Technology Adoption and Productivity Growth: Evidence from Industrialization in France

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Motivation

Puzzling patterns when major new technologies arise:

1. Technology diffusion is often slow (Griliches 1957, Mansfield 1961, Rosenberg 1976)
    - Yet, technology adoption can boost firm-level productivity (Syverson 2011, Bloom et al. 2013, Giorcelli 2019)

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   - Yet, technology adoption can boost firm-level productivity (Syverson 2011, Bloom et al. 2013, Giorcelli 2019)
2. Data do not show major *aggregate* productivity gains when breakthrough innovations (e.g., IT and electricity) spread across firms
   - "You can see the computer age everywhere but in the productivity statistics." (Solow 1987)

The Role of Organizational Challenges

- Prominent hypothesis: Efficient use of revolutionary technology requires major reorganization of production (David 1990, Brynjolffson 1993, Hall and Khan 2003,)
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- Prominent hypothesis: Efficient use of revolutionary technology requires major reorganization of production (David 1990, Brynjolffson 1993, Hall and Khan 2003,)
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- But this hypothesis is difficult to test:
  - Data on the use of specific technology are rare
  - Old and new technologies often co-exist within the same sector or even firms
  - Adoption of new technologies (and the necessary organizational changes) may be related to initial firm productivity
  - For systematic analysis of productivity: Need to isolate firm productivity distribution of *adopting* firms

This Paper

- Bypass typical limitations by studying a unique historical setting
- Breakthrough innovation: Adoption of mechanized cotton spinning technology in France
    - Allows us to isolate productivity distribution of adopters
    - Adopting mechanization required a radical reorganization of production
- Results can shed light on both motivating puzzles

This paper: Historical Setting

- Focus on mechanized cotton spinning
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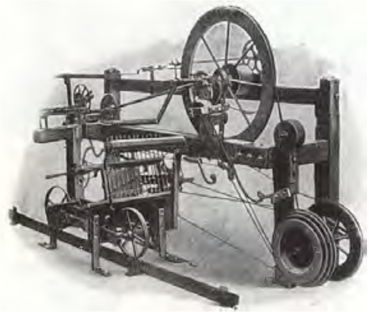
  - Old technology: handspinning in *home production*

The Spinning Wheel

Home Spinning

This paper: Historical Setting

- New technology (spinning jenny and then spinning mule) required production in *central* location $\Rightarrow$ Factory-based production emerged



Water-Powered Spinning Mule

Spinning Mule Operated in a Mill

Key Features of Historical Setting and Data

- We construct a novel plant-level dataset from historical French surveys in 1800 and 1840
- Main sector: Mechanized Cotton Spinning
  - *All* cotton spinning plants use the new technology $\Rightarrow$ Isolate the plant productivity distribution for adopters of the *new technology*

Key Features of Historical Setting and Data

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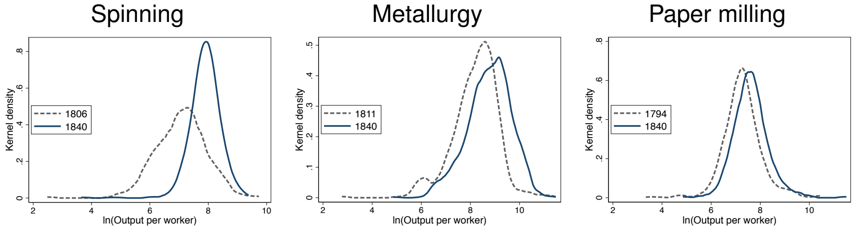
- Main sector: Mechanized Cotton Spinning
  - *All* cotton spinning plants use the new technology ⇒ Isolate the plant productivity distribution for adopters of the *new technology*
- Comparison sectors: Metallurgy and Paper Milling
  - Production already organized in a central location (plants) in 1800 (high fixed-cost machinery and water power)
  - Gradual technology upgrading ⇒ *No reorganization* of production

⇒ Disentangle effects common to all three sectors (shocks and gradual improvements in technology) from the need to reorganize production in cotton spinning.

⇒ Similar in spirit to a difference-in-difference estimation strategy

Main Finding: Lower Tail Bias of Productivity Growth in Cotton Spinning



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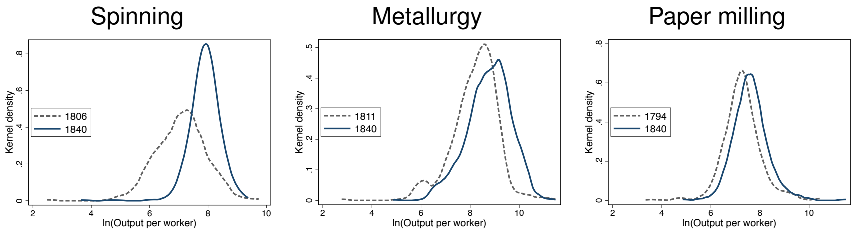

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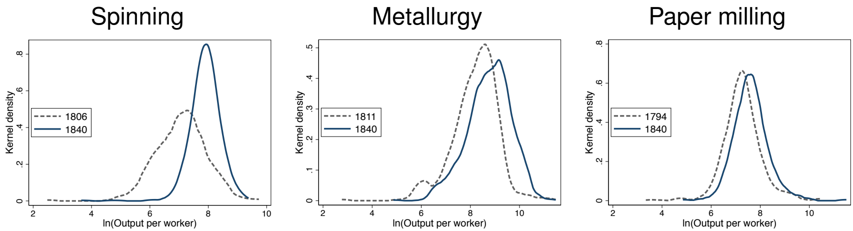

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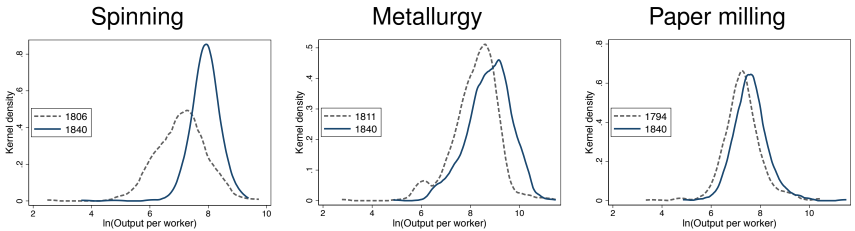

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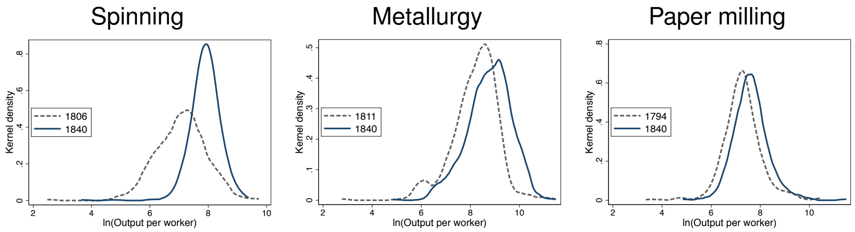

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4. Comparison sectors: Whole distribution shifts right

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  - “The cotton mill, in other words, had to be invented as well as the spinning machinery per se.” (Allen, 2009)

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    - “The cotton mill, in other words, had to be invented as well as the spinning machinery per se.” (Allen, 2009)
- We provide additional empirical evidence in line with this mechanism

Empirical Evidence Consistent With Learning

1. Plant survival rates much lower in cotton spinning ▸ Results
2. Exiting plants particularly unproductive in cotton spinning ▸ Results
3. Younger plants *more* productive in cotton spinning in 1800, but not later and not in metallurgy ▸ Results
4. Spatial diffusion of knowledge? Cotton plants closer to high-productivity plants are themselves more productive

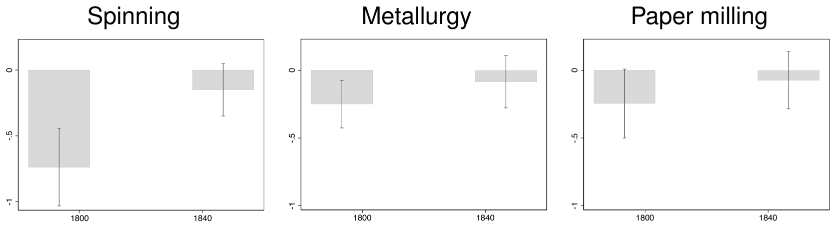
How Does Knowledge Diffuse?

- Proposed mechanism: Firms learn from each other by observing successful experimenters
- Test for spatial diffusion of knowledge from ‘frontier’ firms

$$ln(Y/L)_{ij} = \beta_0 + \beta_1 ln(dist^{p90})_{ij} + FE_j \epsilon_i$$

- $dist^{p90}$ is log distance to closest firm with productivity in the 90th percentile

Importance of Proximity to High-Productivity Firms



Standardized beta coefficient on distance to most productive firms

⇒ Strongest in cotton spinning in 1800 – the sector & period where firms were conducting most experimentation

Maps Placebo Robustness

Robustness to Alternative Mechanisms

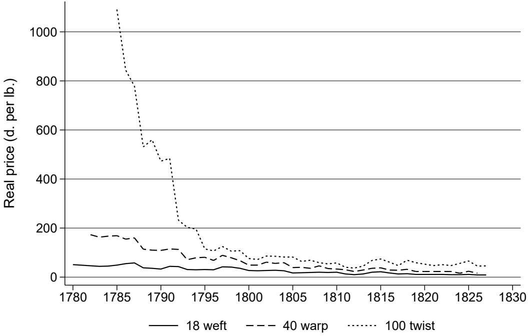
1. Economy-wide effects unlikely to drive pattern in cotton: Different pattern observed across comparison sectors
2. Firm size
    - Focusing on firms with at least 10 workers
        - ★ Productivity distributions & Quantile regressions
    - Controlling for total number of workers
3. Pattern robust to controlling for capital deepening
4. Accounting for market integration
    - Market access & Region FE & Maps
5. Other shocks specific to cotton spinning
    - Napoleonic blockade: Spitting sample into firms in Northern vs. Southern regions
6. Robustness to data construction choices
    - Using prices not adjusted for quality
    - Using TFP

Conclusion

- What does this setting teach us more generally about technology diffusion?
  - Slow technology adoption
    - ★ Firms face high initial uncertainty about their efficiency in operating new technology
    - $\Rightarrow$ There may be a strategic incentive to delay adoption until tacit knowledge about efficient firm organization has diffused
  - Why do aggregate efficiency gains take time to materialize?
    - ★ Early adopters experiment with organization of production, and many of them will operate the new technology inefficiently
    - $\Rightarrow$ The promised benefits of the new technology may materialize relatively slowly for the average firm

- Important role for organizational innovations in driving productivity growth during the IR

Cotton Yarn Prices – Britain



Source: Harley (1998)

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Historical Setting: First Industrial Revolution in France

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- IR originated in Britain ... but what about industrialization in France?
- Consensus: rapid technological development and widespread industrialization in France during the First IR (Crouzet, 2003)
  - French economic growth accelerated in the late 18th century
  - *“[i]n an astonishing number of sectors, French entrepreneurs of the 1780s competed successfully with their English counterparts”* (Horn, 2006)
  - France initially depended on the adoption of British technology, but (by the 1850s), it became *"a centre of invention and diffusion for modern technologies"* (Crouzet 2003)

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Mechanized Cotton Spinning: “Macro-invention”

Flagship industry of the First IR

- Production: raw cotton fiber twisted into yarn
- Traditionally: home production using the spinning wheel.
  - Each spinner could spin one thread of yarn
- “Macro-invention”: spinning jenny of James Hargreaves.
  - Spin multiple threads simultaneously (using spindles) $\rightarrow$ 25% of TFP growth in Britain between 1780-1860 (Crafts 1985)

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  - Spin multiple threads simultaneously (using spindles) $\rightarrow$ 25% of TFP growth in Britain between 1780-1860 (Crafts 1985)
- Why did mechanization lead to factory-based production?
  - use of high fixed-cost inanimate power sources (water and steam) led to the concentration of production in one location
  - changes in monitoring incentives (Huberman 1996)

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Cotton Spinners by Background

Table: Occupation of 185 cotton spinners active between 1785-1815

Nobility or administrator pre-1789	10.2%
Traders, bankers and commercial employees	62.5%
Industrialist	9.5%
Worker or mechanic	10.2%
Liberal profession	6%
Other	3.5%

Source: Chassagne 1991 p. 274

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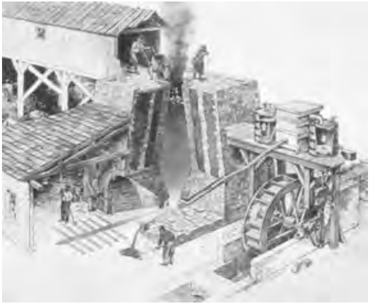
‘Old’ 18th Century Charcoal-Based Technology in Metallurgy



18C Charcoal Iron Blast Furnace

Organization of 18C Metallurgy Plant

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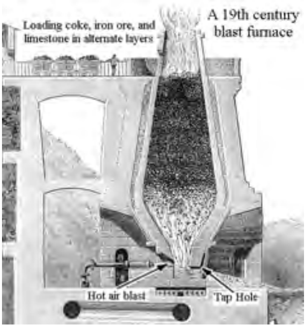
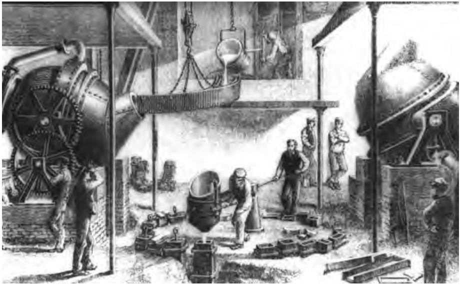
‘New’ 19th Century Coal-Based Technology in Metallurgy



19th Century Coal Blast Furnace



Organization of 19C Metallurgy Plant

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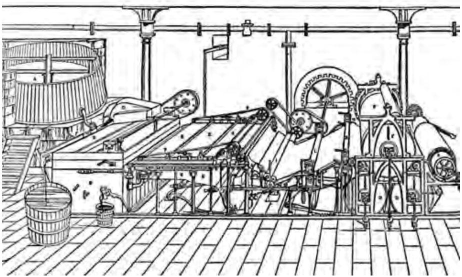
Old Technology in a Paper Milling Plant

Water-Powered Stamping

Handling by Vatman, Coucher, and Layer

Back to Talk   Back to Detail

New Technology in Paper Milling


Sketch of Fourdrinier Machine


Fourdrinier Machine in a Plant

Fourdrinier Machine: Important not just because of the productivity improvements that it yielded, but also because it enabled the production of continuous rolls.
It replaced the work of the *vatman*

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Management and Firm Size

- Large firm size (above 100-200 workers) was undesirable
  - *"Management was a function of direct involvement by ownership, and if it had to be delegated (...), the business was courting trouble (...) This was a powerful argument against the enlargement of firms beyond the point at which an intermediate stratum of managers became necessary. (...) In the centuries preceding the industrial revolution, firms engaged in production were unable to cope with size, essentially because they could not cope with the problems of management which it involves."* (Pollard, 1965).

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Examples of the data: Cotton Spinning, 1806

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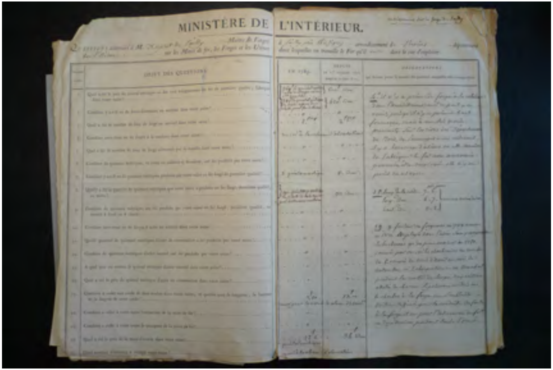
Examples of the Data: Metallurgy, 1811



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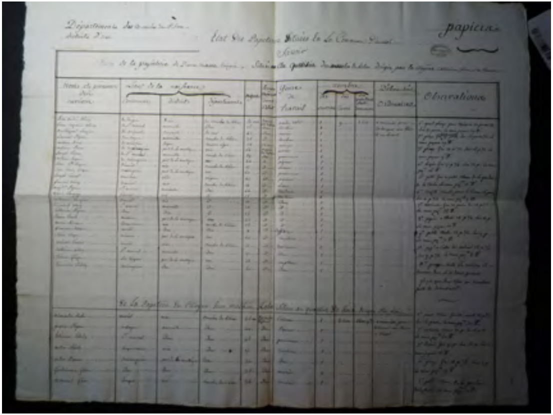
Examples of the data: Paper milling, 1794



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Data: Detail

- Handwritten surveys for the early period
  - Paper milling: 1794: 593 firms
  - Cotton spinning: 1806: 389 firms
  - Metallurgy: 1811: 477 firms
- Industrial firm census (Chanut et al., 2000)

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Linking

Two ways to link firms across time:

1. Match on owner name and location (commune)
2. Match firms that are the only active firm in the given sector in a commune – fairly common in the data.
   - Does ‘local matching’ identify the same firm? Likely – reliance on water-power.
   - Validate assumption: how frequently do communes with a single firm active in 1800 show up in 1840 with multiple firms? Very rarely (6%-8%)

Construct two measures of survival rates:

1. Baseline: the percentage of firms from the initial period that survive into the later period based on matching either on name or on location.
2. ‘Restricted sample’: examine survival on the subset of firms that are the only ones in their commune in 1800 and that commune either does not show up in 1840 or shows up with only one firm
   - Adjusts for differences across sectors in single-firm communes

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Constructing Revenues

- Challenge: Output in 1800 is reported in physical units; only total revenue of the firm is reported in the 1840 census.
- Solution: Use sector level prices for 1800 to compute inflation-adjusted output per worker
- Revenue-based productivity problematic if markups changed differentially across sectors... but unlikely to be quantitatively important: all three sectors produced standardized, often intermediate products

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Data: Deflating revenues

- For all three sectors, we deflate revenue data using the producer price index (PPI) from Mitchell (2003). The PPI in 1800 is 1.18. The PPIs in 1806 and in 1811 are 1.25 and 1.68, respectively – and we use these to deflate revenues in cotton spinning and in metallurgy in the corresponding years. Finally, for all three sectors, we use the PPI in 1840, which is equal to 0.88.

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Quantile Regressions

Table: Annual Productivity Growth (in %) at Different Quantiles of the Distribution

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average	At the following quantiles:					N
		0.1	0.25	0.5	0.75	0.9	
Spinning (1806-1840)	2.420***	3.917***	3.293***	2.234***	1.651***	1.014***	868
	(0.154)	(0.204)	(0.229)	(0.151)	(0.167)	(0.297)	
Metallurgy (1811-1840)	1.949***	1.700***	1.776***	1.787***	2.025***	2.465***	1296
	(0.185)	(0.415)	(0.271)	(0.236)	(0.187)	(0.226)	
Paper milling (1794-1840)	0.734***	0.713***	0.681***	0.779***	0.759***	0.726***	868
	(0.111)	(0.157)	(0.137)	(0.098)	(0.137)	(0.256)	

Notes: The table reports the average annual productivity growth (in %) between the initial sample period (around 1800) and 1840 for the three sectors (column 1), and annual productivity growth estimated at different quantiles (columns 2-6). Column 7 reports the number of observations. Robust standard errors in parentheses. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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Stylized Framework

Standard production function with complementarity across inputs

- $Y = A \cdot f(\tau_K K, \tau_M M, \tau_L L)$
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  - Normalize $K = M = L = 1$

- Output per worker: $y = Y/L$
  - Leontief: $y = A \cdot min(\tau_K, \tau_M, \tau_L)$
  - Cobb-Douglas $y = A \cdot \tau_K^{\alpha} \tau_M^{\beta} \tau_L^{1-\alpha-\beta}$

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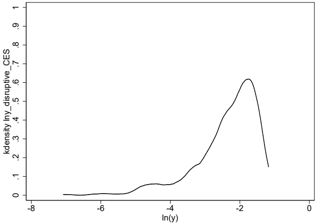
Technology Adoption

No knowledge about optimal use of inputs

- New producer draws input efficiency τ_i from uniform [0,1]
- Possibility of low τ_i and complementarity across input $\Rightarrow$ fat lower tail of $ln(y)$

Initial Productivity



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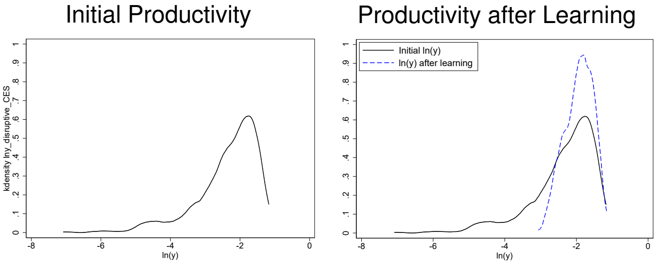

- Learning about best practice: τ_i from $[\underline{\tau},1]$, $\underline{\tau} > 0$ (worst-possible draw goes up, but best-possible draw stays the same)

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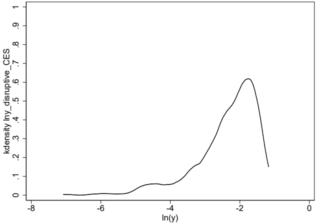
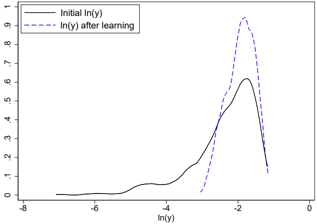


Productivity after Learning



- Learning about best practice: τ_i from $[\underline{\tau},1]$, $\underline{\tau} > 0$ (worst-possible draw goes up, but best-possible draw stays the same)
- $\Rightarrow$ Lower tail disappears, but no change in max. productivity

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"Regular" Sector: Innovation

- Same production function
- Existing knowledge about optimal use of inputs – Draw τ_i from $[\underline{\tau},1]$
  $\Rightarrow$ *No fat lower tail*

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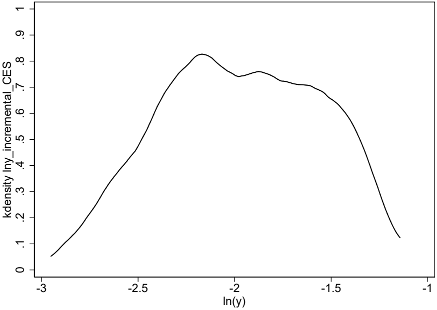

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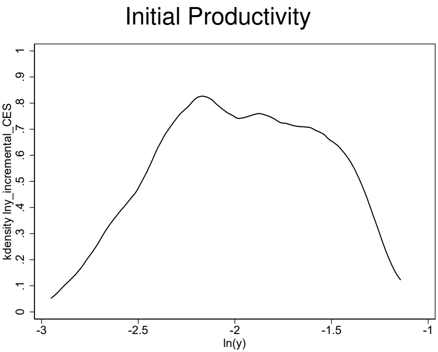

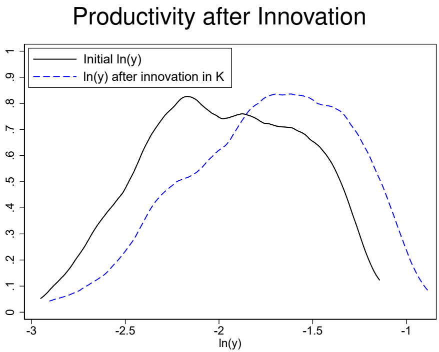

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Plant Survival Rates Lower in Cotton Spinning

	Spinning 1806-1840	Metallurgy 1811-1840	Paper Milling 1794-1840
Firm survival rate	7%	34%	9%
Number of firms	389	477	593
Restricted sample survival rate	6.5%	49%	20%
Number of firms	93	303	218

Notes: "Firm survival rate" is defined as the percentage of firms from the initial period that survive into the later period based on matching either on owner name or local matching. "Restricted sample survival rate" adjusts for the fact that different sectors have single firm communes to a varying degree. It is based on the subset of firms located in communes that have only one firm in the initial period and that either do not show up in the 1840 data or they show up with still only one firm.

- Some early adopters will be too unproductive to survive ⇒ exit market
  - Owners that invested in a cotton spinning mill with poor layout had to exit the market, and the structure of the mill was not subsequently used by other firms in cotton spinning.

Linking firms Back to Talk

Exiting Plants in 1800 Were Less Productive Than Surviving Plants

	(1)	(2)	(3)	
Dependent variable	log(Y/L)	log L	Log Y	N
Spinning (exit = 1)	-0.533***	-0.869***	-1.402***	340
	(0.165)	(0.218)	(0.251)	
Metallurgy (exit = 1)	-0.139	-0.439***	-0.578***	457
	(0.087)	(0.089)	(0.097)	
Paper milling (exit = 1)	-0.179	-0.151	-0.331*	520
	(0.150)	(0.131)	(0.172)	

Notes: Robust standard errors in parentheses. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

- Pattern is particularly strong in cotton spinning
- Consistent with large organizational challenges and low initial guidance in switching to factory-based cotton spinning.

▸ Back to Talk

Younger Plants Systematically More Productive in Cotton Spinning in 1806

Dependent variable: log(Y/L)

	(1)	(2)	(3)	(4)	(5)	(6)	
Young plant	0.575***	0.374***	0.543***	0.575***	0.493***	0.608***	0.534***
	(0.088)	(0.079)	(0.083)	(0.089)	(0.085)	(0.086)	(0.085)
log(Yarn quality)		0.673***					
		(0.074)					
Spinning jenny			-0.626***				
			(0.087)				
Throstle				-0.003			
				(0.092)			
Mule jenny					0.481***		
					(0.086)		
log(Workers)						0.107***	
						(0.025)	
log(Spindles per worker)							0.336***
							(0.070)
R^2	0.11	0.32	0.20	0.11	0.18	0.14	0.17
N	340	323	340	340	340	340	340

Notes: Robust standard errors in parentheses. Low-tech spindles and high-tech spindles are binary indicators equal to 1 for firms are using the earliest (jenny) and latest (mule jenny) vintage of machinery respectively. 'Young' firm is a binary indicator for firms with below-median age. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

- Younger firms have higher productivity in 1806
- Patterns in line with younger firms adopting (evolving) best practices of mill design
- Similar pattern does not hold in metallurgy or in 1840 in spinning

1840 | Metallurgy 1811 | Metallurgy 1840 | Back to Talk

Productivity and Plant's Age Profile, 1840 – Cotton Spinning

Dependent variable: log(Y/L)

	(1)	(2)	(3)	(4)	(5)
Entrant 1840	-0.084	-0.029	-0.080	-0.078	-0.144**
	(0.077)	(0.077)	(0.078)	(0.077)	(0.065)
Water power		0.327***			
		(0.062)			
Steam power			-0.045		
			(0.076)		
Other power				-0.193**	
				(0.090)	
log(Workers)					-0.373***
					(0.027)
R^2	0.00	0.03	0.00	0.01	0.24
N	839	839	839	839	839

Notes: Robust standard errors in parentheses. Entrant 1840 is a binary indicator equal to 1 for firms that entered the market after 1806. Water power, steam power, and other (wind or animal) power are binary indicators equal to 1 for firms using the respective source of power. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

- Entrant firms do not have higher productivity in 1840
- In 1840s, factory layout practices had already been established

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Productivity and Plants' Age Profile, 1811 – Metallurgy

Dependent variable: log(Y/L)

	(1)	(2)
Young 1811	0.226*	0.101
	(0.118)	(0.117)
log(Workers)		-0.313***
		(0.051)
R^2	0.01	0.10
N	448	448

Notes: Robust standard errors in parentheses. Entrant 1811 is a binary indicator equal to 1 for firms that entered the market after 1788. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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Productivity and Plants' Age Profile, 1840 – Metallurgy

Dependent variable: log(Y/L)

	(1)	(2)	(3)	(4)	(5)
Entrant 1840	-0.084	-0.029	-0.080	-0.078	-0.144**
	(0.077)	(0.077)	(0.078)	(0.077)	(0.065)
Water power		0.327***			
		(0.062)			
Steam power			-0.045		
			(0.076)		
Other power				-0.193**	
				(0.090)	
log(Workers)					-0.373***
					(0.027)
R^2	0.00	0.03	0.00	0.01	0.24
N	839	839	839	839	839

Notes: Robust standard errors. Entrant 1840 is a binary indicator equal to 1 for firms that entered the market after 1811. Water power, steam power, and other (wind or animal) power are binary indicators equal to 1 for firms using the respective source of power. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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Linking

Two ways to link firms across time:

1. Match on owner name and location (commune)
2. Match firms that are the only active firm in the given sector in a commune – fairly common in the data.
    - Does 'local matching' identify the same firm? Likely – reliance on water-power.
    - Validate assumption: how frequently do communes with a single firm active in 1800 show up in 1840 with multiple firms? Very rarely (6%-8%)

Construct two measures of survival rates:

1. Baseline: the percentage of firms from the initial period that survive into the later period based on matching either on name or on location.
2. 'Restricted sample': examine survival on the subset of firms that are the only ones in their commune in 1800 and that commune either does not show up in 1840 or shows up with only one firm
    - Adjusts for differences across sectors in single-firm communes

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Additional Specifications: Proximity Regressions

- Baseline table ▸ Table
- Local density control ▸ Table
- Location fundamentals control ▸ Table
- Firms' age profile ▸ Table
- Placebo ▸ Table

▸ Back to Talk

Effect of Distance - Baseline Specification

Dependent variable: log(Output per worker)

	(1)	(2)	(3)	(4)	(5)	(6)
	Spinning		Metallurgy		Paper milling	
	1806	1840	1811	1840	1794	1840
Dist to p90 (1800)	-0.814***		-0.249***		-0.245*	
	(0.143)		(0.088)		(0.128)	
Dist to p90 (1840)		-0.176		-0.084		-0.073
		(0.106)		(0.097)		(0.106)
Department FE	✓	✓	✓	✓	✓	✓
R^2	0.56	0.15	0.37	0.27	0.29	0.42
N	290	471	377	746	456	312

Notes: $Dist^{p90}$ ($\sim$ 1800) and $Dist^{p90}$ (1840) measure the log distance to the nearest plant in the same sector with productivity in the 90th percentile in 1800 and in 1840, respectively. The number of observations in these specifications is smaller than the full sample size as all plants that belong to the 90th percentile are excluded. Standard errors (clustered at the departmental level) in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

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Effect of Distance - Local Density of Production Control

Dependent variable: log(Output per worker)

	(1)	(2)	(3)	(4)	(5)	(6)
	Spinning		Metallurgy		Paper milling	
	1806	1840	1811	1840	1794	1840
Dist to p90 (1800)	-0.743***		-0.245***		-0.210	
	(0.186)		(0.088)		(0.131)	
Dist to p90 (1840)		-0.147		-0.094		-0.064
		(0.115)		(0.092)		(0.114)
Production density	0.019	0.008	0.004	-0.003	0.019	0.004
	(0.021)	(0.013)	(0.012)	(0.008)	(0.015)	(0.017)
Department FE	✓	✓	✓	✓	✓	✓
R^2	0.57	0.15	0.37	0.27	0.30	0.42
N	290	471	377	746	456	312

Notes: Standard errors (clustered at the departmental level) in parentheses. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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Effect of Distance - Location Fundamentals Controls

Dependent variable: log(Output per worker)

	(1)	(2)	(3)	(4)	(5)	(6)
	Spinning		Metallurgy		Paper milling	
	1806	1840	1811	1840	1794	1840
Dist to p90 (1800)	-0.848***		-0.259***		-0.228*	
	(0.123)		(0.081)		(0.133)	
Dist to p90 (1840)		-0.192*		-0.090		-0.076
		(0.106)		(0.091)		(0.105)
Access high stream flow	-0.085	0.253**	-0.038	0.243	-0.163	-0.032
	(0.304)	(0.118)	(0.160)	(0.216)	(0.250)	(0.306)
Proximity to coal	0.007	-0.099	-0.248	0.074	0.159	-0.112
	(0.199)	(0.311)	(0.185)	(0.156)	(0.356)	(0.191)
Share forest area	-1.307***	0.440	-0.172	-0.005	0.458	-0.273
	(0.482)	(0.299)	(0.302)	(0.388)	(0.502)	(0.803)
Department FE	✓	✓	✓	✓	✓	✓
R^2	0.58	0.16	0.38	0.28	0.30	0.42
N	290	471	369	746	456	312

Notes: Standard errors (clustered at the departmental level) in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

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Effect of Distance – Testing for Selection Effects

Dependent variable: log(Output per worker)

	Spinning 1806				
	(1)	(2)	(3)	(4)	(5)
			Only firms entering before high productivity firms		
Dist to p90 (1800)	-0.791***	-0.845***	-0.439***	-0.393**	-0.481**
	(0.136)	(0.129)	(0.153)	(0.153)	(0.196)
Plant age (in 1806)	-0.046	-0.203		-0.153	-0.388*
	(0.085)	(0.135)		(0.133)	(0.205)
Plant Age* Dist to p90 (1800)		0.237			0.365
		(0.203)			(0.258)
Department FE	Yes	Yes	Yes	Yes	Yes
R^2	0.56	0.57	0.66	0.66	0.67
N	284	284	176	176	176

Notes: Standard errors (clustered at the departmental level) in parentheses. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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Effect of Distance - Placebo Using Timing

Dependent variable: log(Output per worker)

	Spinning 1806	Metallurgy 1811	Paper milling 1794
	(1)	(2)	(3)
Dist to p90 (1840)	-0.055	-0.245	0.083
	(0.237)	(0.161)	(0.129)
Department FE	✓	✓	✓
R^2	0.55	0.30	0.22
N	321	415	507

Notes: Standard errors (clustered at the departmental level) in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

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Distance to Top Decile: Cotton Spinning

1806

1840

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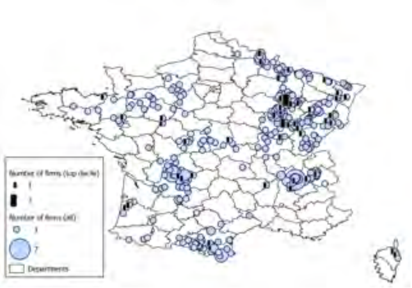
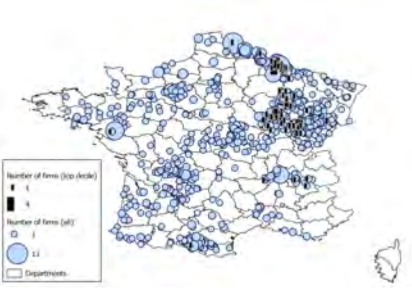
Distance to Top Decile: Metallurgy

1811



1840



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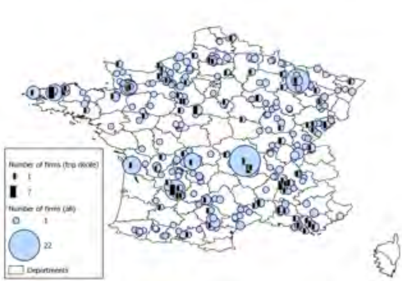
Distance to Top Decile: Paper Milling

1794



1840

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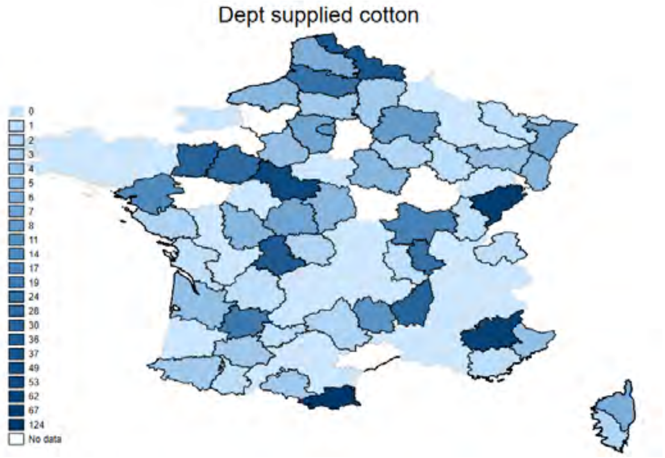
Cotton Spinning Already Had a High Degree of Market Integration

Number of districts to which each department supplied cotton



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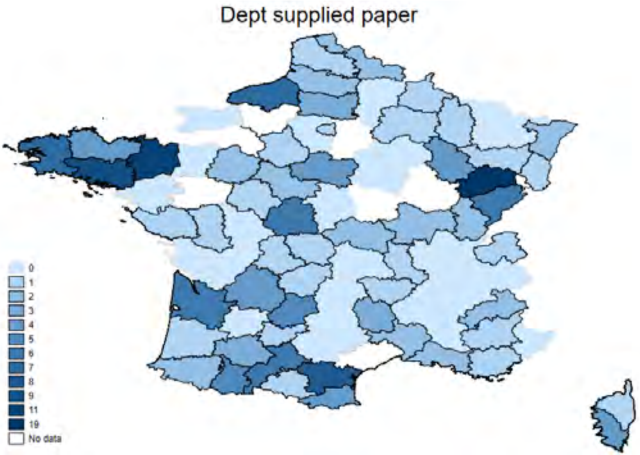
Metallurgy Had Lower Market Integration Than Cotton Spinning

Number of districts to which each department supplied metal



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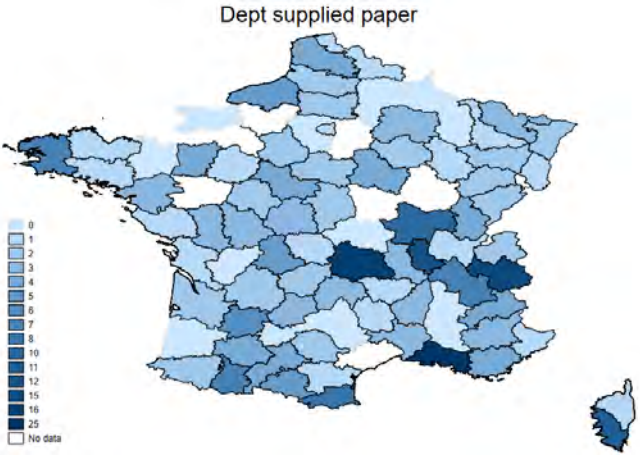
Paper Milling Had Lower Market Integration Than Cotton Spinning

Number of districts to which each department supplied paper



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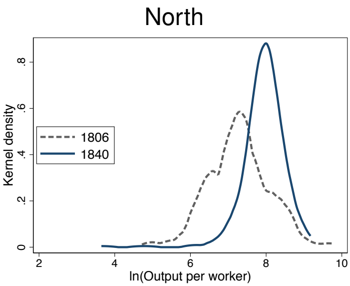
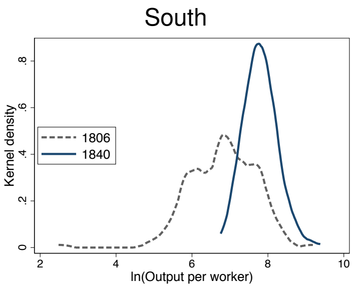
Spinning: Productivity Growth in the ‘North’ and ‘South’ of France





Notes: Northern communes are those located in above-median latitude. Southern communes are those located in below-median latitude.

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Productivity Growth Concentrated at Different Parts of the Distribution – Plants With At Least 10 Workers

	(1) Average	(2)	(3)	(4) At the following quantiles:	(5)	(6)	(7) N
		0.1	0.25	0.5	0.75	0.9	
Spinning (1806-1840)	2.261***	3.917***	3.191***	2.179***	1.612***	0.309	777
	(0.177)	(0.227)	(0.258)	(0.170)	(0.240)	(0.292)	
Metallurgy (1811-1840)	1.990***	1.751**	1.578***	1.523***	2.029***	1.845***	905
	(0.235)	(0.759)	(0.405)	(0.275)	(0.235)	(0.243)	
Paper milling (1794-1840)	1.245***	1.024***	1.086***	1.186***	1.434***	1.289***	507
	(0.136)	(0.225)	(0.162)	(0.121)	(0.159)	(0.274)	

Notes: Robust standard errors in parentheses. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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Productivity Growth Concentrated at Different Parts of the Distribution – Controlling for Number of Workers

	(1) Average	(2)	(3)	(4)	(5)	(6)	(7) N
		At the following quantiles:					
		0.1	0.25	0.5	0.75	0.9	
Spinning (1806-1840)	2.427***	3.941***	3.427***	2.292***	1.836***	0.974***	868
	(0.162)	(0.231)	(0.243)	(0.165)	(0.185)	(0.304)	
Number workers	-0.006	-0.073	-0.072	-0.048	-0.169**	-0.257**	
	(0.063)	(0.092)	(0.090)	(0.058)	(0.071)	(0.115)	
Metallurgy (1811-1840)	2.852***	3.296***	2.539***	2.552***	2.916***	2.507***	1296
	(0.177)	(0.438)	(0.275)	(0.214)	(0.184)	(0.202)	
Number workers	-1.219***	-1.338***	-1.183***	-1.193***	-1.105***	-1.066***	
	(0.082)	(0.143)	(0.093)	(0.099)	(0.081)	(0.083)	
Paper milling (1794-1840)	0.808***	0.744***	0.627***	0.780***	0.955***	1.505***	868
	(0.125)	(0.139)	(0.157)	(0.112)	(0.161)	(0.188)	
Number workers	-0.100*	0.206***	0.111	-0.002	-0.124*	-0.432***	
	(0.060)	(0.066)	(0.073)	(0.046)	(0.073)	(0.051)	

Notes: Robust standard errors in parentheses. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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Productivity Growth Concentrated at Different Parts of the Distribution – Capital Deepening

	(1) Average	(2) 0.1	(3) 0.25	(4) 0.5	(5) 0.75	(6) 0.9	(7) N
		At the following quantiles:					
Spinning (1806-1840)	1.960***	3.555***	2.930***	1.966***	1.254***	0.755***	868
	(0.167)	(0.267)	(0.247)	(0.178)	(0.190)	(0.281)	
K/L	0.522***	0.374***	0.467***	0.389***	0.379***	0.542***	
	(0.075)	(0.082)	(0.085)	(0.068)	(0.090)	(0.141)	

Notes: Robust standard errors in parentheses. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

- In 1800, key technology adopted in cotton spinning and no major technological changes until 1840 $\Longrightarrow$ but learning about efficient organization of factory-based production

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Productivity Growth Concentrated at Different Parts of the Distribution – Controlling for Market Access

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average	At the following quantiles:					N
		0.1	0.25	0.5	0.75	0.9	
Spinning (1806-1840)	2.444***	3.978***	3.028***	2.170***	1.697***	1.251***	844
	(0.157)	(0.221)	(0.203)	(0.158)	(0.167)	(0.313)	
Market access	0.349***	0.401***	0.397***	0.229***	0.279***	0.483***	
	(0.095)	(0.138)	(0.097)	(0.075)	(0.104)	(0.186)	
Metallurgy (1811-1840)	1.951***	1.438***	1.687***	1.881***	2.161***	2.488***	1242
	(0.189)	(0.431)	(0.287)	(0.232)	(0.213)	(0.248)	
Market access	0.136	0.979**	0.190	-0.378	-0.114	-0.421*	
	(0.198)	(0.431)	(0.409)	(0.320)	(0.142)	(0.236)	
Paper milling (1794-1840)	0.710***	0.735***	0.685***	0.759***	0.743***	0.409	853
	(0.110)	(0.164)	(0.135)	(0.098)	(0.136)	(0.259)	
Market access	0.680***	0.209	0.314	0.433**	0.537*	1.775***	
	(0.187)	(0.205)	(0.271)	(0.171)	(0.307)	(0.664)	

Notes: Robust standard errors in parentheses. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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Productivity Growth Concentrated at Different Parts of the Distribution – Controlling for Region FE

	(1) Average	(2)	(3)	(4)	(5)	(6)	(7) N
		At the following quantiles:					
		0.1	0.25	0.5	0.75	0.9	
Spinning (1806-1840)	2.028***	2.941***	2.352***	1.982***	1.943***	1.659***	844
	(0.158)	(0.455)	(0.208)	(0.168)	(0.218)	(0.191)	
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	
Metallurgy (1811-1840)	1.766***	2.012***	1.317***	1.781***	1.838***	1.786***	1243
	(0.181)	(0.211)	(0.273)	(0.158)	(0.139)	(0.214)	
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	
Paper milling (1794-1840)	0.785***	0.928***	0.827***	0.730***	0.614***	0.664***	853
	(0.118)	(0.099)	(0.132)	(0.098)	(0.120)	(0.106)	
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	

Notes: Robust standard errors in parentheses. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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Productivity Growth Concentrated at Different Parts of the Distribution – Prices Not Quality-Adjusted and TFP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average	At the following quantiles:					N
		0.1	0.25	0.5	0.75	0.9	
PANEL A: Baseline							
Spinning (1806-1840)	2.420***	3.917***	3.293***	2.234***	1.651***	1.014***	868
	(0.154)	(0.204)	(0.229)	(0.151)	(0.167)	(0.297)	
PANEL B: Using prices not quality-adjusted							
Spinning (1806-1840)	2.373***	3.381***	2.828***	2.105***	1.829***	1.628***	868
	(0.138)	(0.285)	(0.199)	(0.193)	(0.160)	(0.188)	
PANEL C: Using TFP							
Spinning (1806-1840)	2.845***	3.233***	3.107***	2.834***	2.647***	2.317***	868
	(0.050)	(0.080)	(0.072)	(0.056)	(0.083)	(0.072)	

Notes: Robust standard errors in parentheses. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

▸ TFP Estimation ▸ Back to Talk

TFP Estimation

- To estimate TFP we use data on the labor employed by the firm and proxy for the capital stock with the number of spindles â a standard measure of production capacity in the industry.
- We regress the revenue of the firm on a constant, log labor, and the log number of spindles of the plant, separately for each year. This allows for the capital and labor shares to be time-varying.
- Log TFP for each plant i in a given year t is thus the regression constant plus the residual of the regression.

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