Robots at Work?
Pitfalls of Industry Level Data

Karim Bekhtiar, Benjamin Bittschi & Richard Sellner

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The Fear of Automation: A recurring theme

1964   **1978**   **2016**

The Fear of Automation: A recurring theme

"(...) **technological unemployment**. *This means unemployment due to our discovery of means of economising the use of labour outrunning the pace at which we can find new uses for labour."*

- John Maynard Keynes (1930)

"According to our estimates around 47% of total US employment (...) could be automated relatively soon, perhaps over the next decade or two."

- Frey and Osborne (2017)

The seminal paper by Graetz and Michaels (2018)

⋄ First Study to analyze the impact of industrial robots

⋄ Introduced detailed data on robot stocks from the International Federation of Robotics (IFR, 2017)

⋄ Findings: Robots...

   ... increase labor productivity
   ... reduce output prices
   ... increase wages
   ... decrease the employment share of low skilled workers

"(...) the contribution of robots to productivity growth is on a similar order of the steam engine in the nineteenth century and a little lower than highways in the middle of the twentieth century, and ICT in more recent decades."

- Graetz and Michaels (2018) (p. 765)

Contribution:

◇ Critical appraisal of Graetz and Michaels (2018) (henceforth G&M 2018)

◇ G&M 2018 results hold only when comparing hardly-robotizing sectors with highly-robotizing sectors

◇ Controlling for the demographic structure of the workforce (following Acemoglu and Restrepo, forthcoming)
  − re-establishes productivity effects
  − reverses the sign of the wage effect (from positive to negative)
  − rejects skill-biased technological change

◇ No significant robotization effects when examining the most recent data (2010-2015) [Appendix]

◇ Non-monotonicity in one of the instruments

Related Literature I: Routine Biased Technological Change (RBTC)

◇ Earlier literature examining the effect of automation technologies in a task based framework (following Autor et al., 2003)

◇ See for example Autor et al. (2008), Dustmann et al. (2009), Autor and Dorn (2013), Goos et al. (2014) among many others

▶ de Vries et al. (2020): RBTC closely connected to robotization!

Related Literature II: Local Labor Market Studies

$\diamond$ Acemoglu and Restrepo (2020):
Negative effect of robots on employment and wages in US local labor markets between 1990-2007

$\diamond$ Dauth et al. (2021):
Robots increase productivity but not wages $\rightarrow$ decline in labor share; no employment effect in the aggregate

$\blacktriangleright$ Both papers use shift-share research designs to analyze effects on the local labor market level
  – No micro information on actual robot use
  – Assumption: All firms in a given industry have the same ability and willingness to adopt robots

Related Literature III: Firm Level Studies

◇ Koch et al. (2019):
- Firm level data for Spain (1990-2016)
- Larger and more productive firms select into robot usage; more skill intensive firms are less likely to do so
- Substantial output gains of adoption (20-25% within 4 years) Reduced Labor Costs (5-7%) and net job creation (10%)
- Substantial job losses in firms not adopting robots

◇ Acemoglu et al. (2020):
- Firm level data for France (2010-2015)
- Labor share and share of production workers reduced in robot adopting firms
- Overall employment, value added and productivity increase
- Substantial job losses and decreases in value added for non-adopters
- Overall employment effect is negative

Related Literature IV: Robotization and Demographics

◇ Acemoglu and Restrepo (forthcoming):
  – Analysis on the country level, as well as for US local labor markets
  – Aging leads to increased adoption of robots and other automation technologies
  – Shortage of middle-aged workers specialized in manual production tasks
  – Relative price of robots (compared to manual labor) decreases because of worker shortage

▶ The demographic structure of the workforce plays a crucial role for robotization

Data Sources:

- ◇ **International Federation of Robotics (IFR):** Stock of industrial robots per industry, country and year
- ◇ **EU-KLEMS:** Value-added, prices, capital stock, hours worked, wages, composition of workforce
  1. 1993-2007: March 2011 Update of November 2009 version (NACE Rev. 1.1)
  2. 2010-2015: September 2017 version (NACE Rev. 2)
- ◇ **Comtrade:** Import and export data by SITC-Rev. 3 commodities[1]
  (following Autor et al. (2013) and Dauth et al. (2014))

Countries covered:

- ▶ 1993-2007: AU, AT, BE, DK, ES, FI, FR, DE, HU, IE, IT, NL, SE, UK, US
- ▶ 2010-2015: AT, CZ, DE, DK, ES, FI, FR, IT, NL, SE, SK, UK and US

[1]Crosswalked to industry level

Definition of Industrial Robot:

An industrial robot is defined by ISO 8373 (see IFR, 2017) as:

- ⋄ An automatically controlled,
- ⋄ reprogrammable,
- ⋄ multi-purpose manipulator,
- ⋄ programmable in three or more axes,
- ⋄ which may be either fixed in place or mobile for use in industrial automation applications

Change in Robotization (1993–2007):

	#Robots/Mio. Hours			Percentiles of Δ		
	1993	2007	Δ	Mean	Min	Max
Manufacturing Sectors						
Transport equipment	5.36	13.42	8.07	0.87	0.01	1.00
Chemical	1.16	4.50	3.34	0.88	0.64	0.99
Metal	2.37	4.04	1.67	0.79	0.01	0.98
Electronics	0.95	2.26	1.32	0.71	0.01	0.97
Food	0.34	1.55	1.21	0.76	0.25	0.96
Wood products	0.77	1.61	0.84	0.53	0.01	0.97
Other Mineral	0.34	1.15	0.81	0.68	0.04	0.95
Textiles	0.12	0.42	0.3	0.46	0.01	0.95
Paper	0.06	0.20	0.14	0.46	0.01	0.83
Non-Manufacturing Sectors						
Mining	0.07	0.36	0.29	0.35	0.04	0.95
Education, R&D	0.02	0.08	0.06	0.44	0.02	0.75
Agriculture	0.01	0.04	0.03	0.33	0.04	0.74
Construction	0.01	0.03	0.02	0.35	0.03	0.66
Utilities	0.00	0.02	0.02	0.22	0.04	0.69

Change in Robotization (1993–2007):
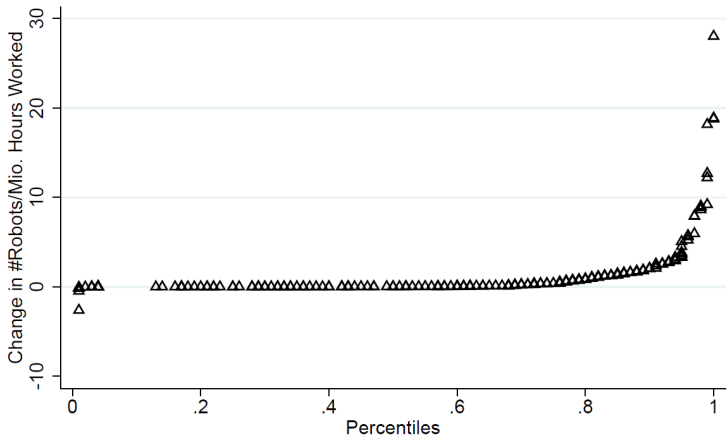
Change in Robotization (1993–2007):
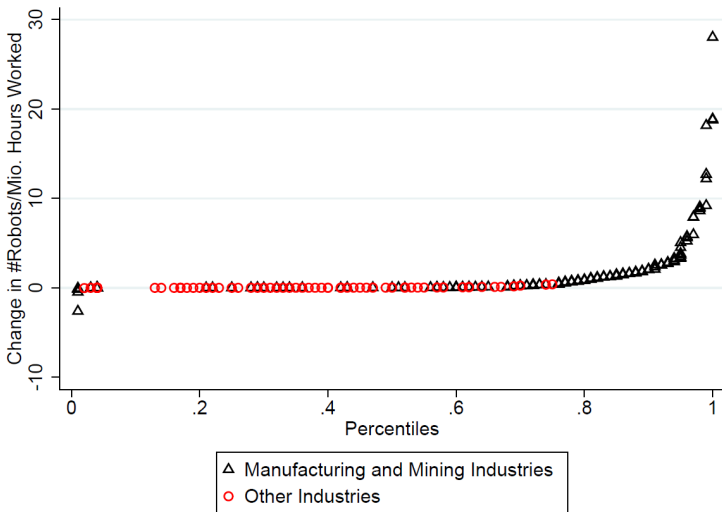
Average Change in Robots/Mio. Hours Worked:
- ▶ Manufacturing and Mining: 1.799
- ▶ Other Industries: 0.032

Empirical Specifications I:

Following G&M (2018), we estimate the following equation:

$$\Delta Y_{ci} = \beta_1 + \beta_2 f(\Delta robots_{ci}) + \beta_3 controls_{ci} + \epsilon_{ci}$$

for all available countries c and industries i, whereby:

- ◇ Dependent Variable: ΔY_{ci}
  - − log-change in the outcome of interest
  - − Labor productivity, TFP, prices, hours worked, or wages

- ◇ Explanatory Variable: $f(\Delta robots_{ci})$:
  - − Percentile of change in robotization (also used by G&M 2018)
  - − $\Delta robots_{ci}$: Raw change in Robots/Mio. Hours Worked
  - − $f(\cdot)$: percentile transformation

Empirical Specifications II:

    $\diamond$ <u>Control Variables:</u> *controls$_{ci}$*

        – Controls from G&M 2018:
         Country FE, inital period values and changes of capital/labor
         ratio and ICT-capital/capital stock ratio and changes in wage
         rate

        – Trade controls:
         initial period value and change in net-import exposure from
         China and Eastern Europe

        – Demographic controls:
         initial period shares of workers aged 30-49 and 50+

        – Wage regressions only:
         change in skill composition of workforce,
         change in share of female workers

Empirical Specifications III:

◇ Cross-sectional data (country $\times$ industry)
- Full Sample: All available industries
- Reduced Sample: Only manufacturing and mining industries

◇ OLS, Industry-FE and 2SLS specifications[2]

◇ Standard Errors: Clustered by country and industry

◇ Instrument: Fraction of hours replacable by industrial robots in 1980 US-industries

▶ Instrument does not vary within industries. Therefore industry-FE cannot be included in the 2SLS estimations

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[2]Weighted by initial period employment shares (country level)

The 'Replacable Hours' Instrument:
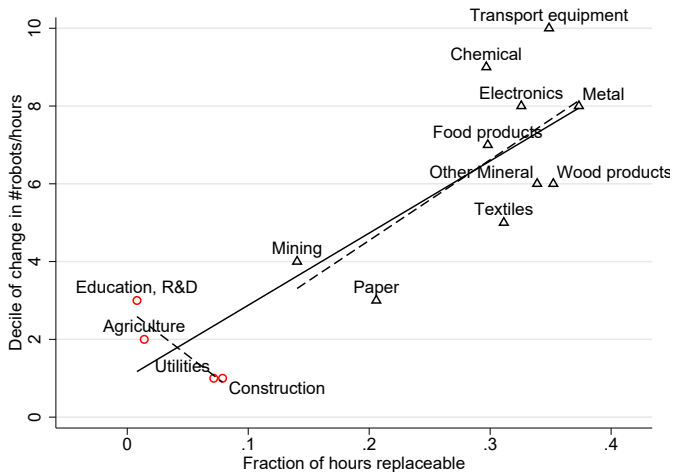
Results:
Labor Productivity

Labor Productivity

	Full Sample				Reduced Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Δ ln(VA/H)								
OLS								
Robot adoption	0.646*	0.637**	0.650**	0.657**	0.166	0.160	0.289	0.325
	(0.251)	(0.245)	(0.241)	(0.242)	(0.198)	(0.201)	(0.200)	(0.202)
Industry FE								
Robot adoption	0.251	0.253	0.321	0.332	0.262	0.264	0.461	0.490
	(0.172)	(0.172)	(0.223)	(0.226)	(0.231)	(0.224)	(0.371)	(0.361)
IV: Replaceable hours								
Robot adoption	1.032**	1.046**	1.203**	1.207**	0.516	0.522	0.568*	0.614*
	(0.394)	(0.395)	(0.309)	(0.312)	(0.321)	(0.329)	(0.269)	(0.294)
First Stage	1.198**	1.186**	1.258**	1.254**	2.366**	2.358**	2.146**	2.192**
	(0.187)	(0.180)	(0.199)	(0.193)	(0.378)	(0.408)	(0.371)	(0.406)
F-Statistic	34.4	36.2	32.5	33.7	30.5	25.6	25.3	21.6
Observations	224	224	168	168	160	160	120	120
Countries	16	16	12	12	16	16	12	12
Industries	14	14	14	14	10	10	10	10
G&M Controls:	x	x	x	x	x	x	x	x
Trade Controls:		x		x		x		x
Demographic Controls:			x	x			x	x

Note: $* < 0.05, ** < 0.01$

Labor Productivity

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Trade Controls:		x		x		x		x
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Summary: Labor Productivity

◇ Labor Productivty:
  – Focusing on robotizing sectors only, roughly cuts the estimate in half
  – Demographic controls are crucial for re-establishing the significance of the effect

▶ These estimates imply that, in the absence of robotization, productivity in the overall economy would have been around 3.5% lower in 2007 (compared to 5.1% in G&M 2018)

Results:
Labor Market Outcomes

Hours Worked

	Full Sample				Reduced Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Panel A: Δ ln(Hours worked)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
OLS								
Robot adoption	-0.177	-0.215	-0.224	-0.252	0.314**	0.265**	0.277**	0.252**
	(0.170)	(0.175)	(0.191)	(0.193)	(0.113)	(0.094)	(0.105)	(0.093)
Industry FE								
Robot adoption	0.008	-0.002	-0.023	-0.030	-0.021	-0.025	0.052	0.056
	(0.114)	(0.110)	(0.124)	(0.123)	(0.090)	(0.094)	(0.061)	(0.063)
IV: Replaceable hours								
Robot adoption	-0.472	-0.492	-0.680*	-0.682*	0.717*	0.629	0.705	0.617
	(0.316)	(0.304)	(0.325)	(0.317)	(0.348)	(0.324)	(0.401)	(0.356)
First Stage	1.198**	1.186**	1.258**	1.254**	2.366**	2.358**	2.146**	2.192**
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G&M Controls:	x	x	x	x	x	x	x	x
Trade Controls:		x		x		x		x
Demographic Controls:			x	x			x	x

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Trade Controls:		x		x		x		x
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Average Wages

	Full Sample				Reduced Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel B: Δ ln(Wages)								
OLS								
Robot adoption	0.033	0.033	0.002	0.001	-0.001	-0.003	-0.020	-0.016
	(0.017)	(0.017)	(0.011)	(0.011)	(0.013)	(0.013)	(0.016)	(0.015)
Industry FE								
Robot adoption	0.007	0.005	-0.017	-0.018	-0.004	-0.002	-0.024	-0.020
	(0.026)	(0.026)	(0.025)	(0.025)	(0.034)	(0.034)	(0.044)	(0.044)
IV: Replaceable hours								
Robot adoption	0.084**	0.083**	0.049	0.049	-0.021	-0.032	-0.052**	-0.054**
	(0.026)	(0.026)	(0.037)	(0.037)	(0.018)	(0.024)	(0.013)	(0.011)
First Stage	1.279**	1.280**	1.190**	1.200**	2.367**	2.345**	2.056**	2.110**
	(0.177)	(0.164)	(0.194)	(0.192)	(0.385)	(0.422)	(0.320)	(0.350)
F-Statistic	43.1	50.0	29.5	30.4	28.7	23.1	29.6	25.6
Observations	224	224	168	168	160	160	120	120
Countries	16	16	12	12	16	16	12	12
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G&M Controls:	x	x	x	x	x	x	x	x
Trade Controls:		x		x		x		x
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G&M Controls:	x	x	x	x	x	x	x	x
Trade Controls:		x		x		x		x
Demographic Controls:			x	x			x	x

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Results:
Labor Market Outcomes by Skill Groups

Employment Shares by Skill Group

	Full Sample			Reduced Sample		
	High	Medium	Low	High	Medium	Low
Panel A: Δ Share of hours worked						
OLS						
Robot adoption	3.297**	3.578	-6.876**	1.148	-1.574**	0.426
	(1.228)	(2.099)	(1.954)	(0.724)	(0.483)	(0.712)
Industry FE						
Robot adoption	2.620	2.332	-4.952	1.703	-2.559**	0.856
	(1.886)	(2.654)	(2.988)	(1.604)	(0.974)	(0.644)
IV: Replaceable hours						
Robot adoption	4.269*	9.382	-13.651**	0.915**	-0.388	-0.527
	(2.117)	(5.927)	(4.873)	(0.264)	(0.613)	(0.560)
First Stage	1.227**	1.227**	1.227**	2.178**	2.178**	2.178**
	(0.210)	(0.210)	(0.210)	(0.359)	(0.359)	(0.359)
F-Statistic	27.1	27.1	27.1	27.0	27.0	27.0
Observations	168	168	168	120	120	120
Countries	12	12	12	12	12	12
Industries	14	14	14	10	10	10
G&M Controls:	x	x	x	x	x	x
Trade Controls:	x	x	x	x	x	x
Demographic Controls:	x	x	x	x	x	x

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First Stage	1.227**	1.227**	1.227**	2.178**	2.178**	2.178**
	(0.210)	(0.210)	(0.210)	(0.359)	(0.359)	(0.359)
F-Statistic	27.1	27.1	27.1	27.0	27.0	27.0
Observations	168	168	168	120	120	120
Countries	12	12	12	12	12	12
Industries	14	14	14	10	10	10
G&M Controls:	x	x	x	x	x	x
Trade Controls:	x	x	x	x	x	x
Demographic Controls:	x	x	x	x	x	x

Note: $* < 0.05, ** < 0.01$

Average Wages by Skill Groups

	Full Sample			Reduced Sample		
	High	Medium	Low	High	Medium	Low
Panel B: Δ ln(Wages)						
OLS						
Robot adoption	-0.025	-0.014	0.063	-0.034**	-0.017	0.031
	(0.019)	(0.021)	(0.038)	(0.012)	(0.022)	(0.019)
Industry FE						
Robot adoption	-0.085*	-0.031	0.009	-0.044	-0.008	0.019
	(0.037)	(0.026)	(0.054)	(0.036)	(0.039)	(0.025)
IV: Replaceable hours						
Robot adoption	0.108	0.024	0.133*	-0.054	-0.060**	0.002
	(0.061)	(0.047)	(0.058)	(0.035)	(0.023)	(0.031)
First Stage	1.200**	1.200**	1.200**	2.110**	2.110**	2.110**
	(0.192)	(0.192)	(0.192)	(0.350)	(0.350)	(0.350)
F-Statistic	30.4	30.4	30.4	25.6	25.6	25.6
Observations	168	168	168	120	120	120
Countries	12	12	12	12	12	12
Industries	14	14	14	10	10	10
G&M Controls:	x	x	x	x	x	x
Trade Controls:	x	x	x	x	x	x
Demographic Controls:	x	x	x	x	x	x

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	(0.019)	(0.021)	(0.038)	(0.012)	(0.022)	(0.019)
Industry FE						
Robot adoption	-0.085*	-0.031	0.009	-0.044	-0.008	0.019
	(0.037)	(0.026)	(0.054)	(0.036)	(0.039)	(0.025)
IV: Replaceable hours						
Robot adoption	0.108	0.024	0.133*	-0.054	-0.060**	0.002
	(0.061)	(0.047)	(0.058)	(0.035)	(0.023)	(0.031)
First Stage	1.200**	1.200**	1.200**	2.110**	2.110**	2.110**
	(0.192)	(0.192)	(0.192)	(0.350)	(0.350)	(0.350)
F-Statistic	30.4	30.4	30.4	25.6	25.6	25.6
Observations	168	168	168	120	120	120
Countries	12	12	12	12	12	12
Industries	14	14	14	10	10	10
G&M Controls:	x	x	x	x	x	x
Trade Controls:	x	x	x	x	x	x
Demographic Controls:	x	x	x	x	x	x

Note: $* < 0.05, ** < 0.01$

Summary: Labor Market Outcomes:

▶ Focusing on robotizing sectors only, reverses the sign and interpretation of the estimates!

◇ Hours worked:
   – Full Sample: Negative employment effect
   – Reduced Sample: No (i.e. insignificant) employment effect;

◇ Average Wages:
   – Full Sample: insignificant wage effect
   – Reduced Sample: negative wage effect

◇ By skill groups:
   – No evidence for skill biased technological change
   – Rather job- and wage polarization
     (although not significant in all specifications)

Non-monotonicity in the 'Reaching and Handling' Instrument:

Non-monotonicity in the 'Reaching and Handling' Instrument:

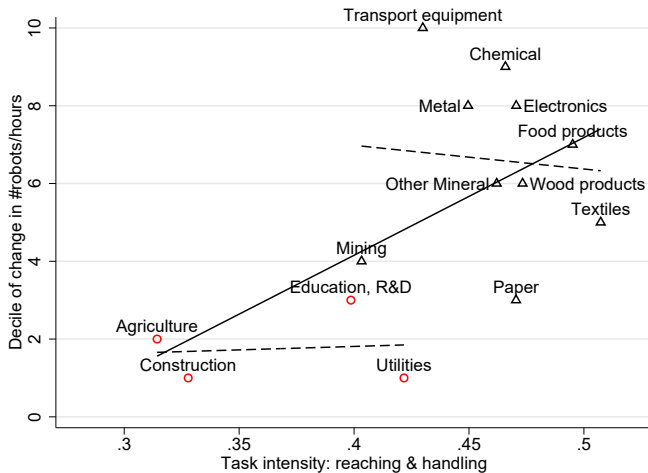G&M 2018 also proposed a second instrumental variable:

- ⋄ Fraction of reaching and handling tasks in an industry
- ⋄ Again calculated for 1980 US-industries;
  No within industry variation in the instrument → controlling for industry-FE not possible
- ⋄ Already in use in several studies
  (see for example de Vries et al., 2020, or Aksoy et al., 2021)

▶ Recap: The monotonicity assumption of 2SLS
  "The instrument affects the participation or selection decision in a monotone way" (Imbens and Angrist, 1994).
  In our context: Higher fraction of reaching and handling tasks must be associated with higher robot adoption for all industries.

Non-monotonicity in the 'Reaching and Handling' Instrument:

Non-monotonicity in the 'Reaching and Handling' Instrument:

	Full Sample				Reduced Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Panel A: Reduced Sample: Manufacturing Sectors

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
OLS								
Robot adoption	0.663**	0.637**	0.650**	0.657**	0.024	0.108	0.267	0.298
	(0.236)	(0.245)	(0.241)	(0.242)	(0.191)	(0.231)	(0.202)	(0.205)
IV: Reaching & handling								
Robot adoption	1.020*	1.050*	1.290**	1.295**	-0.990	-1.104	-0.637	-0.682
	(0.421)	(0.433)	(0.335)	(0.341)	(0.851)	(0.864)	(0.713)	(0.828)
First Stage	2.141**	2.178**	2.162**	2.175**	-4.466**	-4.076**	-4.522**	-4.077**
	(0.448)	(0.395)	(0.402)	(0.377)	(1.604)	(1.493)	(1.185)	(1.482)
F-Statistic	19.3	25.3	23.5	26.7	5.9	5.6	10.6	5.4
Observations	224	224	168	168	144	144	108	108
Countries	16	16	12	12	16	16	12	12
Industries	14	14	14	14	9	9	9	9

Panel B: Reduced Sample: Manufacturing & Mining Sectors

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
OLS								
Robot adoption	0.663**	0.637**	0.650**	0.657**	0.086	0.160	0.289	0.325
	(0.236)	(0.245)	(0.241)	(0.242)	(0.153)	(0.201)	(0.200)	(0.202)
IV: Reaching & handling								
Robot adoption	1.020*	1.050*	1.290**	1.295**	-1.665	-1.286	-0.572	-0.643
	(0.421)	(0.433)	(0.335)	(0.341)	(2.253)	(1.401)	(1.086)	(0.915)
First Stage	2.141**	2.178**	2.162**	2.175**	-1.793	-2.107	-1.885	-1.885
	(0.448)	(0.395)	(0.402)	(0.377)	(2.197)	(1.839)	(1.979)	(1.979)
F-Statistic	19.3	25.3	23.5	26.7	0.5	1.0	0.7	0.7
Observations	224	224	168	168	160	160	120	120
Countries	16	16	12	12	16	16	12	12
Industries	14	14	14	14	10	10	10	10
G&M Controls:	x	x	x	x	x	x	x	x
Trade Controls:		x		x		x		x
Demographic Controls:			x	x			x	x

Note: $* < 0.05, ** < 0.01$

Non-monotonicity in the 'Reaching and Handling' Instrument:

	Full Sample				Reduced Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Reduced Sample: Manufacturing Sectors								
OLS								
Robot adoption	0.663**	0.637**	0.650**	0.657**	0.024	0.108	0.267	0.298
	(0.236)	(0.245)	(0.241)	(0.242)	(0.191)	(0.231)	(0.202)	(0.205)
IV: Reaching & handling								
Robot adoption	1.020*	1.050*	1.290**	1.295**	-0.990	-1.104	-0.637	-0.682
	(0.421)	(0.433)	(0.335)	(0.341)	(0.851)	(0.864)	(0.713)	(0.828)
First Stage	2.141**	2.178**	2.162**	2.175**	-4.466**	-4.076**	-4.522**	-4.077**
	(0.448)	(0.395)	(0.402)	(0.377)	(1.604)	(1.493)	(1.185)	(1.482)
F-Statistic	19.3	25.3	23.5	26.7	5.9	5.6	10.6	5.4
Observations	224	224	168	168	144	144	108	108
Countries	16	16	12	12	16	16	12	12
Industries	14	14	14	14	9	9	9	9
Panel B: Reduced Sample: Manufacturing & Mining Sectors								
OLS								
Robot adoption	0.663**	0.637**	0.650**	0.657**	0.086	0.160	0.289	0.325
	(0.236)	(0.245)	(0.241)	(0.242)	(0.153)	(0.201)	(0.200)	(0.202)
IV: Reaching & handling								
Robot adoption	1.020*	1.050*	1.290**	1.295**	-1.665	-1.286	-0.572	-0.643
	(0.421)	(0.433)	(0.335)	(0.341)	(2.253)	(1.401)	(1.086)	(0.915)
First Stage	2.141**	2.178**	2.162**	2.175**	-1.793	-2.107	-1.885	-1.885
	(0.448)	(0.395)	(0.402)	(0.377)	(2.197)	(1.839)	(1.979)	(1.979)
F-Statistic	19.3	25.3	23.5	26.7	0.5	1.0	0.7	0.7
Observations	224	224	168	168	160	160	120	120
Countries	16	16	12	12	16	16	12	12
Industries	14	14	14	14	10	10	10	10
G&M Controls:	x	x	x	x	x	x	x	x
Trade Controls:		x		x		x		x
Demographic Controls:			x	x			x	x

Note: $* < 0.05, ** < 0.01$

Summary: Findings

Findings

$\diamond$ Insignificant Effects when focusing on robotizing industries only

$\diamond$ Additional controls for unobserved industry-heterogeneity (via demographics)...
  - ... restores significant productivity effect
  - ... still rejects positive wage effects and skill biased technological change
  - ... Industry-FE specifications point towards job polarization

$\diamond$ Non-monotonicity in the 'reaching and handling' instrument
  $\rightarrow$ caution when using this instrument!

$\diamond$ In contrast to firm level results, we do not find any effects at the current data edge (2010-2015) [Appendix]

$\diamond$ Beware of institutional subtleties with industry data

Open Issues:

⋄ Data constraints on important countries (e.g. Japan)

⋄ Robots per Mio. Hours worked show little variation (long right tail)
  → percentile transformation potentially problematic

⋄ Small sample size limits interpretation of results

⋄ Unobserved industry heterogeneity probably still an issue
  → suitable instrument?

⋄ Different effects for tier 1 and tier 2 companies (and respective countries)?

Thank you for your attention!

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Appendix:

Additional Results: Total Factor Productivity

	Full Sample				Reduced Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel B: Δ ln(TFP)								
OLS								
Robot adoption	0.444*	0.430*	0.442*	0.446*	0.105	0.096	0.272	0.325
	(0.203)	(0.198)	(0.186)	(0.186)	(0.168)	(0.174)	(0.151)	(0.202)
Industry FE								
Robot adoption	0.147	0.147	0.195	0.203	0.139	0.134	0.381	0.403
	(0.154)	(0.155)	(0.192)	(0.194)	(0.167)	(0.168)	(0.312)	(0.317)
IV: Replaceable hours								
Robot adoption	0.762*	0.766*	0.909**	0.905**	0.651**	0.663*	0.672**	0.716**
	(0.334)	(0.332)	(0.216)	(0.217)	(0.251)	(0.262)	(0.212)	(0.230)
First Stage	1.155**	1.148**	1.202**	1.208**	2.343**	2.334**	2.178**	2.171**
	(0.182)	(0.172)	(0.196)	(0.192)	(0.354)	(0.381)	(0.336)	(0.407)
F-Statistic	33.9	37.0	30.3	31.4	34.1	28.8	31.5	20.9
Observations	210	210	154	154	150	150	110	110
Countries	15	15	11	11	15	15	11	11
Industries	14	14	14	14	10	10	10	10
G&M Controls:	x	x	x	x	x	x	x	x
Trade Controls:		x		x		x		x
Demographic Controls:			x	x			x	x

Note: $* < 0.05, ** < 0.01$

Additional Results: Prices

	Full Sample				Reduced Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
OLS								
Robot adoption	-0.512*	-0.510*	-0.487*	-0.493*	-0.189	-0.190	-0.282	-0.312
	(0.212)	(0.207)	(0.197)	(0.199)	(0.139)	(0.146)	(0.156)	(0.159)
Industry FE								
Robot adoption	-0.212	-0.222	-0.211	-0.224	-0.244	-0.250	-0.400	-0.224
	(0.148)	(0.147)	(0.186)	(0.188)	(0.161)	(0.152)	(0.281)	(0.188)
IV: Replaceable hours								
Robot adoption	-0.728*	-0.741*	-0.876**	-0.879**	-0.415	-0.431	-0.446	-0.496
	(0.356)	(0.354)	(0.287)	(0.289)	(0.336)	(0.362)	(0.271)	(0.298)
First Stage	1.198**	1.186**	1.258**	1.254**	2.366**	2.358**	2.146**	2.192**
	(0.187)	(0.180)	(0.199)	(0.193)	(0.378)	(0.408)	(0.371)	(0.406)
F-Statistic	34.4	36.2	32.5	33.7	30.5	25.6	25.3	21.6
Observations	224	224	168	168	160	160	120	120
Countries	16	16	12	12	16	16	12	12
Industries	14	14	14	14	10	10	10	10
G&M Controls:	x	x	x	x	x	x	x	x
Trade Controls:		x		x		x		x
Demographic Controls:			x	x			x	x

Note: $* < 0.05, ** < 0.01$

Additional Results: Extended Period: 2010-2015

	$\Delta ln(VA/H)$		$\Delta ln(TFP)$		$\Delta ln(P)$		$\Delta ln(H)$		$\Delta ln(W/H)$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
OLS										
Robot adoption	0.047	0.178	0.128	0.201	-0.113*	-0.136	0.208	0.286	-0.007	-0.001
	(0.076)	(0.130)	(0.118)	(0.117)	(0.056)	(0.153)	(0.129)	(0.153)	(0.009)	(0.001)
Industry FE										
Robot adoption	0.065	0.232	0.060	0.217	-0.229**	-0.277	-0.083	-0.031	-0.004	-0.000
	(0.072)	(0.122)	(0.089)	(0.135)	(0.059)	(0.155)	(0.105)	(0.112)	(0.015)	(0.001)
IV: Replaceable hours										
Robot adoption	0.899	0.749	1.377*	0.850	-0.524	-0.130	0.324	0.587*	-0.008	-0.003
	(0.582)	(0.562)	(0.683)	(0.685)	(0.501)	(0.335)	(0.456)	(0.265)	(0.018)	(0.005)
First Stage	1.047*	2.755**	1.063*	2.743**	1.047*	2.755**	1.047*	2.755**	1.356**	2.934**
	(0.438)	(0.872)	(0.433)	(0.861)	(0.438)	(0.872)	(0.438)	(0.872)	(0.268)	(0.863)
F-Statistic	4.5	7.1	4.8	7.2	4.5	7.1	4.5	7.1	19.6	7.8
Observations	156	108	155	107	156	108	156	108	156	108
Countries	12	12	12	12	12	12	12	12	12	12
Industries	13	9	13	9	13	9	13	9	13	9
Reduced Sample:	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
G&M Controls:	x	x	x	x	x	x	x	x	x	x
Trade Controls:	x	x	x	x	x	x	x	x	x	x
Demographic Controls:	x	x	x	x	x	x	x	x	x	x

Note: $* < 0.05, ** < 0.01$

Robustness Check: Only Observations with all available controls (Dependent variable: Log-change in labor productivity)

	Full Sample				Reduced Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Δ ln(VA/H)								
OLS								
Robot adoption	0.666**	0.668**	0.650**	0.657**	0.231	0.247	0.289	0.325
	(0.253)	(0.253)	(0.241)	(0.242)	(0.247)	(0.252)	(0.200)	(0.202)
Industry FE								
Robot adoption	0.326	0.337	0.321	0.332	0.410	0.440	0.461	0.490
	(0.224)	(0.227)	(0.223)	(0.226)	(0.369)	(0.363)	(0.371)	(0.361)
IV: Replaceable hours								
Robot adoption	1.106**	1.119**	1.203**	1.207**	0.518	0.540	0.568*	0.614*
	(0.381)	(0.389)	(0.309)	(0.312)	(0.321)	(0.348)	(0.269)	(0.294)
First Stage	1.082**	1.066**	1.258**	1.254**	2.219**	2.257**	2.146**	2.192**
	(0.204)	(0.199)	(0.199)	(0.193)	(0.423)	(0.459)	(0.371)	(0.406)
F-Statistic	23.1	23.3	32.5	33.7	21.2	18.3	25.3	21.6
Observations	168	168	168	168	120	120	120	120
Countries	12	12	12	12	12	12	12	12
Industries	14	14	14	14	10	10	10	10
G&M Controls:	x	x	x	x	x	x	x	x
Trade Controls:		x		x		x		x
Demographic Controls:			x	x			x	x

Note: $* < 0.05, ** < 0.01$

Robustness Check: Alternative Functional Forms
(Dependent variable: Log-change in labor productivity)

	Full Sample				Reduced Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Δ # Robots/Mio. Hours								
OLS								
Robot adoption	0.035*	0.034*	0.034	0.034	-0.001	-0.001	0.007	0.007
	(0.015)	(0.015)	(0.018)	(0.018)	(0.009)	(0.009)	(0.007)	(0.007)
IV: Replaceable hours								
Robot adoption	0.173*	0.176*	0.150	0.151*	0.068	0.064	0.087	0.085
	(0.084)	(0.085)	(0.077)	(0.077)	(0.050)	(0.048)	(0.060)	(0.059)
First Stage	7.145*	7.048*	10.090*	10.036*	17.965*	19.297*	13.992	15.802
	(2.863)	(2.792)	(4.669)	(4.569)	(8.747)	(9.085)	(9.572)	(9.471)
F-Statistic	5.2	5.3	3.8	3.9	3.3	3.5	1.6	2.1
Panel B: Δ log(1+# Robots/Mio. Hours)								
OLS								
Robot adoption	0.438*	0.429*	0.508*	0.511**	0.106	0.104	0.221*	0.239*
	(0.176)	(0.171)	(0.200)	(0.198)	(0.104)	(0.103)	(0.102)	(0.096)
IV: Replaceable hours								
Robot adoption	0.934**	0.943**	0.989**	0.992**	0.565*	0.562*	0.639**	0.681*
	(0.357)	(0.354)	(0.286)	(0.286)	(0.271)	(0.280)	(0.215)	(0.273)
First Stage	1.324**	1.315**	1.531**	1.526**	2.161**	2.191**	1.907*	1.974*
	(0.274)	(0.265)	(0.287)	(0.274)	(0.792)	(0.847)	(0.782)	(0.848)
F-Statistic	19.6	20.5	23.0	24.8	5.8	5.1	4.5	4.0
Observations	224	224	168	168	160	160	120	120
Countries								
Industries								
G&M Controls:	x	x	x	x	x	x	x	x
Trade Controls:		x		x		x		x
Demographic Controls:			x	x			x	x

Note: * < 0.05, ** < 0.01