The Rise of the Engineer

Inventing the Professional Inventor During the Industrial Revolution

W. Walker Hanlon

June 3, 2022

Data from Broadberry et al. (2015)

The Industrial Revolution

Typically dated as starting in the 1760-1780 period

- Initiated by macroinventions in textile machinery and steam engines

"The true miracle is not that the classical Industrial Revolution happened, but that it did not peter out like so many earlier waves of innovation"

– Joel Mokyr (2004)

Why was technological progress sustained?

The Industrial Revolution

Typically dated as starting in the 1760-1780 period

- Initiated by macroinventions in textile machinery and steam engines

"The true miracle is not that the classical Industrial Revolution happened, but that it did not peter out like so many earlier waves of innovation"

– Joel Mokyr (2004)

Why was technological progress sustained?

"The great invention of the nineteenth century was the invention of the method of invention."

– Alfred North Whitehead (1925)

- Did such a change in the process of innovation occur?
- If so, what did it look like? How did it work?

This paper (1)

Documents that a fundamental change in the innovation system *did* take place in Britain during the Industrial Revolution

- Professionalization of invention through the arrival of a new occupation: Engineering
- New profession filling a gap between scientists and working mechanics
- Core occupational functions were design and invention

Main empirical findings

(1) Engineers emerged as an important group of inventors and designers starting in the third quarter of the 18th century

- "Rise" is visible in both biographical and patent data

(2) Engineers were fundamentally different than other types of patenting inventors

- Produce more and higher quality patents, work with more coinventors, and patent across a broader set of technology types
- Contrast with manufacturer-inventors, the other major group of patentees
- Not just a re-labeling of some pre-existing inventor type

(3) The "Rise" was a specifically British phenomenon

- No similar pattern apparent in France

(4) Similar pattern of professionalization apparent among civil engineers

Outline

- The meaning of engineer
- Analysis of biographical data (brief)
- Analysis of British patent data
- Comparison of patterns in Britain to France
- Discussion of changes in civil engineering (brief)
- An endogenous growth theory with engineers

Defining an Engineer

What makes someone an engineer?

Today we would say a specific type of education

- But that was not the case during eighteenth and most of the nineteenth centuries
- Formal engineering education followed the emergence of the engineering profession

What about the subject matter they worked on?

- No, as I show, engineers were uniquely diverse in the subjects that they worked on

What defined the emerging engineering profession?

Henry Robinson Palmer at the inaugural meeting of the Institution of Civil Engineers:

> *"An Engineer is a mediator between the Philosopher and the working Mechanic; and like an interpreter between two foreigners must understand the language of both"*

Watson (1989) in the *History of the Society of Civil Engineers*:

> *"When John Smeaton described himself as a civil engineer for the first time...he identified a new profession" which combined "The craftsman's fund of knowledge, based on natural genius and practical experience...with the assimilation of scientific principles."*

Alternatively, a more quantitative approach

Using biographies from the *Oxford Dictionary of National Biography* (ODNB) I identify the activities (verbs) most associated with engineers

Compare to two natural comparison groups

- Other individuals involved in science and technology
- Manufacturers

Top-20 activities most associated with engineers

Verb	t-stat	Verb	t-stat	Verb	t-stat	Verb	t-stat
design	14.61	employ	6.74	complete	5.10	advise	4.40
build	11.53	report	6.23	open	5.01	supply	4.36
construct	9.58	erect	6.10	supervise	4.87	connect	4.24
consult	8.16	survey	5.59	improve	4.83	propose	4.11
patent	6.74	drive	5.27	lay	4.56	invent	4.01

T-stats are from OLS regressions. All of these verbs have sharpened p-values below 0.001 after accounting for multiple hypothesis testing.

- Defining features are stable over time
- Similar regardless of how engineers are identified:
  - self-reports vs. judgment of historians

So how should we define engineering?

A new occupation where the core functions were invention and design, applied to a wide range of practical problems by mechanically-inclined individuals with (in Bessemer's words) "an inventive turn of mind"

This distinguishes engineers from other common types of inventors:

- **Gentleman-tinkerers**, the main inventors of the early 18th century
- **Manufacturer-inventors**, who typically produced innovations within a narrow space related to their existing business

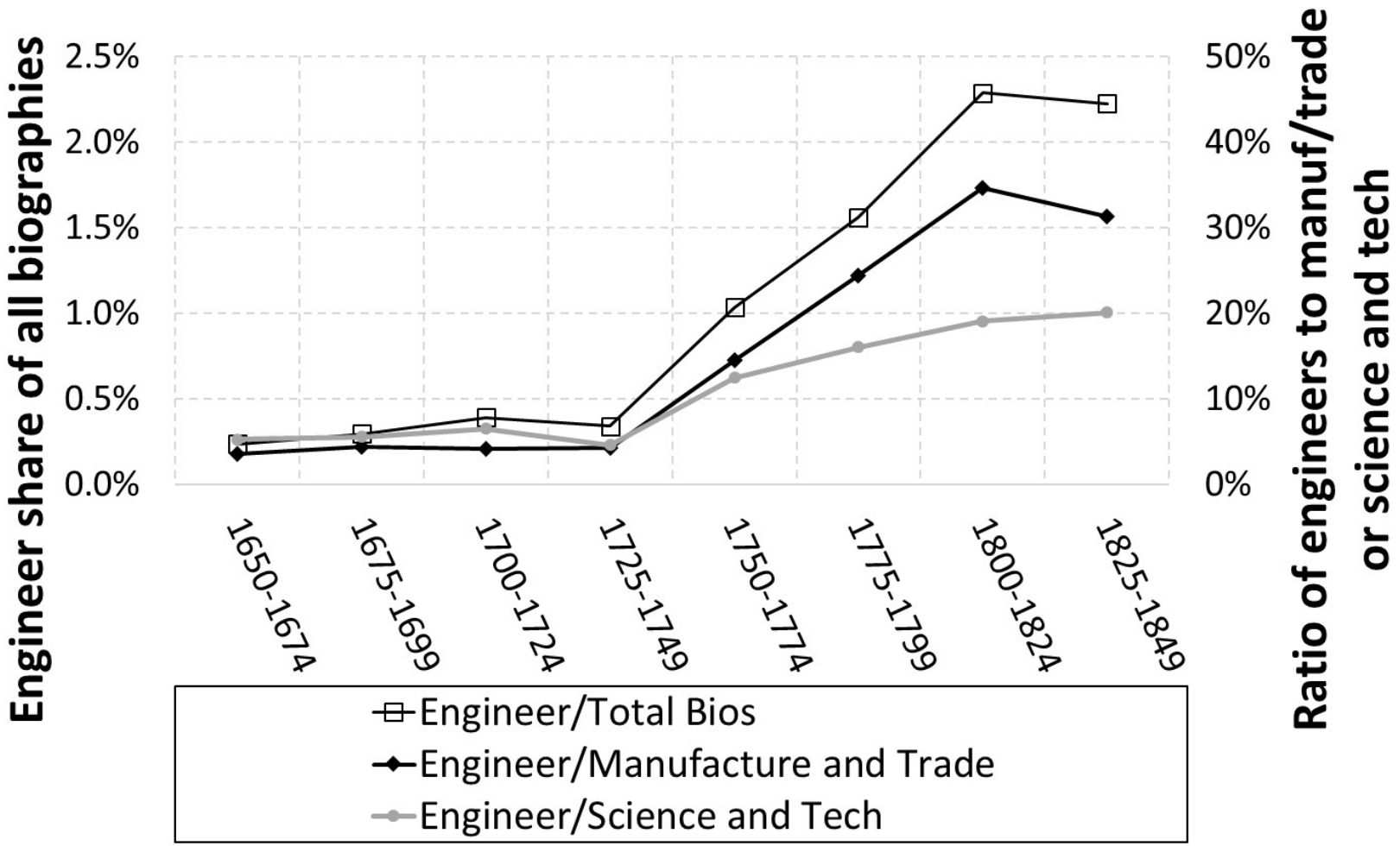
An example: Joseph Bramah (1749-1814)

- Father was a farmer, he apprenticed as a carpenter
- Began working installing waterclosets, became famous for lock design
- Listed as Cabinet Maker in patents in 1778, 1783, 1784
- Listed as Engine Maker in patents in 1785, 1790, 1793
- Then listed as an Engineer in 12 subsequent patents
- Inventions ranged from waterclosets and locks to a hydraulic press, beer engine, fountain pen, banknote numbering machine

Rise of the Engineer

Evidence from Biographical Data

Rising share of engineers among ODNB biographies



Rise of the Engineer

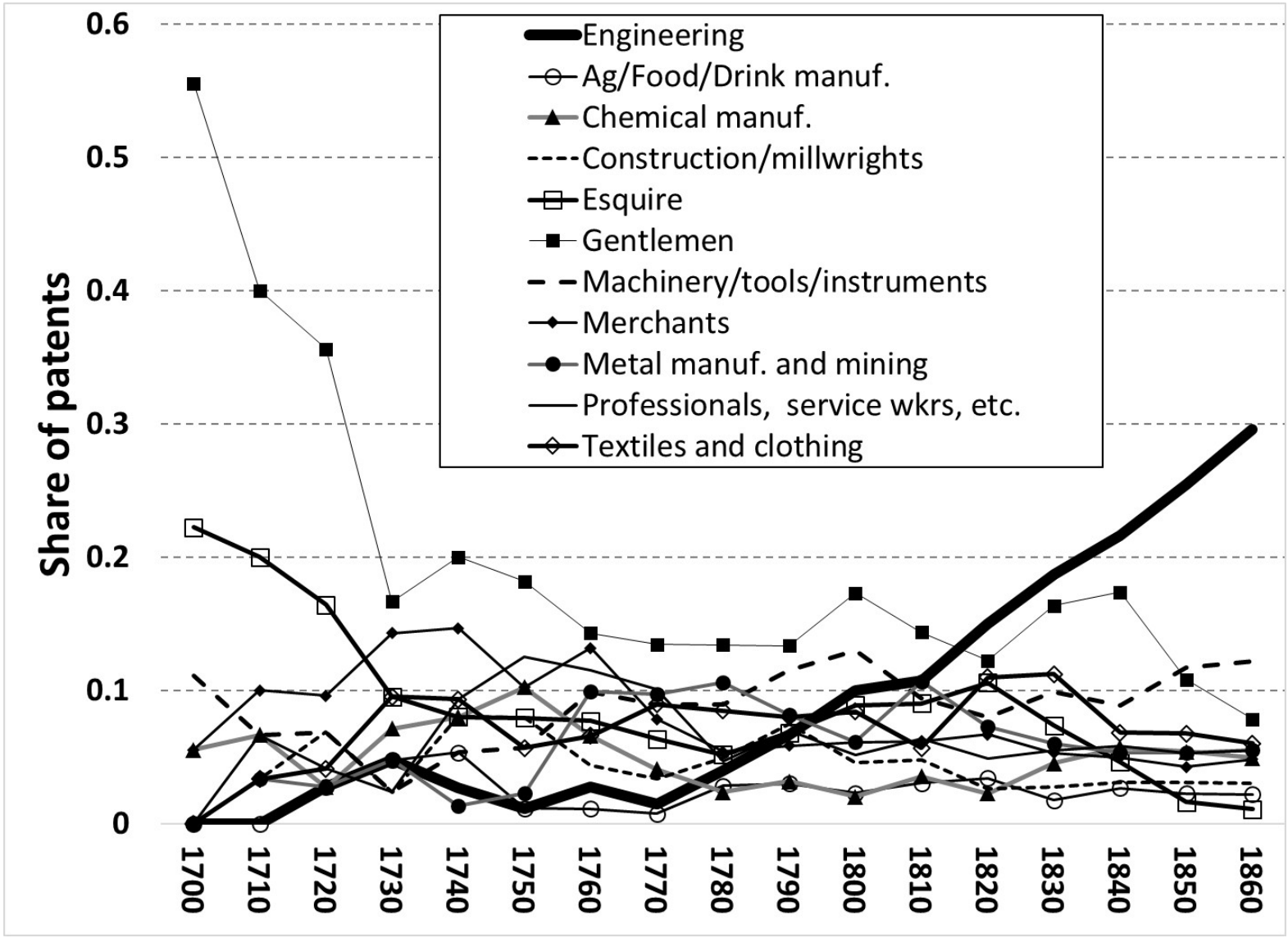
Evidence from Patent Data

British patent data overview

Patent data

- Main patent data cover 1700-1849 with additional data to 1869
- Listing of patents with inventor name, occupation, address, and technology category
- Hand-linked patents to individual inventors
- Over 12,500 patents and 8,000 individual inventors

Rise of the Engineer in British patents



Note: Shows the share of patents relative to those with any listed occupation.

Were Engineers different?

Part 1: Productivity and patent quality

Engineers produced more patents

Using the linked inventor data I can study the number of patents produced by individuals in different occupation groups

- Based on inventors' modal occupation

Occupation group	**Avg. patents per inventor**	**Occupation group**	**Avg. patents per inventor**
Ag/Food/Drinks	1.258	Merchants	1.246
Chemical Manuf.	1.586	Mining & Metals	1.436
Construction	1.188	Misc. Manuf.	1.372
Engineers	**2.069**	Textile Manuf.	1.463
Esquire	1.727	Prof. services	1.349
Gentry	1.571	Other	1.265
Machinery & Tools	1.473	Unknown	1.152

Productivity regressions in patent data

	DV: Number of patents per inventor					
	All years (1)	All years (2)	1770-1789 (3)	1790-1809 (4)	1810-1829 (5)	1830-1849 (6)
Engineer	0.689***	0.616***	1.023**	0.802***	0.339***	0.448***
	(0.0865)	(0.0903)	(0.468)	(0.237)	(0.131)	(0.0921)
Manufacturer	0.0618*	0.0272	0.0136	-0.0240	-0.0285	-0.00298
	(0.0325)	(0.0368)	(0.0579)	(0.0585)	(0.0580)	(0.0529)
Tech. cat. FEs		Yes	Yes	Yes	Yes	Yes
Observations	7,966	7,966	652	1,209	1,802	4,215
R-squared	0.018	0.044	0.187	0.121	0.061	0.055

- Large relative to sample mean of 1.52

What about patent quality?

I use several available patent quality measures:

1. **Patent renewals** – based on the payment of expensive fees to keep the patent in force after 3 or 7 years, introduced by the 1852 reform

2. **Reference-based** – mentions in contemporary and modern publications (from Nuvolari & Tartari 2011 and Nuvolari et al., 2019)

3. **Exhibition-based** – whether the invention was exhibited in the Great Exhibition of 1851 in London

4. **Biography-based** – whether the inventor was included among the 'notable' individuals in the Oxford Dictionary of National Biography

Engineers produced better quality inventions

	Patent renewals		**Reference indices**		**Great Exhibition**	**ODNB Biography**
	Year Three	Year Seven	WRI	BCI		
	(1)	(2)	(3)	(4)	(5)	(6)
Engineer	0.0462***	0.0200***	0.0400	0.231***	0.0441***	0.0808***
	(0.00899)	(0.00637)	(0.0307)	(0.0434)	(0.0131)	(0.0262)
Manuf.	0.0140*	0.00870*	-0.0486*	-0.104***	0.0159*	-0.0374**
	(0.00772)	(0.00520)	(0.0253)	(0.0307)	(0.00835)	(0.0149)
**Fixed effects included vary by specification*						
Obs.	54,742	41,215	18,473	18,473	4,469	1,987
R-squared	0.020	0.015	0.134	0.058	0.003	0.013
Testing difference between engineer and manufacturer coefficients						
F-stat	10.0	2.37	7.42	55.9	4.18	20.92
P value	0.002	0.124	0.007	0.000	0.041	0.000

- Another difference: engineers also more likely to patent with coinventors

Engineers were broader than other types of inventors

Average number of technology categories per inventor

Occupation group	Avg. number of tech. categories per inventor	Occupation group	Avg. number of tech. categories per inventor
Agric/food/drink	1.548	Merchant	1.483
Chemical manuf.	1.740	Metals and mining	1.589
Construction	1.470	Misc. manuf.	1.462
Engineering	**2.459**	Textile Manuf.	1.388
Esquire	1.897	Prof. services	1.605
Gentry	1.822	Other occ.	1.490
Machinery/tools	1.547	Unknown	1.519

Were Engineers different?

Part 2: Changing behavior upon becoming an engineer

Changes when individuals become engineers

For individuals with 2+ patents, it is possible to look for changes in behavior after a person begins referring to themselves as an engineer

Focus on two outcomes:

- Share of patents with coinventors (change in behavior)
- Number of patents per year (change in output)

Estimate whether these changed after the first patent in which an individual appears as an engineer

- Including inventor fixed effects

Within-individual regression results

	DV: Share of patents with multiple inventors			DV: Patents per year		
	(1)	(2)	(3)	(4)	(5)	(6)
Engineer	0.051**	0.062***	0.092***	0.25***	0.266***	0.069**
	(0.023)	(0.024)	(0.031)	(0.033)	(0.034)	(0.033)
Years since first patent		-0.0009	-0.0008		-0.0012***	-0.0006
		(0.0006)	(0.0006)		(0.0005)	(0.0004)
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes
Drop first year as Eng.			Yes			Yes
Obs.	5,333	5,333	5,152	18,787	18,787	18,641
R-squared	0.547	0.548	0.552	0.234	0.234	0.233

International Comparison

Engineering in Britain vs. France

French patent data

French patent data for 1791-1843

- End just before major reform in 1844
- Generally similar to the British data
- Manually link 14,161 patent-inventor observations to identify 10,559 individual inventors

Notable difference:

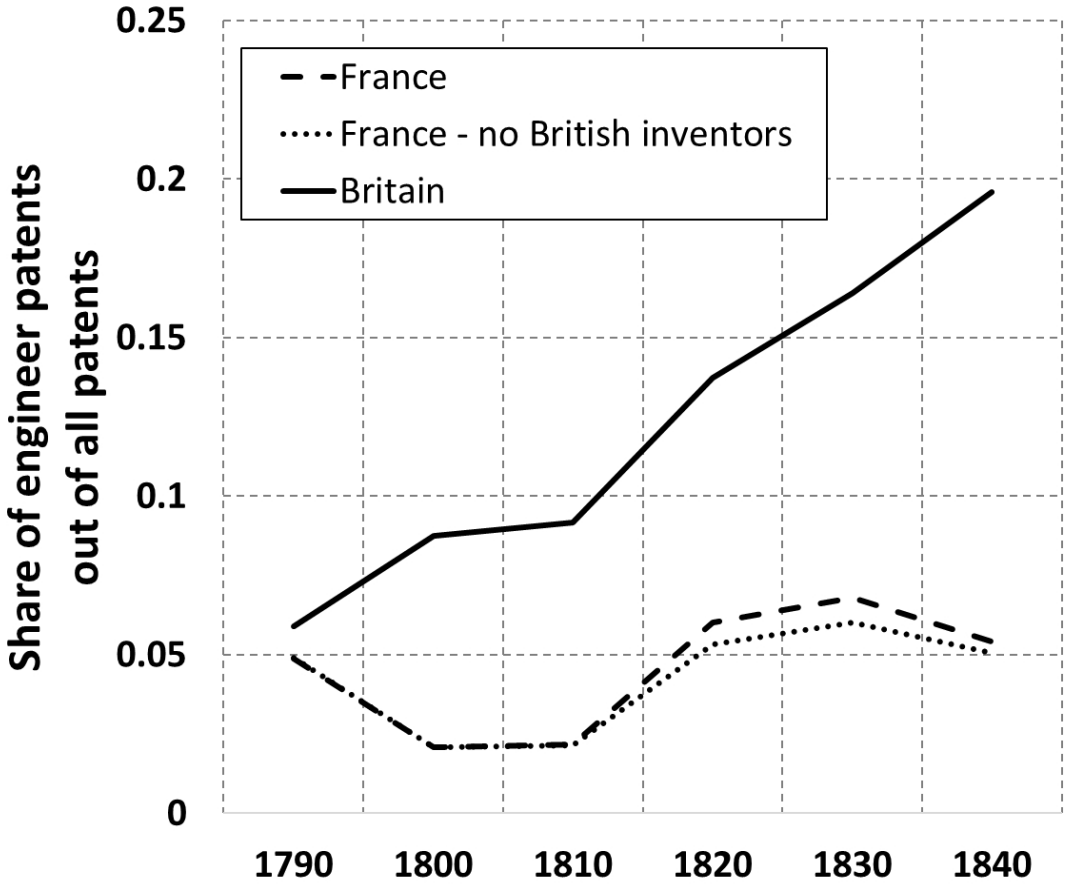
- Patents available for 5, 10, or 15 years
- Provides an ex ante measure of expected quality

Engineers (ingénieure) in France differ from other inventors

	Patents per person		Avg. length of patent term		Tech. categories per person	
	All inventors	Excluding UK-based	All inventors	Excluding UK-based	All inventors	Excluding UK-based
Engineer	0.965***	0.838***	1.156***	1.045***	0.690***	0.594***
	(0.147)	(0.137)	(0.204)	(0.218)	(0.108)	(0.0993)
Manuf.	-0.059***	-0.059***	-1.195***	-1.047***	-0.095***	-0.095***
	(0.018)	(0.018)	(0.074)	(0.074)	(0.020)	(0.021)
Obs.	10,556	9,980	10,541	9,967	10,557	9,981
R-sq.	0.032	0.025	0.031	0.026	0.011	0.008

- Patterns very similar to those observed in the UK

But France did not experience the "Rise of the Engineer"



Why not?

- France had a better-developed system of engineering education
- But the profession was largely oriented toward public and especially military applications

Professionalization of Civil Engineering

Civil Engineering was changing at the same time

Before 1760, major civil engineering projects often overseen by people with little experience

Example: Westminster Bridge

- Largest civil engineering project in the first half of the 18th century
- Engineered by Charles Labalye – had never built a bridge or any other major infrastructure project

Situation had changed dramatically by the early 19th century

- Major projects overseen by established and experienced engineers
- John Smeaton, William Jessop, John Rennie, James Brindley, etc.
- Younger engineers trained at established firms before being awarded major projects
- Society of Civil Engineers est. 1771
- Institution of Civil Engineers est. 1818

Theory

Endogenous growth with engineers

Overview of the theory

Goal:

- Growth theory that incorporates the emergence of a professional research sector (engineers) into a model of endogenous growth
- Connects this mechanism to existing theories on the causes of the Industrial Revolution

"Smith-Romer" model

- Smith: Specializing in research allows researchers to be more productive
- Romer: Knowledge spillovers allow sustained endogenous growth

Reflects the transition from a "pre-modern" period of slow technology growth to a "modern" period of more rapid growth

- As in Unified Growth Theory (Galor & Weil 2000; Galor 2011) as well as Jones (2001), Hansen & Prescott (2002), Peretto (2015)

Core of the model: two sources of innovation

Manufacturer-inventors

- Generate new technologies as a byproduct of production activities
- I.e., learning by doing

Professional inventors (e.g., engineers)

- Specialize in developing new technologies
- Research involves paying a fixed cost for a chance of a new invention

Key assumption motivated by empirical results:

- Professional inventors are more productive at developing new technology than manufacturer-inventors

Summary of the development path

Starting from a low technology level (N) economy experiences slow pre-modern growth

- No professional inventor sector
- All innovation is a byproduct of production activity
- Could last for a very long time

If (1) access to skills is not too costly and (2) inventors can monetize inventions then eventually N will reach a point where some individuals choose to become professional researchers

- Emergence of professional researchers begins the transition to modern economic growth
- Modern economic growth not inevitable!

Economy then asymptotically approaches a new balanced growth path

- Characterized by rapid modern economic growth and a higher share of skilled workers

Conclusions

Summary

A new approach to explaining how the Industrial Revolution led to a transition to modern economic growth

- Professionalization of invention, represented by a new type of worker: Engineers
- Invention and design was the core function of this new occupation
- Specialization helps explain why Engineers were more productive than other types of inventors
- The model shows how the emergence of this more productive way of developing new technologies can shift the economy to a permanently higher growth rate