

What Are the Labor and Product Market Effects of Automation? New Evidence from France

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Any opinions and conclusions expressed in this work are those of the authors and do not necessarily represent the views of the Banque de France.

Motivation

- Why did major technological revolutions (steam engine, electricity) not generate mass unemployment anticipated by some?
 - ▶ Luddites in 1811-1812
 - ▶ Keynes (1930): technological unemployment
- Policy implications: **robot tax** (Bill Gates, Andrew Yang, Benoît Hamon)
- Tradeoff: **displacement vs. productivity**
(e.g., Zeira 1998, Acemoglu-Restrepo 2019)
 - ▶ Automation is labor-**displacing** at task level
 - ▶ But could induce **productivity** gains, lower prices, higher demand, and need for implementing new tasks
- Several challenges when assessing this tradeoff empirically
 - ▶ Measurement of *automation*
 - ▶ Net effect likely depends on level of aggregation

This paper: Main Findings

- Consistent with **productivity effect**:
 - ▶ Automation \uparrow , marginal cost and prices \downarrow , demand \uparrow , employment \uparrow
- Data: French manufacturing industry between 1995 and 2017
- Estimates indicate that:
 - ▶ At firm-level, a **1% increase in automation** at year t leads to a **0.2% increase in employment at t** , and a **0.4% increase after 10 years**
 - ▶ Automation **increases sales** and **induces business-stealing**
 - ▶ **No evidence** of an impact of automation on **average wage** or firm-level **wage inequality**

Literature

- Labor Market / Industry-level studies find mixed results
 - ▶ Industrial robots: Acemoglu and Restrepo 2019, Michaels and Graetz 2018, Dauth et al. 2021
 - ▶ Automation (patents): Dechezleprêtre et al. 2021, Mann and Puttmann 2020
- Recent/ongoing work studies robots at firm level
 - ▶ Acemoglu et al. 2020, Bonfiglioli et al. 2020, Bessen et al. 2019, Chandler and Webb 2019, Dixon et al. 2019, Humlum 2019, Koch et al. 2019
 - ▶ Relative to these studies, we:
 - ★ Consider broader set of automation technologies
 - ★ Use shift-share design to estimate impacts on firm and industry

Data: Worker/Firm Data

- Detailed information on workers and firms available from French administrative data
 - ▶ Matched employer-employee data (DADS) and balance sheet data (Ficus/Fare) covering all firms in French manufacturing industry from 1995 to 2017
 - ▶ Firms: employment, sales, industry, etc.
 - ▶ Workers: wages, occupation

Data: Measuring Automation

- **First measure: Balance sheet value of industrial machines**
 - ▶ "All machines used for extraction, processing, shaping, packaging of materials or supplies"
 - ▶ Stock of industrial machines at firm level
 - ▶ Distinguishes between (i) industrial machines, (ii) land, (iii) buildings and (iv) others (IT, office equipment, etc.)
 - ▶ Measure is available for all manufacturing firms, but there is no explicit list describing all machines that are accounted for

Data: Measuring Automation

- **Second measure: Acemoglu-Restrepo (2022)'s automation measure**
 - ▶ Defined as a "range of technologies that relate to industrial automation"
 - ▶ Based on imported intermediate goods, defined as products whose two-digit HS code correspond to :
 - ★ Industrial robots
 - ★ Dedicated machinery
 - ★ Numerically controlled machines
 - ★ Automatic machine tools
 - ★ Automatic welding machines
 - ★ Weaving and knitting machines
 - ★ Other dedicated textile machinery
 - ★ Automatic conveyors
 - ★ Regulating and control instruments
 - ▶ This measure is restricted to importing French firms

Examples



(a) Chemicals



(b) Paper

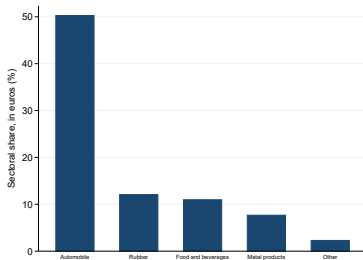


(c) Food

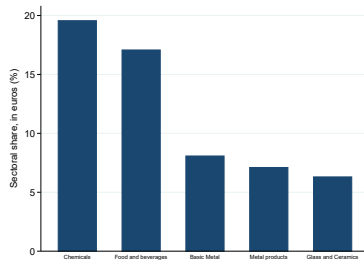
Data: Measuring Automation

- Advantages:

- ▶ Covers broader set of automation technologies than IFR definition of an industrial robot, i.e. an "automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes" (ISO 8373)



(a) Imported Industrial Robots



(b) Balance-sheet Value of Industrial Machines

Event studies

- **Question:** when a firm relies more extensively on **automation**, what happens to **employment**, **prices** and **sales**?
- Implementation of *event studies*:
 - ▶ Event defined as a major investment in automation technologies a given year

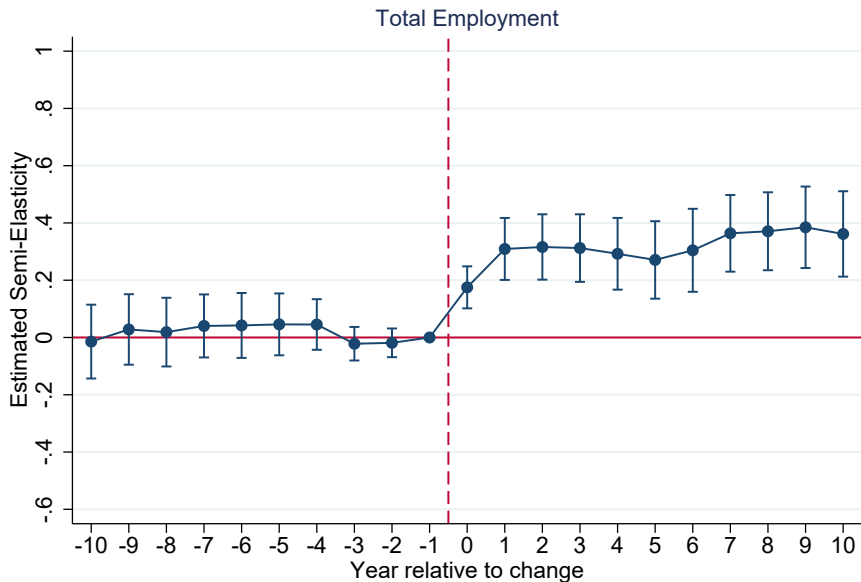
Event studies: Specification

$$\log L_{it} = \alpha + \sum_{k=-n}^n \beta_k \mathbb{1}_{t-E_i=k} \mathbb{1}_{Invest_i > p_X(Invest)} + \mu_i + \lambda_{st} + \varepsilon_{it}$$

with employment L_{it} , firm F.E. μ_i and industry-year F.E. λ_{st} (mitigate potential correlated shocks)

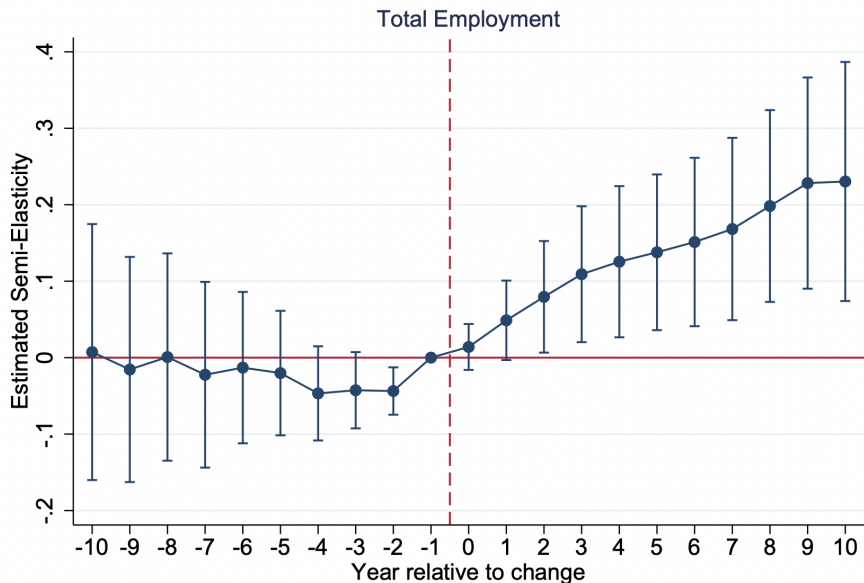
- Specification allows for delayed response of employment to increased automation
- Pre-trends (leads) can be used as a falsification test

Event studies: Employment



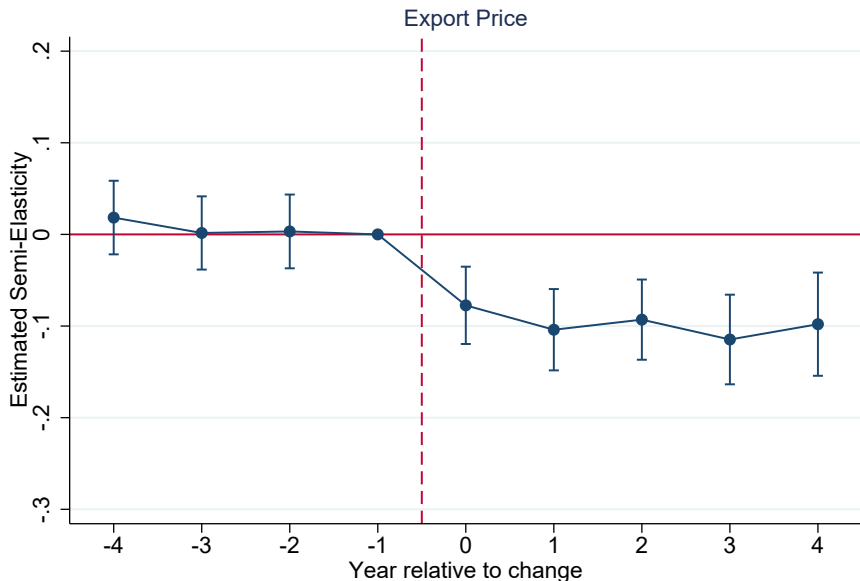
Treated = Top 10% - Controlling for 5-digit-industry by year F.E. + Firm F.E.

Event studies: Employment - AR's automation measure



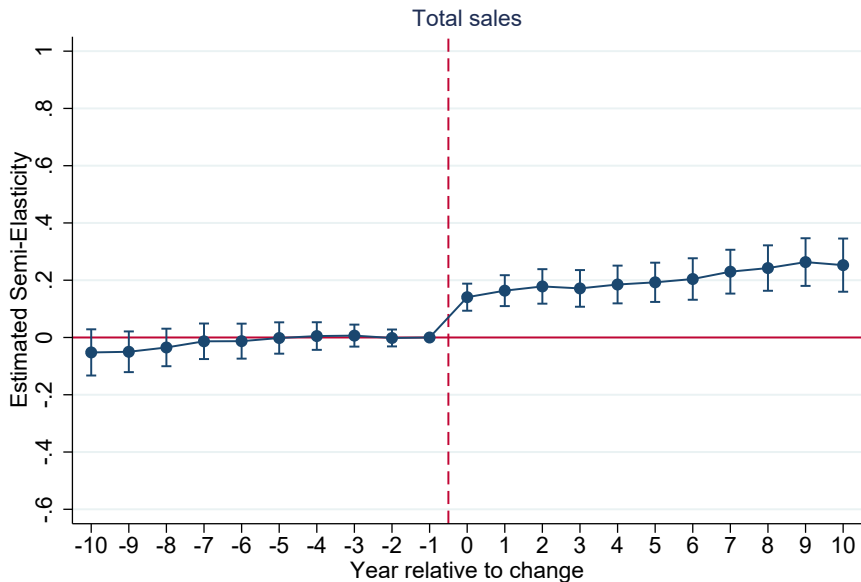
Treated = Top 25% - Controlling for 5-digit-industry by year F.E. + Firm F.E.

Event studies: Prices



Treated = Top 10% - Controlling for CN8-Product by year F.E. + Country by year F.E. + Firm F.E.

Event studies: Sales



Treated = Top 25% - Controlling for 5-digit-industry by year F.E. + Firm F.E.

Shift-Share IV

- Limitation: event studies cannot rule out potential demand/supply shocks in contemporaneous period
- Ideal experiment would randomly assign purchasing prices for machines across firms
- Approximate with a **shift-share research design**, leveraging two components:
 - ① Variation in the cost of imported machines over time across international trading partners (“shocks”)
 - ② Variation in pre-existing supplier relationships across French firms (“exposure shares”)
- Intuitively, **French firms are differentially exposed** to changes in product-specific foreign productivity of **imported machines**

Shift-Share IV: Shocks and Exposure Shares

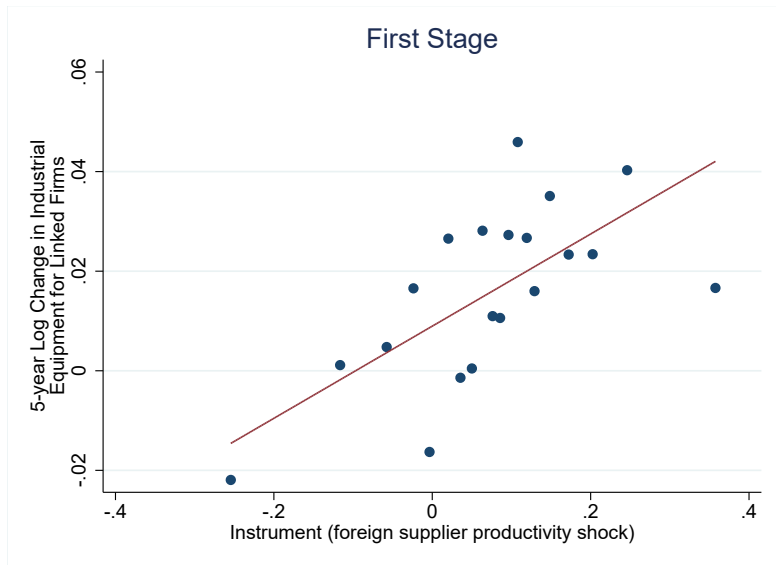
- **Shocks** are observed across trading partners by HS6 products:
 - ▶ We cannot directly observe changes in foreign machines' quality-adjusted prices
 - ▶ $g_{n,t}$ is change in imports flows of machines from each trading partners (Germany, Italy, China, etc.) for each HS6 product category into countries "similar to France" (EU + Switzerland – France) across 5-year periods

$$g_{n,t} = \frac{ImportMachines_{n,t} - ImportMachines_{n,t-1}}{ImportMachines_{n,t} + ImportMachines_{n,t-1}}$$

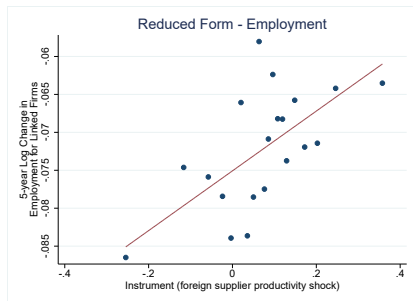
where n indexes "trading partner by HS6 product" cells

- **Exposure shares** of French firms:
 - ▶ s_{in} is share of trading partner n in firm i 's total imports of machines in initial period (1995-1999).

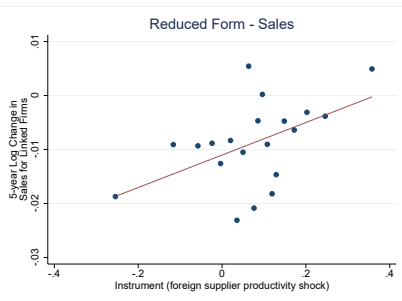
Firm SSIV: First Stage



Firm SSIV: Reduced Form



(a) Employment



(b) Sales

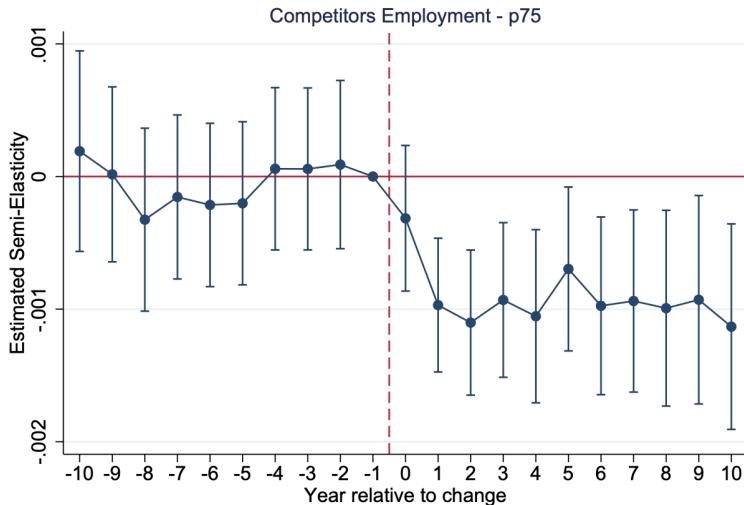
Firm SSIV: Employment

	Δ_5 Employment				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Machines	0.426*** (0.084)	0.425*** (0.100)	0.424*** (0.100)	0.433*** (0.098)	0.433*** (0.098)
First-Stage F	17.65	20.59	21.43	20.88	21.62
Partner-period F.E.	✓	✓	✓	✓	✓
4-digit Product-period F.E.	✓	✓	✓	✓	✓
2-digit Industry-period F.E.	✓	✓	✓	✓	✓
Lagged Firm Controls		✓	✓	✓	✓
Lagged Machines			✓	✓	✓
Lagged Other Capital				✓	✓
Contemporaneous Exports					✓
<i>N(partner – product – period)</i>	4,460	4,460	4,460	4,460	4,460

Firm SSIV: Sales

	Δ_5 Sales				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Machines	0.325*** (0.131)	0.340*** (0.123)	0.340*** (0.121)	0.345*** (0.114)	0.346*** (0.103)
First-Stage F	17.65	20.59	21.43	20.88	21.62
Partner-period F.E.	✓	✓	✓	✓	✓
4-digit Product-period F.E.	✓	✓	✓	✓	✓
2-digit Industry-period F.E.	✓	✓	✓	✓	✓
Lagged Firm Controls		✓	✓	✓	✓
Lagged Machines			✓	✓	✓
Lagged Other Capital				✓	✓
Contemporaneous Exports					✓
<i>N(partner – product – period)</i>	4,460	4,460	4,460	4,460	4,460

Evidence of business stealing



Controlling for 4-digit-industry by year F.E. + Firm F.E. - 33579 observations

Industry-Level Employment and International Competition

	Δ Employment 1996-2017		
	International Competition		
	All Industries	Above Median	Below Median
	(1)	(2)	(3)
Δ Machines 1996-2017	0.345***	0.404***	0.171
	(0.059)	(0.055)	(0.133)
2-digit industry by year F.E.	✓	✓	✓
Δ Other types of capital 1996-2017	✓	✓	✓
<i>N</i>	255	134	121

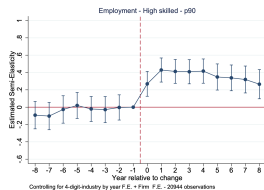
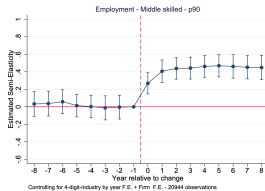
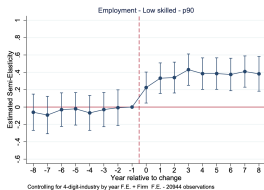
Conclusion

- **Automation increases employment of firms that automate**, which indicates that in practice the productivity effect of automation on employment tends to outweigh the displacement effect
- Automation also **increases sales and profits**, and **reduces prices**
 - ▶ Hence overall **automation generates gains** that are **broadly shared** across workers, firm owners and consumers
- At **industry level** the relationship between automation and employment **remains positive on average**, but this is mainly driven by industries facing international competition
- Hence, particularly in a globalized world, **taxing robots** or other attempts to curb domestic automation **in order to protect domestic employment may be self-defeating**

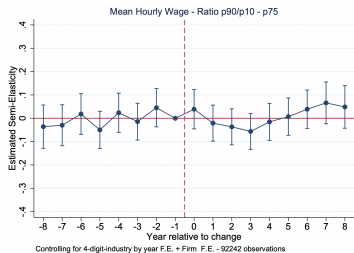
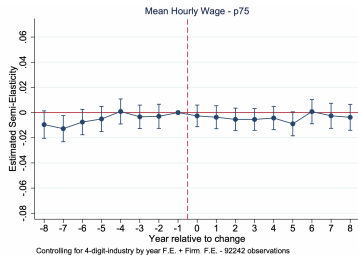
Thank you!

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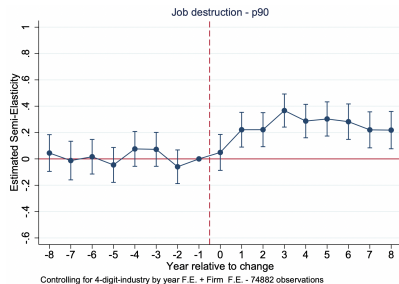
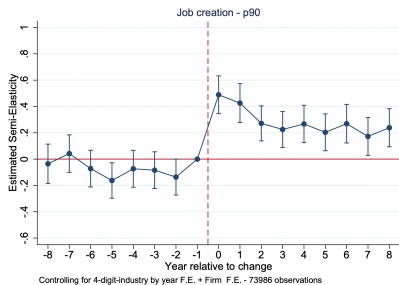
Event studies: Employment - Heterogeneity?



Event studies: Wage

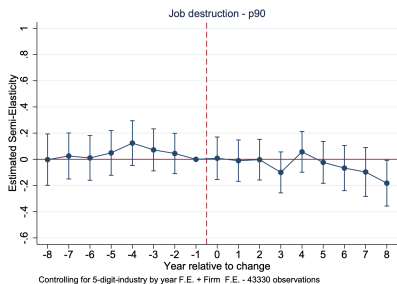
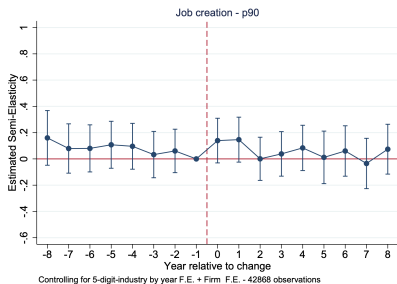


Event studies: Job Creation & Job Destruction

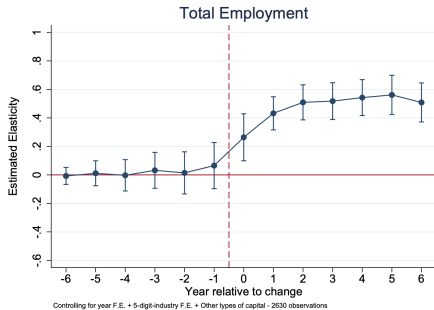


Event studies: Job Creation & Job Destruction

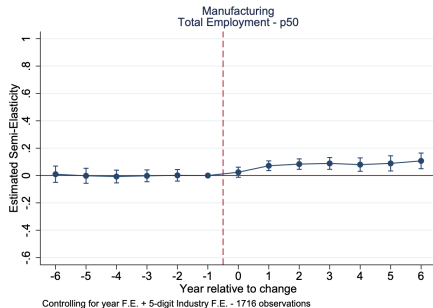
Placebo Test with Investments in Real Estate



Industry Level Employment

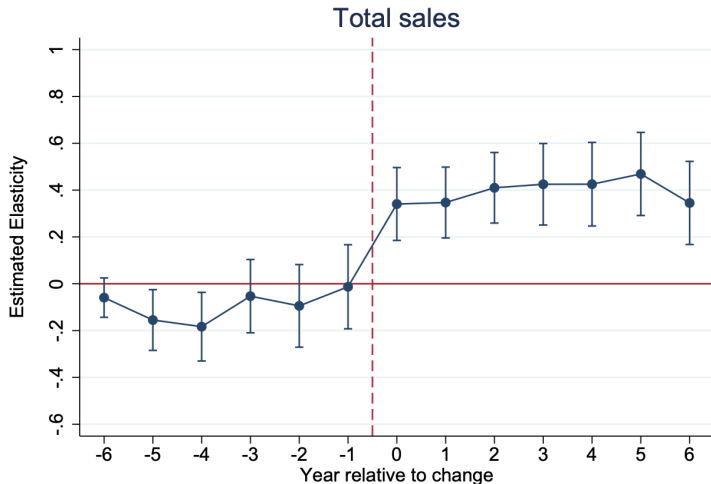


(a) Extensive margin



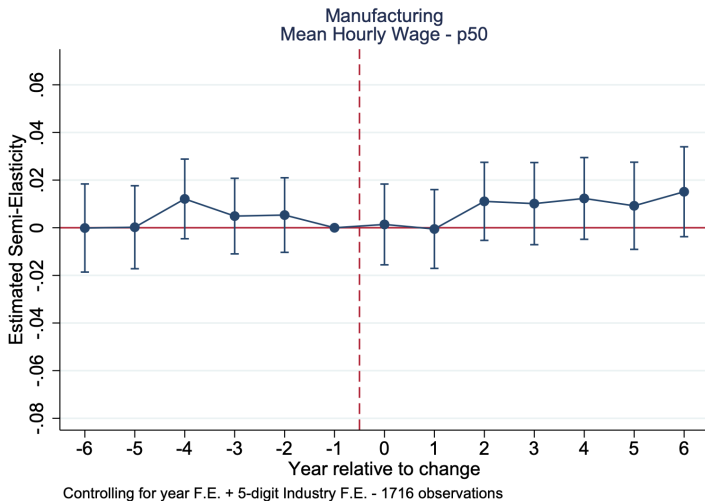
(b) Intensive margin

Industry Level Sales

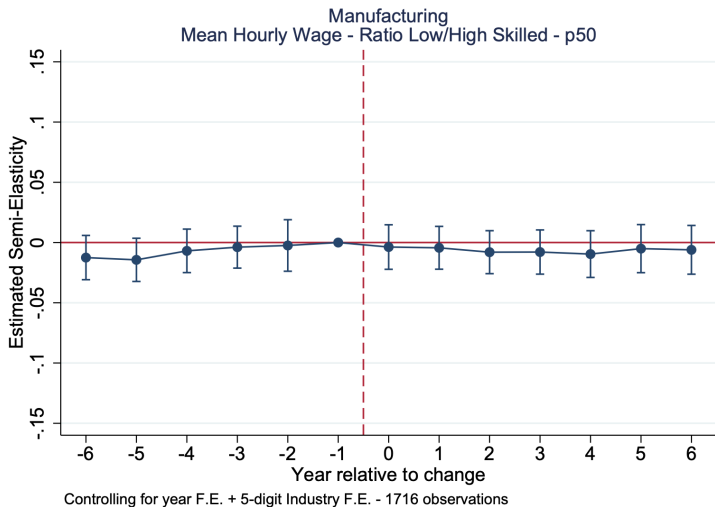


Controlling for year F.E. + 5-digit-industry F.E. + Other types of capital - 2630 observations

Industry Level Wages



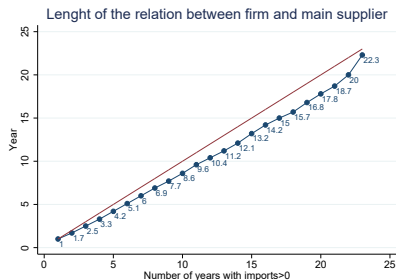
Industry Level Wage Inequality



Shift-Share IV: Exposure Shares

- **Exposure shares** of French firms:

- ▶ s_{in} is share of trading partner n in firm i 's total imports of machines in initial period (between 1995 and 1999)
- ▶ Contemporaneous shares liable to reverse causality: use initial shares instead (and analyze outcomes from 2000 onward)
- ▶ Because of switching costs, French firm more likely to benefit from a trading partner's productivity shock if it has a more important pre-existing importing relationship with them



Shift-Share IV: Identification Assumptions

- Relevance: need supplier relationships to be sufficiently persistent
 - ▶ Check power with first-stage F-statistic
 - ▶ Standard errors clustered by trading partner
- Exclusion restriction: firms linked to increasingly productive suppliers should not be unobservably different
 - ▶ Run falsification test with lagged outcome variable

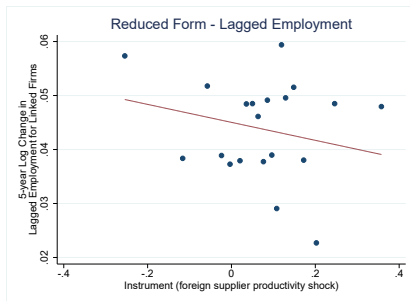
Firm SSIV: Profits

	Δ_5 Profits				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Machines	0.995** (0.448)	0.824* (0.432)	0.824* (0.432)	0.827* (0.424)	0.828** (0.412)
First-Stage F	17.65	20.59	21.43	20.88	21.62
Partner-period F.E.	✓	✓	✓	✓	✓
4-digit Product-period F.E.	✓	✓	✓	✓	✓
2-digit Industry-period F.E.	✓	✓	✓	✓	✓
Lagged Firm Controls		✓	✓	✓	✓
Lagged Machines			✓	✓	✓
Lagged Other Capital				✓	✓
Contemporaneous Exports					✓
<i>N(partner – product – period)</i>	4,460	4,460	4,460	4,460	4,460

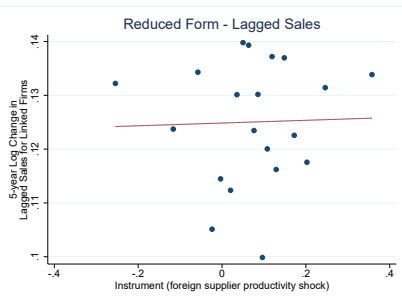
Firm SSIV: Labor Cost / Sales

	Δ_5 Labor Cost / Sales				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Machines	0.00453 (0.0164)	0.00604 (0.0173)	0.00607 (0.0172)	0.00697 (0.0166)	0.00686 (0.0157)
First-Stage F	17.65	20.59	21.43	20.88	21.62
Partner-period F.E.	✓	✓	✓	✓	✓
4-digit Product-period F.E.	✓	✓	✓	✓	✓
2-digit Industry-period F.E.	✓	✓	✓	✓	✓
Lagged Firm Controls		✓	✓	✓	✓
Lagged Machines			✓	✓	✓
Lagged Other Capital				✓	✓
Contemporaneous Exports					✓
$N(\text{partner} - \text{product} - \text{period})$	4,460	4,460	4,460	4,460	4,460

Firm SSIV: Reduced Form - Falsification tests



(a) Lagged Employment



(b) Lagged Sales

Falsification Test: Lagged Firm Employment

	Lagged Δ_5 Employment				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Machines	-0.180 (0.219)	-0.198 (0.220)	-0.199 (0.223)	-0.199 (0.220)	-0.200 (0.218)
First-Stage F	17.65	20.59	21.43	20.88	21.62
Partner-period F.E.	✓	✓	✓	✓	✓
4-digit Product-period F.E.	✓	✓	✓	✓	✓
2-digit Industry-period F.E.	✓	✓	✓	✓	✓
Lagged Firm Controls		✓	✓	✓	✓
Lagged Machines			✓	✓	✓
Lagged Other Capital				✓	✓
Contemporaneous Exports					✓
$N(\text{partner} - \text{product} - \text{period})$	4,460	4,460	4,460	4,460	4,460

Firm SSIV: Competitors' Employment

	Δ_5 Competitors' Employment				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Machines	-0.00578* (0.0032)	-0.00920*** (0.0033)	-0.00920*** (0.0032)	-0.00914*** (0.0033)	-0.00913*** (0.0033)
First-Stage F	17.65	20.59	21.43	20.88	21.62
Partner-period F.E.	✓	✓	✓	✓	✓
4-digit Product-period F.E.	✓	✓	✓	✓	✓
2-digit Industry-period F.E.	✓	✓	✓	✓	✓
Lagged Firm Controls		✓	✓	✓	✓
Lagged Machines			✓	✓	✓
Lagged Other Capital				✓	✓
Contemporaneous Exports					✓
$N(\text{partner} - \text{product} - \text{period})$	4,460	4,460	4,460	4,460	4,460

Falsification Test: Lagged Firm Sales

	Lagged Δ_5 Sales				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Machines	0.0274 (0.202)	0.166 (0.209)	0.165 (0.218)	0.155 (0.214)	0.155 (0.211)
First-Stage F	17.65	20.59	21.43	20.88	21.62
Partner-period F.E.	✓	✓	✓	✓	✓
4-digit Product-period F.E.	✓	✓	✓	✓	✓
2-digit Industry-period F.E.	✓	✓	✓	✓	✓
Lagged Firm Controls		✓	✓	✓	✓
Lagged Machines			✓	✓	✓
Lagged Other Capital				✓	✓
Contemporaneous Exports					✓
$N(\text{partner} - \text{product} - \text{period})$	4,460	4,460	4,460	4,460	4,460

Industry Level SSIV: Employment

	Δ_5 Employment			
	(1)	(2)	(3)	(4)
Δ_5 Machines	1.080*** (0.185)	1.076*** (0.186)	1.081*** (0.190)	1.091*** (0.193)
First-Stage F	17.98	18.03	15.53	15.53
Partner-period F.E.	✓	✓	✓	✓
4-digit Product F.E.	✓	✓	✓	✓
Lagged Industry Controls	✓	✓	✓	✓
Lagged Machines		✓	✓	✓
Lagged Other Capital			✓	✓
Contemporaneous Exports				✓
$N(\text{partner} - \text{product} - \text{period})$	7,687	7,687	7,687	7,687

Industry Level SSIV: Sales

	Δ_5 Sales			
	(1)	(2)	(3)	(4)
Δ_5 Machines	1.309*** (0.338)	1.312*** (0.338)	1.245*** (0.337)	1.207*** (0.327)
First-Stage F	17.98	18.03	15.53	15.53
Partner-period F.E.	✓	✓	✓	✓
4-digit Product F.E.	✓	✓	✓	✓
Lagged Industry Controls	✓	✓	✓	✓
Lagged Machines		✓	✓	✓
Lagged Other Capital			✓	✓
Contemporaneous Exports				✓
$N(\text{partner} - \text{product} - \text{period})$	7,687	7,687	7,687	7,687