VAGUES TECHNOLOGIQUES

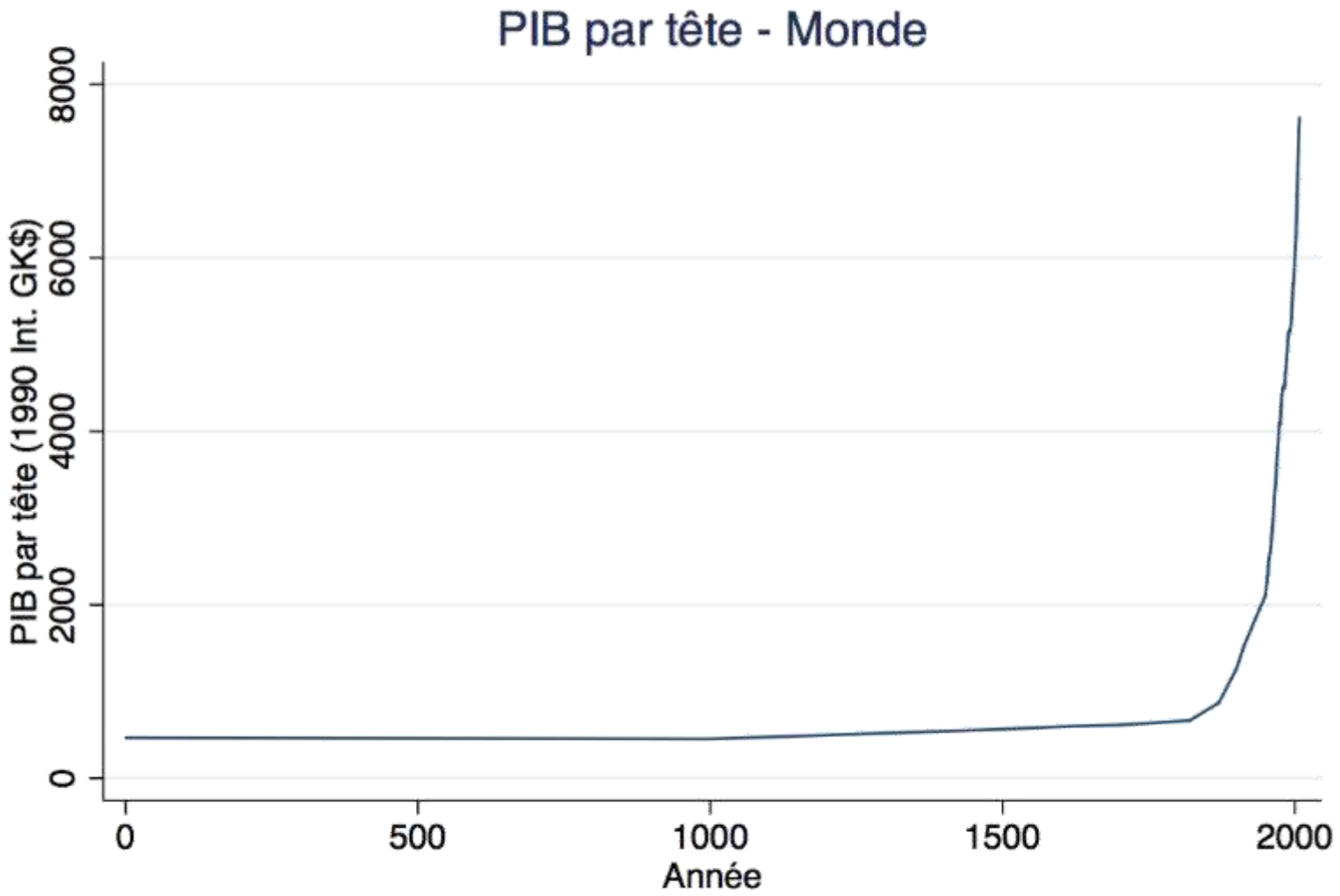
PRODUIT INTÉRIEUR BRUT

- Le PIB représente le résultat final de l'activité de production des unités productrices résidentes d'un pays. Il peut se calculer selon 3 approches :

1. La production : PIB = Valeurs ajoutées + Impôts sur la production – Subventions .
2. Les revenus : PIB = Salaires + Excédant brut d’exploitation des enterprises – Subventions + Impôts sur la production
3. La demande : PIB = Consommation Finale + Investissement + (Exportations-Importations)

- Ces trois définitions doivent donner un résultat identique

INTRODUCTION



Source : Maddison Project - 2010

COLLÈGE DE FRANCE 1530

INTRODUCTION

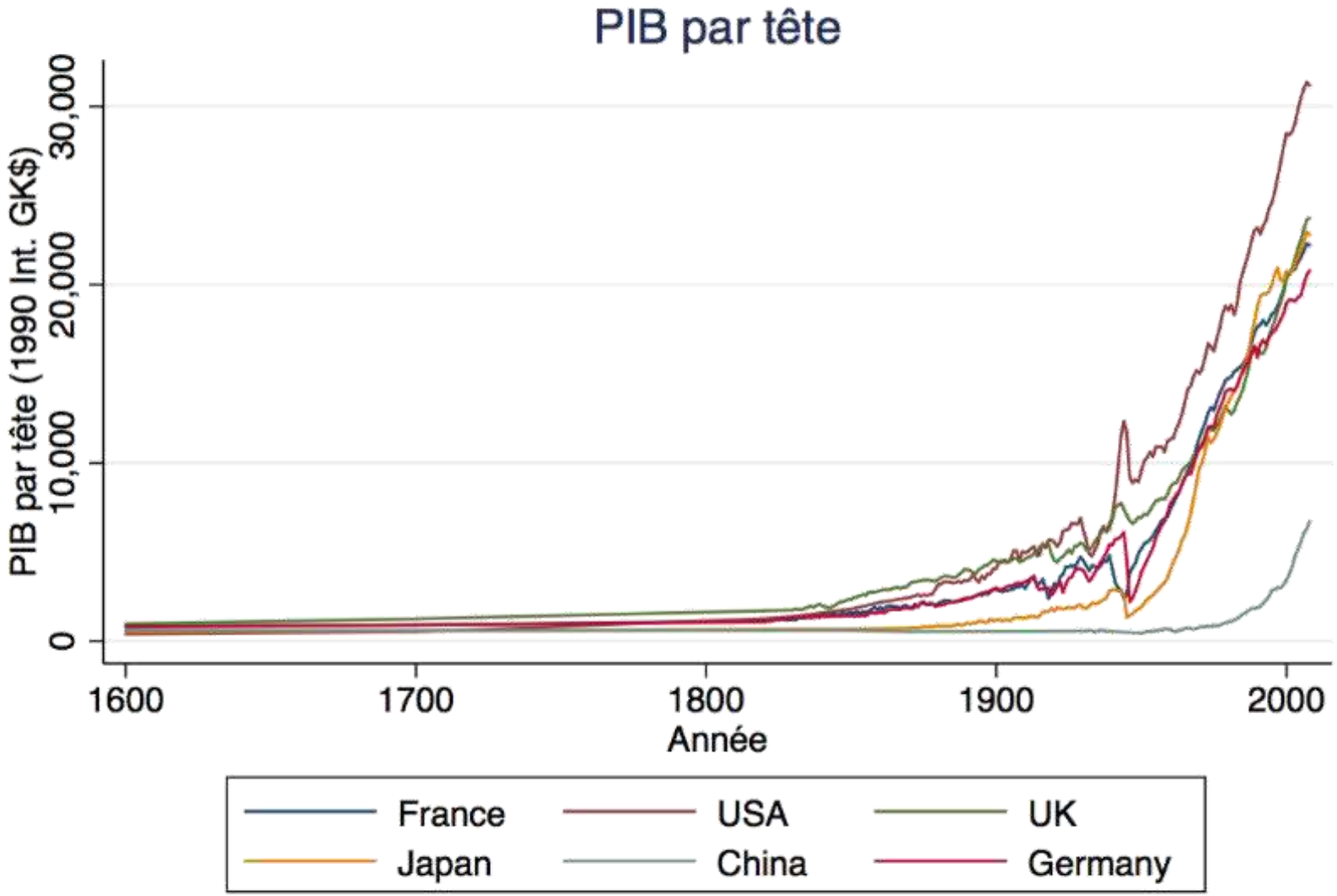
La croissance du PIB par tete est donc un phenomene recent

PIB Mondial est le meme en l'an zero et en l'an 1000

Taux de croissance moyen du PIBpar tete mondial est de 1/19eme par an entre l'an 1000 et l'an 1820

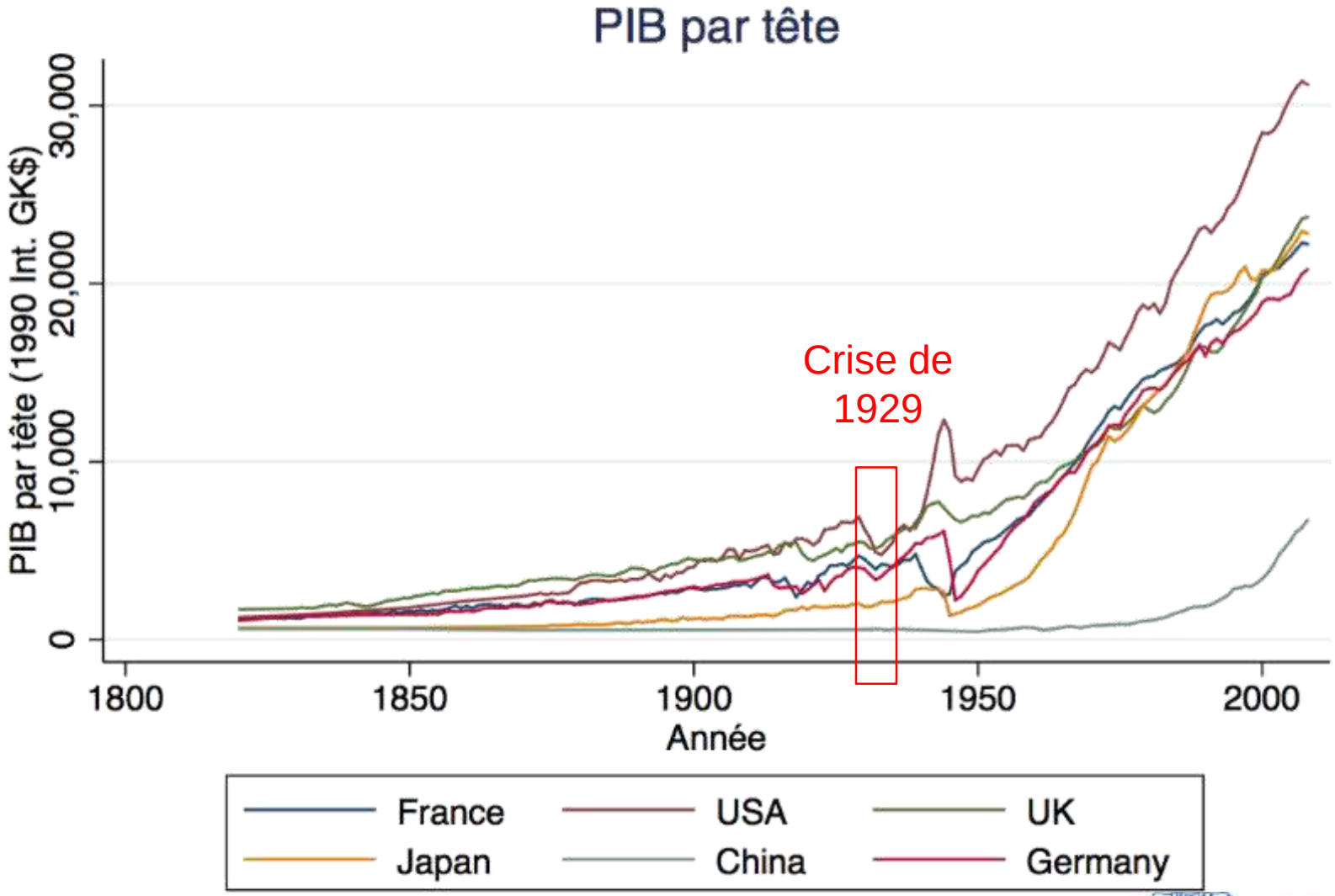
Ce taux de croissance monte a 0,5% entre 1820 et 1870, et depasse les 3-4% entre 1950 et 1973

EVOLUTION DE LA CROISSANCE

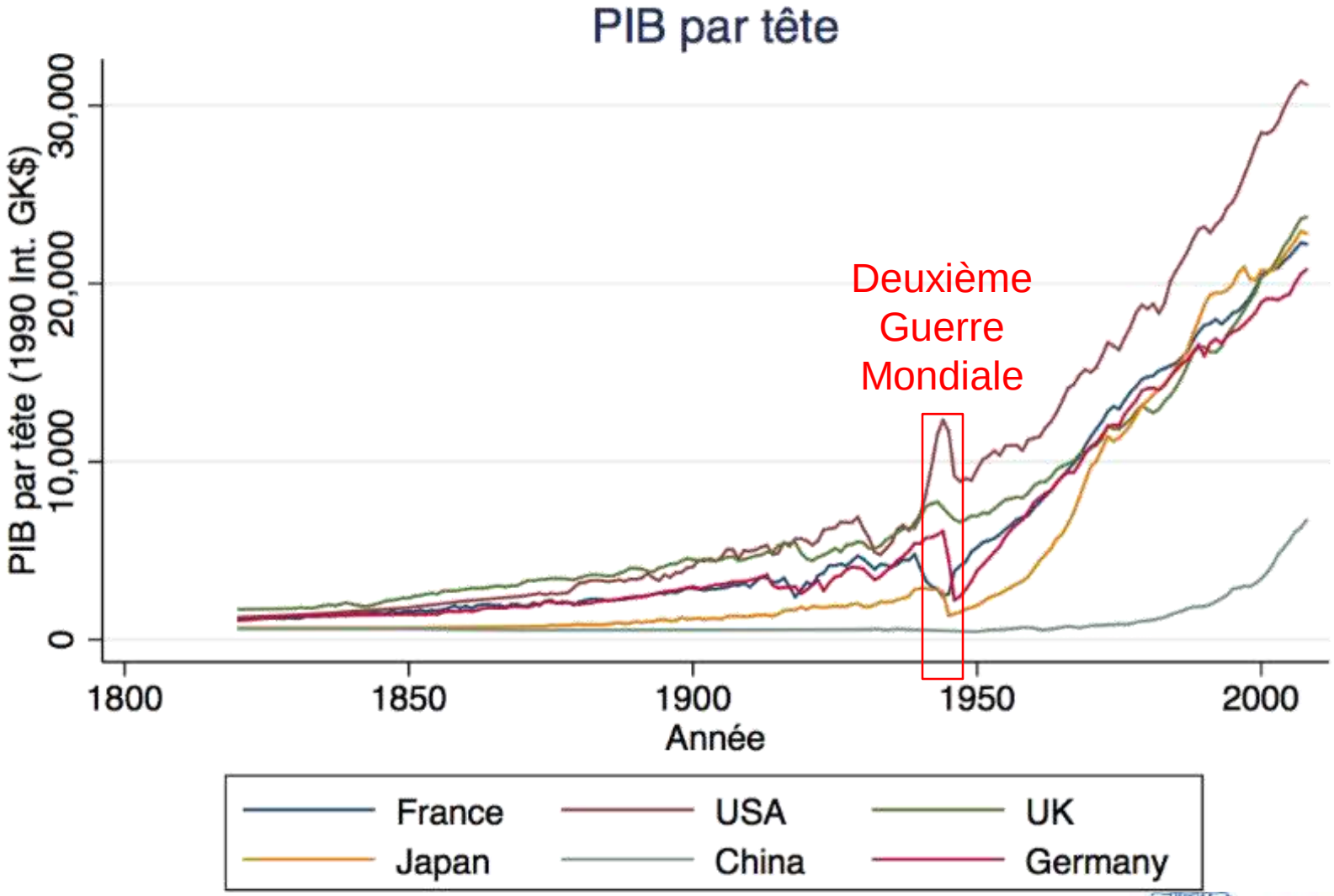


Source : Maddison Project - 2010

COLLÈGE DE FRANCE 1530



Source : Maddison Project - 2010



Source : Maddison Project - 2010

BERGEAUD-CETTE-LECAT (2018)

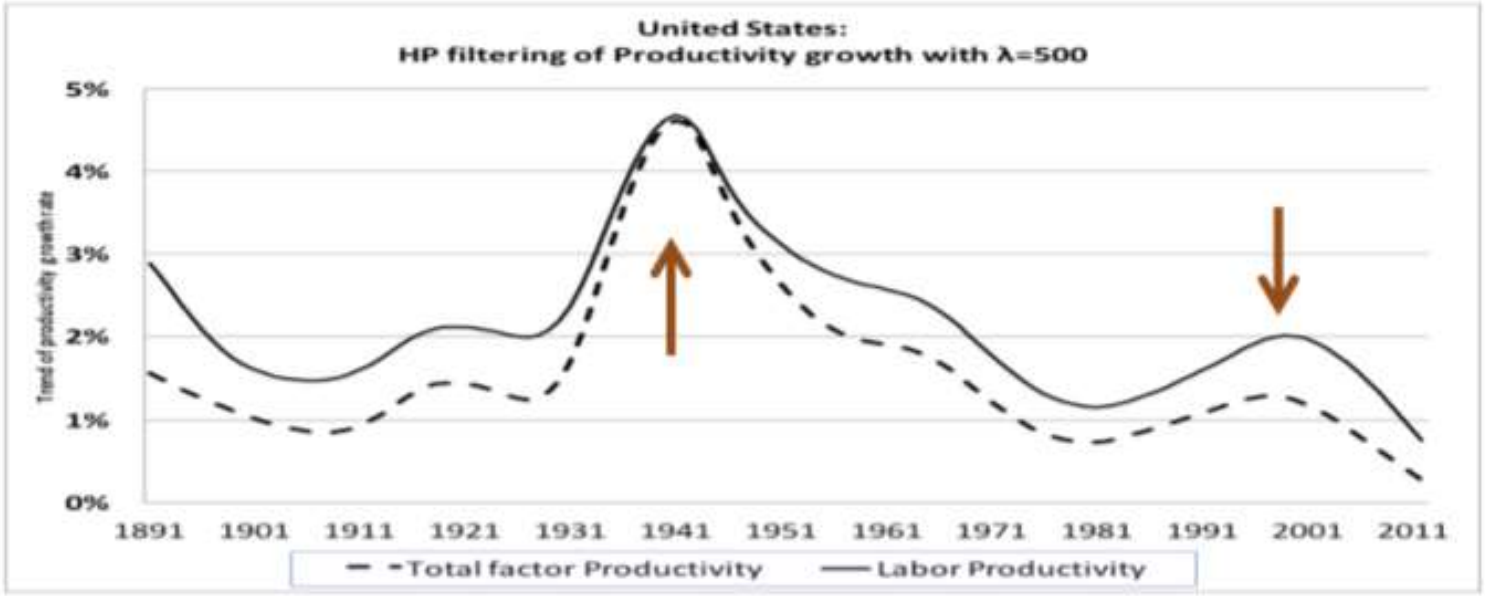
COLLÈGE DE FRANCE 1530

INTRODUCTION

- ***Productivity Trends in Advanced Countries between 1890 and 2012*** , Bergeaud, Cette et Lecat, Review of Income and Wealth (2016)

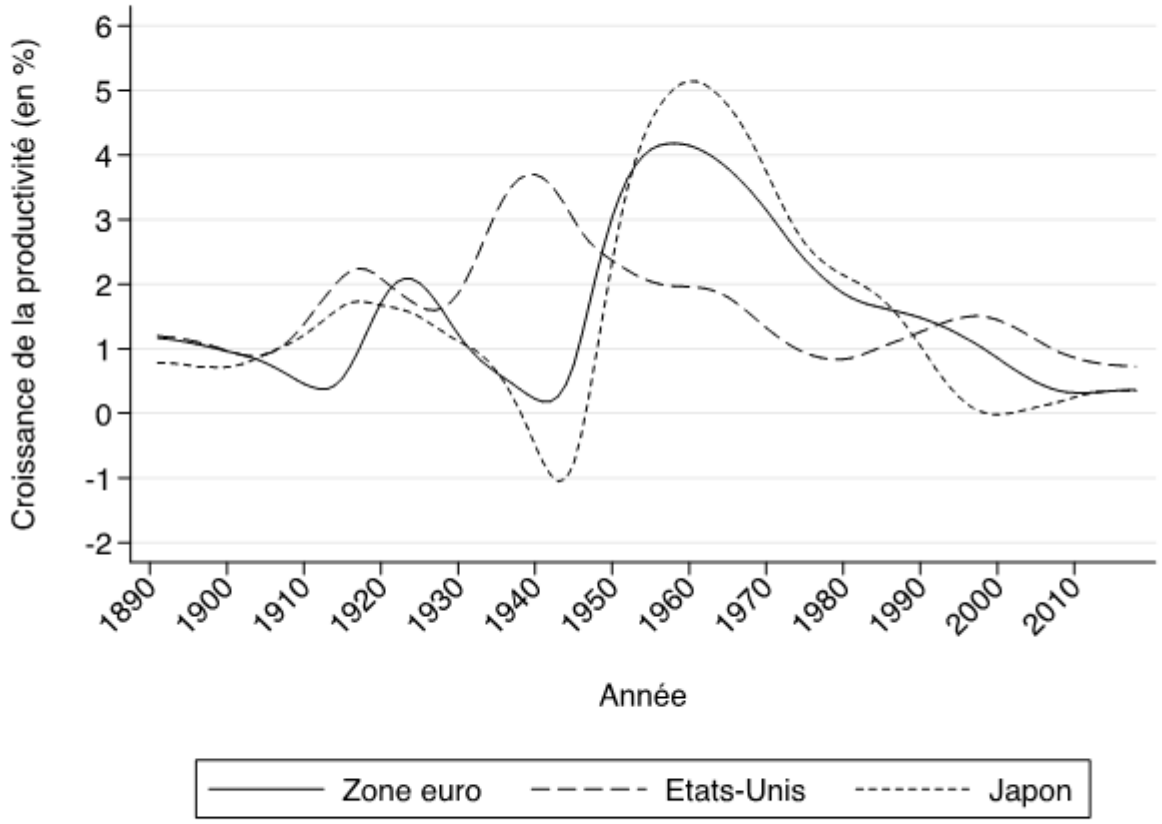
- **Objectifs :**
  - Extraire de la courbe de croissance annuelle du PIB par tête des tendances de long terme
  - Comprendre ce qui sous-tend l'évolution du PIB par tête en le décomposant
  - Pays/regions consideres: Europe, USA, Japon, Australie, etc.

COLLÈGE DE FRANCE 1530



Source: Bergeaud, Cette and Lecat (2016) Long term productivity project - www.longtermproductivity.com

Figure 1 : Taux de croissance annuel de la productivité globale des facteurs

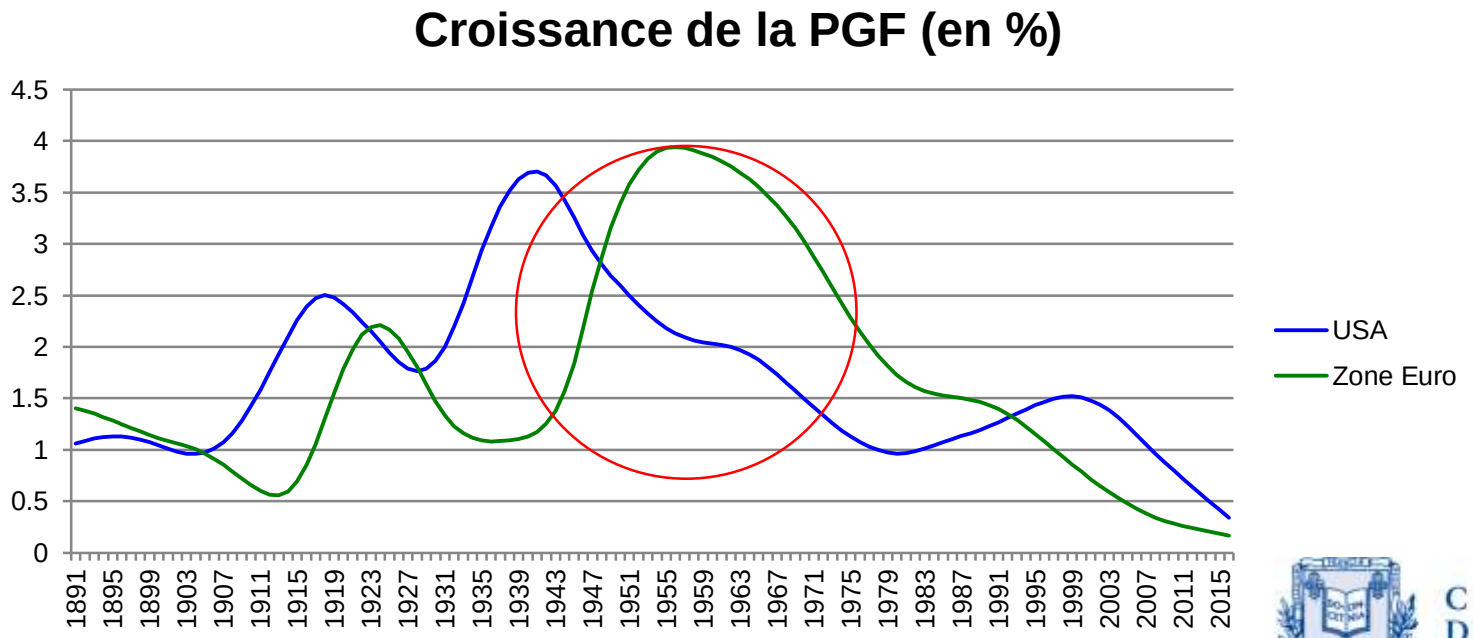


Note : Indicateur filtré par le filtre Hodrick-Prescott (λ=500)

Source : Bergeaud, Cette et Lecat (2016) ; voir : www.longtermproductivity.com.

DIFFUSION DES VAGUES

- En Europe, vague de croissance a lieu 20 ans plus tard, après la guerre
- Elle est stimulée par la reconstruction (habitations, machines, etc.) et la réorganisation des moyens de production : nouvelles technologies, nouvelles usines adaptées à l'électricité, nouvelles pratiques de management
- Elle est également soutenue financièrement par le plan Marshall

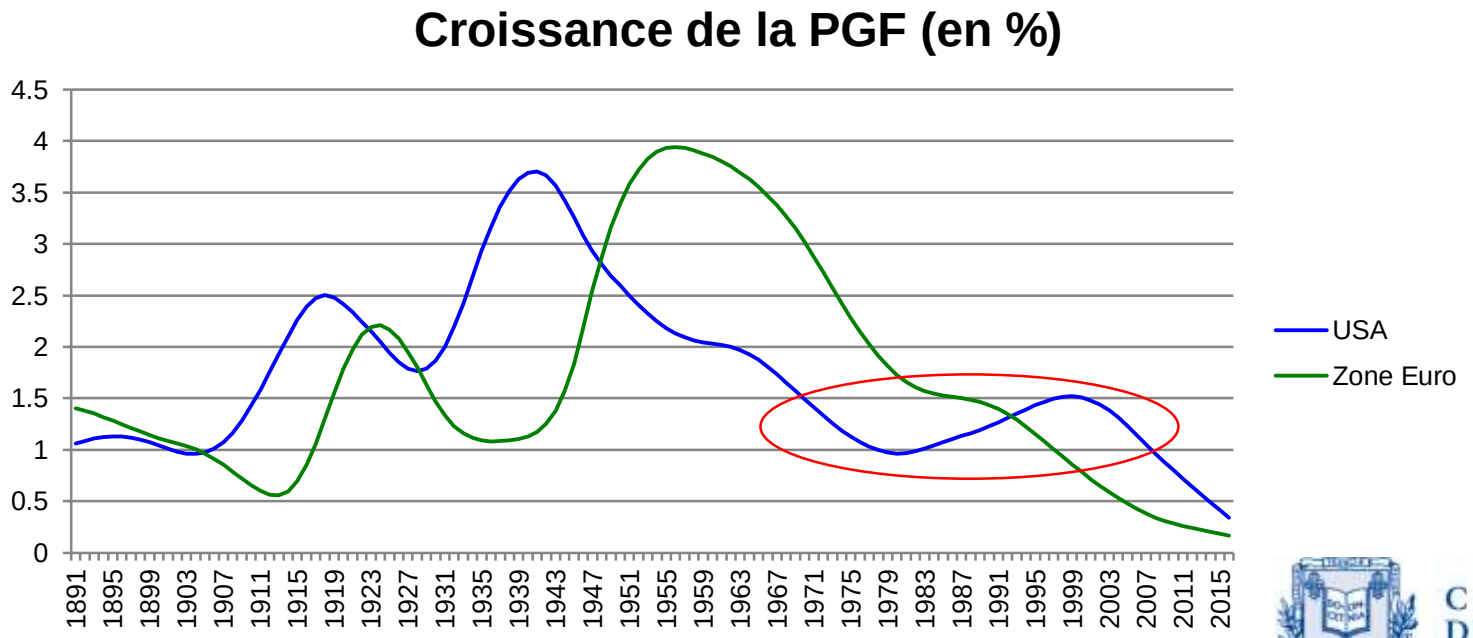


Source : Bergeaud, Cette et Lecat (2016)

COLLÈGE DE FRANCE 1530

RÉVOLUTION NUMÉRIQUE

- Ralentissement de la productivité aux USA dans les années 1970 et 1980 (choc pétrolier et essoufflement des innovations des années 1930)
- Puis nouvelle vague, dans les années 1990 jusqu'au début des années 2000, avec la révolution des technologies de l'information et de la communication (TIC)



Source : Bergeaud, Cette et Lecat (2016)

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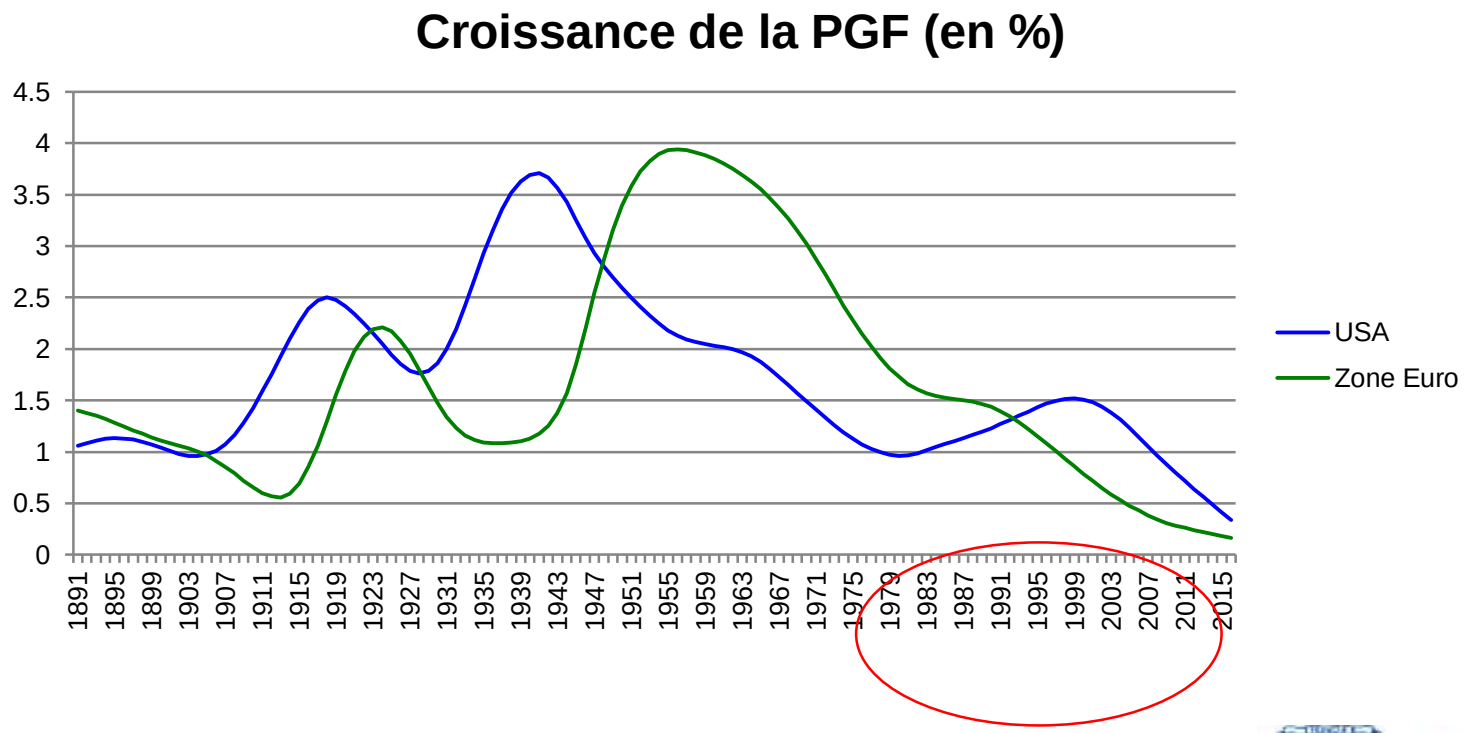
RÉVOLUTION NUMÉRIQUE

- Toutefois, cette vague de croissance de la productivité est bien plus faible que la précédente et presque inexistante en Europe
- Pourquoi pas de vague récente en Europe ?



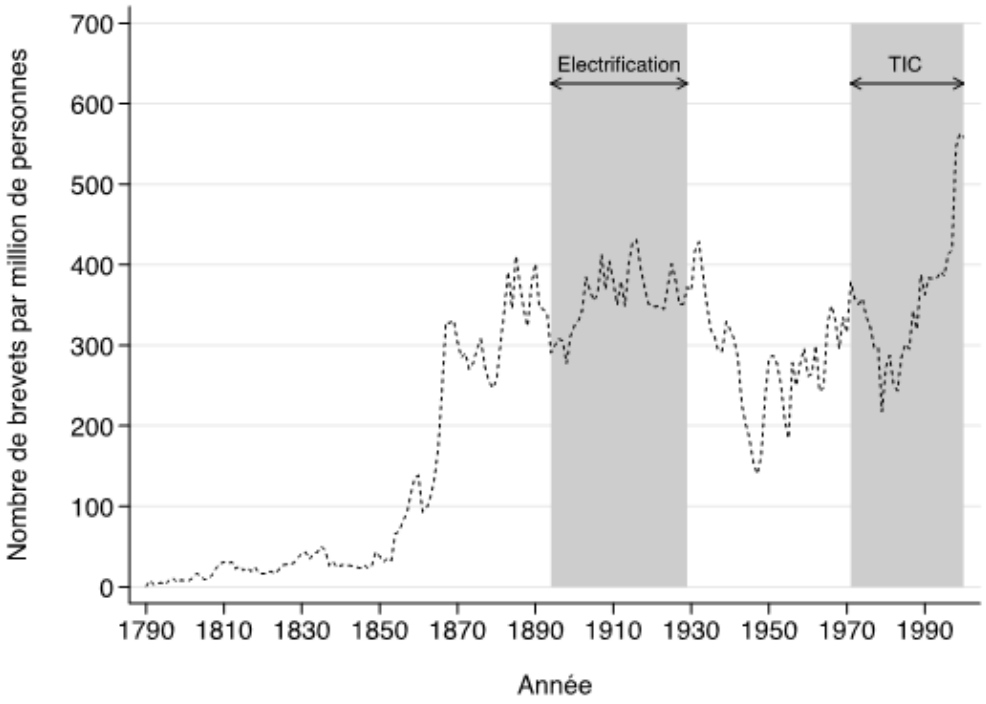
Source : Bergeaud, Cette et Lecat (2016)

COLLÈGE DE FRANCE 1530

POURQUOI UN RETARD DANS LA DIFFUSION DES VAGUES

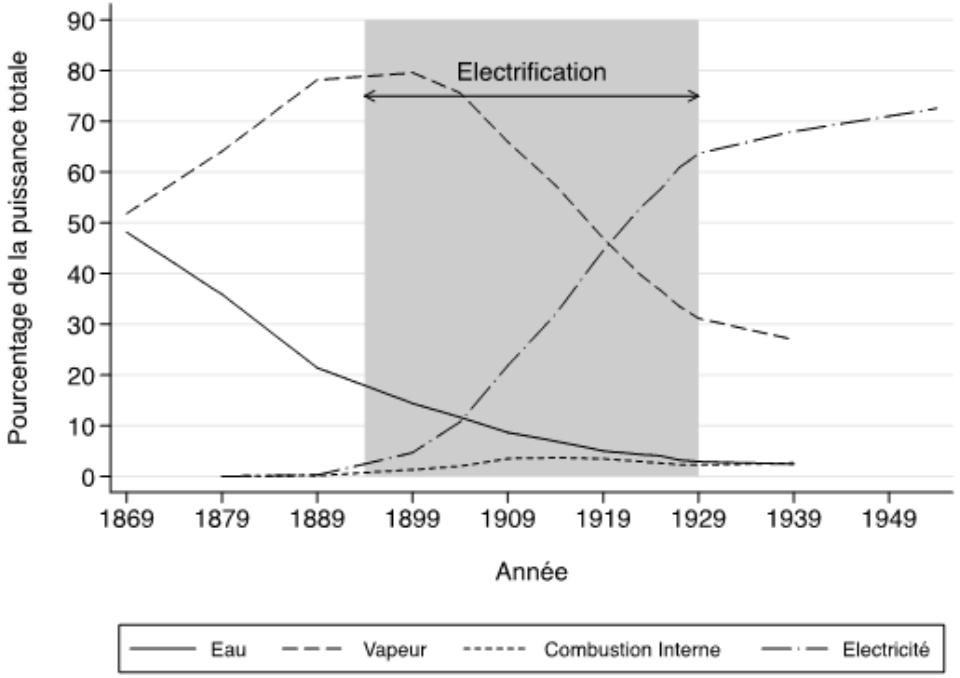
1) **Importance des innovations secondaires**

Figure 2 : Brevets relatifs aux inventions enregistrés aux Etats-Unis, par million de personnes, 1790-2002



Source : Jovanovic et Rousseau (2005).

Figure 3 : Part de la puissance totale générée par les sources principales d'énergie dans le secteur manufacturier américain, 1869-1954



Source : Jovanovic et Rousseau (2005).

POURQUOI UN RETARD DANS LA DIFFUSION DES VAGUES

2) Delai de diffusion dans les entreprises: « la dynamo et l'ordinateur »

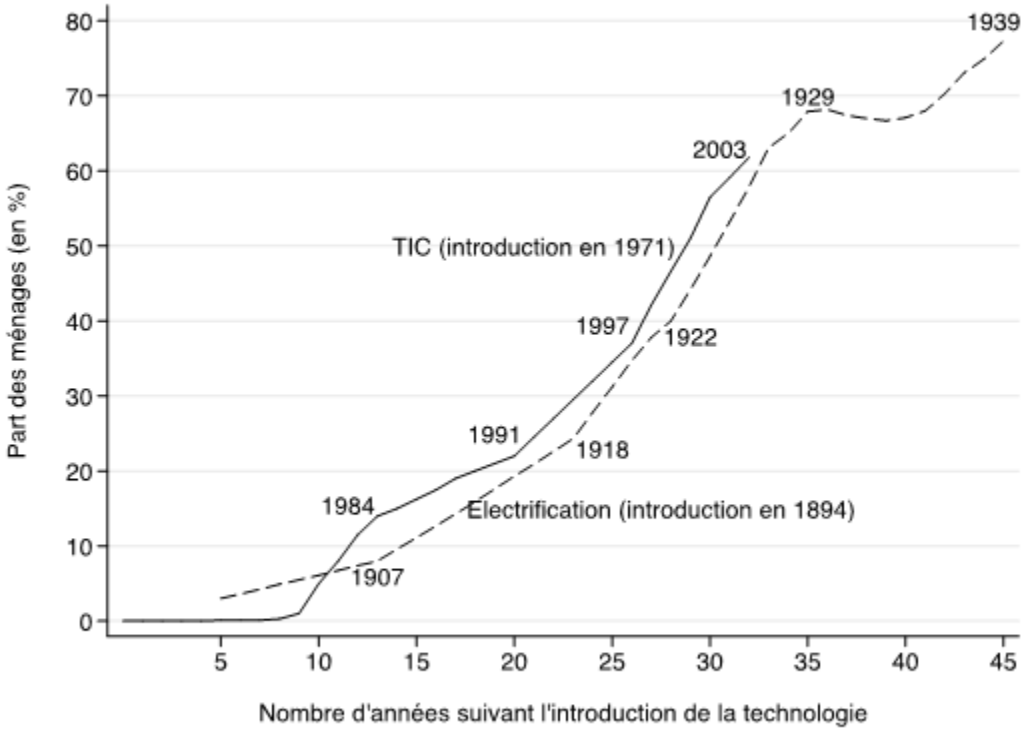
POURQUOI UN RETARD DANS LA DIFFUSION DES VAGUES

3) L’amelioration dans l’utilisation des technologies generiques

POURQUOI UN RETARD DANS LA DIFFUSION DES VAGUES

4) L’adoption d’une nouvelle technologie generique par les menages

Figure 4 : Pourcentage des ménages ayant adopté l'électricité et l'ordinateur au cours des périodes de diffusion des technologies génériques



Source : Jovanovic et Rousseau (2005).

POURQUOI UN RETARD DANS LA DIFFUSION DES VAGUES

5) L’inadequation des infrastructures et institutions locales

POURQUOI UN RETARD DANS LA DIFFUSION DES VAGUES

6) Les limites de la mesure de productivite: le cas de la revolution des TIC

CONCLUSIONS

- Au total, depuis 1820, le PIB par tête a connu une évolution spectaculaire (take-off)
- Toutefois, cette évolution a été marquée par des phases de hausse plus ou moins importantes
- Le moteur sous-jacent le plus important de cette croissance du PIB par tête reste la productivité globale des facteurs, qui est elle-même résultante de l'innovation, de l'éducation, etc.
- La diffusion des nouvelles technologies generiques tend a etre retarde pour plusieurs raisons

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

Philippe Aghion, *College de France*
Celine Antonin, *Sciences-Po*
Simon Bunel, *Insee and PSE*
Xavier Jaravel, *London School of Economics*

October 5, 2020

Motivation

- Tradeoff: productivity vs. displacement
  (e.g., Zeira 1998, Acemoglu-Restrepo 2019)
  - Automation is labor-displacing at task level
    (e.g., Keynes 1930, Leontief 1952, Autor, Levy, and Murnane 2003)
  - But could induce productivity gains, lower prices, higher demand, and need for implementing new tasks
    (e.g., Autor 2015, Acemoglu-Restrepo 2018, Bessen 2018)

- Several challenges when assessing this tradeoff empirically
  - Measurement of "automation"
  - Net effect likely depends on level of aggregation

This Paper

- Contribute to literature in three ways
  - Study automation at **plant, firm and industry levels**
  - Quasi-experimental variation from **shift-share IV design**s
  - Distributional effects: **workers (employment) vs. consumers (prices) vs. profits**
- Use linked employer-employee data set covering the French manufacturing sector (1994-2015)
- Measure automation from
  - (a) Balance sheet value of industrial machines at firm-level
  - (b) Records of "motive power" at plant level, b/c common automation technologies operate with electric motors
    - ⋆ Scope: not about AI/machine learning/computers

This Paper: Research Design

- Descriptive evidence on population of firms and plants
  - Event studies exploiting timing of adoption of industrial machines across plants (in same firm) or across firms (in same industry)
- Causal effect from firm-level shift-share research designs
  - Covers subset of firms which import industrial machines from abroad
  - Research design uses (a) changes in the productivity of foreign suppliers of machines ("shifters"), along with (b) pre-determined importer-supplier relationships ("exposure shares")
  - Approximates an "ideal experiment" that would randomly assign price of automation technologies across firms
- Repeat shift-share design at the level of industries

Main Findings

- Estimates indicate that increased automation leads to:
  - **Increased plant-level, firm-level, and industry-level employment**: elasticity **+0.3** after 5 years
  - **Increased firm-level and industry-level sales**: elasticity **+0.4** after 5 years
  - **Falling firm-level prices**: elasticity **-0.3** after 5 years
  - Also find increased profits, and cannot reject stable labor share at firm and industry levels
- Consistent with simple productivity - demand reallocation channel:
  - Automation $\uparrow$, marginal cost and prices $\downarrow$, demand $\uparrow$, employment $\uparrow$
  - Continues to operate at industry-level because of international trade

Roadmap

1. **Data**
2. **Plant and Firm Level Analysis**
3. **Industry Level Analysis**
4. **Demand Reallocation Channel**

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 French manufacturing sector from 1994 to 2015
  - Firms and plants: sales, industry, balance sheet
  - Workers: wages, occupation, education

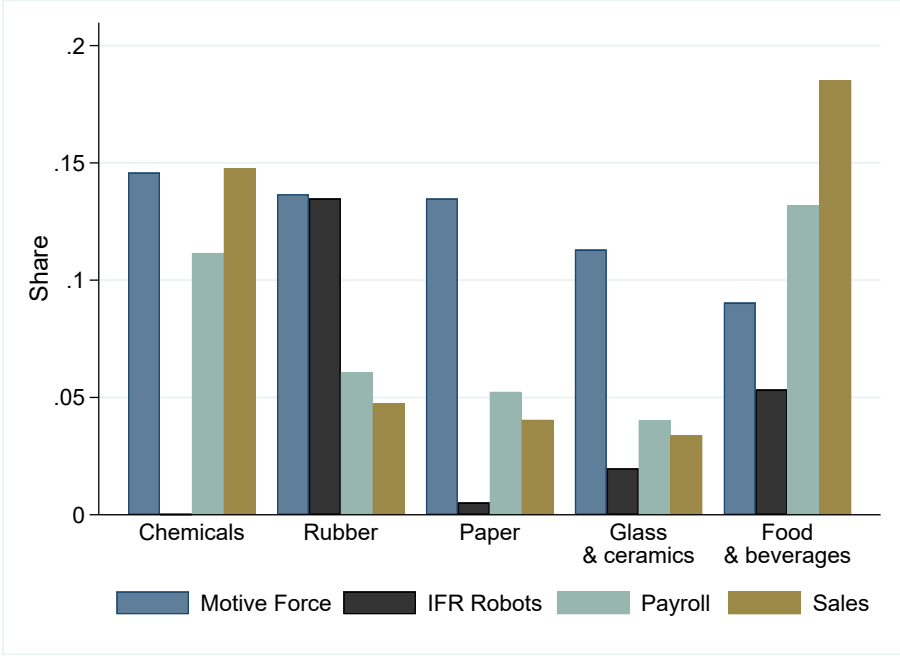
Measuring Automation

- Automation defined 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)
- Firm-level: **balance sheet value of industrial machines**
- Plant level: common automation technologies typically based on electro-motive force, i.e. set in motion using electric motors
  - Use plant-level records of **peak electric capacity for motors (motive power)** used in production process
  - Assembled by INSEE on large sample of plants; distinguishes between motive power, thermic/thermodynamic uses, and other uses (electrolysis)
  - Focus on motive power to exclude heating, cooling, servers

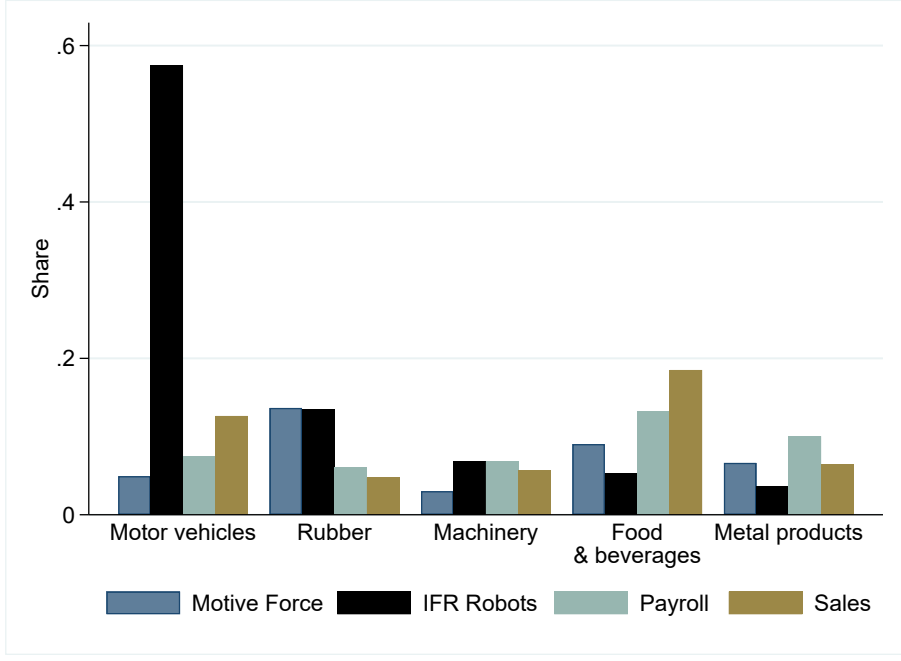
Motive Power Peak Capacity Measure

- Advantages of motive power measure: available at plant level
- Limitations:
  - Would not want to simply capture changes in electricity consumption as a variable input $\Rightarrow$ to capture investments, use changes in "peak capacity" for motive power
  - Due to variation in efficiency, difficult to draw comparisons across industries and over time $\Rightarrow$ analysis with industry/time fixed effects

Coverage



Top 5 for Motive Force



Top 5 for Robots

Food

Chemicals

Rubber

Roadmap

1. Data
2. **Plant and Firm Level Analysis**
   - Descriptive evidence
   - Shift-share IV
3. Industry Level Analysis
4. Demand Reallocation Channel

Distributed Lead-Lag Model

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

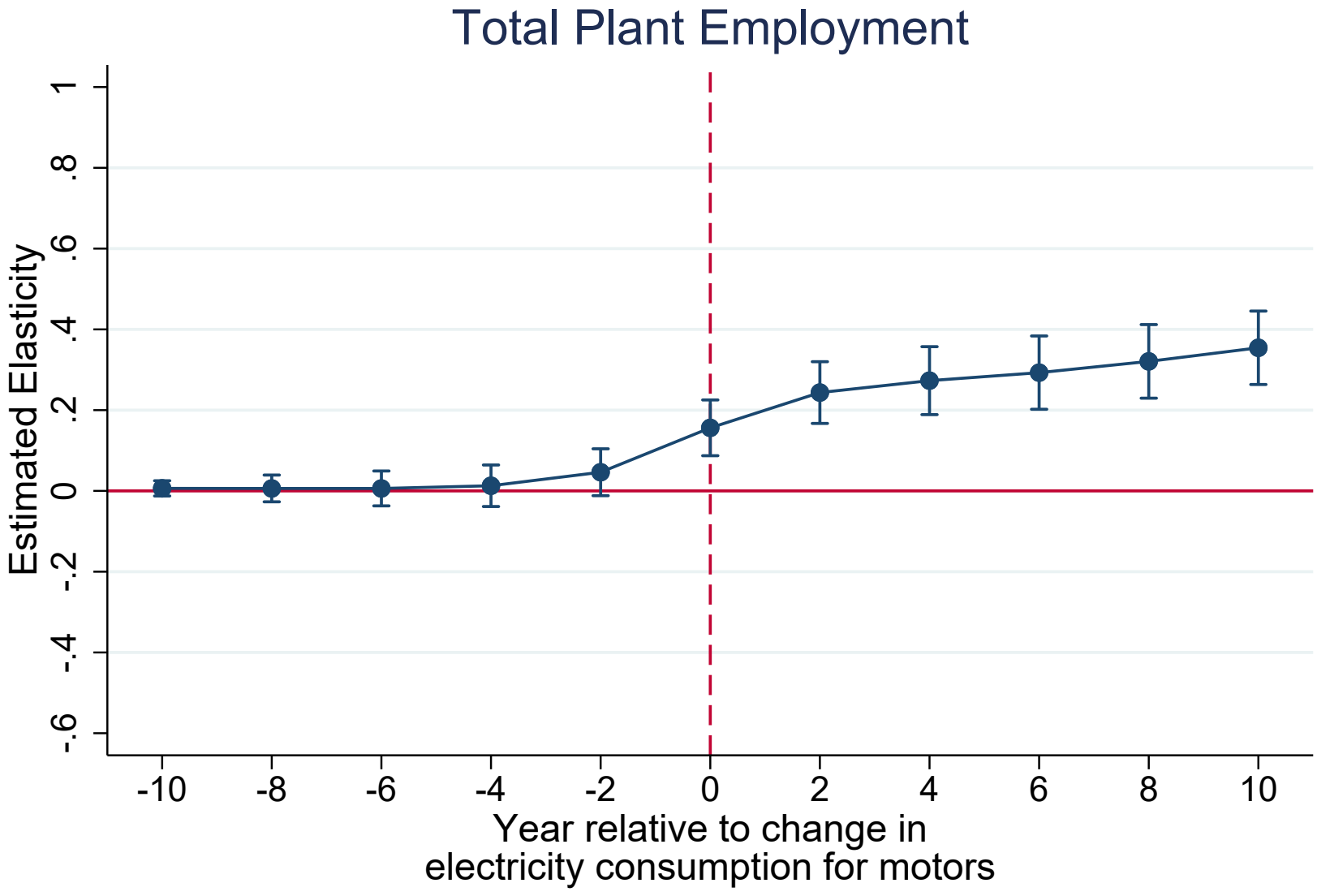
with employment L_{it}, change in electric motor consumption $\Delta M_{i,t}$ and plant F.E. μ_i

- Specification allows for delayed response of outcomes to increased automation
- Causal interpretation requires $E[\Delta M_{i,t-k} \cdot \varepsilon_{it} | \mu_i, \lambda_{st}] = 0 \; \forall \, (t,k)$
  - Pre-trends (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

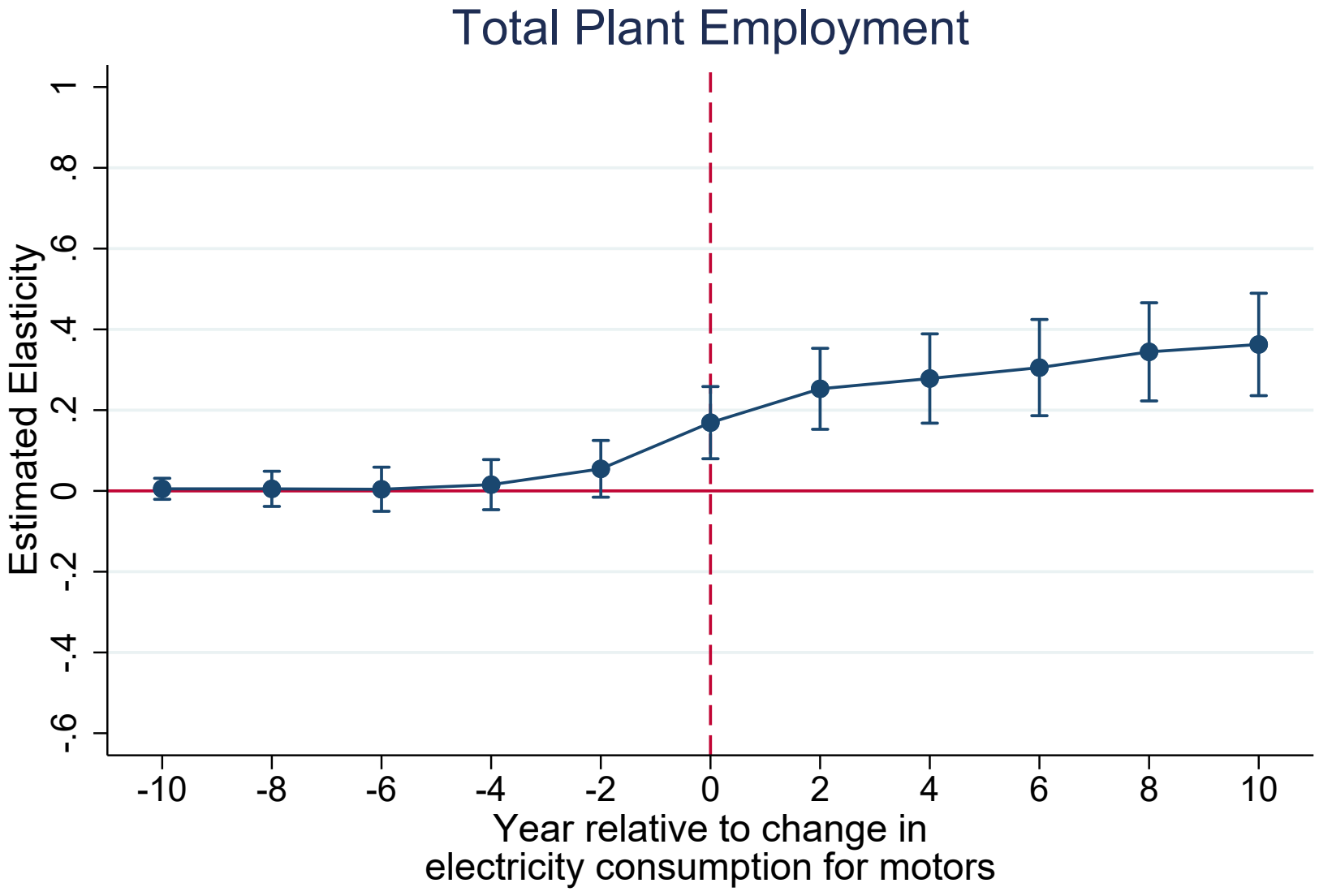
- Start by documenting employment dynamics across across plants (with peak motive power measure)
- Find that employment *increases* following increased automation
  - Elasticity of $+0.2$ on impact
  - Cumulative response increases further over time, with an elasticity of $+0.4$ after 8 years
- No pre-trends and magnitudes robust to changes in industry-year and firm-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 2019)

2-digit Industry by year F.E.



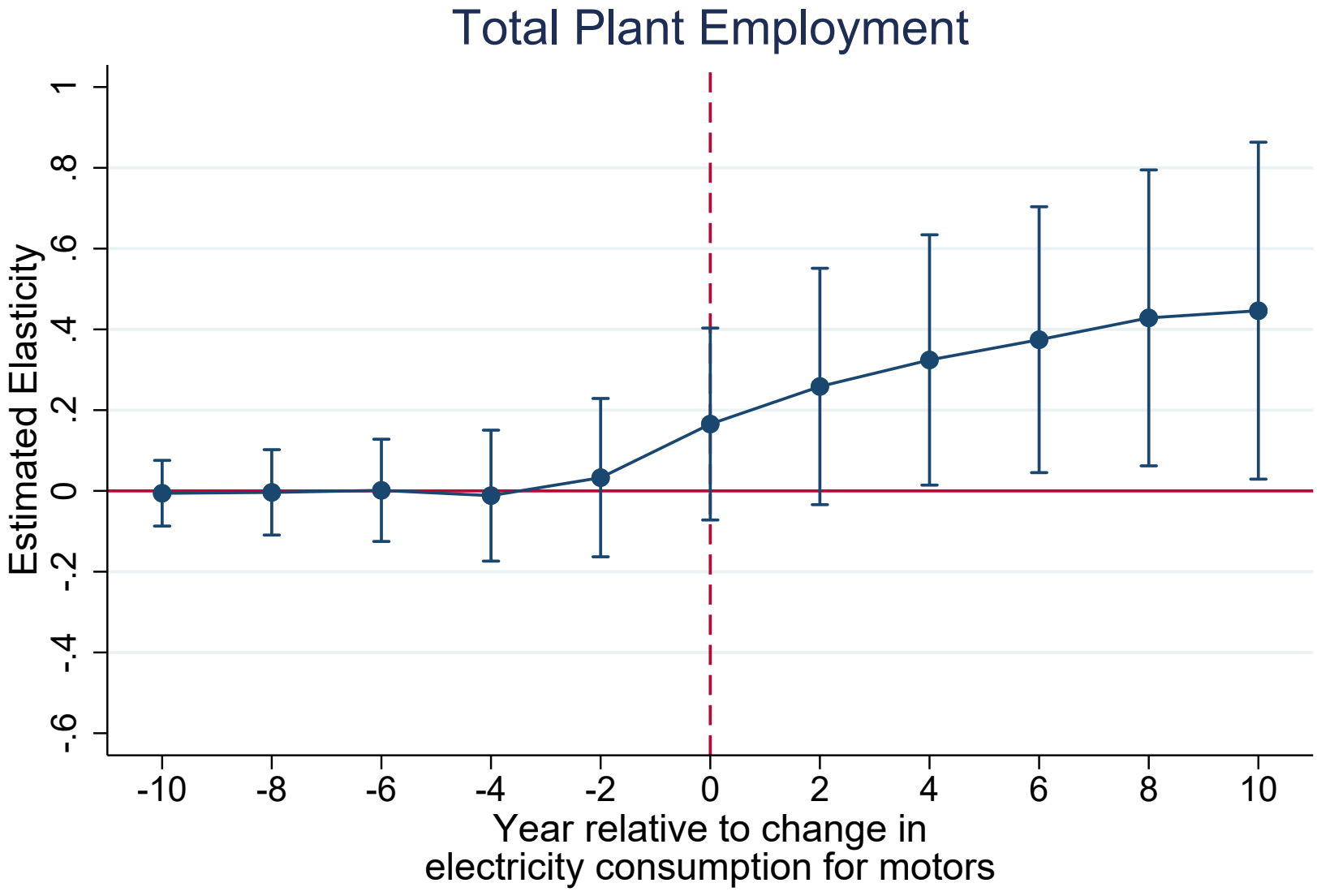
Controlling for 2-digit-industry by year F.E.

4-digit Industry by year F.E



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

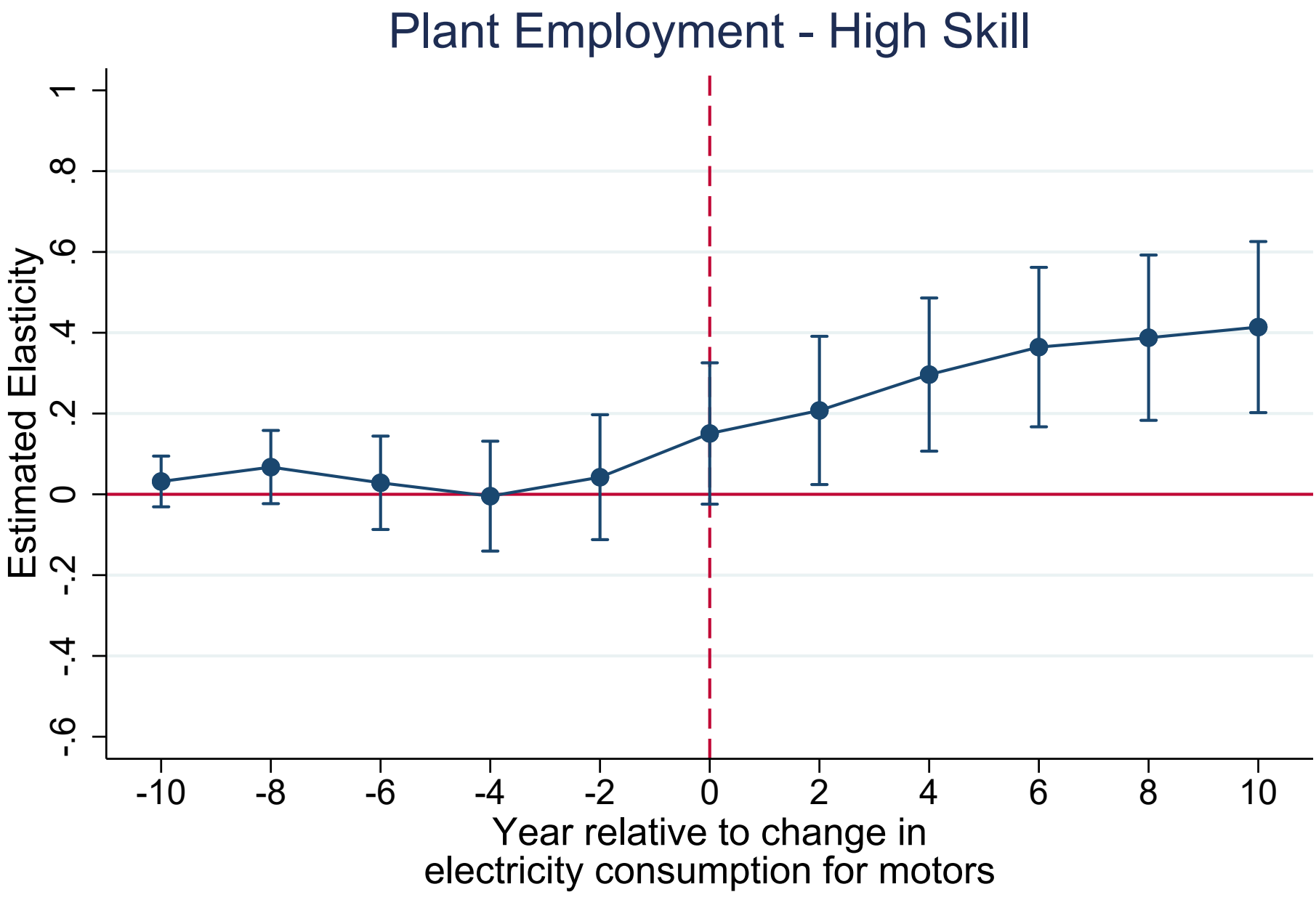
Firm by year F.E.



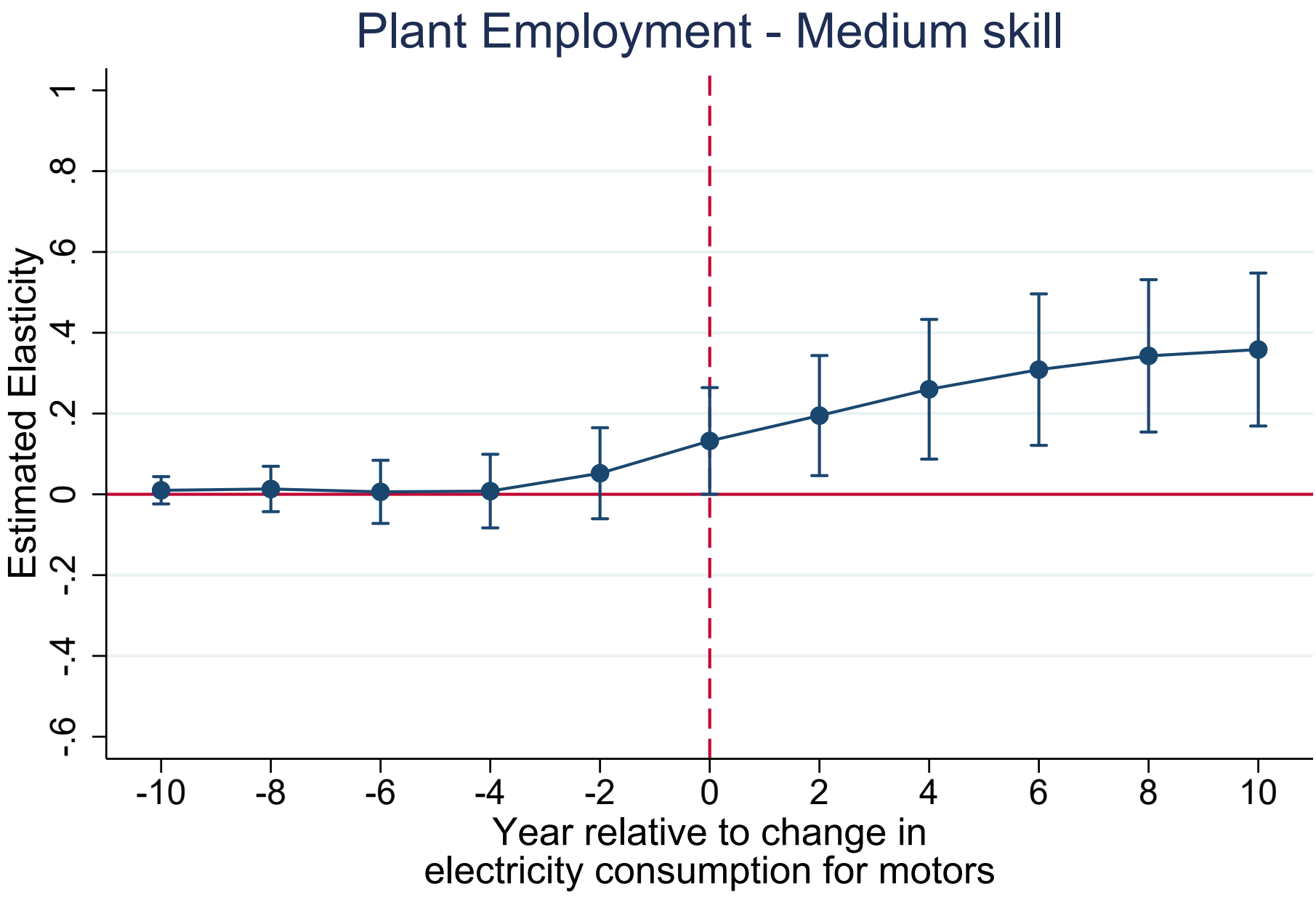
Controlling for firm-by-year F.E.

Employment Dynamics: Heterogeneity?

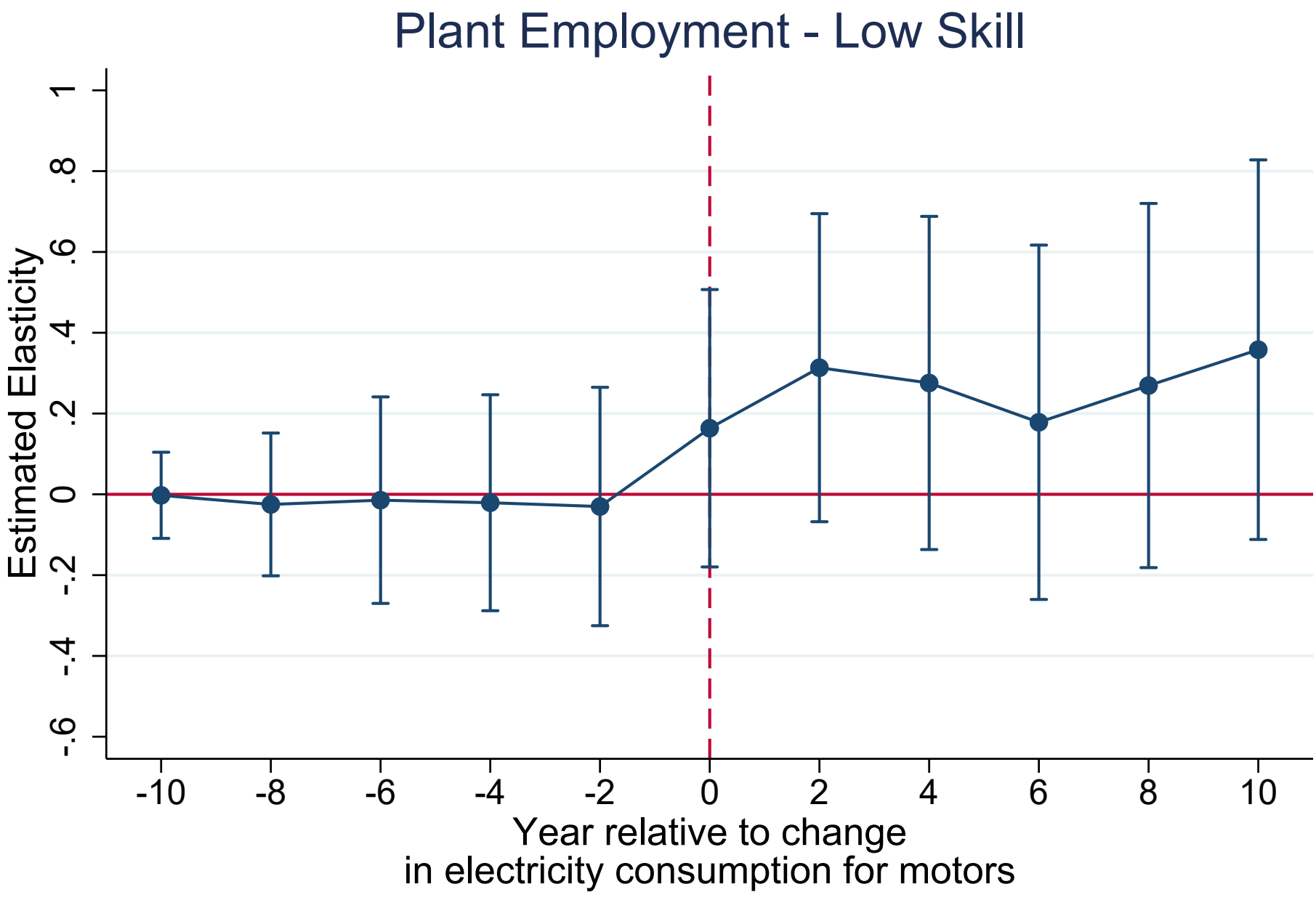
- Are effects different across skill groups?
  - High/medium/low skills as in Charnoz-Orand 2017: non-production vs. skilled production vs. unskilled production workers
- Find no heterogeneity across these skill groups
  - Positive employment response for all, no change in relative wage
  - Suggests no broad effect on inequality
  - However heterogeneous effects could arise within skill groups, depending on set of tasks performed (consistent with Doms et al. 1997, Hummels et al. 2014)



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

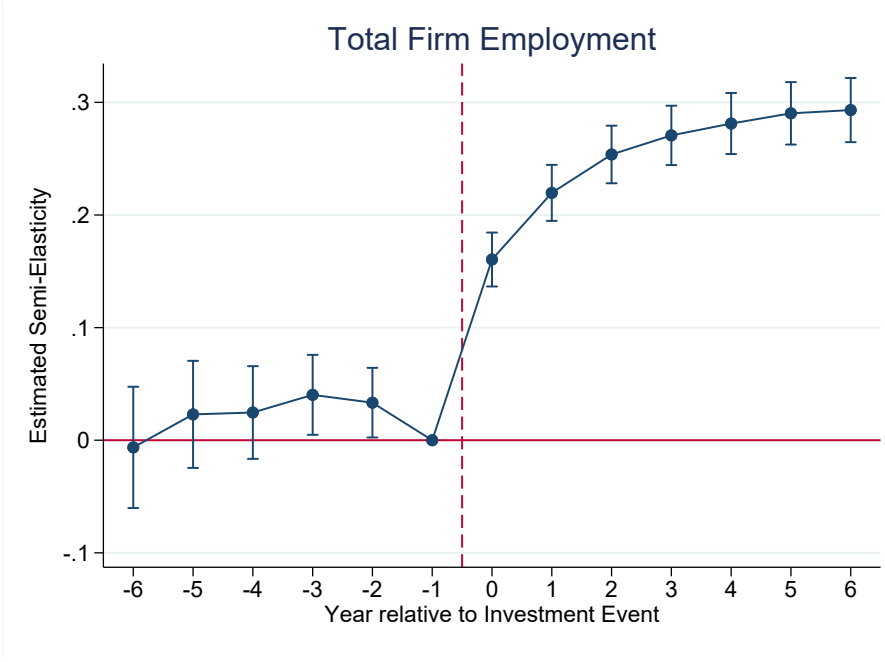


Controlling for 4-digit-industry by year F.E.

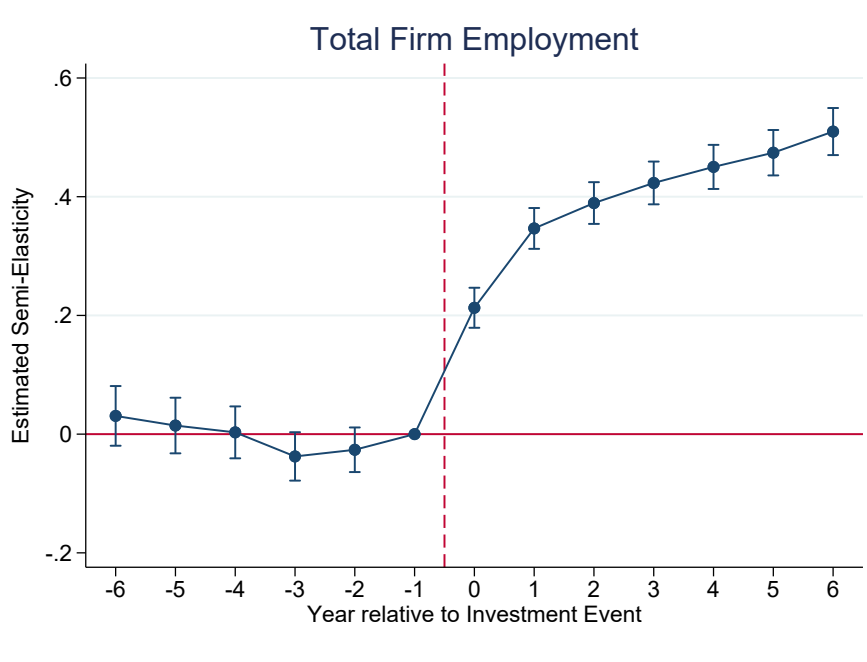


Controlling for 4-digit industry by year F.E.

Robustness: Semi-Elasticity with Investment Event (> Threshold)



(a) > p75

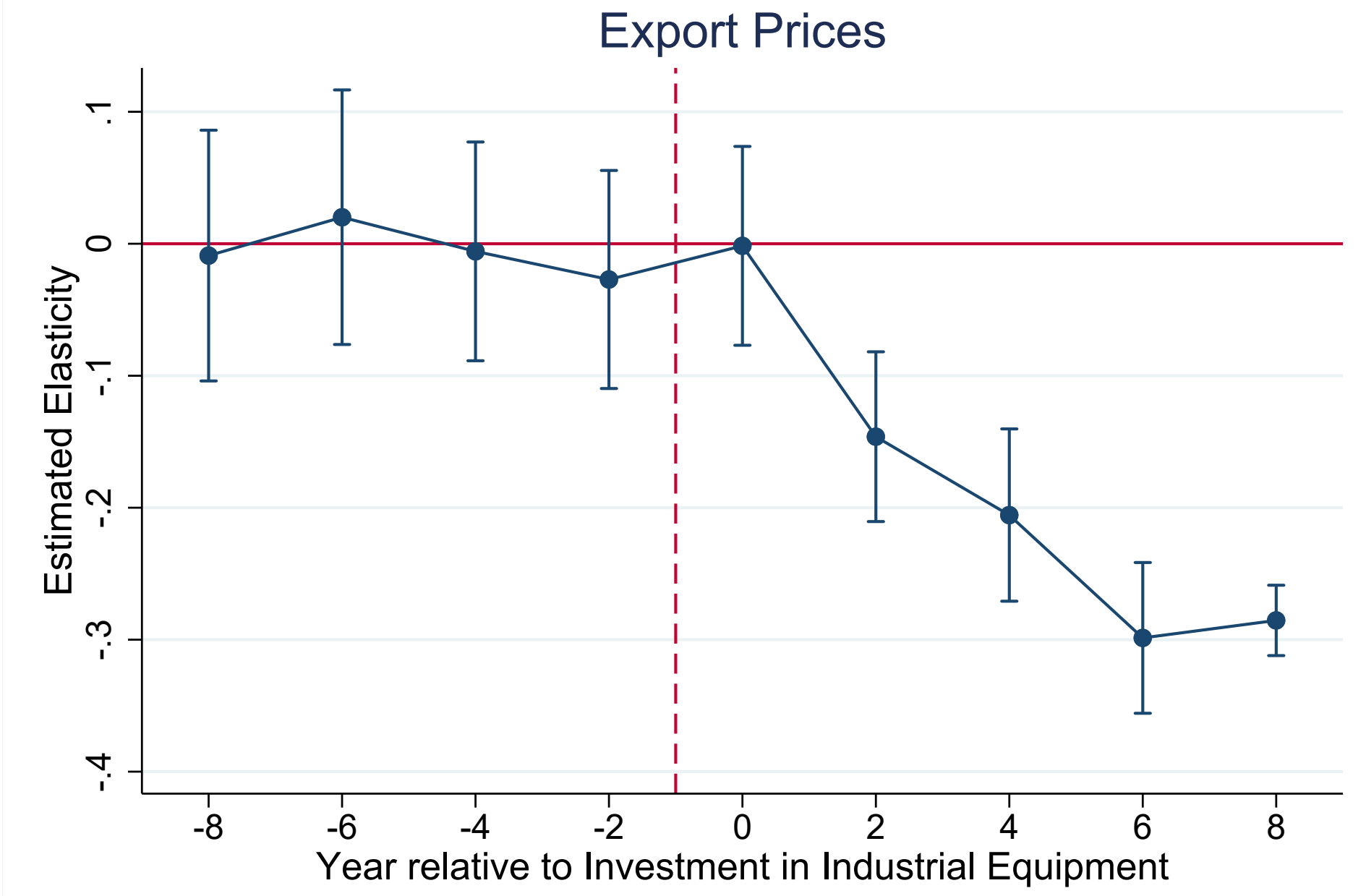


(b) > p99

More

Price Dynamics

- Next, document the relationship between changes in automation and price changes using export prices
  - Export prices are measured as the unit value of exported products (available for all exporting firms from customs data)



Controlling for 4-digit industry by year F.E. and HS6 product F.E.

[2/2] Shift-Share IV

- 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")

- Intutively, French firms are differentially exposed to changes in sector-specific foreign productivity

  - Similar to Hummels et al. (2014), Amity et al. (2019), except that we focus on machines

Shocks

- "Shocks" are observed across trading partners by 4-digit industries:
  - $g_{n,t}$ is change in imports flows of machines/robots from each trading partners (Germany, Italy, Japan, China, etc.) for each 4-digit industry across 5-year periods

$$g_{nt} = \frac{ImportMachines_{n,t,t+5} - ImportMachines_{n,t-5,t}}{ImportMachines_{n,t,t+5} + ImportMachines_{n,t-5,t}}$$

    - ★ where n indexes "trading partner by 4-digit industry" cells
  - Similar result with leave-one-out SSIV (excluding focal firm)

Exposure Shares

- "Exposure shares" of French firms:
  - s_{int} is share of trading partner n in firm i's total imports of machines between $t-5$ and $t-1$
  - 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 lagged shares
    - ⋆ Robustness: keep the shares fixed in the initial period, 1995-1999

Shift-Share IV

- Consider changes in employment ΔL_{it} and changes in motor consumption ΔM_{it} over a five-year period across firmes indexed by i (omitting time subscript t)

- We estimate by 2SLS:

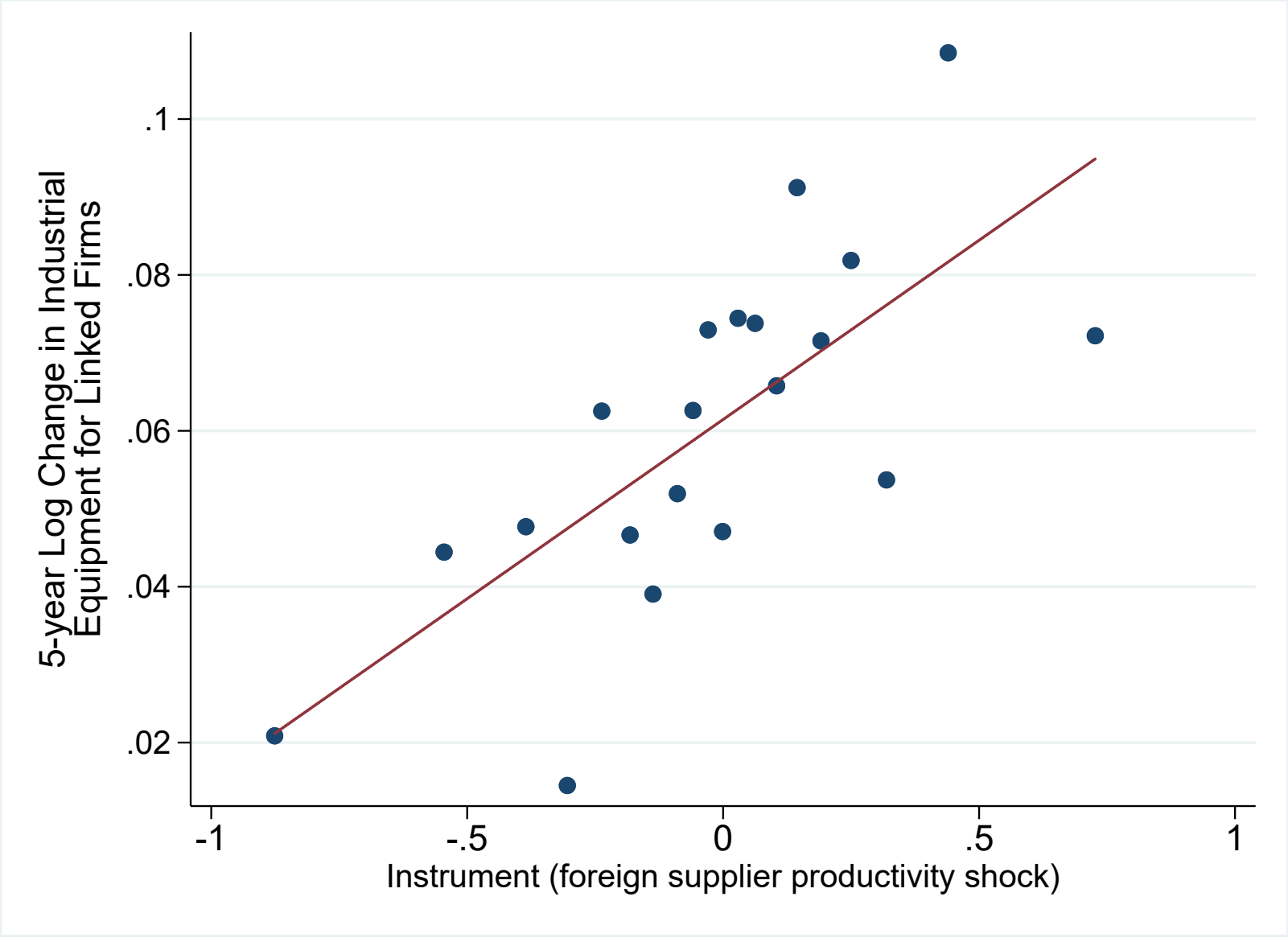
$$\begin{cases} \Delta L_{it} = \beta Z_{it} + \gamma X_{it} + \varepsilon_{it} \\ \Delta M_{it} = \alpha Z_{it} + \widetilde{\gamma} X_{it} + \widetilde{\varepsilon}_{it} \end{cases}$$

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

$$Z_{it} = \sum_{n=1}^{N} s_{int} g_{nt}$$

- Use panel with 5-year periods, 146 trading partners, and 239 4-digit industries

Firm SSIV: First Stage



Firm SSIV: Employment

	Δ_5 Employment				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Motor Cons.	**0.307****	**0.397****	**0.444*****	**0.411*****	**0.430****
	(0.127)	(0.153)	(0.167)	(0.149)	(0.171)
First-stage F	14.39	11.58	8.526	12.08	7.697
4-digit Industry-year F.E.	✓	✓	✓	✓	✓
Lagged Firm Controls		✓	✓	✓	✓
Lagged Motor Cons.			✓		✓
Lagged Machines				✓	
Contemporaneous Exports					✓
N (trading parnter - industry - period)	7,250	7,250	7,250	7,250	7,250

Firm SSIV: Sales

	Δ_5 Sales				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Motor Cons.	**0.395****	**0.449****	**0.512****	**0.462****	**0.461****
	(0.176)	(0.208)	(0.235)	(0.206)	(0.228)
First-stage F	14.39	11.58	8.526	12.08	7.697
4-digit Industry-year F.E.	✓	✓	✓	✓	✓
Lagged Firm Controls		✓	✓	✓	✓
Lagged Motor Cons.			✓		✓
Lagged Machines				✓	
Contemporaneous Exports					✓
N (trading parnter - industry - period)	7,250	7,250	7,250	7,250	7,250

Firm SSIV: Labor Share

	Δ_5 Labor Cost / Value Added				
	(1)	(2)	(3)	(4)	(5)
Δ_5 Motor Cons.	**0.00392**	**−0.0435**	**−0.0416**	**−0.0517**	**−0.0343**
	(0.233)	(0.230)	(0.266)	(0.226)	(0.275)
First-stage F	14.39	11.58	8.526	12.08	7.697
4-digit Industry-year F.E.	✓	✓	✓	✓	✓
Lagged Firm Controls		✓	✓	✓	✓
Lagged Motor Cons.			✓		✓
Lagged Machines				✓	
Contemporaneous Exports					✓
N (trading parnter - industry - period)	7,250	7,250	7,250	7,250	7,250

Falsification Test: Lagged Firm Employment Growth

	Lagged Δ_5 Firm Employment				
	(1)	(2)	(3)	(4)	(5)
Instrument (g_{nt})	**0.0111**	**0.0179**	**0.0167**	**0.0219**	**0.0162**
	(0.0156)	(0.0143)	(0.0145)	(0.0137)	(0.0143)
4-digit Industry-year F.E.	✓	✓	✓	✓	✓
Lagged Firm Controls		✓	✓	✓	✓
Lagged Motor Cons.			✓		✓
Lagged Machines				✓	
Contemporaneous Exports					✓
N (trading parnter - industry - period)	4,817	4,817	4,817	4,817	4,817

Falsification Test: Lagged Firm Sales Growth

	Lagged Δ_5 Total Firm Sales				
	(1)	(2)	(3)	(4)	(5)
Instrument (g_{nt})	**0.00354**	**0.0129**	**0.0117**	**0.0173**	**0.0111**
	(0.0153)	(0.0138)	(0.0142)	(0.0136)	(0.0141)
4-digit Industry-year F.E.	✓	✓	✓	✓	✓
Lagged Firm Controls		✓	✓	✓	✓
Lagged Motor Cons.			✓		✓
Lagged Machines				✓	
Contemporaneous Exports					✓
N (trading parnter - industry - period)	4,817	4,817	4,817	4,817	4,817

Roadmap

1. Data
2. Plant and Firm Level Analysis
3. **Industry Level Analysis**
   - Descriptive evidence
   - Shift-share IV
4. Demand Reallocation Channel

[1/2] Descriptive Evidence

- Positive plant-level and firm-level relationship between employment and automation could in principle be overturned at the industry level
  - Firms that automate less may be displaced by firm that automate more
- Start with descriptive patterns: industry-level panel data with fixed effects
  - Patterns similar to firms
  - Positive relationship with employment is stronger in industries more exposed to international trade (ranked by export ratios)

Industry OLS Results: Employment

	Δ_5 Employment					
			Exposure to International Trade			
	All industries		Above Median		Below Median	
	(1)	(2)	(3)	(4)	(5)	(6)
Δ_5 Motor Cons.	**0.406*****	**0.275*****	**0.401*****	**0.382*****	**0.111**	**0.016**
	(0.065)	(0.082)	(0.124)	(0.150)	(0.082)	(0.136)
2-digit industry by year F.E.	✓	✓	✓	✓	✓	✓
Δ_5 Other types of capital		✓		✓		✓

[2/2] Industry SSIV

- Repeat previous SSIV, except that i is now a 4-digit industry (rather than a firm) and n is a "trading partner by 3-digit industry" cell

$$g_{nt} = \frac{ImportMachines_{n,t,t+5} - ImportMachines_{n,t-5,t}}{ImportMachines_{n,t,t+5} + ImportMachines_{n,t-5,t}}$$

- Measure these shocks across 179 trading partners in the 95 3-digit industries during three 5-year periods, from 2000 to 2015
- Examine the response of employment and sales in industries that source their machines from increasingly productive foreign suppliers
  - For leave-one-out analysis, need to work with "trading partner by 2-digit industry" and 3-year periods to preserve power

Industry SSIV: Employment

	Δ_5 Employment			
	(1)	(2)	(3)	(4)
Δ_5 Motor Cons.	**0.558*****	**0.584*****	**0.589*****	**0.620*****
	(0.193)	(0.174)	(0.184)	(0.196)
First-stage F	23.52	14.43	13.66	11.67
3-digit Industry-year F.E.	✓	✓	✓	✓
Lagged Industry Controls		✓	✓	✓
Lagged Machines			✓	✓
Lagged Other Capital				✓
N (trading partner - industry - period)	7,482	7,482	7,482	7,482

Industry SSIV: Sales

	Δ_5 Sales			
	(1)	(2)	(3)	(4)
Δ_5 Motor Cons.	**0.486*****	**0.585*****	**0.594*****	**0.627*****
	(0.169)	(0.186)	(0.199)	(0.207)
First-stage F	23.52	14.43	13.66	11.67
3-digit Industry-year F.E.	✓	✓	✓	✓
Lagged Industry Controls		✓	✓	✓
Lagged Machines			✓	✓
Lagged Other Capital				✓
N (trading partner - industry - period)	7,482	7,482	7,482	7,482

Industry SSIV: Labor Share

	Δ_5 Labor Cost / Value Added			
	(1)	(2)	(3)	(4)
Δ_5 Motor Cons.	**−0.0311**	**−0.0286**	**−0.0285**	**−0.0282**
	(0.0768)	(0.0603)	(0.0610)	(0.0671)
First-stage F	23.52	14.43	13.66	11.67
3-digit Industry-year F.E.	✓	✓	✓	✓
Lagged Industry Controls		✓	✓	✓
Lagged Machines			✓	✓
Lagged Other Capital				✓
N (trading partner - industry - period)	7,482	7,482	7,482	7,482

Industry SSIV: Accounting Profits

	Δ_5 Profits			
	(1)	(2)	(3)	(4)
Δ_5 Motor Cons.	**0.787*****	**0.752*****	**0.761*****	**0.834*****
	(0.255)	(0.222)	(0.234)	(0.234)
First-stage F	23.52	14.43	13.66	11.67
3-digit Industry-year F.E.	✓	✓	✓	✓
Lagged Industry Controls		✓	✓	✓
Lagged Machines			✓	✓
Lagged Other Capital				✓
N (trading partner - industry - period)	7,482	7,482	7,482	7,482

Falsification Test: Lagged Industry Employment Growth

	Lagged Δ_5 Industry Employment			
	(1)	(2)	(3)	(4)
Instrument (g_{nt})	**0.0313**	**0.0209**	**0.0207**	**0.0203**
	(0.0282)	(0.0173)	(0.0166)	(0.0165)
3-digit Industry-year F.E.	✓	✓	✓	✓
Lagged Industry Controls		✓	✓	✓
Lagged Machines			✓	✓
Lagged Other Capital				✓
N (trading partner - industry - period)	5,170	5,170	5,170	5,170

Falsification Test: Lagged Industry Sales Growth

	Lagged Δ_5 Total Industry Sales			
	(1)	(2)	(3)	(4)
Instrument (g_{nt})	**−0.00807**	**−0.00559**	**−0.00496**	**−0.00309**
	(0.0253)	(0.0179)	(0.0177)	(0.0178)
3-digit Industry-year F.E.	✓	✓	✓	✓
Lagged Industry Controls		✓	✓	✓
Lagged Machines			✓	✓
Lagged Other Capital				✓
N (trading partner - industry - period)	5,170	5,170	5,170	5,170

Conclusion

- Contribute to literature in three ways
  - Study automation at **plant, firm and industry levels**
  - Causal identification using a **shift-share design**
  - Document impacts on **workers (employment), consumers (prices) and profits**

- Estimates indicate that automation can increase labor demand and can generate productivity gains that are **broadly shared across workers, consumers and firm owners**

- **In a globalized world, attempts to curb domestic automation in order to protect domestic employment may be self-defeating** due to foreign competition.