



Effects of Robotization on productivity in Russian firms

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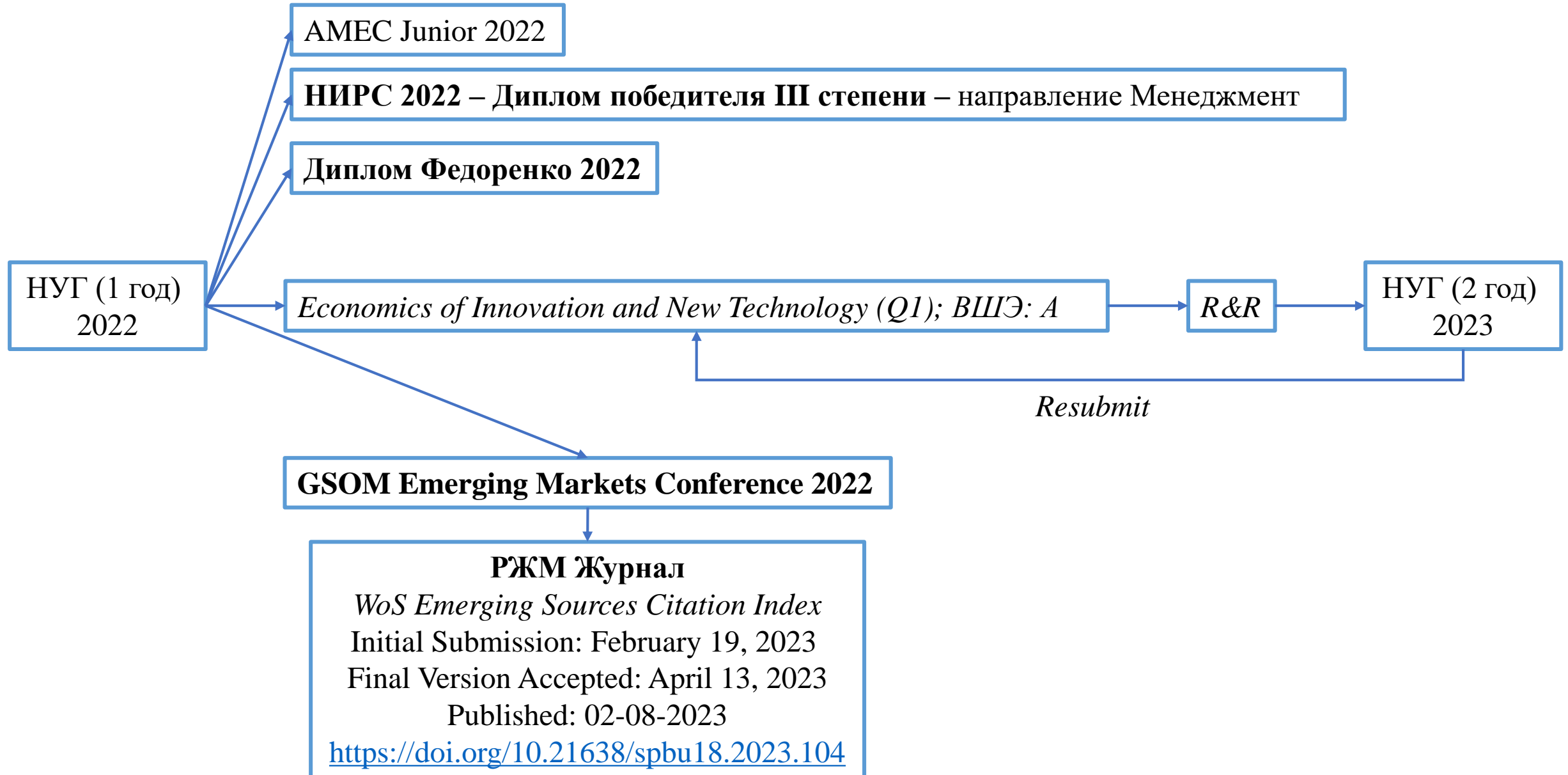
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History & Achievements

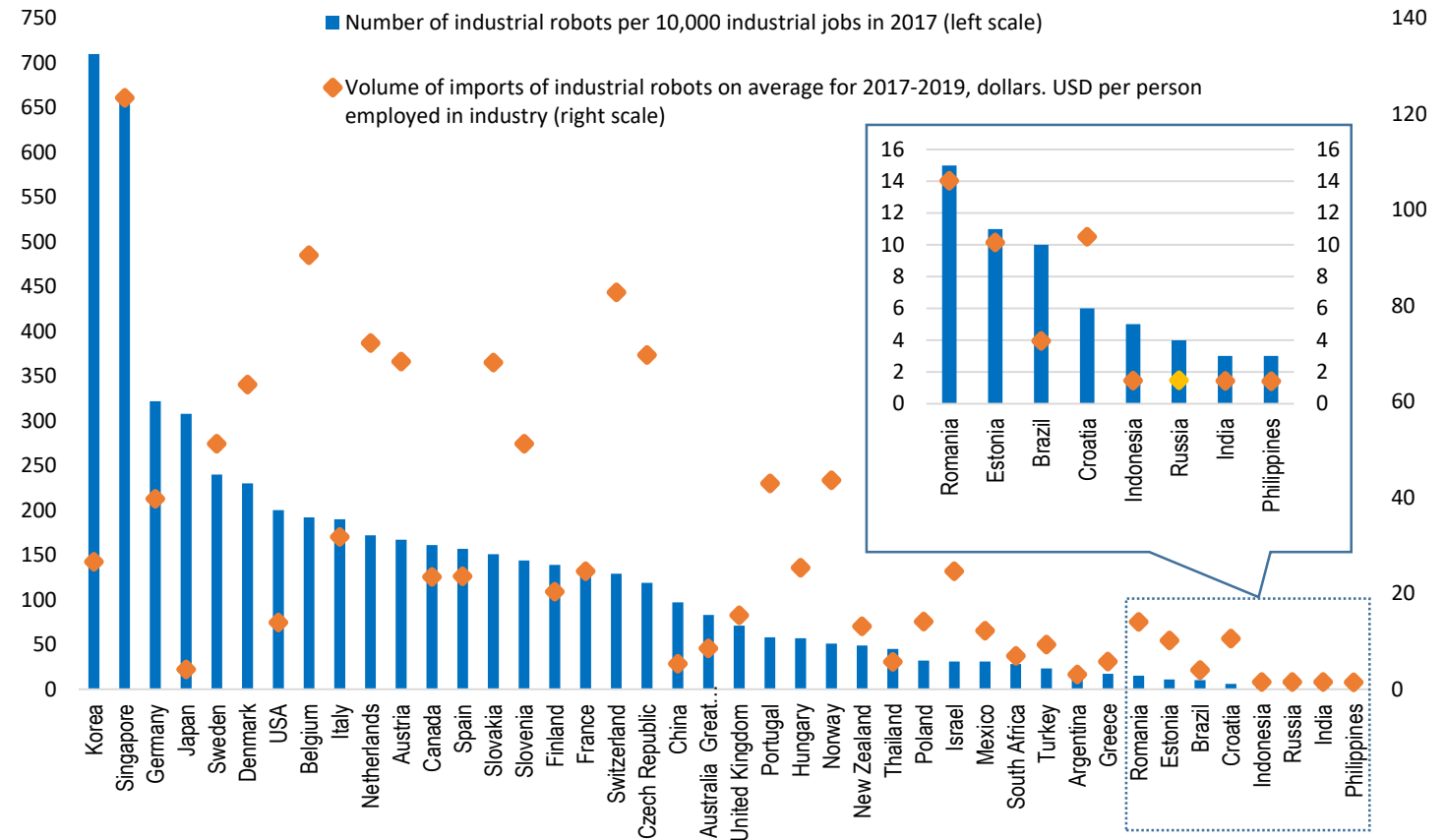
Topic: Effects of Robotization on productivity in Russian firms



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 (*Simachev et al., 2021*);
- Research interest in the specifics and effects of robotization has grown exponentially over the past two decades

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](#))

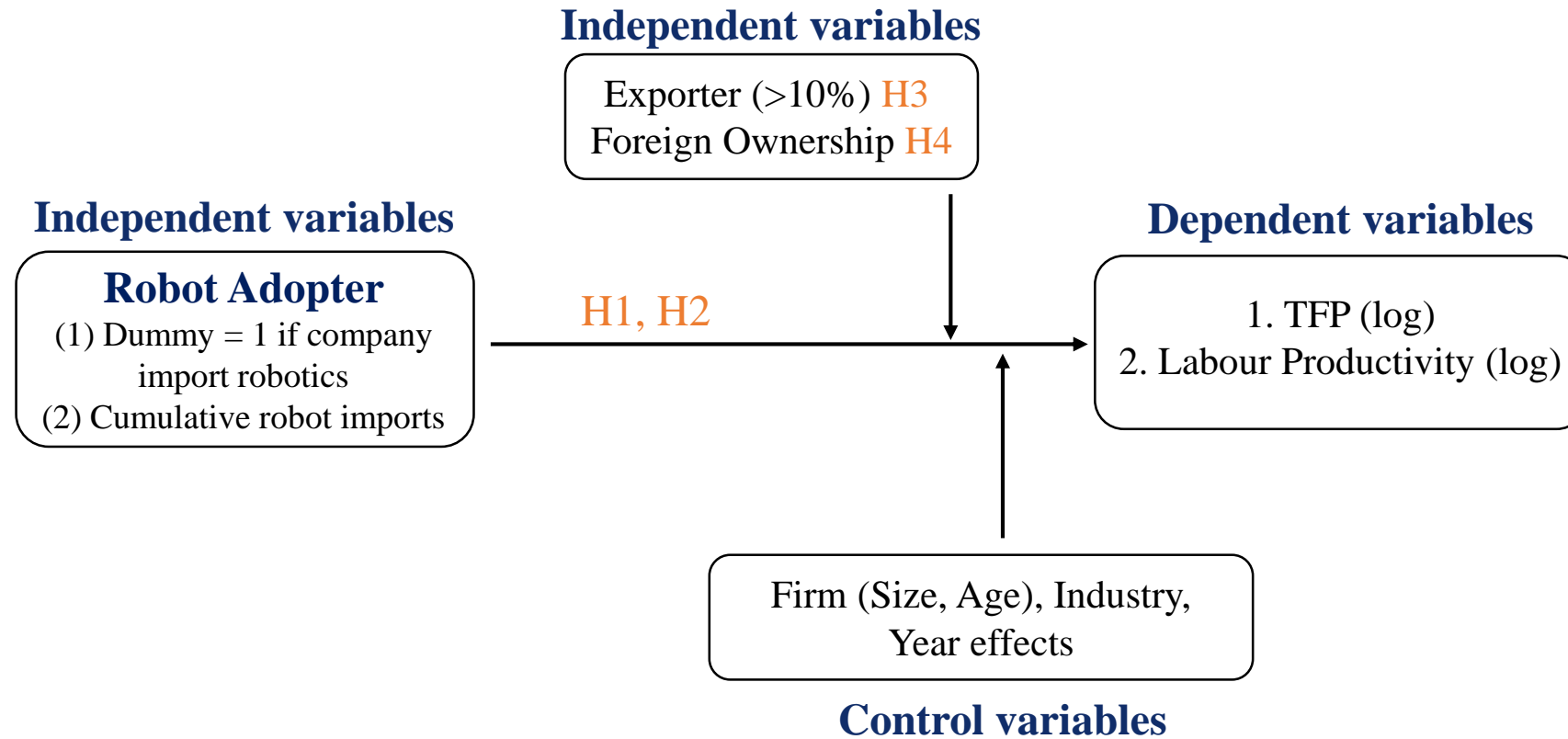
- (1) effects related to robots displacing labor from specific tasks and related work on the effects of robotics on employment;
- (2) effects arising when the introduction of robotics creates new jobs, respectively, discussing the creation of new types of tasks in the economy;
- (3) effects of productivity and output growth in the economy.

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 in 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 Federation of Robotics
- 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



Hypothesis 1. Firms importing robots have higher total factor productivity. *Acemoglu et al., (2020); Bonfiglioli et al., (2020); Cetto et al., (2021), Stiebale, et al., (2020); Koch et al., (2019); Graetz and Michaels, (2018); Ballestar et al., (2020)*

Hypothesis 2. Firms importing robots have higher labour productivity. *Dauth et al. (2018); Stapleton and Webb, (2020); Ballestar et al., (2020); Dinlersoz and Wolf, (2018)*

Hypothesis 3. Robot imports decreases productivity gap between exporters and non-exporters: exporting firms have lower productivity premium for robots import than non-exporting firms. *Farinas and Martín-Marcos, (2007); Strange & Zucchella, (2017); Ghadge et al., (2020); Artuc et al., (2020); DeStefano & Timmis, (2021); Alguacil et al., (2020)*

Hypothesis 4. Robot imports decreases productivity gap between firms with foreign and domestic ownership: firms with foreign ownership have lower productivity premium for robots import than firms with domestic ownership. *Griffith et al., (2004); Benfratello and Sembenelli, (2006); Xu et al., (2022)*

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%
Est. 1992-1998	19%	11%
Est. in 1999-2010	54%	35%
Est. in 2011-2016	20%	52%

Robot Adopters account for

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

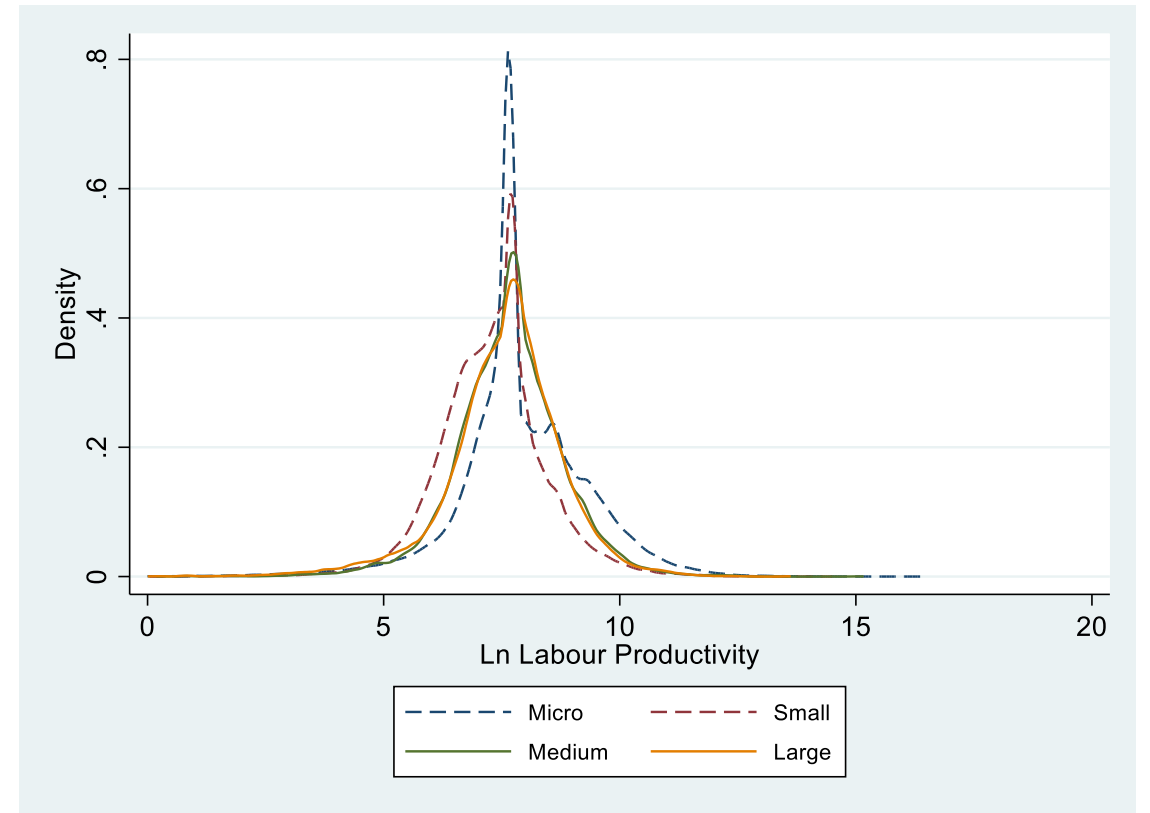
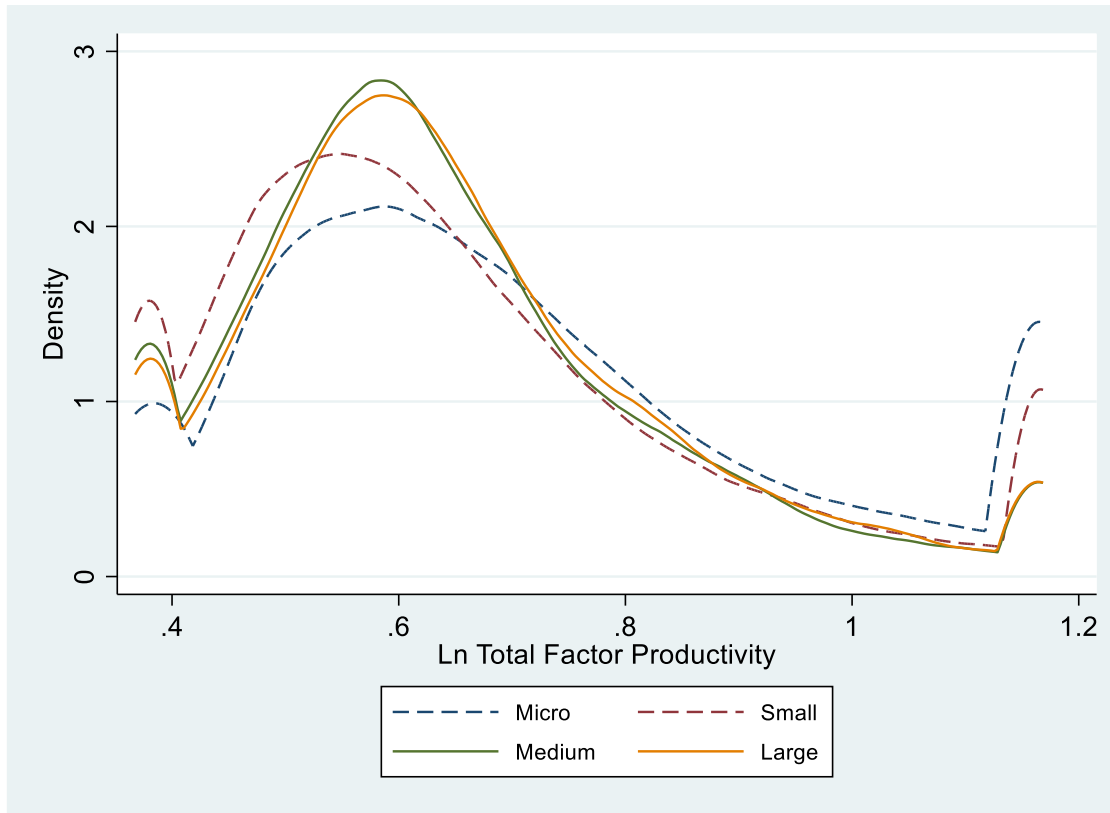
Descriptive Statistics

Variable	Robot Adopters				
	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

Empirical Model

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

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



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

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

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

Results (H1). Total Factor Productivity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	OLS	Random Effects	Random Effects	Random Effects	Random Effects	Random Effects	Random Effects
	Ln(TFP)	Ln(TFP)	Ln(TFP)	Ln(TFP)	Ln(TFP)	Ln(TFP)	Ln(TFP)
Robot Adopter (t)	0.00406	0.0305**					
Robot Adopter (t-1)			0.0424***				
Robot Adopter (t-2)				0.0415***			
Robot Adopter (t-3)					0.0390***		
Robot Adopter (t-4)						0.0188*	
Robot Adopter (t-5)							0.00433
SME	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>
Large	0.0197***	0.0134***	0.0133***	0.0133***	0.0139***	0.0155***	0.0168***
USSR	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>
Est. 1992-1998	0.00427	0.00663	0.00663	0.00663	0.00569	0.00643	0.00712
Est. 1999-2010	0.0298***	0.0327***	0.0327***	0.0327***	0.0322***	0.0333***	0.0363***
Est. 2011-2016	0.0470***	0.0575***	0.0575***	0.0575***	0.0558***	0.0552***	0.0569***
Exporter	0.0395***	0.00909***	0.00911***	0.00918***	0.0111***	0.0243***	0.0220***
Foreign ownership	0.0745***	0.0740***	0.0738***	0.0740***	0.0757***	0.0765***	0.0769***
Constant	0.611***	0.608***	0.608***	0.608***	0.610***	0.611***	0.610***
Industry FE	+	+	+	+	+	+	+
Year Effects	-	+	+	+	+	+	+
Firm Effects	-	+	+	+	+	+	+
Observations	113 756	113 756	113 756	113 756	104 913	91 705	74 834
R-squared	0,05	0,06	0,06	0,06	0,06	0,06	0,06
Number of ID		35 139	35 139	35 139	34 868	34 397	33 489

Source: Authors' calculations, data Ruslana Bureau van Dijk

Notes: Robust standard errors are reported ***Significance level ($p < 0.01$), **significance level ($p < 0.05$), *significance level ($p < 0.1$)

Results (H2). Labour Productivity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	Random Effects	Random Effects	Random Effects	Random Effects	Random Effects	Random Effects
VARIABLES	Ln(Labour Productivity)	Ln(Labour Productivity)	Ln(Labour Productivity)	Ln(Labour Productivity)	Ln(Labour Productivity)	Ln(Labour Productivity)	Ln(Labour Productivity)
Robot Adopter (t)	0.464***	0.498***					
Robot Adopter (t-1)			0.527***				
Robot Adopter (t-2)				0.510***			
Robot Adopter (t-3)					0.371***		
Robot Adopter (t-4)						0.309***	
Robot Adopter (t-5)							0.388***
SME	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>
Large	0.546***	0.442***	0.442***	0.443***	0.482***	0.523***	0.537***
USSR	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>
Est. 1992-1998	0.0270**	0.0208	0.0207	0.0207	0.0203	0.0253	0.0461**
Est. 1999-2010	0.298***	0.298***	0.298***	0.298***	0.300***	0.316***	0.361***
Est. 2011-2016	0.561***	0.636***	0.636***	0.636***	0.632***	0.642***	0.692***
Exporter	0.313***	0.200***	0.200***	0.201***	0.220***	0.313***	0.301***
Foreign ownership	0.686***	0.692***	0.693***	0.696***	0.719***	0.732***	0.731***
Constant	7.378***	7.401***	7.401***	7.401***	7.408***	7.422***	7.443***
Industry FE	+	+	+	+	+	+	+
Year Effects	-	+	+	+	+	+	+
Firm Effects	-	+	+	+	+	+	+
Observations	208 174	208 174	208 174	208 174	195 054	173 642	144 305
R-squared	0,07	0,10	0,10	0,10	0,11	0,11	0,12
Number of ID		62 840	62 840	62 840	62 810	62 742	62 565

Source: Authors' calculations, data Ruslana Bureau van Dijk

Notes: Robust standard errors are reported ***Significance level ($p < 0.01$), **significance level ($p < 0.05$), *significance level ($p < 0.1$)

Results (H3). Exporters and Non-Exporters

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Non-exporters	Exporters Ln(TFP)	Total sample	Non-exporters	Exporters Labour productivity (log)	Total sample
Robot Adopter (t-1)	0.0472***	-0.00303	0.0424***	0.520***	0.466**	0.549***
SME	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>
Large	0.0118***	0.0363***	0.0133***	0.444***	0.358***	0.443***
USSR	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>
Est. 1992-1998	0.00848	0.0253*	0.00663	0.0231	0.138**	0.0208
Est. 1999-2010	0.0361***	0.0252**	0.0327***	0.299***	0.421***	0.298***
Est. 2011-2016	0.0610***	0.0326**	0.0575***	0.636***	0.663***	0.636***
Foreign Ownership	0.0756***	0.0411***	0.0738***	0.723***	0.477***	0.693***
Exporter			0.00911***			0.202***
Exporter * Robot Adopter			0.000166			-0.171
Constant	0.604***	0.663***	0.608***	7.390***	7.916***	7.401***
Industry Effects	+	+	+	+	+	+
Year Effects	+	+	+	+	+	+
Firm Effects	+	+	+	+	+	+
Observations	107 594	6 162	113 756	200 331	7 843	208 174
R-squared	0,06	0,06	0,06	0,10	0,14	0,10
Number of ID	34 244	2 559	35 139	61 686	3 426	62 840

Source: Authors' calculations, data Ruslana Bureau van Dijk

Notes: Robust standard errors are reported ***Significance level ($p < 0.01$), **significance level ($p < 0.05$), *significance level ($p < 0.1$);

Random Effects model are used for each specification

Results (H4). Domestic and Foreign ownership

	(1)	(2)	(3)	(4)	(5)	(6)
	Domestic ownership	Foreign ownership	Total sample	Domestic ownership	Foreign ownership	Total sample
VARIABLES	Ln(TFP)			Labour productivity (log)		
Robot Adopter (t-1)	0.0579***	0.0344*	0.0511***	0.533***	0.487***	0.493***
SME	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>
Large	0.0108***	0.0279***	0.0134***	0.438***	0.401***	0.442***
USSR	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>
Est. 1992-1998	0.00493	0.0383	0.00665	0.0115	0.173	0.0207
Est. 1999-2010	0.0338***	0.0120	0.0327***	0.291***	0.405***	0.298***
Est. 2011-2016	0.0602***	-0.00860	0.0575***	0.637***	0.340**	0.636***
Exporter	0.0105***	0.00147	0.00910***	0.232***	-0.0234	0.200***
Foreign Ownership			0.0745***			0.691***
Foreign Ownership * Robot Adopter			-0.0268			0.0866
Constant	0.606***	0.751***	0.608***	7.401***	8.267***	7.401***
Industry Effects	+	+	+	+	+	+
Year Effects	+	+	+	+	+	+
Firm Effects	+	+	+	+	+	+
Observations	107 159	6 597	113 756	201 114	7 060	208 174
R-squared	0,05	0,12	0,06	0,94	0,11	0,10
Number of ID	33 535	1 604	35 139	61 114	1 726	62 840

Source: Authors' calculations, data Ruslana Bureau van Dijk

Notes: Robust standard errors are reported ***Significance level ($p < 0.01$), **significance level ($p < 0.05$), *significance level ($p < 0.1$);

Random Effects model are used for each specification

Robustness check

VARIABLES	(1) Ln(TFP)	(2) Ln(TFP)
Cumulative Robot Adoption (1)	0.128*** (0.0122)	
Cumulative Robot Adoption (2)		0.278*** (0.0561)
SME	<i>base</i>	<i>base</i>
Large	0.0132*** (0.00335)	0.0132*** (0.00335)
USSR	<i>base</i>	<i>base</i>
Est. 1992-1998	0.00936 (0.00596)	0.00937 (0.00596)
Est. 1999-2010	0.0407*** (0.00548)	0.0407*** (0.00548)
Est. 2011-2016	0.0648*** (0.00554)	0.0648*** (0.00554)
Exporter	0.0429*** (0.00596)	0.0429*** (0.00596)
Foreign Ownership	0.0753*** (0.00549)	0.0753*** (0.00549)
Constant	0.611*** (0.00580)	0.611*** (0.00580)
Industry Effects	+	+
Year Effects	+	+
Firm Effects	+	+
Observations	30 011	30 011
R-squared	0.056	0.056

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

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

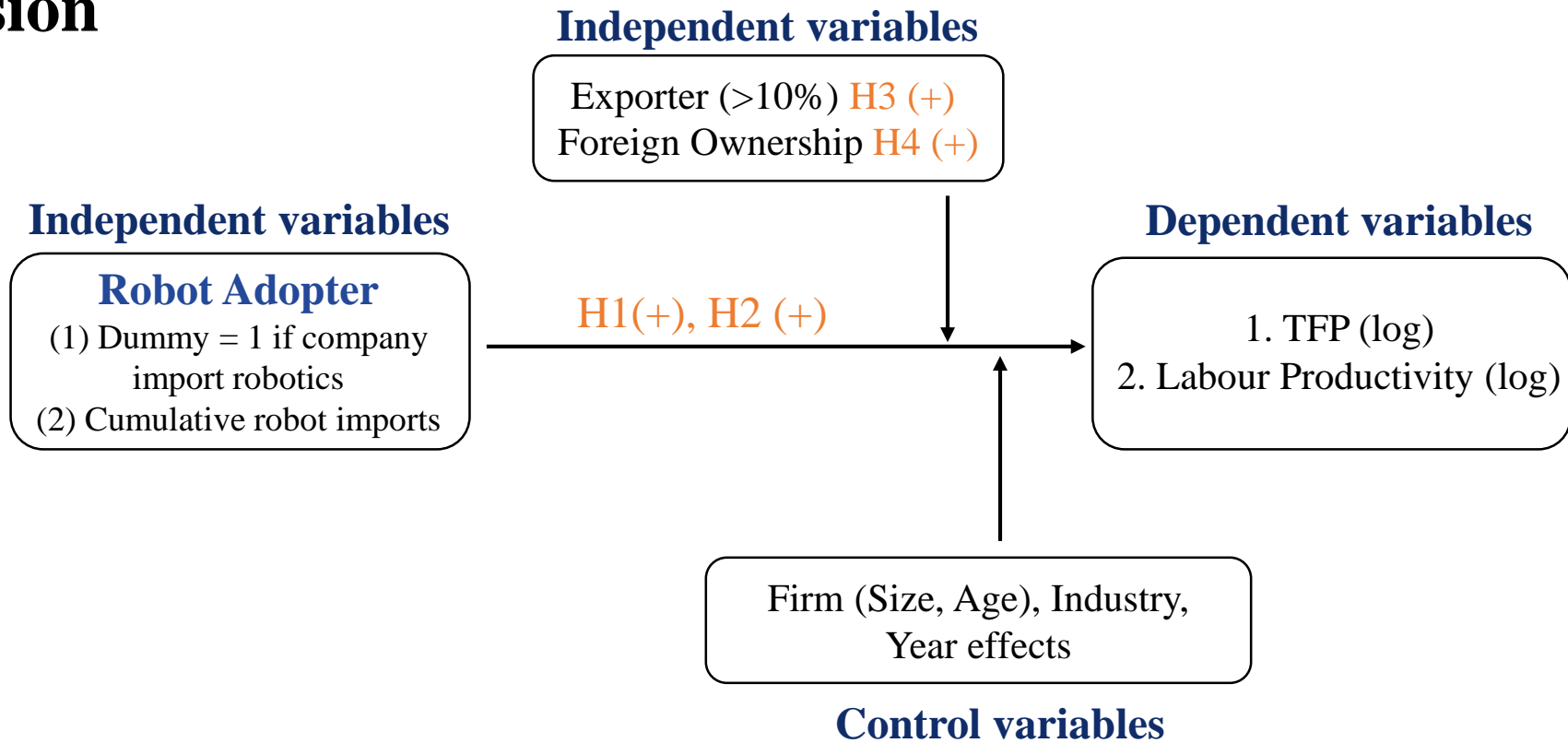
Source: Authors' calculations, data Ruslana Bureau van Dijk

Notes: Robust standard errors in parentheses ***Significance level ($p < 0.01$), **significance level ($p < 0.05$),

*significance level ($p < 0.1$);

Random Effects model are used for each specification

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**);

Study Implications

Theoretical Implications

1. Robots contribute to increasing in labour productivity
2. Significant presence of substantial lags
3. Non-exporting companies (companies with lower productivity) benefit more
4. The effects of robots do not differ between domestic and foreign owned companies

Managerial Implications

1. Assess the effects of robotization in industrial enterprises in the Russian economy
2. Understanding the particular effects from robotization for different types of companies
3. 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.
4. Recommendations aimed at improving the efficiency of state support for the creation and distribution of robotics in Russia

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: more specific to companies by size and type of industries (labour intensive/capital intensive)
2. Determinants from which labour productivity growth arises: (1) reduction in employment; (2) the number of employees is maintained while the company's revenue grows

Ключевые доработки

1. Были пересчитаны все спецификации и скорректированы на уровень цен. Производительность была пересчитана – приведена к реальной с использованием индекса цен производителей промышленных товаров согласно данным Росстата. Использование реальной производительности труда не привело к изменению знака и статистической значимости при объясняющих переменных, что особенно важно для ключевой переменной импорта роботов.
2. Усилена аргументация правомерности аппроксимации переменной материалы (используемой в модели расчета TFP Levinsohn-Petrin) переменной себестоимости продукции.
3. Аргументирована аппроксимация переменной производительности труда переменной выручки на одного занятого на предприятии.
4. Более четко сформулированы критерии формирования выборки.
5. Более четко сформулирована новизна проведенного исследования
6. Даны рекомендации по улучшению существующей ситуации на рынке робототехники.

Ключевые доработки

Таблица 4

Влияние импорта роботов на производительность предприятий: панельная оценка со случайными эффектами

Переменная	Зависимая переменная					
	СФП, логарифм			Производительность труда, логарифм		
	(1)	(2)	(3)	(4)	(5)	(6)
Импорт роботов ($t-I$)	0,0360*** (0,0141)	0,0360*** (0,0144)	0,0436*** (0,0150)	0,518*** (0,0911)	0,540*** (0,0988)	0,485*** (0,115)
Крупное предприятие	0,0236*** (0,00268)	0,0236*** (0,00268)	0,0237*** (0,00268)	0,445*** (0,0160)	0,445*** (0,0160)	0,445*** (0,0160)
Возраст (период основания предприятия):						
1992–1998	0,00181 (0,00526)	0,00181 (0,00526)	0,00183 (0,00526)	0,0209 (0,0222)	0,0209 (0,0222)	0,0208 (0,0222)
1999–2010	0,0303*** (0,00482)	0,0303*** (0,00482)	0,0303*** (0,00482)	0,297*** (0,0209)	0,297*** (0,0209)	0,297*** (0,0209)
2011–2016	0,0509*** (0,00488)	0,0509*** (0,00488)	0,0509*** (0,00488)	0,633*** (0,0209)	0,633*** (0,0209)	0,633*** (0,0209)
Экспортер	0,0166*** (0,00306)	0,0166*** (0,00307)	0,0166*** (0,00306)	0,206*** (0,0184)	0,208*** (0,0184)	0,206*** (0,0184)
(Экспортер · Импорт роботов)	—	0,000074 (0,0173)	—	—	0,172 (0,162)	—
Иностранная собственность	0,0804*** (0,00503)	0,0804*** (0,00503)	0,0810*** (0,00507)	0,695*** (0,0269)	0,696*** (0,0269)	0,693*** (0,0271)
(Иностранная собственность · Импорт роботов)	—	—	-0,0233 (0,0222)	—	—	0,0867 (0,148)
Константа	0,669*** (0,00511)	0,669*** (0,00511)	0,669*** (0,00511)	7,314*** (0,0230)	7,314*** (0,0230)	7,314*** (0,0230)
Отраслевые дамми	Да	Да	Да	Да	Да	Да
Число наблюдений	113 716	113 716	113 716	208 117	208 117	208 117
R^2	0,06	0,06	0,06	0,10	0,10	0,10
Число предприятий	35,132	35,132	35,132	62,834	62,834	62,834

Примечания: в скобках указаны робастные стандартные ошибки; *** — значимость при 1%-м уровне; прочерки обозначают, что данная переменная не используется в соответствующей спецификации, поэтому для нее отсутствует коэффициент.

Ключевые доработки

Таблица 5

Влияние импорта роботов на производительность предприятий субъектов МСП и крупных предприятий: панельная оценка со случайными эффектами

Переменная	Зависимая переменная			
	СФП, логарифм		Производительность труда, логарифм	
	МСП	Крупные	МСП	Крупные
Импорт роботов ($t-1$)	0,0409** (0,0200)	0,0281* (0,0146)	0,547*** (0,124)	0,445*** (0,0898)
Возраст (период основания предприятия):				
1992–1998	0,00555 (0,00612)	–0,00291 (0,00953)	0,00568 (0,0249)	0,111** (0,0493)
1999–2010	0,0343*** (0,00566)	0,0248*** (0,00847)	0,271*** (0,0234)	0,512*** (0,0461)
2011–2016	0,0570*** (0,00569)	0,0211** (0,00926)	0,623*** (0,0234)	0,575*** (0,0504)
Экспортер	0,0156*** (0,00355)	0,0183*** (0,00603)	0,231*** (0,0206)	0,0581 (0,0408)
Иностранная собственность	0,0715*** (0,00583)	0,100*** (0,00920)	0,669*** (0,0309)	0,689*** (0,0539)
Константа	0,661*** (0,00593)	0,728*** (0,00852)	7,304*** (0,0254)	7,919*** (0,0504)
Отраслевые дамми	Да	Да	Да	Да
Число наблюдений	97 473	16 243	189 078	19 039
R^2	0,06	0,06	0,09	0,14
Число предприятий	31 920	3 771	59 196	4 355

Примечания: в скобках указаны робастные стандартные ошибки; **, *** — значимость при 5%-м и 1%-м уровнях соответственно.

Планы по доработке (major improvements)

Referee 1

1. В спецификации производительности труда необходимо добавить в качестве объясняющей переменной отношение капитала к труду.
2. Представить результаты оценок на постоянном наборе данных, а результаты для разных размеров наборов данных привести в приложении.
3. «Пруфридинг» текста на ошибки, лексику

Referee 2

1. Сделать проверку устойчивости результатов с учетом непрерывных оценок роботизации. Возможно, добавить какую-то описательную статистику по компаниям, которые непрерывно импортируют роботов.
2. Прочие комментарии относительно уточнений по тексту