.078	0.007	0.355	The UIBE-GVC-Indicators
Backward linkage–based complex GVC participation index (fraction)	0.046	0.027	0.011	0.140	The UIBE-GVC-Indicators
Forward linkage–based complex GVC participation index (fraction)	0.112	0.036	0.006	0.321	The UIBE-GVC-Indicators
Average production length of GVC activities based on forward linkages (fraction)	4.956	0.408	4.058	5.757	The UIBE-GVC-Indicators
Average production length of GVC activities based on backward linkages (fraction)	4.632	0.207	4.165	5.040	The UIBE-GVC-Indicators
Average production length of complex GVC activities based on forward linkages[a]	5.883	0.451	4.930	6.856	The UIBE-GVC-Indicators
Average production length of complex GVC activities based on backward linkages[a]	5.642	0.339	5.151	6.313	The UIBE-GVC-Indicators

Source: Author's compilation and analysis.
Note: N = 74,950. The UIBE-GVC Indicators database is a non-profit database for academic research available at http://rigvc.uibe.edu.cn/english/D_E/database_database/index.htm.
[a] Variable lacks meaningful units of measurement.

Appendix table 2. Distribution of companies in the database across industries (2014)

OKVED code	Industry	No. of companies
10	Food production	3 570
11	Beverage industry	728
12	Tobacco products	6
13	Textiles	451
14	Clothing	706
15	Leather and leather products	182
16	Wood and cork products, except furniture	1 073
17	Paper and paper products	475
18	Printing activities and copying of information carriers	874
19	Coke and petroleum products	99
20	Chemicals and chemical products	922
21	Medicines and materials used for medical purposes	260
22	Rubber and plastic products	1 669
23	Other non-metallic mineral products	2 046
24	Metallurgical production	390
25	Finished metal products, except for machinery and equipment	2 698
26	Computers, electronic and optical products	486
27	Electrical equipment	1 008
28	Machinery and equipment not included in other categories	1 691
29	Motor vehicles, trailers and semi-trailers	433
30	Other vehicles and equipment	188
31	Furniture	686
32	Other finished goods	549
33	Repair and installation of machinery and equipment	1 902
Total		23 092

Source: Authors' calculations.

Appendix table 3. Pairwise correlation between GVC variables

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Domestic value added in exports as share of sector GDP	(1)	1									
Foreign value added share in final products	(2)	-0.341	1								
Backward linkage–based GVC participation index	(3)	-0.340	1	1							
Forward linkage–based GVC participation index	(4)	0.965	-0.390	-0.390	1						
Backward linkage–based complex GVC participation index	(5)	-0.195	0.955	0.954	-0.308	1					
Forward linkage–based complex GVC participation index	(6)	0.952	-0.382	-0.381	0.989	-0.307	1				
Backward linkage–based simple GVC participation index	(7)	-0.414	0.983	0.983	-0.423	0.883	-0.410	1			
Forward linkage–based simple GVC participation index	(8)	0.961	-0.391	-0.391	0.994	-0.305	0.997	-0.426	1		
Average production length of GVC activities based on forward linkages	(9)	-0.804	0.357	-0.358	-0.825	0.287	-0.780	0.385	-0.835	1	
Average production length of GVC activities based on backward linkages	(10)	0.54	-0.663	-0.664	0.565	-0.549	-0.556	-0.705	0.563	-0.357	1

Source: Authors' calculations.