HIGHER SCHOOL OF ECONOMICS
NATIONAL RESEARCH UNIVERSITY

Industry 4.0 technologies as determinants of participation in global and domestic value chains for Russian manufacturing firms

Nikolay Gorodnyi
Research Intern, Center for Industrial Policy Studies, HSE in Moscow

Anna Fedyunina
PhD, Ass. prof., Senior Research Fellow, Center for Industrial Policy Studies, HSE in Moscow

Yuri Simachev
PhD, Prof., Director, Center for Industrial Policy Studies, HSE in Moscow

November 19th, 2021
XVI International Conference “Russian Regions in the focus of changes”

Evidence on GVC determinants

- There has been an extensive body of literature on the growing importance of GVCs in developed and emerging economies: GVCs significantly affect international trade patterns and open new possibilities for participating economies to increase both their exports' quantity and quality, acquire advanced production technologies and improve the overall economic performance (Cieslik et al., 2019)

- (!) However, the empirical evidence from the CEE and CA countries, especially at the firm level is still relatively scarce
- (!) The majority of existing empirical studies on GVCs are based on sectoral input-output data.

- **Country-level determinants for GVC participation**: market size, level of economic development, industrial structure, location and government policies, cultural similarity, geographical proximity and labor costs differentials (IMF, 2013; Kowalski et al., 2015; Stollinger, 2016; Cerovic et al., 2014)

- **Firm-level determinants for GVC participation**: foreign ownership, large size, internationally recognized certificates (OECD, 2015; Orlic, 2017; Dhyne & Rubinova, 2016; Artopoulos et al., 2013; Cieślik & Hagemejer, 2014).

Industry 4.0 technologies in GVCs

- Supply chains are morphing into highly adaptive networks with integrated entities (Schuh et al., 2014; Gotz, Jankowska, 2020), this is mainly driven by technologies that make GVCs more digitalized (Dachs et al. 2017; Rodrik 2018; De Backer and Flaig 2017).

- Industry 4.0 technologies are important in GVCs in at least 3 ways:

  (1) I4.0 in pre-manufacturing stages, such as R&D and design, reduce product development timeline and costs: e.g. CAD, CAM, and 3D scanners are becoming more affordable and have lowered the expertise needed to design and manufacture reverse engineered products (Mayer 2018); machine learning and Big Data analytics for product manufacturing can help firms to de-codify tacit knowledge regarding product definition, detailed design (Banga, 2020);

  (2) I4.0 in manufacturing stages: e.g. CAD and robotics help firms to have higher output without major changeover costs, with faster delivery time, and higher quality (Miglani, 2018);

  (3) I4.0 in customer relations: e.g. AI, big data analytics, and digital design tools help to learn customers' preferences and can make tailoring of products to local markets easier, quicker, and cheaper (Mayer, 2018).

- This is in line with standard international trade literature: Exporters are "the best" firms in the economy according to firm performance and have up-to-date technologies *(Strange & Zucchella, 2017; Ghadge et.al, 2020; Ghobakhloo, 2018; Schmidt et. al, 2020)*

DVCs, GVCs and its determinants

- Developing countries are increasingly recognizing that participation in GVCs is an important kick-start to economic development. At the same time, however, they are also worried that the prospect for upgrading value chains is limited because their production activities are considered to be “locked-in” to the lower value-added segment of global production networks (Inomata, 2017)

- One of the reasons of “locked-in” effects is DVCs.
- DVCs can either be stepping stones or stumbling blocks for GVCs depending on the level of domestic fragmentation and switching costs (Beverelli et al., 2016):
  - Higher domestic fragmentation lowers barriers to GVC integration due to the one-time incidence of fixed fragmentation costs. This would lead, other things being equal, to a positive relationship between DVC and GVC integration.
  - However, domestic fragmentation also implies that GVC integration requires switching from domestic to foreign suppliers. This switching is also associated with fixed costs, which would suggest a negative effect of DVC integration on GVC integration. Overall, the sign of the relationship between DVCs and GVCs is ambiguous and needs to be determined empirically.

- In case of Russia, we see preliminary evidence for DVCs as stumbling blocks:
  - subcontracting networks are limited by rigid vertical relationships in holdings
  - further acquisitions of independent contractors into holdings

- **In this paper we consider determinants for GVCs and DVCs paying special attention to Industry 4.0**

Definitions

We use two criteria to define DVC and GVC: (1) Backward and Forward linkages; (2) Location of strategic partnerships

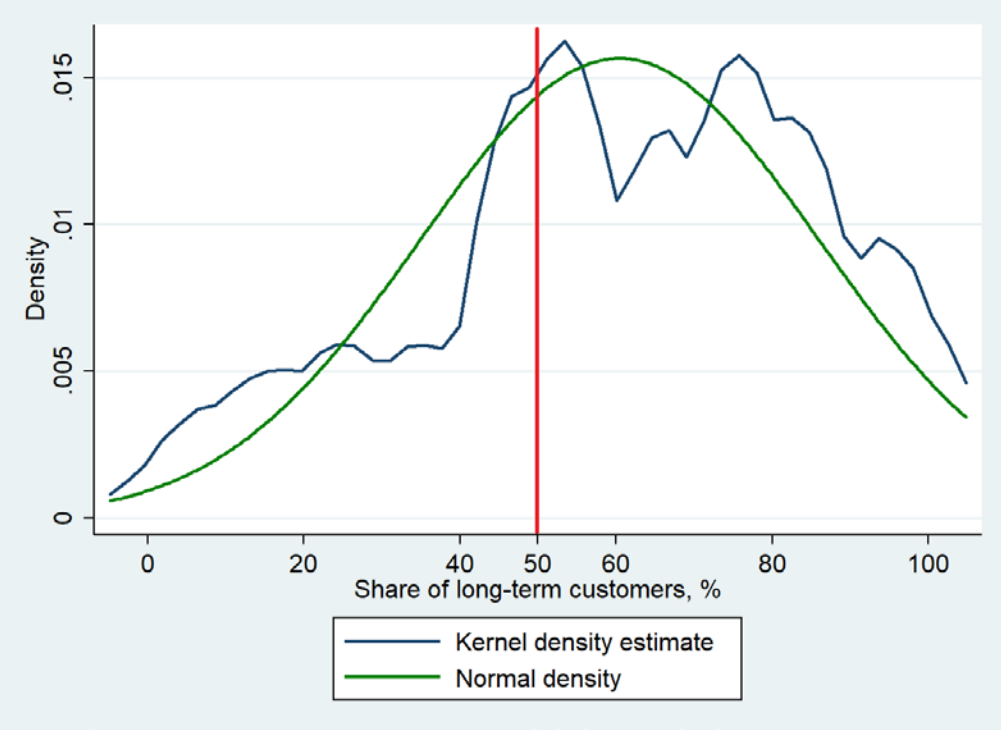
- **Backward linkages** of manufacturing firms – Supplier networks measured as a % of long-term partners;
- **Forward linkages** of manufacturing firms – Customer networks measured as a % of long-term partners;

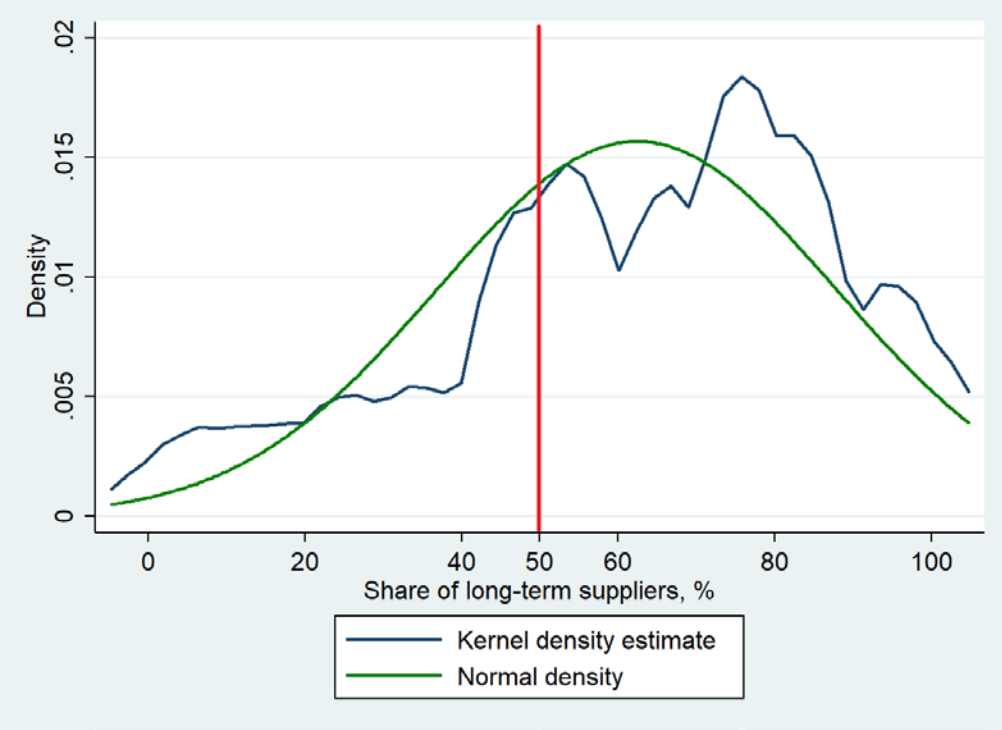
	Domestic strategic partners	Foreign strategic partners
Under 50% of long-term suppliers and customers (<50%)	Not included in any type of value chains	
Greater 50% of long-term suppliers and customers (>50%)	DVC	GVC

- In (Cieslik et al., 2019) GVC are defined using BEEPS and two measures: (1) firms' share of direct or indirect exports in their total sales, (2) firms' share of imported inputs and materials; to identify firms involved in GVCs, they take into account only firms that are simultaneously engaged in two-way trade captured by two-way dummy with the 10 per cent threshold in GVC participation
- But GVCs extend further than just export-import relations. They are: (1) long-term and (2) include other cooperation activities than just export and import

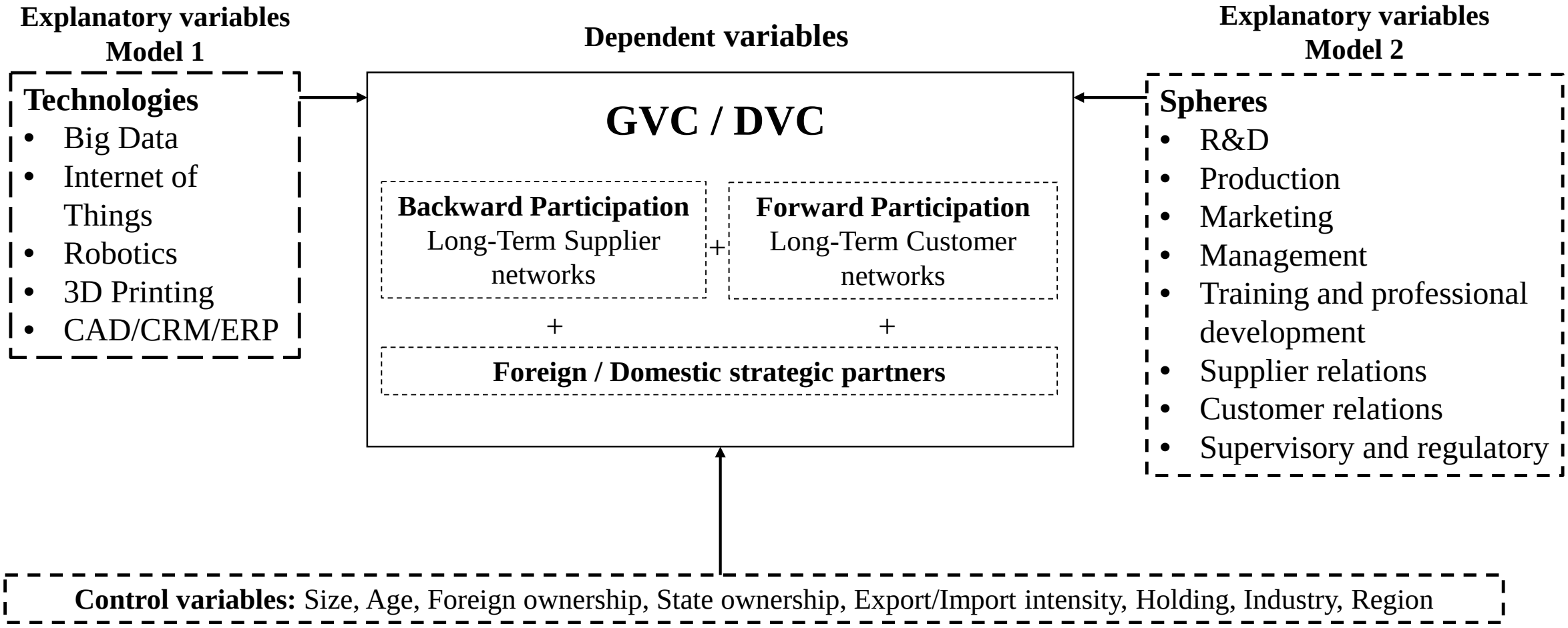
Threshold for backward and forward linkages

- We consider distributions and choose 50 per cent threshold for GVC participation





Conceptual model



Data

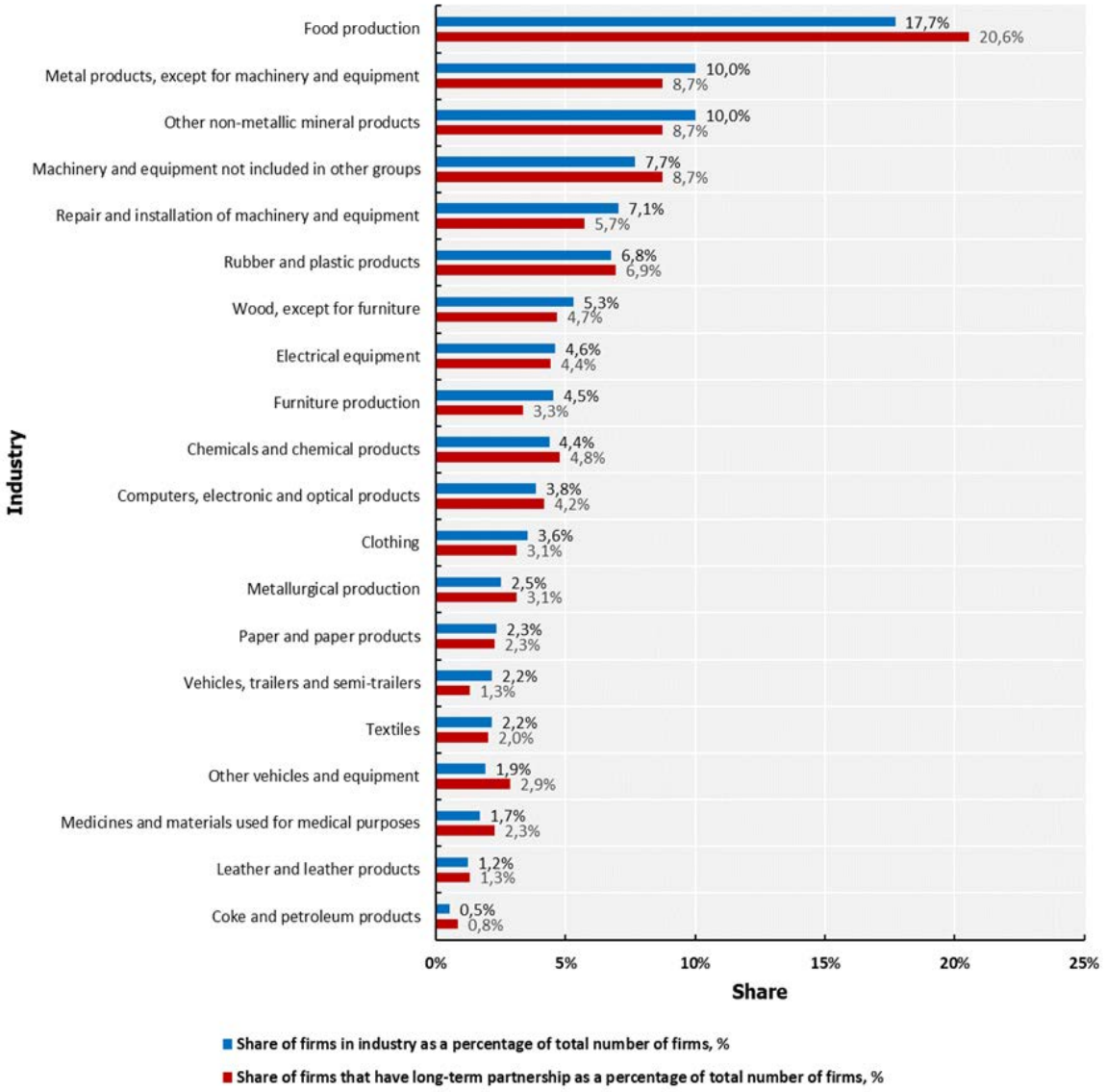
Data

- Cross-sectional data based on survey of Russian manufacturing firms: RUFIGE database (HSE, 2018)

Sample

- 1716 Russian manufacturing companies
- Respondents are CEOs and top managers of companies
- Data is representative across the industry, but not regions (due to limited number of observations)

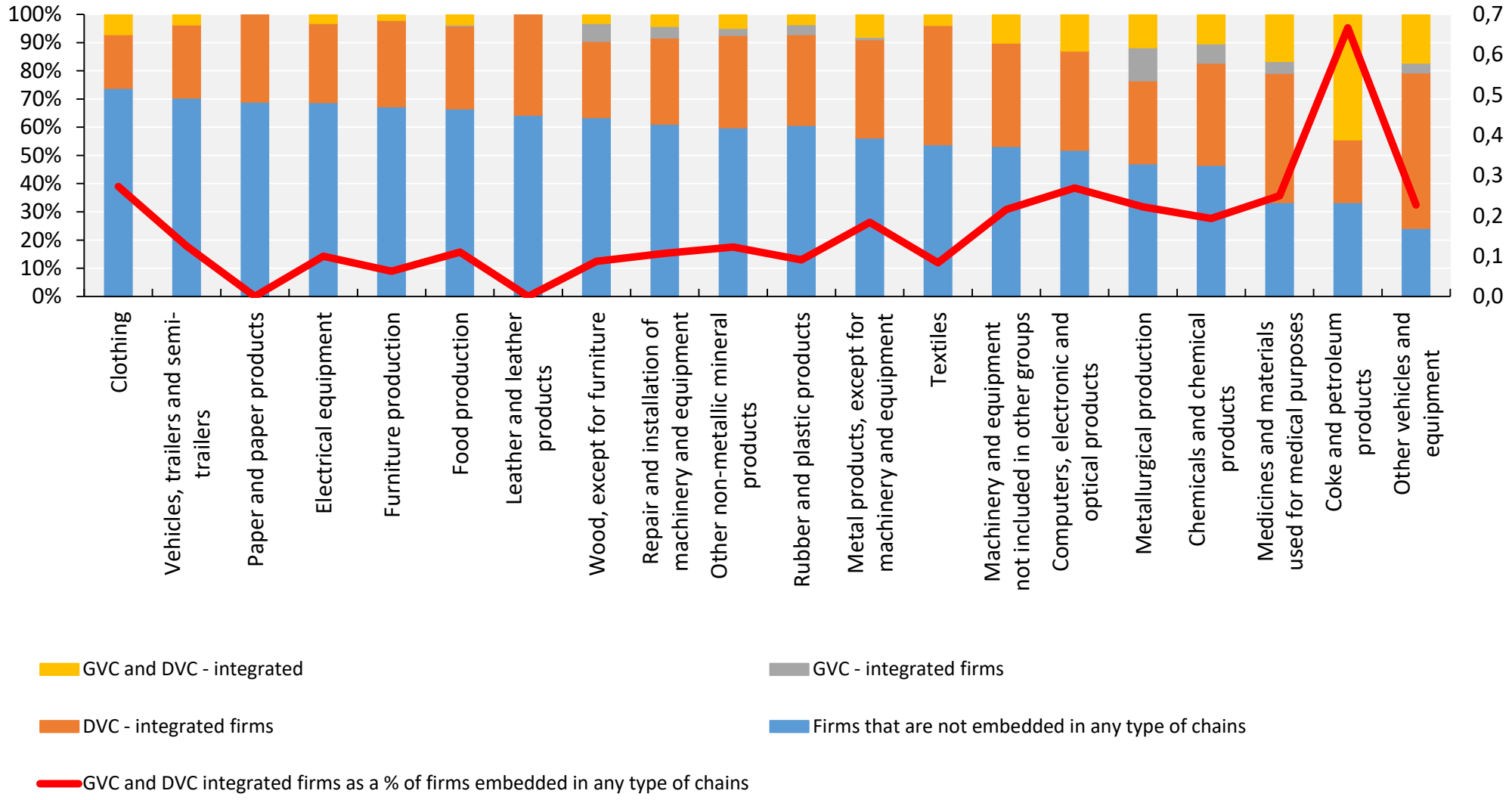
Distribution of firm's industries



Descriptive Statistics partnership types

Share of firms in a group which:	NOT in VCs	DVC	GVC	DVC+GVC
Are in Holding	14%	21%	often in holdings 36%	often in holdings 49%
Medium-sized	11%	10%	12%	10%
Large-sized	40%	57%	60%	often large 74%
Have Foreign – Ownership	3%	3%	often have FDI 48%	16%
Have State – Ownership	3%	5%	4%	5%
Have export intensity>10%	14%	15%	often exporters 48%	often exporters 58%
Est. in 1992-1998	13%	15%	rarely mature 4%	11%
Est. in 2009-2013	often young 17%	14%	8%	9%

Distributions of firm's industry participation in GVC and DVC



Descriptive statistics (1)

Variables	Definition	Mean	Std. dev	Min	Max
Dependent variables					
DVC participation	=1 if share of long-term suppliers and customers greater than 50% and have domestic strategic partners	0,56	0,50	0	1
GVC participation	=1 if share of long-term suppliers and customers greater than 50% and have foreign strategic partners	0,12	0,33	0	1
Value chain participation	The level of integration in value chains, (categorical variable, where 1 – not integrated at all, 2 – DVC integrated, 3 – GVC integrated firms	1,47	0,64	1	3
DVC (Backward participation)	=1 if share of long-term suppliers greater than 50% and have domestic strategic partners	0,45	0,50	0	1
GVC (Backward participation)	=1 if share of long-term suppliers greater than 50% and have foreign strategic partners	0,08	0,27	0	1
DVC (Forward participation)	=1 if share of long-term customers greater than 50% and have domestic strategic partners	0,44	0,50	0	1
GVC (Forward participation)	=1 if share of long-term customers greater than 50% and have foreign strategic partners	0,08	0,28	0	1
Explanatory variables					
Big Data	Analyzing large amount of data	0,20	0,40	0	1
Internet of Things	A system of intelligent sensors	0,35	0,48	0	1
Robotics	Advanced robotics	0,18	0,39	0	1
3D Printing	3D printing and 3D scanning	0,10	0,30	0	1
CRM/CAD/ERP	Automated systems to cooperate with clients	0,36	0,48	0	1
Supplier relations	Relationships with suppliers	0,58	0,49	0	1
Production	Main production activity	0,50	0,50	0	1
R&D	Research and development	0,23	0,42	0	1
Marketing	Marketing	0,40	0,49	0	1
Customer relations	Relationships with consumers, sales	0,52	0,50	0	1
Management	Management of enterprise activities	0,40	0,49	0	1
Supervisory and regulatory	Relationship with control and regulatory staff	0,35	0,48	0	1
Training and professional dev.	Training and professional development of employees	0,21	0,41	0	1

Descriptive statistics (2)

Variables	Definition	Mean	Std. dev	Min	Max
Control variables					
Foreign ownership	If firm have foreign ownership	0,05	0,22	0	1
State ownership	If firm have state ownership	0,03	0,18	0	1
Exporter	If company's export of goods or services >10%	0,16	0,36	0	1
Importer	If company's import of goods or services >10%	0,27	0,44	0	1
Holding	If company belong as a part of the holding	0,17	0,37	0	1
Medium-sized company	If the company has 100-250 employees	0,58	0,49	0	1
Large company	If the company has greater than 250 employees	0,25	0,43	0	1
1992-1998	Post-Soviet firms established in 1992-1998	0,11	0,31	0	1
1999-2008	Firms established in 1999-2008	0,36	0,48	0	1
2009-2013	Firms established in 2009-2013	0,21	0,41	0	1
Industry of the company	Industries are defined based on standard OKVED 2-digit classification				
Region of the company	Regions are defined based on data provided by the company				

Empirical Models

Probit regression models:

(1) $Prob\ (DVC\ or\ GVC\ integration)_y = \alpha + \beta_1 * BigData + \beta_2 * IoT + \beta_3 * Robotics + \beta_4 * 3DP + \beta_5 * CRM/CAD/ERP\ + \beta_6 * Foreign_own + \beta_7 * State_own + \beta_8 * Exporter + \beta_9 * Holding + \beta_{10} * Age + \beta_{11} * Size + \beta_{12} * Industry + \beta_{13} * Region + \varepsilon_I,$

(2) $Prob\ (DVC\ or\ GVC\ integration)_y = \alpha + \beta_1 * Supplier_relations + \beta_2 * Production + \beta_3 * R\&D + \beta_4 * Marketing + \beta_5 * Consumer_{relations} + \beta_6 * Marketing + \beta_7 * Sup_reg_auth + \beta_8 * Training + \beta_9 * ForeignOwn + \beta_{10} * StateOwn + \beta_{11} * Exporter + \beta_{12} * Holding + \beta_{12} * Age + \beta_{13} * Size + \beta_{14} * Industry + \beta_{15} * Region + \varepsilon_I,$

Multinomial Logistic regression models:

(3) $Mlogit\ (DVC\ or\ GVC\ integration)_y = \alpha + \beta_1 * \gamma\ + \beta_2 * \delta + \varepsilon_I,$

γ – set of technologies;
δ – set of control variables;
ε – an error term.

(4) $Mlogit\ (DVC\ or\ GVC\ integration)_y = \alpha + \beta_1 * \theta\ + \beta_2 * \delta + \varepsilon_I,$

θ – set of spheres of technology usage;
δ – set of control variables;
ε – an error term.

- At the first step, we run Probit models for only forward/backward integration (firms on the "ends" of VCs) and for firms in intermediate position that are both backward and forward integrated
- Choice between "Nothing" and "DVC" and Choice between "Nothing" and "GVC" are related, we generalize the regression to the multiclass problem since there is also a choice between "DVC" and "GVC" (thus, there are in fact 3 possible outcomes in a model)
- Thus, at the second step, we run ML models

Results (1) technologies. Probit estimations

	Long-term suppliers & customers > 50%		Long-term suppliers (Backward participation)		Long-term customers (Forward participation)	
	DVC	GVC	DVC	GVC	DVC	GVC
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Medium-sized company (100-250)	0.0666	0.0550	0.0748	0.0381*	0.0767	0.0354
Large company (250+)	0.158***	-0.00248	0.152***	0.00901	0.145***	0.00599
Foreign ownership	-0.181**	0.179***	-0.0491	0.108***	-0.139**	0.111***
State ownership	0.0120	-0.0544	0.0395	-0.0226	0.0646	-0.0230
Exporter	-0.0259	0.142***	0.0145	0.0995***	-0.00314	0.102***
Holding	0.153***	0.0671***	0.0995***	0.0426***	0.105***	0.0429**
Big Data	**0.134*** **	0.0319	**0.0925*** **	0.0160	**0.0940** **	0.0192
Internet of Things	**0.136*** **	0.00232	**0.0601** **	0.00257	**0.0863*** **	0.00341
Robotics	**0.0835***	0.0156	**0.108*** **	0.00857	0.0268	0.00884
3D Printing	-0.00261	-0.0187	0.0418	-0.0103	0.0389	-6.55e-05
CRM/CAD/ERP	**0.0953*** **	**0.0717*** **	**0.0526***	**0.0546*** **	**0.0782** **	**0.0563*** **
Age FE	+	+	+	+	+	+
Region FE	+	+	+	+	+	+
Industry FE	+	+	+	+	+	+
Observations	773	773	1217	1217	1168	1168
Pseudo-R2	0.14	0.30	0.10	0.27	0.10	0.27

+Marginal effects are reported for Probit model

*** p<0.01, ** p<0.05, * p<0.1

Results (2) spheres. Probit estimations

	Long-term suppliers & customers > 50%		Long-term suppliers (Backward participation)		Long-term customers (Forward participation)	
	DVC	GVC	DVC	GVC	DVC	GVC
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Medium-sized company (100-250)	0.0913	0.0544	0.0890*	0.0368	0.0896*	0.0544
Large company (250+)	0.178***	0.0128	0.168***	0.0167	0.162***	0.0128
Foreign ownership	-0.164**	0.178***	-0.0314	0.107***	-0.138**	0.178***
State ownership	0.0356	-0.0213	0.0546	-0.0102	0.0612	-0.0213
Exporter	-0.0175	0.148***	0.0208	0.103***	0.00410	0.148***
Holding	0.142***	0.0729***	0.0915**	0.0477***	0.105***	0.0729***
Supplier relations	0.0437	-0.0123	0.0422	-0.0121	0.0465	-0.0123
Production	0.0479	-0.0250	**0.0673****	-0.0190	0.0312	-0.0250
R&D	**0.114*****	**0.0581****	0.0567	**0.0485*****	**0.103*****	**0.0581****
Marketing	**0.0623***	-0.00553	**0.0573***	-0.0122	0.0292	-0.00553
Consumer relations	0.0277	0.0281	-0.0113	0.0245	0.0276	0.0281
Management	**0.0606***	0.0350	**0.0706****	**0.0345****	0.0189	0.0350
Supervisory and regulatory authorities	0.0607	-0.0111	0.0375	0.00130	**0.0525***	-0.0111
Training and professional development	0.0319	-0.0160	0.0581	-0.0109	0.0560	-0.0160
Age FE	+	+	+	+	+	+
Regional FE	+	+	+	+	+	+
Industry FE	+	+	+	+	+	+
Observations	773	773	1217	1217	1168	1168
Pseudo-R2	0.15	0.30	0.10	0.28	0.10	0.27

+Marginal effects are reported for Probit model

*** p<0.01, ** p<0.05, * p<0.1

Results (3) Multinomial logistic estimations

VARIABLES	(2) DVC	(3) GVC
Medium-sized company (100-250)	0.176	0.679
Large company (250+)	0.627***	0.563
Foreign ownership	-0.346	1.592***
State ownership	0.341	-0.240
Exporter	-0.108	1.578***
Holding	0.143	0.704**
Big Data	**0.472*** **	0.452
Internet of Things	**0.506*** **	0.288
Robotics	0.145	0.172
3D Printing	0.236	0.00191
CRM/CAD/ERP	**0.274***	**1.162*** **
Constant	-1.329***	-4.843***
Age FE	+	+
Regional FE	+	+
Industry FE	+	+
Observations	1179	1179

+Base category: 1 – not integrated in chains

*** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(2) DVC	(3) GVC
Medium-sized company (100-250)	0.276	0.731*
Large company (250+)	0.727***	0.747**
Foreign ownership	-0.322	1.650***
State ownership	0.315	-0.110
Exporter	-0.118	1.669***
Holding	0.127	0.799***
Supplier relations	0.162	-0.180
Production	0.190	-0.192
R&D	0.273	**0.924*** **
Marketing	**0.291***	-0.163
Consumer relations	0.175	**0.556***
Management	0.111	**0.604** **
Supervisory and regulatory authorities	**0.508*** **	0.157
Training and professional development	0.244	0.0633
Constant	-1.812***	-5.035***
Age FE	+	+
Regional FE	+	+
Industry FE	+	+
Observations	1179	1179

+Base category: 1 – not integrated in chains

*** p<0.01, ** p<0.05, * p<0.1

Summary of results

Technologies	Probit	Probit	MLogit	MLogit
	DVC	GVC	DVC	GVC
Size	+***		+***	
Foreign ownership	-**	+***		+***
Holding	+***	+***		+**
Export intensity		+***		+***
Big Data	+***		+***	
Internet of Things	+***		+***	
Robotics	+*			
3D Printing				
CRM/CAD/ERP	+***	+***	+*	+***
Supplier relations				
Production				
R&D	+***	+**		+***
Marketing			+*	
Consumer relations				+*
Management				+**
Supervisory and regulatory	+*		+***	
Training				

Determinants of interest:

- All considered technologies (except of CRM/CAD/ERP) are important only for DVCs, not for GVCs;
- GVC require Industry 4.0 in pre-manufacturing stage (R&D)
- Weak evidence that GVC require Industry 4.0 in other non-production spheres (management and marketing – only in one-side integration, management and consumer relations in ML)
- DVC require Industry 4.0 in supervisory and regulatory sphere (reporting and dealing with authorities using ICT)

Control determinants:

- Firm size is important for DVCs (larger have higher chances), but not for GVCs
- Foreign ownership is important for GVCs (weak evidence suggests that foreign firms are less integrated in DVCs in Russia)
- Export intensity is a good predictor for a firm in GVCs (thus, foreign strategic partners are exporting are related)

Discussion

- Some of the results are in line with previous literature (Cieslik et al., 2019; Orlik, 2017):
  - **foreign-ownership is important for GVCs**
  - **more innovative firms are in GVCs (those that have I4.0 in R&D)**
- Controlling for technologies, we show that *size is important for DVCs, not for GVCs* – on the one hand this is in contrast to the previous literature saying that small size is a barrier for GVCs, on the other hand this is in line with findings arguing that **technologies decrease threshold for scale and allow SMEs to participate in GVCs**
  - In addition, these results support previous findings suggesting that GVCs in Russian economy have limited participation due to (1) scarce subcontracting networks and (2) specifity of Russian large state-owned firms oriented towards national market and public procurement
- **GVCs require I4.0 in pre-manufacturing spheres, DVCs – only in dealing with public authorities (reporting) –** Russian DVCs of manufacturing firms are rigid and less effective, this may prevent localization of foreign firms and block integration in GVCs
- **DVCs as stumbling blocks to GVCs:** The finding that I4.0 pushes participating in DVCs, but not GVCs has three possible explanations:
  - high switching costs from DVCs to GVCs even for more innovative firms
  - different technological protocols that prevent switching from DVCs to GVCs with the same technologies
  - institutions, incl. orientation of national firms towards local market, low innovative activity especially at pre-manufacturing stages

Further work

- **Methods and data quality:** find panel data analysis to explore dynamics of % of long-term partnerships, switching between DVCs and GVCs
- **Scope:** explore DVCs and GVCs at the large sample of developing countries (BEEPS)
- **Determinants:** consider role of institutional factors in switching between DVCs and GVCs