What Is the Impact of Automation on Employment? New Evidence from France

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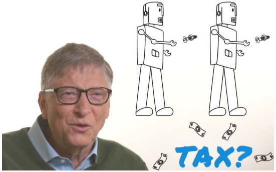
The Robots Are Coming

Will They Take All Our Jobs?



Bill Gates

Andrew Yang

Ned Ludd

Aren't Machines Already Everywhere?

Introduction

- Will automation lead to "technological unemployment" (Keynes 1930, Leontief 1952)?
  - Automation can be defned as *"class of electro-mechanical devices that are relatively self-operating after they have been set in motion on the basis of predetermined instructions or procedures"* (Encyclopaedia Britannica, 2015)
- By definition automation is labor-saving at the task level
  - But could induce productivity gains and need for implementing new tasks (e.g., quality control)
  - Could be labor-augmenting and promote employment/wages at plant level, firm level, industry level or economy-wide

This Paper

- Despite extensive research, employment effects of automation remain debated
  - Industrial robots: Acemoglu-Restrepo 2019, Chiacchio et al. 2019 *vs.* Michaels and Graetz 2018, Dauth et al. 2019. Koch et al. 2019
  - Automation patents: Webb 2019 *vs.* Mann and Puttmann 2019
- Industry-level variation in automation makes causal identification challenging

This Paper

- Study automation at plant and firm levels
  - Primary measure exploits fact that common automation technologies operate with electric motors (e.g., robots or conveyors)
  - Linked employer-employee data set covers population of French firms in manufacutring sectors (1994-2015)

- Two research design for causal identification:
  - Event studies exploiting precise timing of adoption of automation technologies across plants (in same firm)
  - Shift-share research design exploiting changes in the productivity of foreign suppliers of machines

- Estimates indicate that increased automation leads to:
  - **Increased plant-level and firm-level employment**, with elasticities of about **0.3** after 3 years
  - Increased sales, and **stable wages and labor share**

Roadmap

1. **Data and Stylized Facts**
2. **Event Study**
3. **Shift-Share IV**
4. **Extensions**

Data

- Ideal data set would provide detailed information on

  1. Workers: wages, occupation, tasks
  2. Firms and plants: sales, industry, balance sheet
  3. Automation: technology, tasks performed, efficiency, intensity of utilization for each firm/plant

Worker/Firm Data

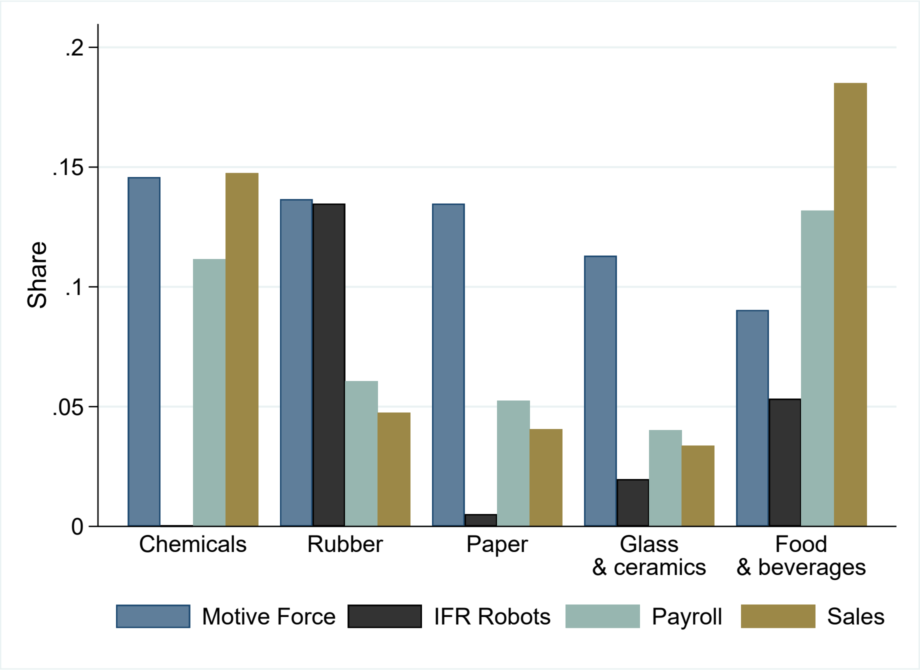
- Detailed information on workers and firms available from French administrative data (DADS and INSEE databases)
  - Matched employer-employee data covering all plants in private sector from 1994 to 2015

Measuring Automation

- Common automation technologies typically based on electro-motive force, i.e. set in motion using electric motors
  - Automation technologies require motive force / motor action
  - *"class of electro-mechanical devices that are relatively self-operating after they have been set in motion on the basis of predetermined instructions or procedures"* (Encyclopaedia Britannica, 2015)
- Use detailed records of electricity consumption for motors directly used in production process
  - Assembled by INSEE since 1983; distinguishes between motive power, thermic/thermodynamic uses, and other uses (electrolysis)
  - Focus on motive power to exclude heating, cooling, servers
- Supplement with firm-level data on industrial equipment/machines

Measuring Automation

- Measuring (changes in) automation using consumption of electricity for motive power has several potential advantages and limitations
- Advantages:
  - Covers broad set of automation technologies
  - Available at plant level
  - Possible to measure using intensity of usage, rather than stock of machines
- Limitations:
  - Due to variation in efficiency, difficult to draw comparisons across industries and over time $\Rightarrow$ analysis with industry/time fixed effects
  - Blends different vintages of automation technologies $\Rightarrow$ can focus on susbet of industries where modern robots account for large share of motive power (e.g. automobile)



Share
.2
.15
.1
.05
0
Chemicals
Rubber
Paper
Glass
& ceramics
Food
& beverages
Motive Force
IFR Robots
Payroll
Sales

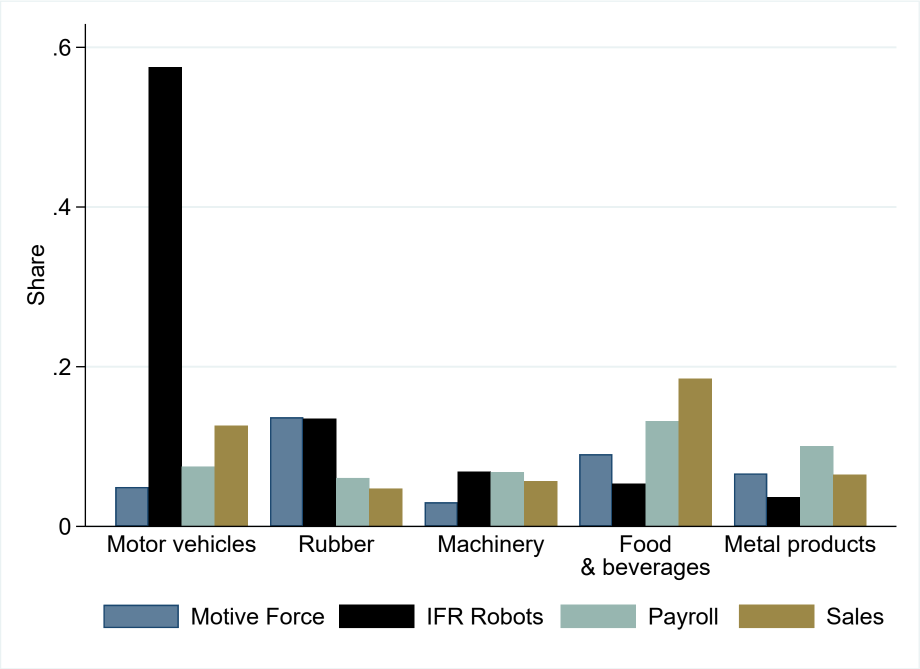
Chemicals

Rubber

Paper

Glass and Ceramics

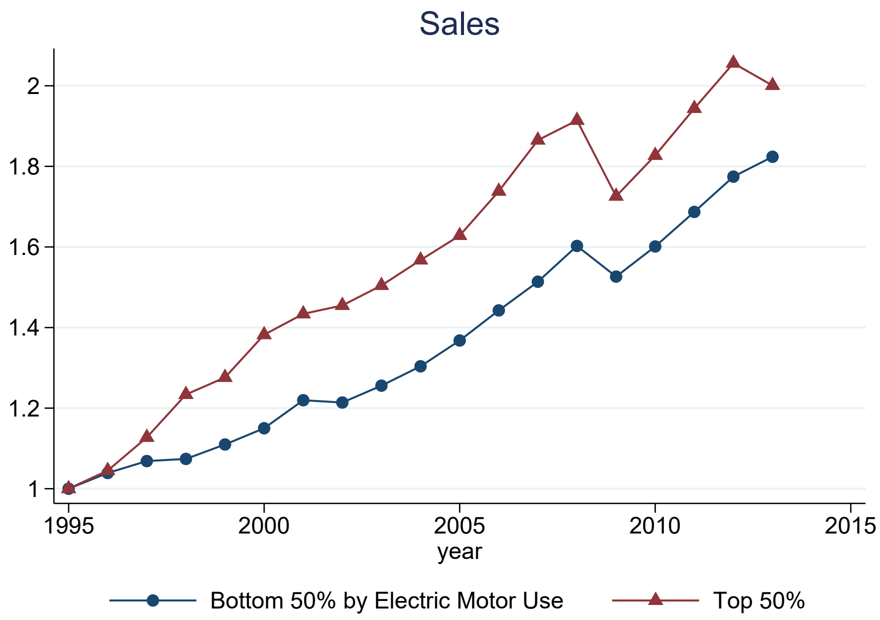
Food



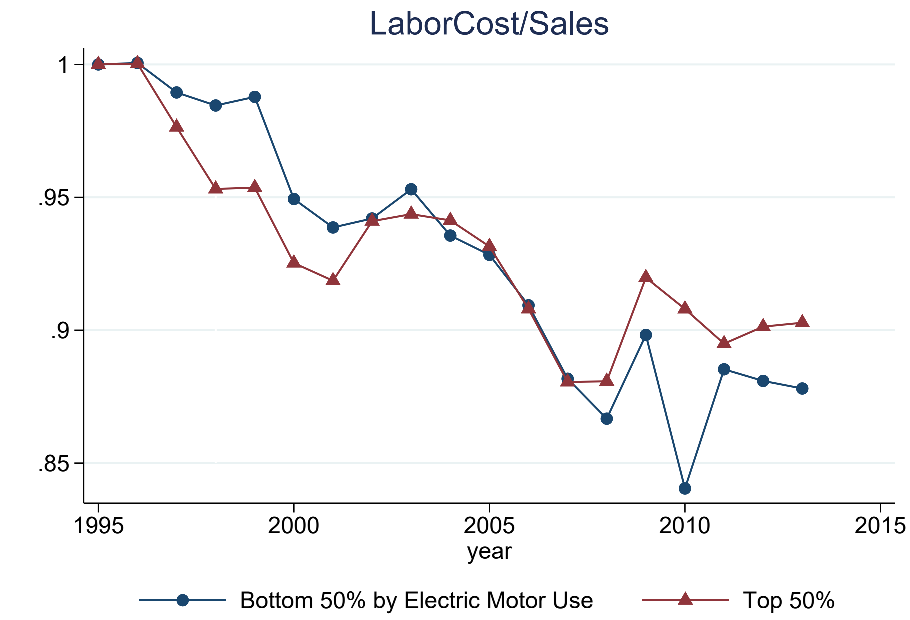
Share
.6
.4
.2
0
Motor vehicles
Rubber
Machinery
Food
& beverages
Metal products
Motive Force
IFR Robots
Payroll
Sales

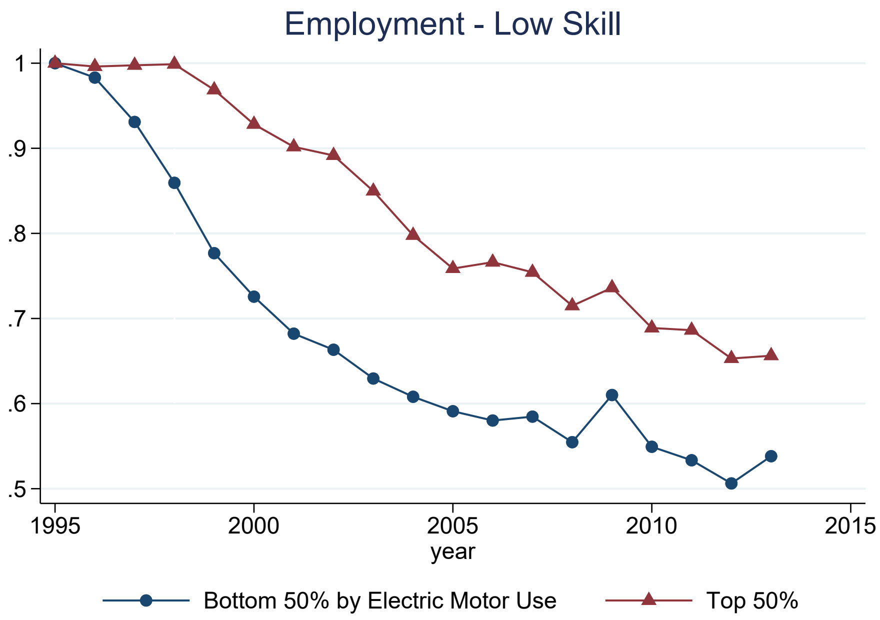
Stylized Facts

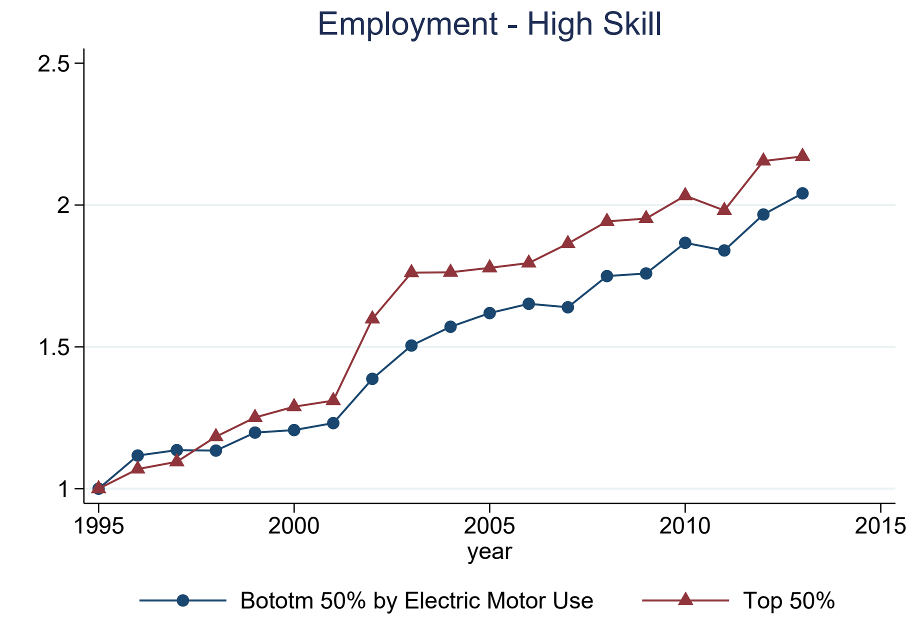
- As a preliminary descriptive exercise, compare path of sales, employment and labor share in plants that increase faster their consumption of electricity for motive power
    - Top 50% vs. bottom 50%



Sales
2
1.8
1.6
1.4
1.2
1
1995
2000
2005
2010
2015
year
Bottom 50% by Electric Motor Use
Top 50%


LaborCost/Sales
1
.95
.9
.85
1995
2000
2005
2010
2015
year
Bottom 50% by Electric Motor Use
Top 50%


Employment - Low Skill
1
.9
.8
.7
.6
.5
1995
2000
2005
2010
2015
year
Bottom 50% by Electric Motor Use
Top 50%


Employment - High Skill
2.5
2
1.5
1
1995
2000
2005
2010
2015
year
Bototm 50% by Electric Motor Use
Top 50%

Roadmap

1. Data and Stylized Facts
2. **Event Study**
3. Shift-Share IV
4. Extensions

Distributed Lead-Lag Model

- How to describe employment dynamics as a firm or plant increases its use of electric motors?
  - "Extensive margin" event study not possible given that almost all firms/plant use electric motors in all years
  - Use standard distributed lead-lag model (Stock and Watson 2015)

Distributed Lead-Lag Model

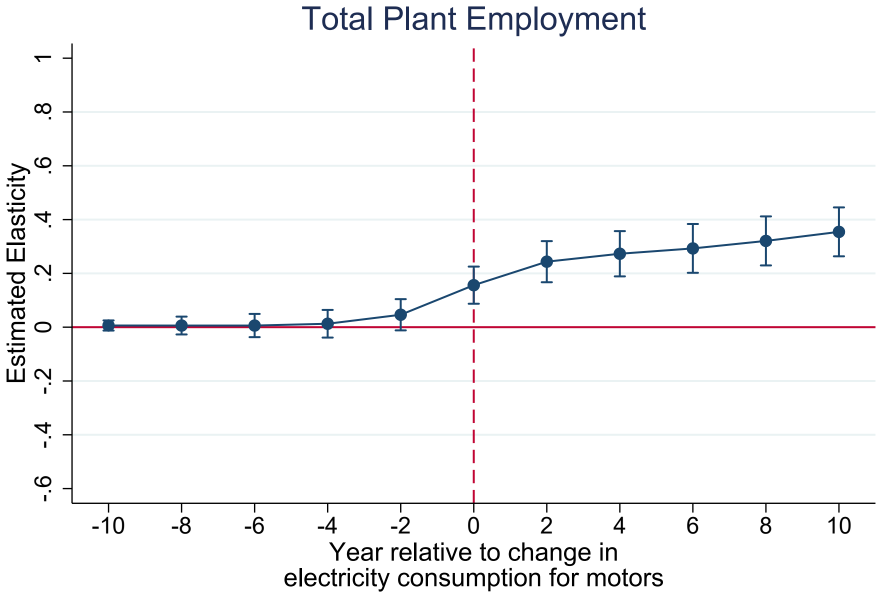
$$L_{it} = \sum_{k=0}^{10} \delta_k^{Lag} \Delta M_{i,t+k} + \sum_{k=-10}^{-1} \delta_k^{Lead} \Delta M_{i,t-k} + \mu_i + \lambda_{st} + \varepsilon_{it}$$

with employment L_{it}, change in electric motor consumption $\Delta M_{i,t}$ and plant F.E. μ_i

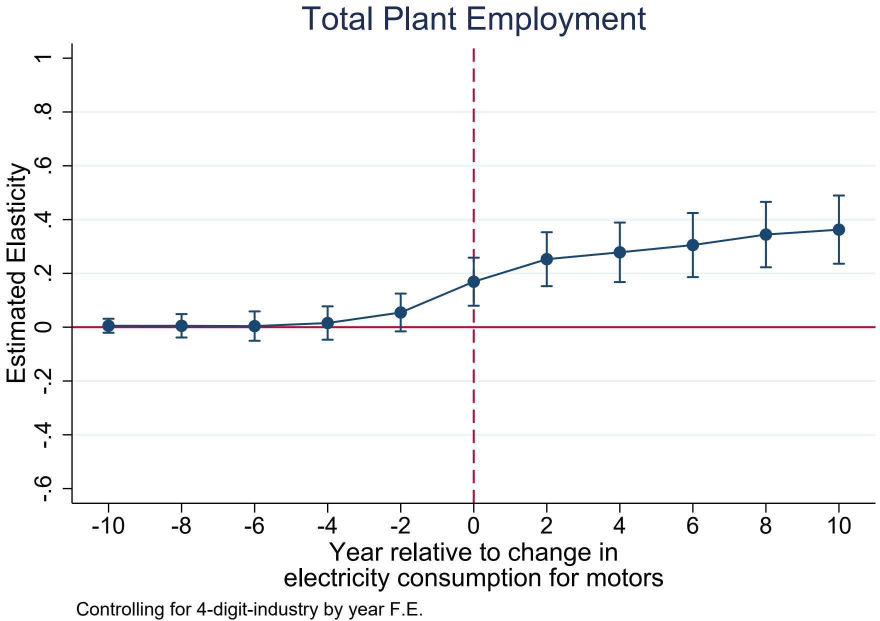
- Specification allows for delayed response of employment to increased automation
- Causal interpretation requires $E[\Delta M_{i,t+k} \cdot \varepsilon_{it} | \mu_i, \lambda_{st}] = 0 \; \forall \, (t,k)$
  - Leads can be used as a falsification test - but cannot rule out potential demand/supply shocks in contemporaneous period
  - Mitigate potential correlated shocks with specifications using industry-year or firm-year F.E., λ_{st}

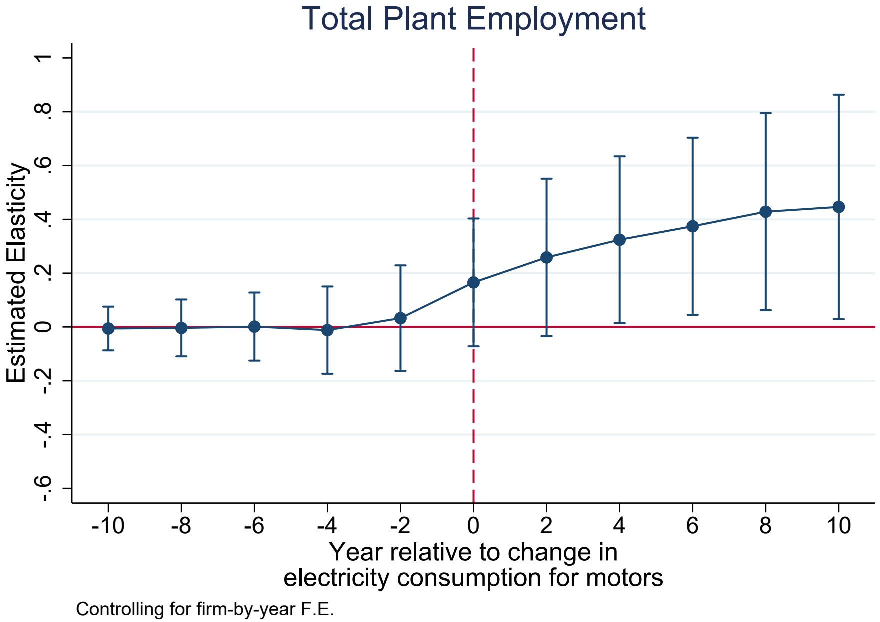
Employment Dynamics: Average

- Start by documenting employment dynamics across all firms
- Find that employment *increases* following increased use of machines
  - Elasticity of $+0.2$ on impact
  - Cumulative response increases further over time, with an elasticity of $+0.4$ after 8 years
- No pre-trends and magnitudes robust to changes in industry-year controls
  - Implies potential confounding factors must have precisely the same timing as automation and have stronger explanatory power than firm-year fixed effects (Oster 2015)



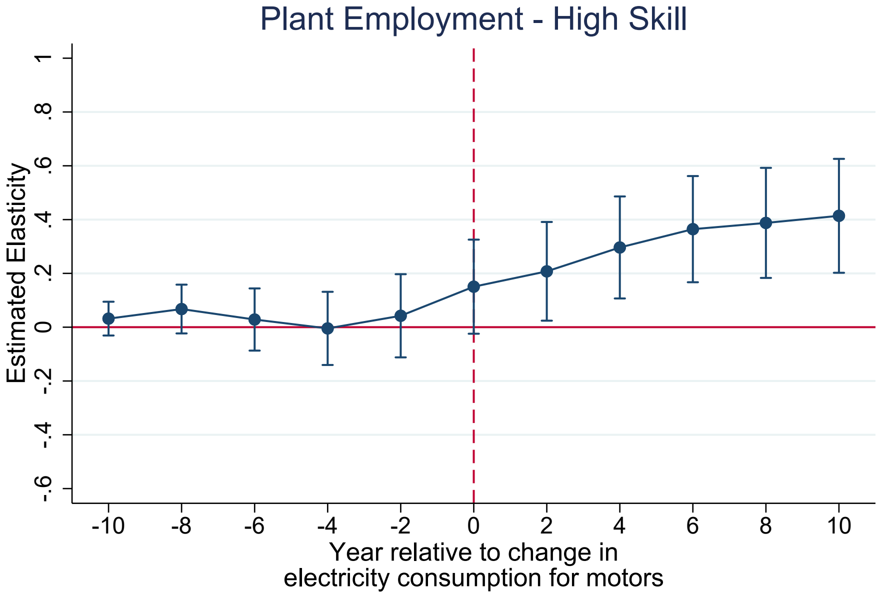
Controlling for 2-digit-industry by year F.E.


Total Plant Employment
Estimated Elasticity
-.6
-.4
-.2
0
.2
.4
.6
.8
1
-10
-8
-6
-4
-2
0
2
4
6
8
10
Year relative to change in
electricity consumption for motors
Controlling for 4-digit-industry by year F.E.

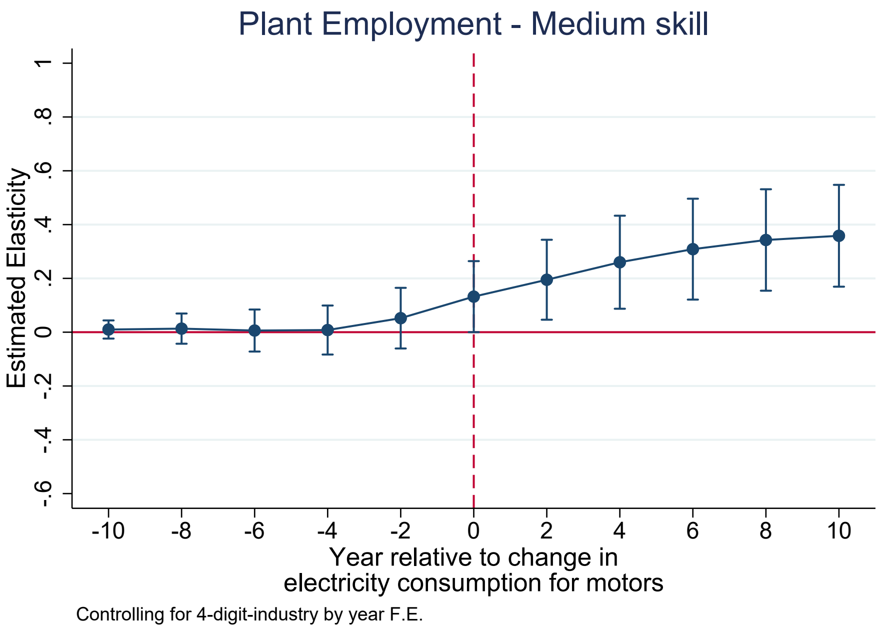

Total Plant Employment
Estimated Elasticity
1
.8
.6
.4
.2
0
-.2
-.4
-.6
-10
-8
-6
-4
-2
0
2
4
6
8
10
Year relative to change in
electricity consumption for motors
Controlling for firm-by-year F.E.

Employment Dynamics: Heterogeneity?

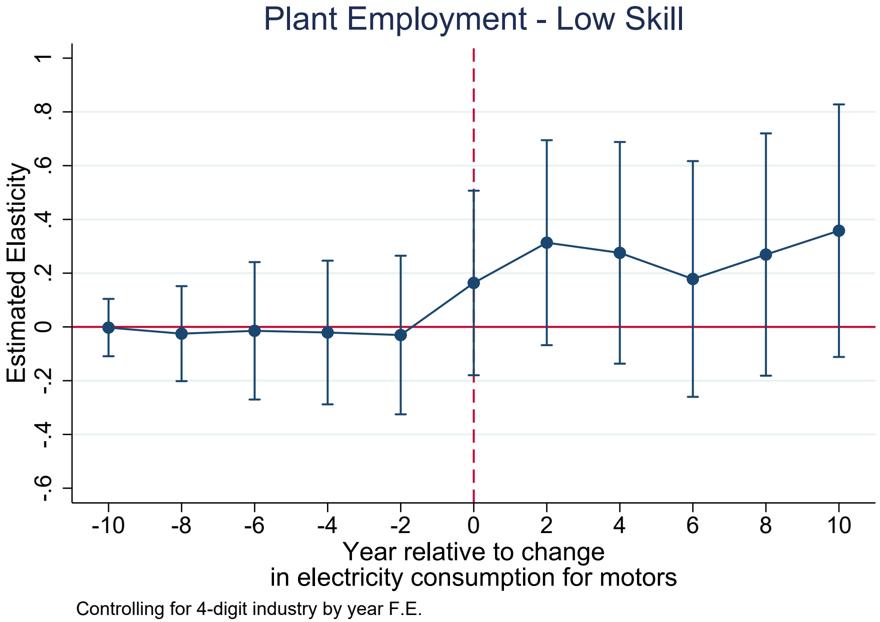
- Are effects different across skill groups?
- Find no heterogeneity across broad skill groups (high/medium/low)
  - Positive employment response for all, no change in relative wage
  - Suggests no broad effect on inequality
  - However heterogeneous effects could arise within skill groups, depending on set of tasks performed (in progress)



Controlling for 4-digit-industry by year F.E.



Plant Employment - Medium skill
Estimated Elasticity
-.6
-.4
-.2
0
.2
.4
.6
.8
1
-10
-8
-6
-4
-2
0
2
4
6
8
10
Year relative to change in
electricity consumption for motors
Controlling for 4-digit-industry by year F.E.


Plant Employment - Low Skill
Estimated Elasticity
-.6
-.4
-.2
0
.2
.4
.6
.8
1
-10
-8
-6
-4
-2
0
2
4
6
8
10
Year relative to change
in electricity consumption for motors
Controlling for 4-digit industry by year F.E.

Additional Results

- Similar results on employment with:
  - Firm-level analysis
  - Alternative definitions of skill groups
  - Industries with large share of IFR robots
- Find no significant change in wages or in labor share

Limitation

- Distributed lead-lag model cannot fully address potential correlated demand/supply shocks
  - When firm grows due to demand or supply shocks unrelated to increased automation, it may decide to increase both employment and automation
  - Turn to IV research design to address this limitation

Roadmap

1. Data and Stylized Facts
2. Event Study
3. **Shift-Share IV**
4. Extensions

Shift-Share IV

- Ideal experiment would randomly assign purchasing prices for machines/robots across firms
- Approximate with a shift-share research design, leveraging two components:
  1. Variation in the cost of imported machines/robots over time across international trading partners ("shocks")
  2. Variation in pre-existing supplier relationships across French firms ("exposure shares")
- Intutively, changes in quality-adjusted price for machines/robots is not observed can be inferred from changes in trade flows
  - French firms are differentially exposed to changes in sector-specific foreign productivity

Shocks

- "Shocks" across trading partners by sectors:
  - g_n is aggregate change in imports flows of machines/robots from each trading partners (Germany, Italy, Japan, China, etc.) for each 2-digit industry
  - Infer from trade flows that some countries do particularly well in machines/robots supply in specific sectors and periods
  - e.g., Italy for textile in the 1990s, Germany for automobiles in the 2000s, the Netherlands for food products after 2010

Exposure Shares

- "Exposure shares" of French firms:
  - s_{in} is share of trading partner n in firm i's total imports of machines and robots
  - Because of switching costs, French firm more likely to benefit from a trading partner's productivity shock if it has a pre-existing importing relationship with them
  - Contemporaneous shares liable to reverse causality: use shares lagged by 5 years

Shift-Share IV

- Consider changes in employment ΔL_i and changes in motor consumption ΔM_i over a five-year period across firmes indexed by i

- We estimate by 2SLS:

$$\begin{cases} \Delta L_i = \beta \Delta Z_i + \gamma X_i + \varepsilon_i \\ \Delta M_i = \alpha \Delta Z_i + \widetilde{\gamma} X_i + \widetilde{\varepsilon}_i \end{cases}$$

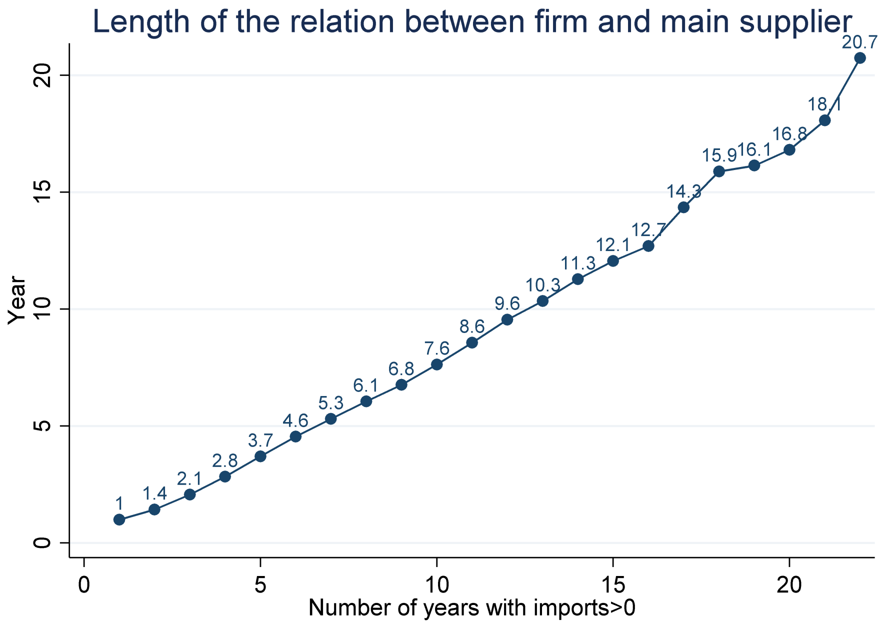
with Z_i the shift-share instrument constructed from shocks g_n and (lagged) exposure shares $s_{in} \geq 0$,

$$Z_i = \sum_{n=1}^{N} s_{in} g_n$$

- Use panel with 5-year periods, 204 trading partners, and 24 2-digit industries

Identification Assumptions

- Standard shift-share IV identification assumptions apply
- Relevance: need supplier relationships to be sufficiently persistent
  - Can check power with first-stage F statistic as usual
  - Can also assess plausibility by documenting stickiness of import relationships



Length of the relation between firm and main supplier
Year
Number of years with imports>0
0
5
10
15
20
1
1.4
2.1
2.8
3.7
4.6
5.3
6.1
6.8
7.6
8.6
9.6
10.3
11.3
12.1
12.7
14.3
15.9
16.1
16.8
18.1
20.7

Identification Assumptions

- Exclusion restriction: firms linked to increasingly productive suppliers should not be unobservably different
  - Run falsification test with lagged outcome variable
  - Can express exclusion restriction at firm level or in space of shocks:

$$\left(\frac{1}{I}\sum_i z_i\varepsilon_i \xrightarrow{p} 0\right) \Longleftrightarrow \left(\frac{1}{N}\sum_n \hat{s}_n g_n \bar{\varepsilon}_n \xrightarrow{p} 0\right)$$

with $\bar{\varepsilon}_n = \left(\sum_i s_{in}\varepsilon_i\right)/\sum_i s_{in}$ and $\hat{s}_n = \frac{1}{I}\sum_i s_{in}$

IV Results

- Implement shift-share design with baseline set of pre-determined firm controls (turnover, investment, total assets, employment)
- Study sensitivity to additional controls and implement falsification test
- Find positive employment response, with an elasticity of $+0.3$ to $+0.4$ across specifications
- Find positive sales response of similar magnitude and no response of average wage, leaving payroll share unchanged

IV Results: Employment

	Δ_5 Employment				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Motor Cons.	**0.341*****	**0.361*****	**0.410****	**0.276****	**0.430*****
	(0.121)	(0.1276)	(0.167)	(0.138)	(0.202)
First-Stage F	29.3	26	16.8	20.6	17.9
Industry-year F.E.	✓	✓	✓	✓	✓
Firm Controls		✓	✓	✓	✓
Lagged Motor Cons.			✓		✓
Lagged Machines				✓	
Exports					✓
N	29,109	29,109	29,109	29,109	29,109

Falsification Test

	Lagged Δ_5 Employment				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Motor Cons.	$-$**0.194**	$-$**0.0283**	$-$**0.156**	$-$**0.233**	**0.120**
	(0.185)	(0.177)	(0.236)	(0.200)	(0.247)
First-Stage F	25.8	23.8	15.2	20.1	13.1
Industry-year F.E.	✓	✓	✓	✓	✓
Firm Controls		✓	✓	✓	✓
Lagged machines (consumption)			✓		✓
Lagged machines (balanced sheet)				✓	
Exports					✓
N	17,250	16,609	16,609	16,574	15,641

IV Results: Sales

	Δ_5 Sales				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Motor Cons.	$\mathbf{0.552}^{***}$	$\mathbf{0.422}^{***}$	$\mathbf{0.498}^{**}$	$\mathbf{0.349}^{**}$	$\mathbf{0.561}^{***}$
	(0.148)	(0.148)	(0.197)	(0.164)	(0.197)
First-Stage F	29.3	26	16.8	20.6	17.9
Industry-year F.E.	✓	✓	✓	✓	✓
Firm Controls		✓	✓	✓	✓
Lagged Motor Cons.			✓		✓
Lagged Machines				✓	
Exports					✓
N	29,109	29,109	29,109	29,109	29,109

IV Results: Labor Share

	Δ_5 Labor Cost / Sales				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Motor Cons.	**−0.134**	**−0.00851**	**−0.0298**	**−0.00607**	**−0.0691**
	(0.0944)	(0.0936)	(0.122)	(0.107)	(0.118)
First-Stage F	29.3	26	16.8	20.6	17.9
Industry-year F.E.	✓	✓	✓	✓	✓
Firm Controls		✓	✓	✓	✓
Lagged Motor Cons.			✓		✓
Lagged Machines				✓	
Exports					✓
N	29,109	29,109	29,109	29,109	29,109

Robustness

- Similar results with
  - Alternative automation measure from balance sheet data
  - Labor share defined as a share of value added

Roadmap

1. Data and Stylized Facts
2. Event Study
3. IV Estimates
4. **Extensions**

Extensions

1. **Heterogeneity** across industries, occupations, and types automation technologies
   - Characterize which occupations perform routine tasks
   - Examine differences between robots and other forms of automation
2. Effect on **wages** accounting for changes in firm's worker composition
   - Track long-term wage effects using worker panel identifier
3. **Industry-level** impact on concentration and labor share accounting for reallocation/exit
   - Find that firms that automate more have a lower labor share *ex ante*
4. Effect on consumer **prices**

Thank you!

OLS: Employment

	Δ_5 Employment				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Motor Cons.	**0.235*****	**0.207*****	**0.215*****	**0.199****	**0.211*****
	(0.00637)	(0.00611)	(0.00611)	(0.00608)	(0.00630)
Industry-year F.E.	✓	✓	✓	✓	✓
Firm Controls		✓	✓	✓	✓
Lagged Motor Cons.			✓		✓
Lagged Machines				✓	
Exports					✓
N	30,180	30,180	30,180	30,180	30,180