Energy intensity and the productivity race in Industry (1870-1935)

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Past Energy Transitions, Esbjerg| 2017-03-10

[1]Cambridge University

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1. Motivation and problem definition

Sugar refining

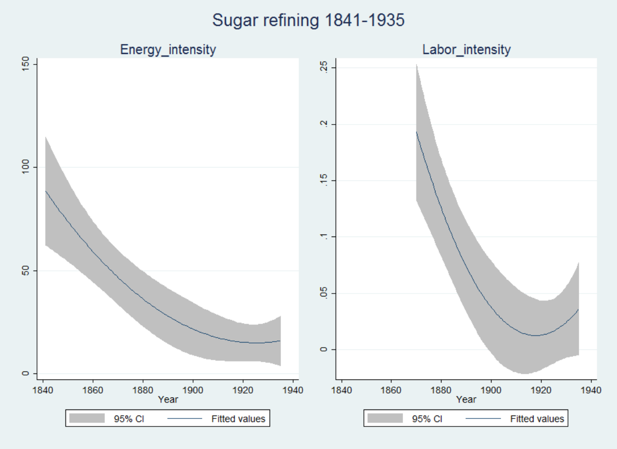

Figure: Energy and labor intensity in sugar refining

Pig iron

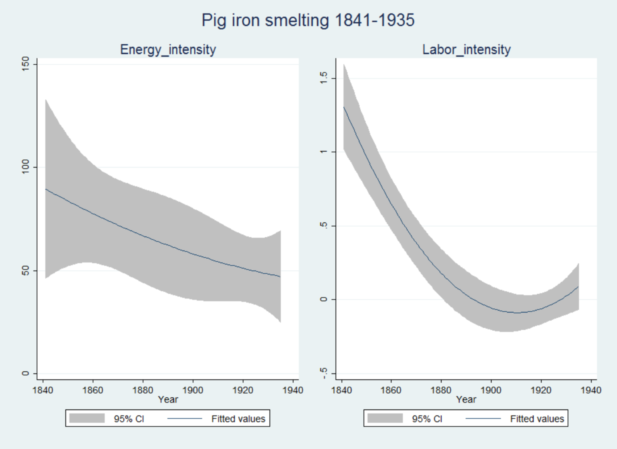

Figure: Energy and labor intensity in pig iron smelting

Iron and steel goods

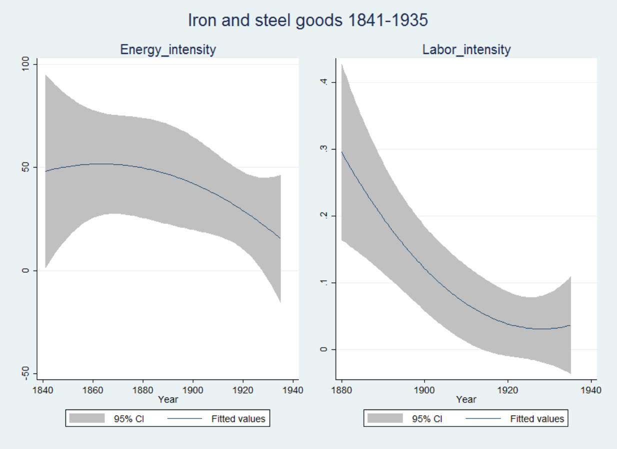

Figure: Energy and labor intensity in production of iron and steel goods

Cotton goods

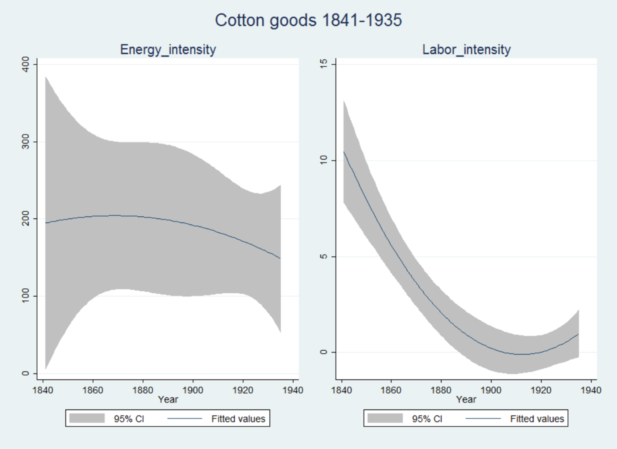

Figure: Energy and labor intensity in production of cotton goods

Paper

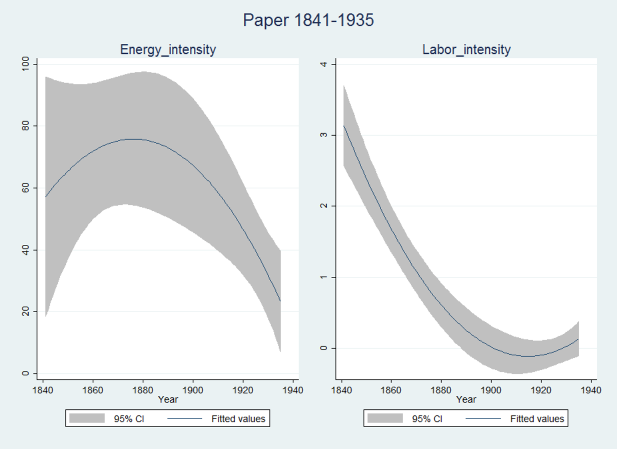

Figure: Energy and labor intensity in paper production

Beer brewing

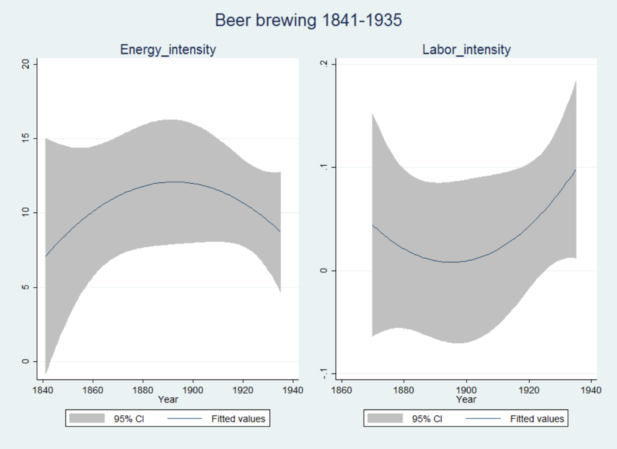

Figure: Energy and labor intensity in beer brewing

RQ: The developments in the historical energy intensity of manufacturing processes

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- How does the development in energy productivity relate to that other factor of production (labor productivity) and what does it say about the direction of technical change?

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2. The research context

The productivity race in manufacturing

- Largely debated topic in **economic history**
- Very much confined to cross-country comparisons of England, the USA and Germany
- Focus on labor productivity
- The rise of the US manufacturing: an exceptional tale of unique labor productivity growth, rapid technological change and an apt organization style
  - the American exceptionalism

The debates: labor productivity (1)

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- Global industrial labor productivity increased by a factor of 200 since the mid-19th century (Grubler, 1998)
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  - tremendous impact on productivity changes within various industrial sectors

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- But little is know about the role of energy utilization in productivity growth or as a substitute to labor

The debates: energy productivity (1)

- The use of fuel and power are some of the “most homogenous natural resources and the two most comparable to labor” (Habakkuk, 1962)

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- Cross-country differences in energy productivity found to be larger than the differences in labor productivity (Mulder and de Groot, 2004)
- Energy productivity convergence in the world manufacturing sectors since 1970 and particularly after 1990s

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    - paralleled with the ***1,000-fold*** increase in labor productivity

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- The role of energy in long-run productivity growth
  - The long-run relationship between the rate and direction of technical change with respect to energy and labor in some of the major manufacturing countries of the industrializing word

3. Method and data

Data overall

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- Capital goods
  - mining (coal), mining (ores), cement, pig iron smelting, iron and steel goods

Data: sources

- Denmark: Produktionsstatistik, several issues, Erhverstaellingen 1935; Danmarks Mejeri- Drifts-Statistik, Sveistrup, P. and R. Willerslev (1945)
- UK: Royal Coal Comission 1871, Census of Production, 1907, 1924 and 1935
- Czech: 1841 (Schnabel, 1848), 1934/1935 (Ceskoslovensky urad statisticky, 1936); 1863-1910 stats (Österreichische Statistik, n.d.)
- Sweden: "Bränsleförbrukingen åren 1913-1917"; SOS, Industri, several issues
- US: Census of Manufactures 1914, Biennal Census of Manufactures 1937
- Portugal: Informacões de Estatistica Industrial (1861-1865) - Coimbra, Leiria, Aveiro, Funchal, (1910-1913) Boletim do Trabalho Industrial: 50,53,53, 63.64, 65, 66, Inquérito Industrial 1881, Inquérito Industrial 1890, Estatistica Industrial 1943

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  - Drawbacks: differences in the product mix and quality

Additional measures of productive intensity

- Labor intensity
  - Labor per ton of production (employees/ton)
- Capital intensity
  - Horsepower per ton of production (HP/ton)

The role of energy in labor productivity growth

- An increasing returns to scale-based model of technical change (Semieniuk, 2016)
  - Labor productivity growth refers to the rate, and changes in the energy-labor ratio represent the direction of technical change
- Proportional growth rates of energy productivity, labor productivity and energy/labor ratio $\hat{\phi} = \hat{\lambda} - \hat{e}$

Data as of now: summary statistics

- 165 observations on energy intensity
- 188 observations on labor intensity
- 143 observations on energy-labor ratios
- *49 observations on horsepower intensity*

4. Results

Overall energy and labor intensity in manufacturing

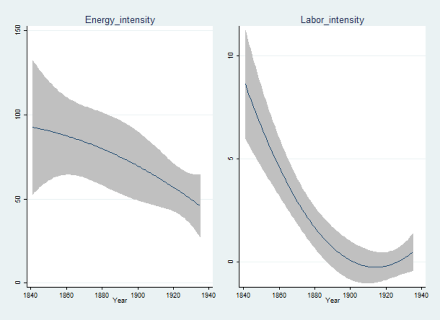


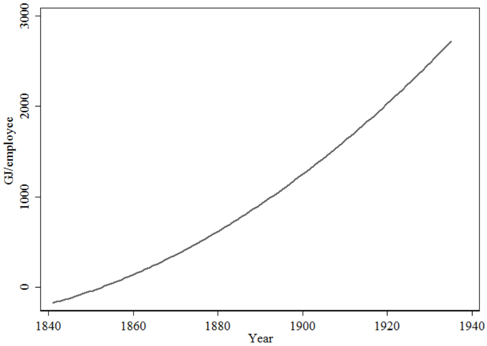
Figure: Energy and labor intensity in manufacturing

	1870-1913			1914-1935		
	GJ/ton	Labor/ton	HP/ton	GJ/ton	Labor/ton	HP/ton
Beer brewing	46%	53%	141%	20%	189%	56%
Butter	31%	90%	*	67%	86%	
Cement	31%	91%	*	39%	194%	
Cotton goods	44%	148%	88%	64%	60%	
Distilling	45%	99%	133%	24%	66%	25%
Glass production	53%	98%	171%	14%	149%	
Iron and steel goods	68%	161%	101%	43%	80%	73%
Mining (coal)	47%	83%	189%	29%	92%	14%
Paper	56%	152%	144%	37%	100%	
Pig iron smeltin	37%	206%	58%	31%	106%	29%
Sugar refining	86%	190%	60%	33%	131%	81%
Woollen goods	56%	44%	106%	52%	113%	

Table: Coefficients of variation

Coefficient of variation has been calculated following a standard formula of $c_v = \frac{\sigma}{\mu}$; where σ refers to

Energy/labor ratio (GJ/employee)



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- It is predominantly the standardized and uniform goods which experienced the largest rise in the E/L ratio
- The two sectors which experienced the most significant change in the energy/labor ratio are the production of pig iron and cement - the impact of industry and unit scaling

Productivity and the direction of technical change

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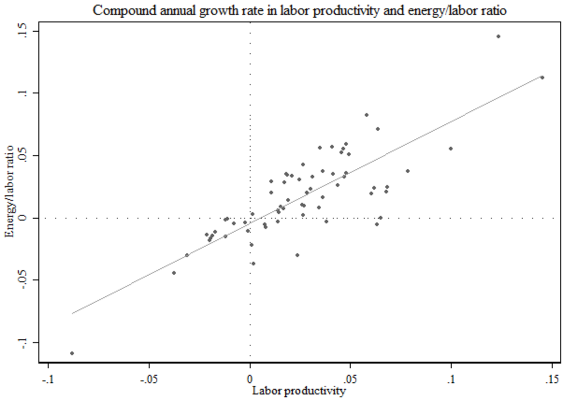

Figure: Compound annual growth rate in energy/labor ratio and labor productivity

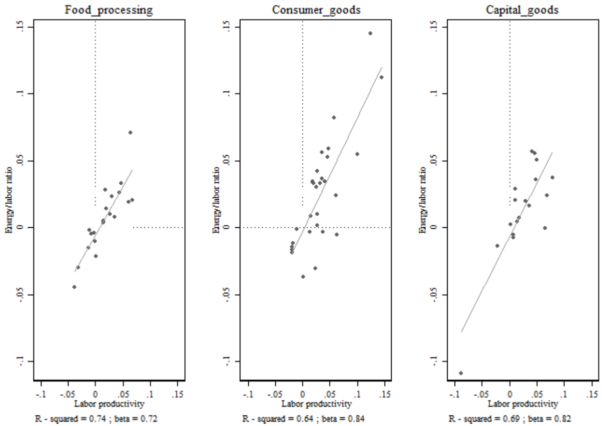

Figure: Compound annual growth rate in energy/labor ratio and labor productivity by productive sector

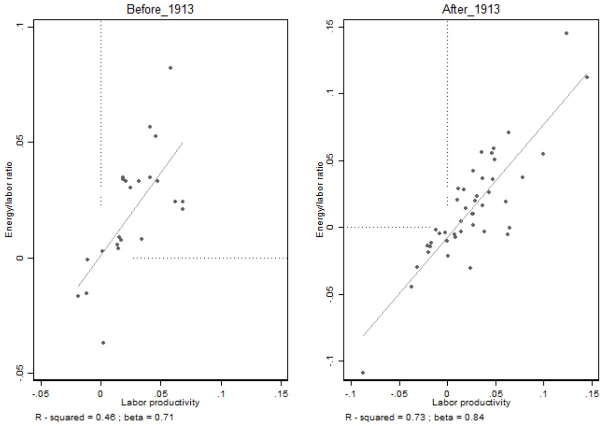

Figure: Compound annual growth rate in energy/labor ratio and labor productivity by time period (before and after 1913)

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- Semieniuk (2016) finds similar conclusion that technical change is largely of energy-using and labor-saving character between 1950-2012

5. Conclusions

Conclusions (1)

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  - Increased deployment of new electric motors was the primary driver of labor productivity gains but also cross-country convergence???

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  - constantly rising labor productivity, wages were increasing and this may have initiated further search for labor-saving methods?
  - energy prices, and importantly its share in the total factor costs, offered less motivation to innovate?

Thank you!

Questions? Now or hana.nielsen@ekh.lu.se

Energy/labor ratio of manufacturing processes (1870-1935)

$$\frac{E}{L} = \frac{EI_{s,i}}{LI_{s,i}} = \frac{\frac{1}{EI_{s,i}}}{\frac{1}{LI_{s,i}}} = \frac{EP_{s,i}}{LP_{s,i}}$$

Where E denotes total energy consumption (GJ), L denotes labor (in number of workers), EI is energy intensity (GJ/ton), LI labor intensity (workers/ton) and inversely LP labor productivity (output-based, ton/GJ) and EP is energy productivity (output-based, ton/worker).