HIGHER SCHOOL OF ECONOMICS
NATIONAL RESEARCH UNIVERSITY

Effects of Robotization on productivity in Russian firms

Nikolay Gorodnyi
Junior Research Fellow, Center for Industrial Policy Studies, HSE Moscow

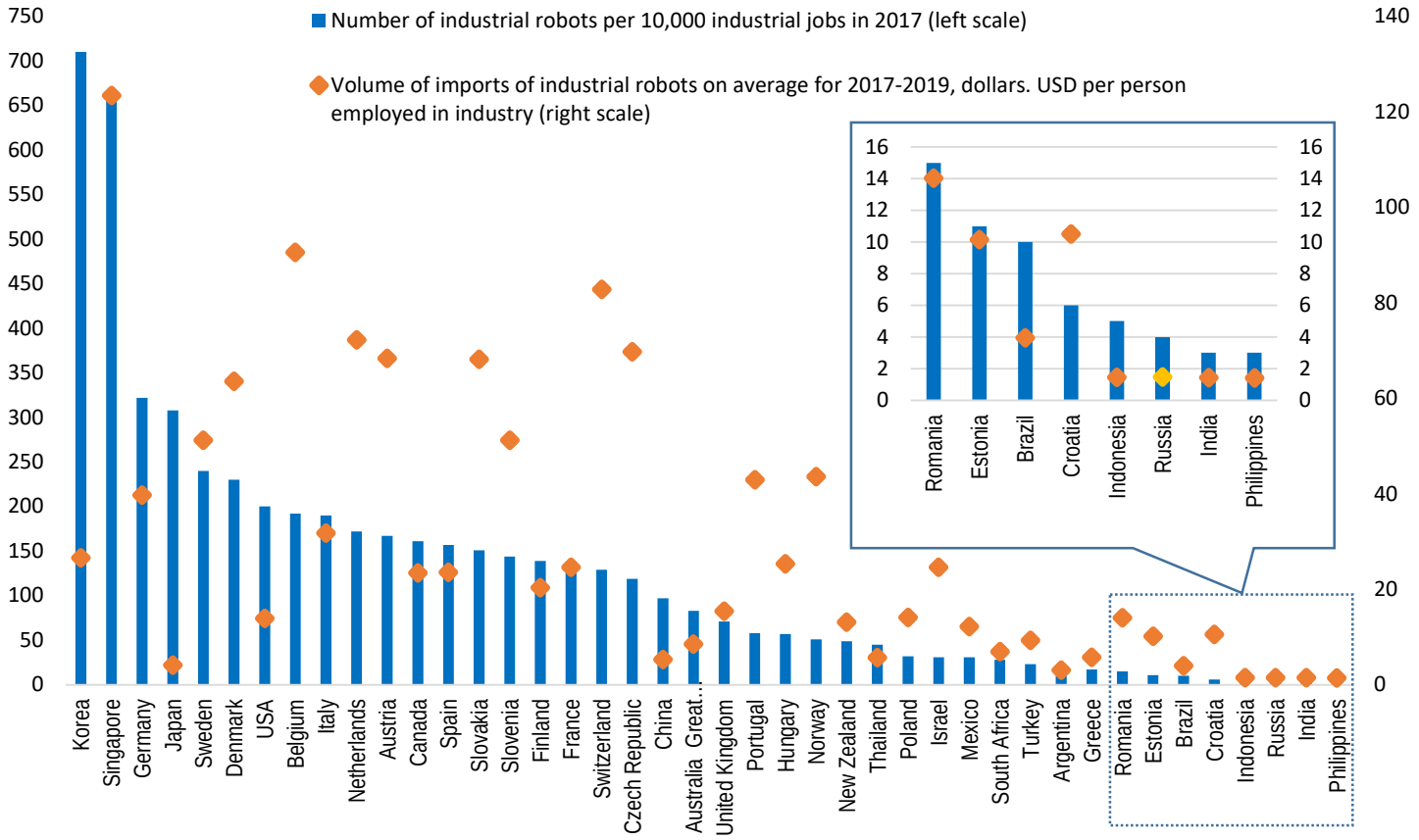
Anna Fedyunina
PhD, Associate Prof., Senior Research Fellow, Center for Industrial Policy Studies, HSE Moscow

May 19th, 2022

Research Problem

- Previous studies have not evaluate the value of robot adoption effects – scale and specificity, which is primarily necessary for company management
- Low integration is related to the non-obvious effects of robotization on production
- There remains a significant gap in the level of robotization between pioneer and follower countries;
- Research interest in the specifics and effects of robotization has grown exponentially over the past two decades

Figure 1. The use of industrial robots - cross-country comparisons



Source: Authors, data from International Federation of Robotics, COMTRADE, World Bank

Research Question and Gap

The main trends in literature *(Fernández-Macías et al., 2021; Acemoglu and Autor, 2011; Acemoglu and Restrepo, 2018a, 2018b, 2019; Autor et al., 2003; Barbieri et al., 2019)*

(1) effects related to robots displacing labor from specific tasks and related work on the effects of robotics on employment;

(2) effects arising when the introduction of robotics creates new jobs, respectively, discussing the creation of new types of tasks in the economy, and finally;

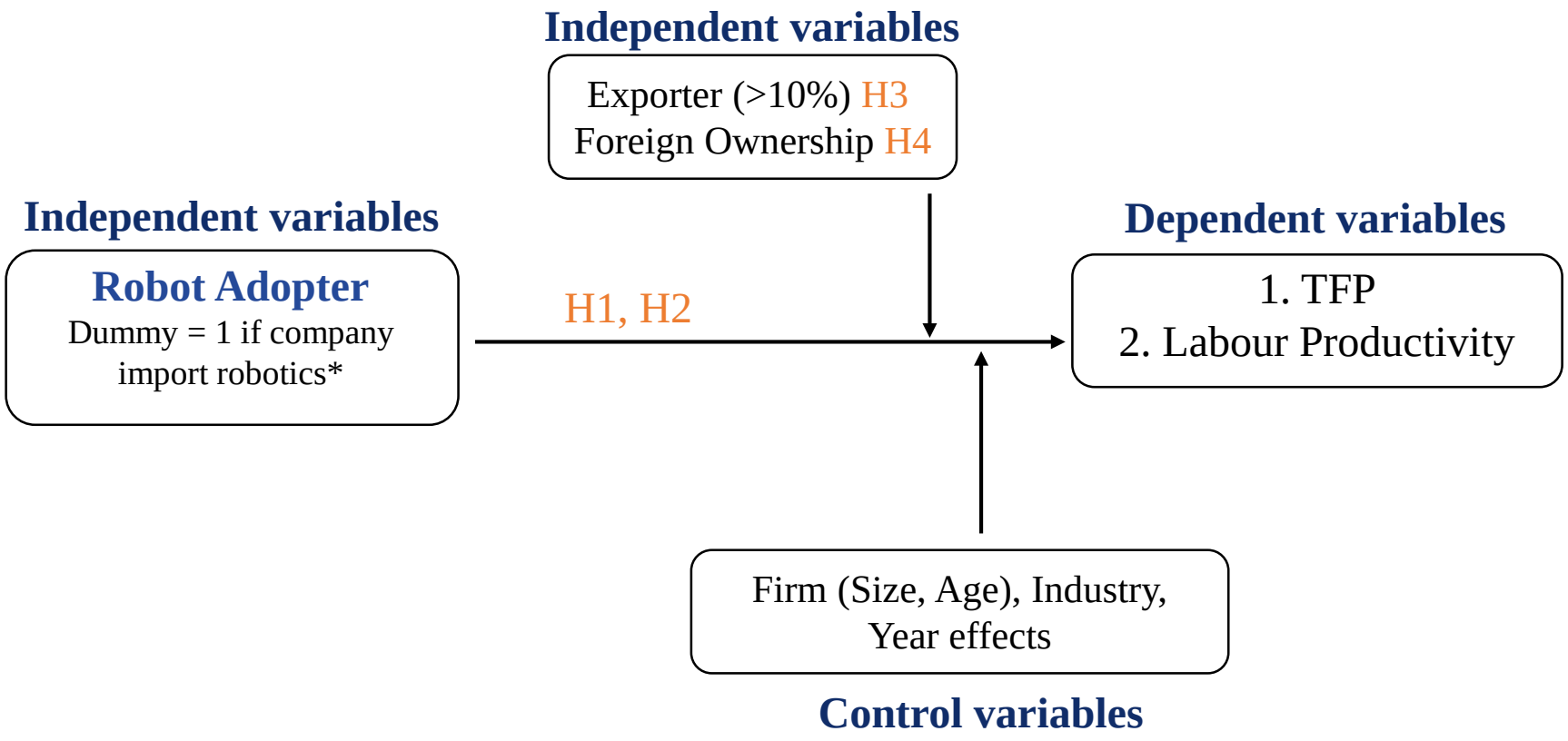
(3) effects of productivity and output growth in the economy.

Theoretical contribution - What is new in our research?

- One of the first studies in the academic literature that examine the effects of industry robotization on the productivity of Russian companies
- Existing studies on the Russian economy are usually based on limited data from sample surveys, or on publicly available statistics from the International Robotics Federation
- Combine several perspectives on robotization in industry at once: (1) at micro, (2) meso (industry) levels

RQ: What are the effects of robot adoption in Russian firms?

Theoretical Model and Hypothesis Development



H1: Robotics implementation leads to higher Total Factor Productivity.
H2: Robotics implementation leads to higher labor productivity.
H3: Non-exporting firms have significant effects of robot adoption on TFP (vs. exporting).
H4: Firms with foreign ownership have positive effect on productivity.

Data

Data

- Panel-structured data from Ruslana Bureau van Dijk database + Customs service of the Russian Federation

Sample

- 81794 firms in Russian manufacturing sector
- 295 Russian firms that purchased industrial robots during taken period
- Time span: 2011-2018

Share of firms in a group which:	Robot Adopters	Non-Robot adopters
Mean TFP	**2,12**	2,05
Mean Ln Labour Productivity	**8,89**	8,3
Have export intensity>10%	**13%**	3%
Have Foreign – Ownership	**38%**	2%
Micro-sized	11%	**53%**
Small-sized	25%	**36%**
Meduim-sized	**19%**	6%
Large-sized	**37%**	5%
USSR	7%	3%
Post-Soviet	19%	11%
Est. in 1999-2010	**54%**	35%
Est. in 2011-2016	20%	**52%**
Overall	**0,4%**	**99,6%**

Robot Adopters account for

- 9,4% of revenue
- 3,9% of employment

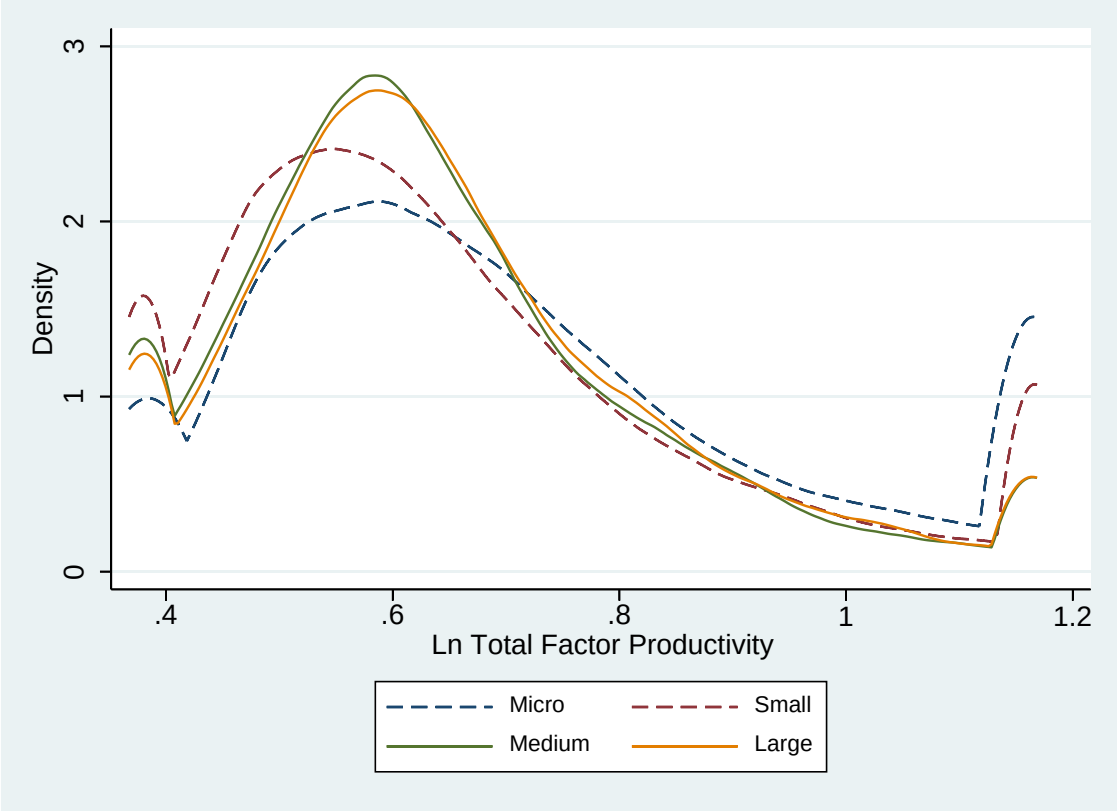
Descriptive Statistics

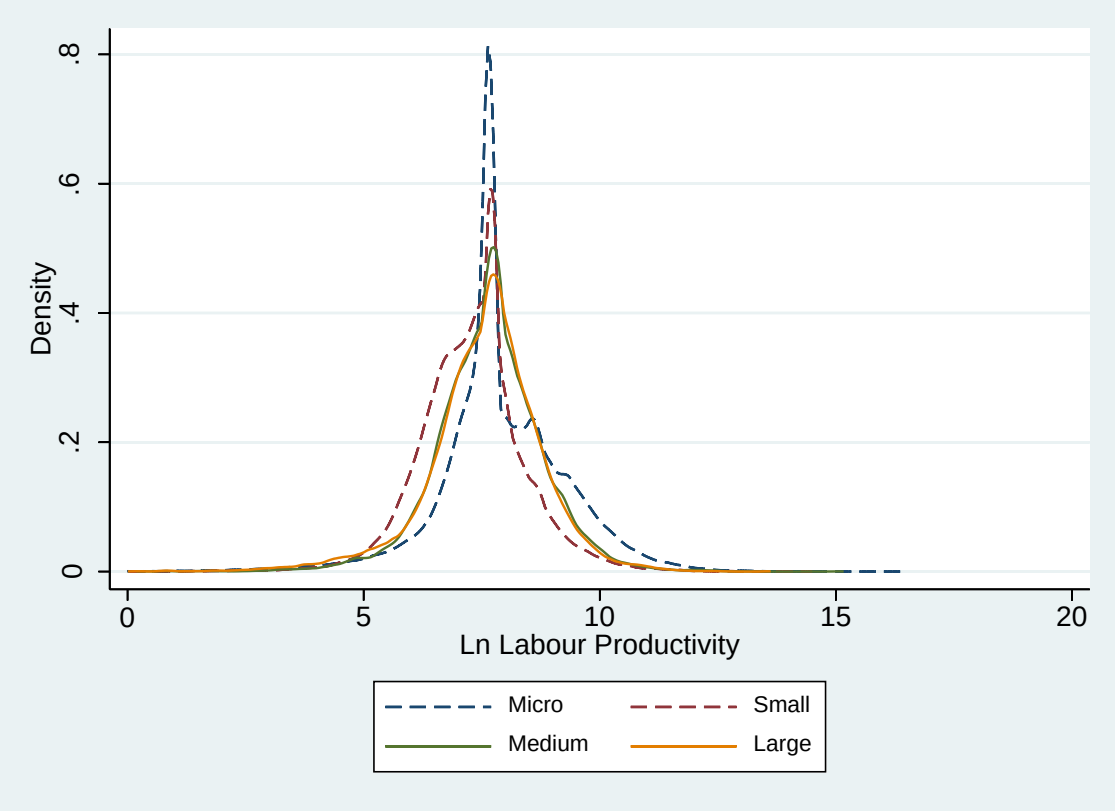
	Robot Adopters				
Variable	Obs	Mean	Std. Dev.	Min	Max
Revenue (‘000 RUB)	1406	12954123	39195238	200	4.582e+08
Ln Revenue	1406	13.846	2.449	5.298	19.943
Capital (‘000 RUB)	1438	6773256.6	26779369	6	2.812e+08
Ln Capital	1438	12.628	2.904	1.792	19.455
Cost (‘000 RUB)	1291	11572594	33799044	206	3.097e+08
Ln Cost	1291	13.914	2.298	5.328	19.551
Employment	1462	1190.743	4678.447	1	74452
Ln Employment	1462	5.192	1.989	0	11.218
Foreign ownership	1664	.413	.493	0	1
Robot Adopter	1808	1	0	1	1
Export (‘000 RUB)	1114	.099	.508	0	11.662
Exporter (>10%)	1114	.171	.377	0	1
TFP	1280	2.046	.428	1.444	3.217
Sum of Robots Imports (‘000 RUB)	1712	19900.262	53300.185	27.687	541616.67
Labour Productivity	1404	14426.314	44928.735	2.807	1094910.5
Ln Labour Productivity	1404	8.504	1.322	1.032	13.906
	Non-Adopters				
Revenue (‘000 RUB)	416060	444115.82	4694393.8	1	4.938e+08
Ln Revenue	416060	10.73942	1.841896	0	20.0177
Capital (‘000 RUB)	329267	299341.46	5176019.1	1	6.837e+08
Ln Capital	431049	100.048	547.029	1	42196
Cost (‘000 RUB)	272021	513514.7	4340403	1	3.92e+08
Ln Cost	272021	10.90851	2.01	0	19.786
Employment	431049	100.0481	547.0292	1	42196
Ln Employment	431049	3.083198	1.58626	0	10.65008
Foreign ownership	597912	.0255957	.1579261	0	1
Export (‘000 RUB)	360236	575279.2	7563369	0	7.30e+08
Exporter (>10%)	360236	.034247	.1818632	0	1
TFP	223579	1.973	.447	1.444	3.217
Labour Productivity	414001	5245.379	49082.508	.016	13525570
Ln Labour Productivity	413908	7.576	1.250	0	16.42

Empirical Model

$$Ln(TFP)_{i,t} = \alpha + \beta_1 RobotAdoption_{i,t} + \beta_2 X_{i,t} + \gamma_1 Z_{i,t} + \varepsilon_{i,t}, \quad (1)$$

$$Ln(LabourProductivity)_{i,t} = \alpha + \beta_1 RobotAdoption_{i,t} + \beta_2 X_{i,t} + \gamma_1 Z_{i,t} + \varepsilon_{i,t}, \quad (2)$$





$$Y_{it} = A_{it} K_{it}^{\beta_k} L_{it}^{\beta_l} M_{it}^{\beta_m}, (3)$$ *(Levinsohn & Petrin, 2003)*

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \omega_i + u_{it}^q, (4)$$

$$Ln(Labour\ Productivity) = ln\left(\frac{Revenue}{Employees}\right), (5)$$

Results (H1). Total Factor Productivity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	**Random Effects**	**Random Effects**	**Random Effects**	**Random Effects**	**Random Effects**	**Random Effects**
VARIABLES	Ln(TFP)	Ln(TFP)	Ln(TFP)	Ln(TFP)	Ln(TFP)	Ln(TFP)	Ln(TFP)
Robot Adopter (t)	**0.0192*** **	**0.0455*** **					
Robot Adopter (t-1)			**0.0505*** **				
Robot Adopter (t-2)				**0.0419*** **			
Robot Adopter (t-3)					**0.0401*** **		
Robot Adopter (t-4)						**0.0256** **	
Robot Adopter (t-5)							**0.0143**
Micro	base	base	base	base	base	base	base
Small	-0.055***	-0.054***	-0.054***	-0.054***	-0.059***	-0.066***	-0.069***
Medium	-0.062***	-0.080***	-0.080***	-0.080***	-0.088***	-0.096***	-0.099***
Large	-0.056***	-0.099***	-0.099***	-0.099***	-0.106***	-0.114***	-0.114***
USSR	base	base	base	base	base	base	base
Est. 1992-1998	-0.0013	-0.014***	-0.014***	-0.014***	-0.015***	-0.015***	-0.014***
Est. 1999-2010	0.0202***	-0.000237	-0.000233	-0.000202	-0.00196	-0.00153	0.00269
Est. 2011-2016	0.0254***	0.00813*	0.00815*	0.00818*	0.00255	-0.00116	0.000901
Exporter	0.0436***	0.00840***	0.00841***	0.00847***	0.0113***	0.0243***	0.0241***
Foreign ownership	0.0843***	0.0934***	0.0934***	0.0938***	0.0958***	0.0958***	0.0942***
Constant	0.664***	0.690***	0.690***	0.690***	0.701***	0.711***	0.712***
Industry Effects	+	+	+	+	+	+	+
Year Effects	-	+	+	+	+	+	+
Firm Effects	-	+	+	+	+	+	+
Observations	176 923	176 923	176 923	176 923	154 142	128 135	99 706
R-squared	0,06	0,06	0,06	0,06	0,06	0,06	0,07
Number of ID		43 689	43 689	43 689	42 735	41 663	40 107

+Robust standard errors in parentheses

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

Results (H2). Labour Productivity

VARIABLES	(1) **OLS** Ln Labour Productivity	(2) **Random Effects** Ln Labour Productivity	(3) **Random Effects** Ln Labour Productivity	(4) **Random Effects** Ln Labour Productivity	(5) **Random Effects** Ln Labour Productivity	(6) **Random Effects** Ln Labour Productivity
Robot Adopter (t)	**0.639*** **	**0.786*** **				
Robot Adopter (t-1)			**0.761*** **			
Robot Adopter (t-2)				**0.655*** **		
Robot Adopter (t-3)					**0.536*** **	
Robot Adopter (t-4)						**0.465*** **
Micro	base	base	base	base	base	base
Small	-0.617***	-0.919***	-0.919***	-0.919***	-0.993***	-1.129***
Medium	-0.263***	-1.096***	-1.096***	-1.095***	-1.143***	-1.232***
Large	-0.363***	-1.412***	-1.411***	-1.409***	-1.432***	-1.487***
USSR	base	base	base	base	base	base
Postsoviet	-0.122***	-0.590***	-0.591***	-0.592***	-0.587***	-0.559***
Est. 1999-2010	0.0926***	-0.530***	-0.531***	-0.532***	-0.516***	-0.471***
Est. 2011-2016	0.189***	-0.504***	-0.505***	-0.506***	-0.521***	-0.514***
Exporter	0.397***	0.259***	0.259***	0.260***	0.291***	0.404***
Foreign	0.773***	0.988***	0.992***	0.997***	1.026***	1.043***
Constant	7.955***	8.920***	8.920***	8.921***	8.995***	9.108***
Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Effects	No	Yes	Yes	Yes	Yes	Yes
Firm Effects	No	Yes	Yes	Yes	Yes	Yes
Observations	334,150	334,150	334,150	334,150	294,848	249,187
R-squared	0,10	0,07	0,07	0,07	0,09	0,12
Number of ID		74,654	74,654	74,654	74,648	74,634

+Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Results (H3). Exporters and Non-Exporters

	Non-Exporter		Exporter	
	(1)	(2)	(3)	(4)
VARIABLES	lnTFP	Ln(Labour Productivity)	lnTFP	Ln(Labour Productivity)
Robot Adopter (t-1)	**0.0559*** **	**0.764*** **	**0.00618**	**0.591*** **
	(0.0136)	**(0.0895)**	**(0.0170)**	**(0.190)**
Micro	base	base	base	base
Small	-0.0551***	-0.917***	-0.0381***	-1.040***
	(0.00137)	(0.00581)	(0.00946)	(0.0501)
Medium	-0.0825***	-1.092***	-0.0497***	-1.263***
	(0.00193)	(0.0126)	(0.0106)	(0.0680)
Large	-0.101***	-1.394***	-0.0674***	-1.736***
	(0.00249)	(0.0197)	(0.0108)	(0.0784)
USSR	base	base	base	base
Est. 1992-1998	-0.0115**	-0.603***	-0.000866	-0.230**
	(0.00496)	(0.0691)	(0.0121)	(0.117)
Est. 1999-2010	0.00313	-0.543***	0.00384	-0.179
	(0.00465)	(0.0690)	(0.0112)	(0.118)
Est. 2011-2016	0.0115**	-0.516***	-0.00593	-0.380***
	(0.00474)	(0.0691)	(0.0132)	(0.125)
Foreign ownership	0.0927***	0.997***	0.0577***	0.788***
	(0.00487)	(0.0300)	(0.00953)	(0.0680)
Constant	0.687***	8.922***	0.734***	9.482***
	(0.00509)	(0.0699)	(0.0170)	(0.143)
Industry Effects	+	+	+	+
Year Effects	+	+	+	+
Firm Effects	+	+	+	+
Observations	167 996	322 573	8 927	11 577
R-squared	0,06	0,07	0,05	0,12
Number of ID	42 796	73 588	3 370	4 521

+Robust standard errors in parentheses

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

Results (H4). Domestic and Foreign ownership

	Domestic ownership		Foreign ownership	
	(1)	(2)	(3)	(4)
VARIABLES	lnTFP	Ln(Labour Productivity)	lnTFP	Ln(Labour Productivity)
Robot Adopter (t-1)	**0.0578*** **	**0.766*** **	**0.0536*** **	**0.787*** **
	(0.0151)	**(0.0993)**	**(0.0195)**	**(0.178)**
Micro	base	base	base	base
Small	-0.0540***	-0.919***	-0.0646***	-0.875***
	(0.00138)	(0.00578)	(0.00908)	(0.0734)
Medium	-0.0806***	-1.078***	-0.0855***	-1.386***
	(0.00194)	(0.0126)	(0.0103)	(0.0857)
Large	-0.0983***	-1.370***	-0.120***	-2.003***
	(0.00252)	(0.0197)	(0.0109)	(0.0963)
USSR	base	base	base	base
Est. 1992-1998	-0.0157***	-0.594***	0.0292	-0.190
	(0.00492)	(0.0648)	(0.0251)	(0.390)
Est. 1999-2010	0.000906	-0.526***	-0.0103	-0.366
	(0.00462)	(0.0648)	(0.0233)	(0.385)
Est. 2011-2016	0.0113**	-0.486***	-0.0583**	-1.000***
	(0.00471)	(0.0649)	(0.0246)	(0.387)
Exporter	**0.00926*** **	**0.278*** **	**0.00196**	**0.0813**
	(0.00278)	**(0.0159)**	**(0.00663)**	**(0.0539)**
Constant	0.687***	8.901***	0.865***	10.29***
	(0.00506)	(0.0659)	(0.0290)	(0.402)
Industry Effects	+	+	+	+
Year Effects	+	+	+	+
Firm Effects	+	+	+	+
Observations	167 902	324 357	9 021	9 793
R-squared	0,05	0,07	0,1	0,1
Number of ID	41 884	72 725	1 805	1 929

+Robust standard errors in parentheses

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

Robustness check

VARIABLES	(1) lnTFP	(2) lnTFP
Accumulated Robots 1	**0.127*** **	
	(0.0296)	
Accumulated Robots 2		**0.242*** **
		(0.0519)
Small	-0.0616***	-0.0616***
	(0.00256)	(0.00256)
Medium	-0.0834***	-0.0834***
	(0.00346)	(0.00346)
Large	-0.0634***	-0.0635***
	(0.00394)	(0.00394)
Est. 1992-1998	0.00132	0.00133
	(0.00564)	(0.00564)
Est. 1999-2010	0.0258***	0.0258***
	(0.00532)	(0.00532)
Est. 2011-2016	0.0326***	0.0326***
	(0.00549)	(0.00549)
Exporter	0.0529***	0.0529***
	(0.00553)	(0.00553)
Foreign ownership	0.0822***	0.0822***
	(0.00508)	(0.00508)
Constant	0.680***	0.680***
	(0.00610)	(0.00610)
Industry Effects	+	+
Year Effects	+	+
Firm Effects	+	+
Observations	36 569	36 569
R-squared	0,08	0,08

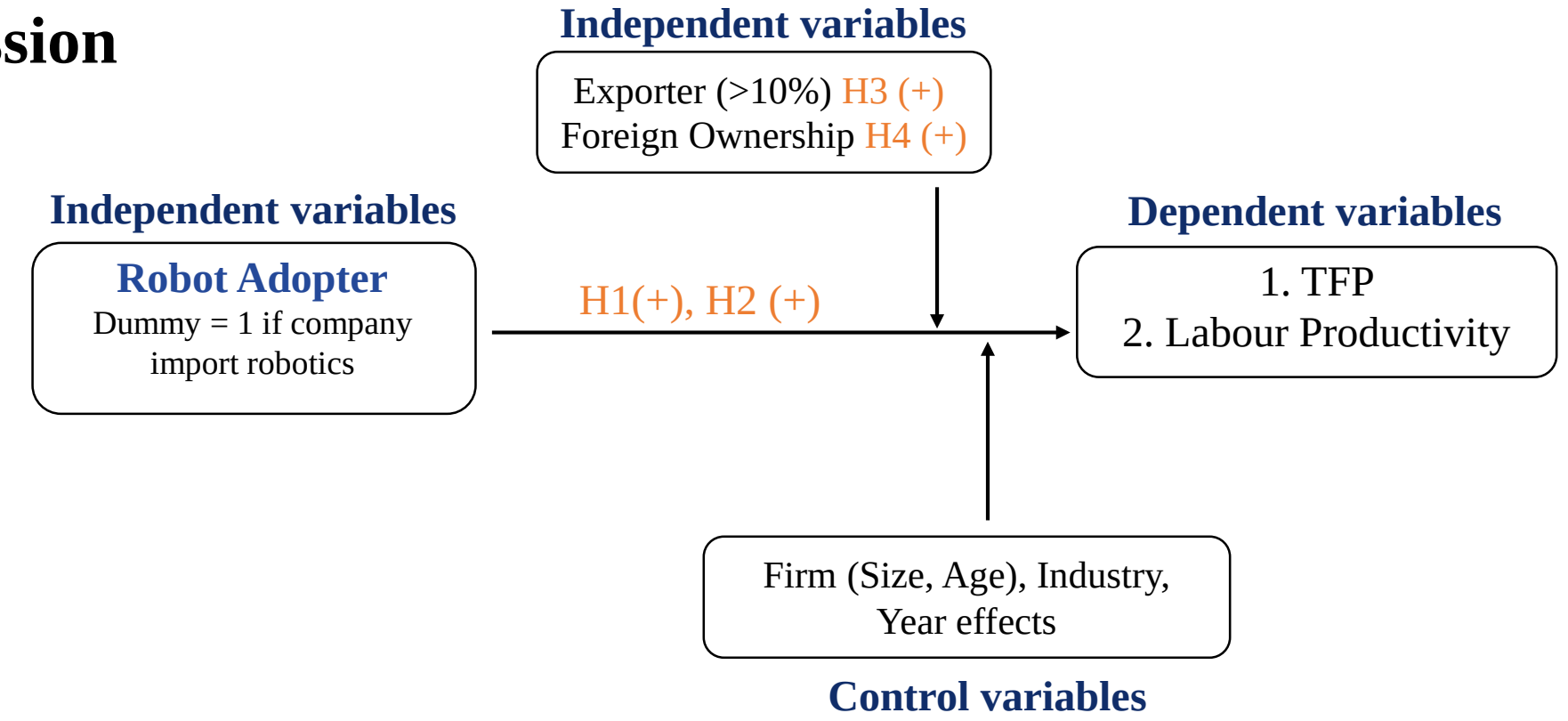
+Robust standard errors in parentheses

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

$$Accumulated\ Robot\ Adoption1 = \frac{\sum Robot\ Imports}{Capital_{2018}} \quad (6)$$

$$Accumulated\ Robot\ Adoption2 = \frac{\sum Robot\ Imports}{Capital_{2018} - Capital_{2014}} \quad (7)$$

Discussion



(1) Robots contribute to increasing in Labour Productivity (**H1** Accept);

(2) Estimations show a significant presence of substantial lags, that is why effects are not constraint through the time (**H2** Accept);

(3) Non-exporting companies (companies with lower productivity) benefit more from the introduction of robots in production (**H3** Accept);;

(4) The effects of robots do not differ between domestic and foreign owned companies (**H4** Accept);;

(5) Negative impact of size: TFP is greater in smaller companies

Study Implications

Theoretical Implications

1. Assess the effects of robotization in industrial enterprises in the Russian economy
2. Develop recommendations aimed at improving the efficiency of state support for the creation and distribution of robotics in Russia

Managerial Implications

1. Understanding the particular effects from robotization for different types of companies
2. The study is expected to help managers in their decision-making process regarding increasing the productivity of Russian firms in order to integrate in global value chains. Proposed to compare companies that use robots in their operations with non-users.

Limitations and Further work

Limitations: Problem of the small number of observations of robot adopter firms

Solution: Propensity Score Matching

Further Research:

1. Understand a more detailed picture of lag effects
2. Determinants from which labour productivity growth arises