Economics 210A
Spring 2015

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Lecture 7
Innovation

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I. Overview

Central Issues

- What determines technological progress?
- Or, more concretely, what determines the pace of inventive activity?

Determinants of Inventive Activity

- Demand-side factors:
  - Greater growth and booms may raise the returns to inventive activity.
- Supply-side factors:
  - More secure property rights could raise the incentives for inventive activity.
  - Learning-by-doing.
  - Education, religion, class structure.

Today's Papers

- Differ in countries and periods covered.
- What unites them is creativity in data collection.

II. Kenneth L. Sokoloff

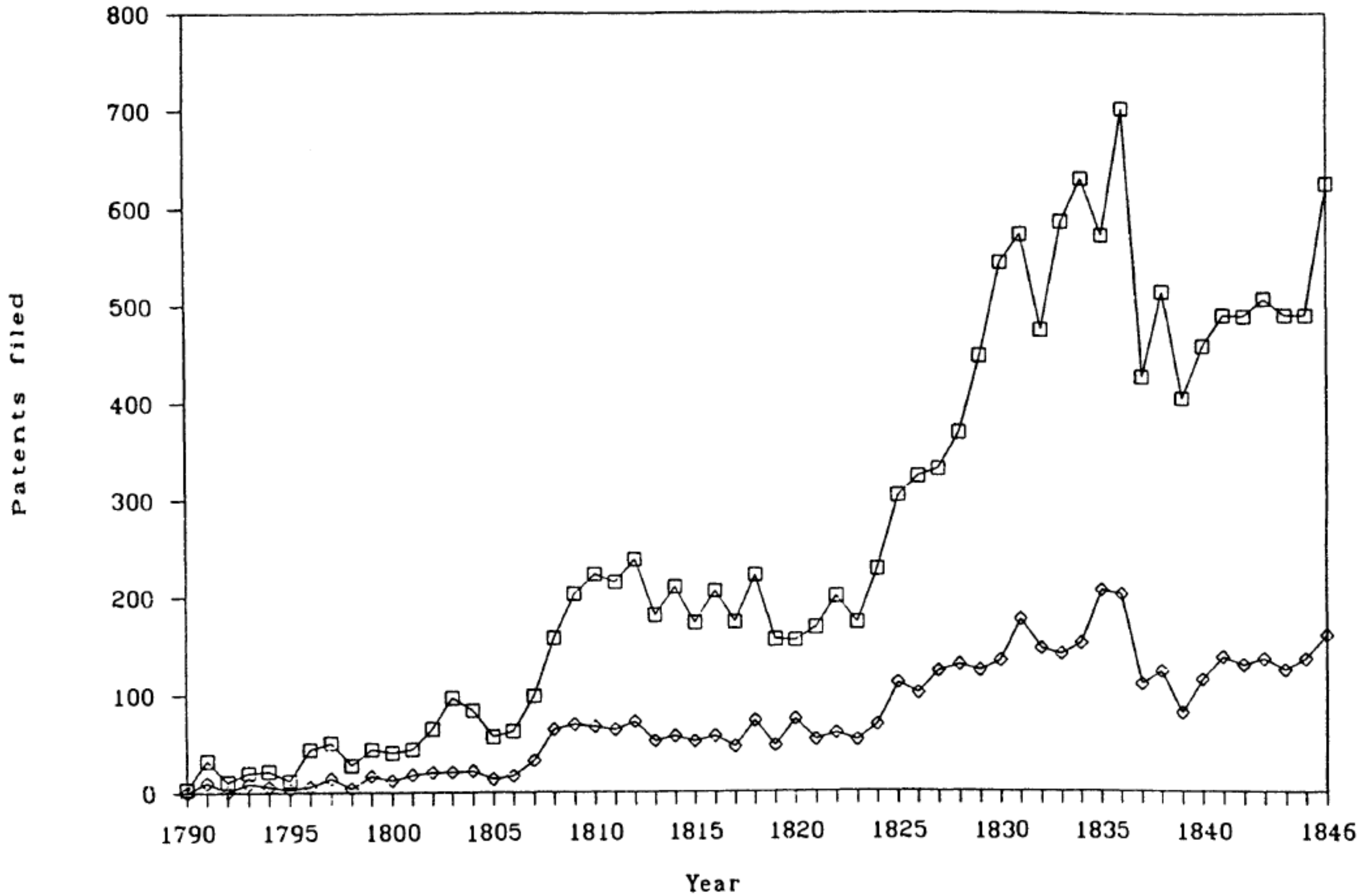
"Inventive Activity in Early Industrial America: Evidence from Patent Records, 1790-1846"

Sokoloff's Data

- Patent records.
- Sample of 4,500 patents for 1790-1846.
- What is good about them?
- What are potential problems?

FIGURE 1

ANNUAL TOTALS OF PATENTS IN THE POPULATION AND THE SAMPLE, 1790–1846



From: Sokoloff, “Inventive Activity in Early Industrial America”

First Issue: Procyclicality of Patenting Activity

- Looking for a time-series relationship between patenting activity and output.

- Wants to argue in favor of a demand-side story for inventive activity.

Table 1
ANNUAL PATENT RATES PER 1,000,000 RESIDENTS, BY SECTOR AND REGION

	1791–1798	1799–1804	1805–1811	1812–1822	1823–1829	1830–1836	1836–1842	1843–1846
Agriculture								
N. New England	0.7	1.9	2.2	4.1	9.6	15.8	6.8	3.5
S. New England	0.0	1.3	10.9	6.5	7.9	8.4	12.6	4.5
New York	0.0	3.4	13.3	12.7	15.2	20.2	6.8	10.6
Pennsylvania	1.5	0.0	3.2	3.6	7.3	11.9	6.3	4.6
S. Mid Atlantic	0.5	3.8	4.6	4.7	6.5	6.8	14.8	4.6
Other U.S.	0.5	0.2	1.5	1.4	4.1	3.6	1.7	4.4
National	0.5	1.3	4.6	4.2	6.9	8.3	4.6	5.2
Construction								
N. New England	0.0	1.1	4.9	1.7	8.8	15.5	8.0	3.5
S. New England	2.4	9.0	16.3	7.9	10.1	22.8	6.6	6.0
New York	3.6	4.6	12.6	6.0	13.0	23.1	12.4	6.9
Pennsylvania	1.8	1.8	6.5	5.2	3.6	9.0	5.4	4.1
S. Mid Atlantic	0.0	1.8	3.4	4.8	4.6	7.0	8.2	4.6
Other U.S.	0.2	0.2	0.5	1.2	1.5	2.5	1.7	1.1
National	1.0	2.4	5.2	3.2	4.8	8.9	4.6	2.9
Manufacturing								
N. New England	1.1	4.5	7.3	6.8	10.5	24.0	14.2	9.6
S. New England	2.4	11.2	27.8	31.2	31.8	59.9	42.2	49.6
New York	6.0	5.6	26.6	17.5	37.7	32.2	15.8	32.2
Pennsylvania	7.0	10.0	16.2	15.5	13.8	21.3	9.7	20.0
S. Mid Atlantic	2.1	8.8	12.3	13.2	10.4	14.1	7.8	19.5
Other U.S.	0.0	2.2	1.0	2.0	3.0	4.0	2.2	2.7
National	2.0	5.7	10.7	9.7	12.5	16.1	8.7	12.9

Business Cycle Conditions: Embargo Contraction Expansion Contraction

From: Sokoloff, “Inventive Activity in Early Industrial America”

TABLE 1 (Continued)

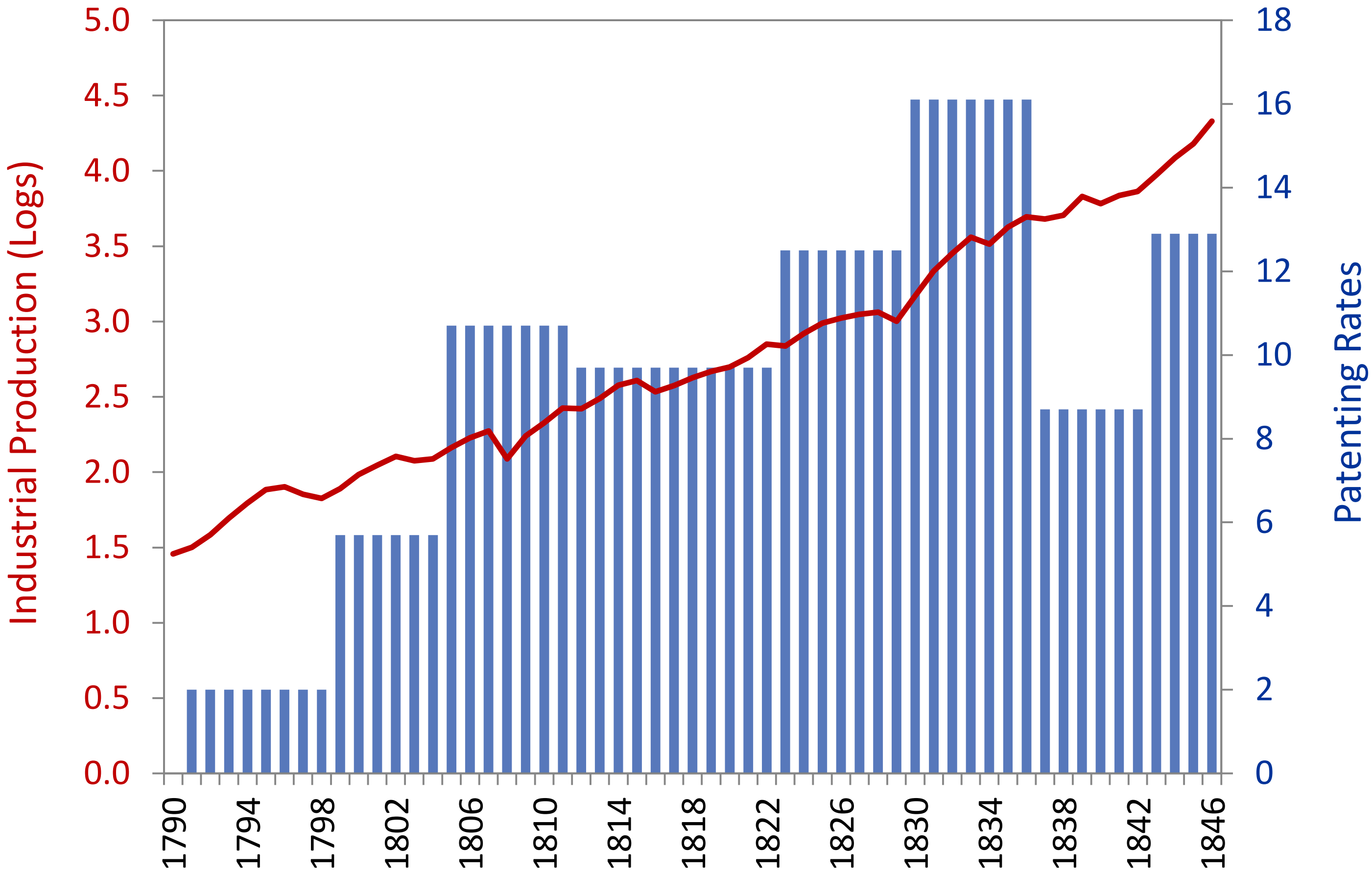
ANNUAL PATENT RATES PER 1,000,000 RESIDENTS, BY SECTOR AND REGION

	1791–1798	1799–1804	1805–1811	1812–1822	1823–1829	1830–1836	1836–1842	1843–1846
Transportation								
N. New England	0.0	0.0	0.8	1.3	1.2	7.5	2.3	2.6
S. New England	1.2	3.0	6.0	5.6	4.0	6.9	13.0	8.3
New York	1.2	0.9	4.4	8.6	10.5	11.2	11.3	9.5
Pennsylvania	3.5	0.9	2.6	3.5	4.7	5.8	9.4	9.2
S. Mid Atlantic	1.4	0.9	2.7	7.6	6.4	8.2	8.2	10.2
Other U.S.	0.5	0.5	0.5	1.2	1.1	1.4	1.6	0.9
National	1.1	0.9	2.0	3.4	3.4	4.6	4.9	4.0
All Sectors								
N. New England	1.9	7.5	15.2	15.1	33.0	65.5	32.9	20.0
S. New England	7.2	26.7	65.2	55.4	60.4	106.4	79.5	74.5
New York	10.9	16.4	62.0	49.9	81.3	95.6	49.6	65.8
Pennsylvania	17.2	14.5	29.7	33.6	32.2	53.3	32.9	42.5
S. Mid Atlantic	4.1	17.0	23.7	34.9	31.9	41.4	40.8	40.0
Other U.S.	1.2	3.4	3.4	6.1	10.4	13.2	7.7	9.9
National	5.2	11.3	23.9	22.9	30.0	41.8	24.5	27.3

Business Cycle Conditions: Embargo Contraction Expansion Contraction

From: Sokoloff, “Inventive Activity in Early Industrial America”

Industrial Production and Patenting Rates



Source: Davis, "An Annual Index of U.S. Industrial Production, 1790-1915," *QJE*, 2004.

TABLE 2
SECTORAL PATENT SHARES, BY REGION
(percentage)

	1791–1798	1799–1804	1805–1811	1812–1822	1823–1829	1830–1836	1836–1842	1843–1846
Agriculture								
N. New England	40.0%	25.0%	14.3%	27.1%	29.0%	24.2%	20.7%	17.4%
S. New England	0.0	4.7	16.7	11.8	13.1	7.9	15.8	6.1
New York	0.0	20.8	21.4	25.5	18.7	15.8	13.7	16.1
Pennsylvania	8.5	0.0	10.9	10.6	22.5	22.3	19.1	10.8
S. Mid Atlantic	11.8	22.4	19.2	13.3	20.5	16.5	36.2	11.6
Other U.S.	43.7	7.1	43.8	23.2	39.5	27.2	21.6	44.3
National	10.0	11.3	19.2	18.2	22.9	19.8	18.9	19.2
Construction								
N. New England	0.0	15.0	32.1	11.2	26.6	23.6	24.4	17.4
S. New England	33.3	33.6	25.0	14.3	16.7	21.4	8.3	8.1
New York	33.3	28.3	20.4	12.1	15.9	24.2	24.9	10.6
Pennsylvania	10.2	12.5	21.7	15.4	11.1	16.9	16.4	9.6
S. Mid Atlantic	0.0	10.3	14.4	13.7	14.5	17.0	20.0	11.6
Other U.S.	18.8	7.1	14.1	18.9	14.1	19.2	21.6	11.3
National	18.8	21.0	21.7	14.1	15.9	21.3	18.9	10.5
Manufacturing								
N. New England	60.0	60.0	48.2	44.9	32.0	36.7	43.1	47.8
S. New England	33.3	42.1	42.6	56.3	52.6	56.3	53.1	66.7
New York	55.6	34.0	42.9	35.1	46.3	33.7	32.0	48.9
Pennsylvania	40.7	68.8	54.3	46.2	43.0	39.9	29.6	47.0
S. Mid Atlantic	52.9	51.7	51.9	37.6	32.5	34.0	19.0	48.8
Other U.S.	0.0	64.3	28.1	31.9	29.1	30.7	29.0	27.0
National	39.4	50.3	44.7	42.1	41.7	38.6	35.6	47.1
Transportation								
N. New England	0.0	0.0	5.4	8.4	3.6	11.4	6.9	13.0
S. New England	16.7	11.2	9.3	10.2	6.7	6.5	16.3	11.1
New York	11.1	5.7	7.1	17.3	12.9	11.7	22.8	14.4
Pennsylvania	20.3	6.3	8.7	10.3	14.8	10.8	28.5	21.7
S. Mid Atlantic	35.3	5.2	11.5	21.7	19.9	19.8	20.0	25.6
Other U.S.	37.5	14.3	9.4	18.9	10.2	10.9	20.5	8.7
National	20.6	8.2	8.6	14.9	11.4	10.9	20.1	14.5

From: Sokoloff, “Inventive Activity in Early Industrial America”

TABLE 3
ANNUAL PATENT RATES PER 1,000,000 RESIDENTS, BY SUB-REGION

	1791–1798	1799–1804	1805–1811	1812–1822	1823–1829	1830–1836	1836–1842	1843–1846
Northern New England								
Rural	0.7	4.5	13.0	15.4	33.8	69.1	28.1	16.3
Urban			9.8	11.4	9.9	50.2	42.1	27.6
Metro								
Total	1.9	7.5	15.2	15.1	33.0	65.5	32.9	20.0
Southern New England								
Rural	2.0	7.5	68.7	51.1	61.9	65.4	49.9	45.9
Urban	0.0	22.4	34.6	37.9	44.0	106.3	68.8	57.0
Metro	11.9	78.5	291.5	244.9	160.0	226.9	213.9	265.5
Total	7.2	26.7	65.2	55.4	60.4	106.4	79.5	74.5
New York								
Rural	0.0	0.8	46.6	32.5	56.5	72.0	20.8	23.6
Urban	12.3	15.3	33.3	39.7	86.5	62.1	34.4	54.1
Metro	24.8	68.0	121.4	116.0	159.7	196.7	131.9	148.4
Total	10.9	16.4	62.0	49.9	81.3	95.6	49.6	65.8
Pennsylvania								
Rural	0.0	0.0	11.9	11.3	20.3	38.1	18.8	22.8
Urban	0.0	8.6	17.3	8.7	8.4	31.4	20.7	22.1
Metro	63.4	6.7	122.2	162.1	118.7	140.7	98.3	130.9
Total	17.2	14.5	29.7	33.6	32.2	53.3	32.9	42.5
Southern Middle Atlantic								
Rural	0.9	6.0	7.8	19.9	17.7	17.3	29.2	8.9
Urban	4.8	11.9	12.3	20.6	8.0	21.1	24.1	47.1
Metro	17.6	35.2	131.7	108.7	105.6	134.4	82.1	111.8
Total	4.1	17.0	23.7	34.9	31.9	41.4	40.8	40.0
Other U.S.	1.2	3.4	3.4	6.1	10.4	13.2	7.7	9.9
National Average	5.2	11.3	23.9	22.9	30.0	41.8	24.5	27.3

From: Sokoloff, “Inventive Activity in Early Industrial America”

Second Issue: Relationship between Patenting Activity and Waterways

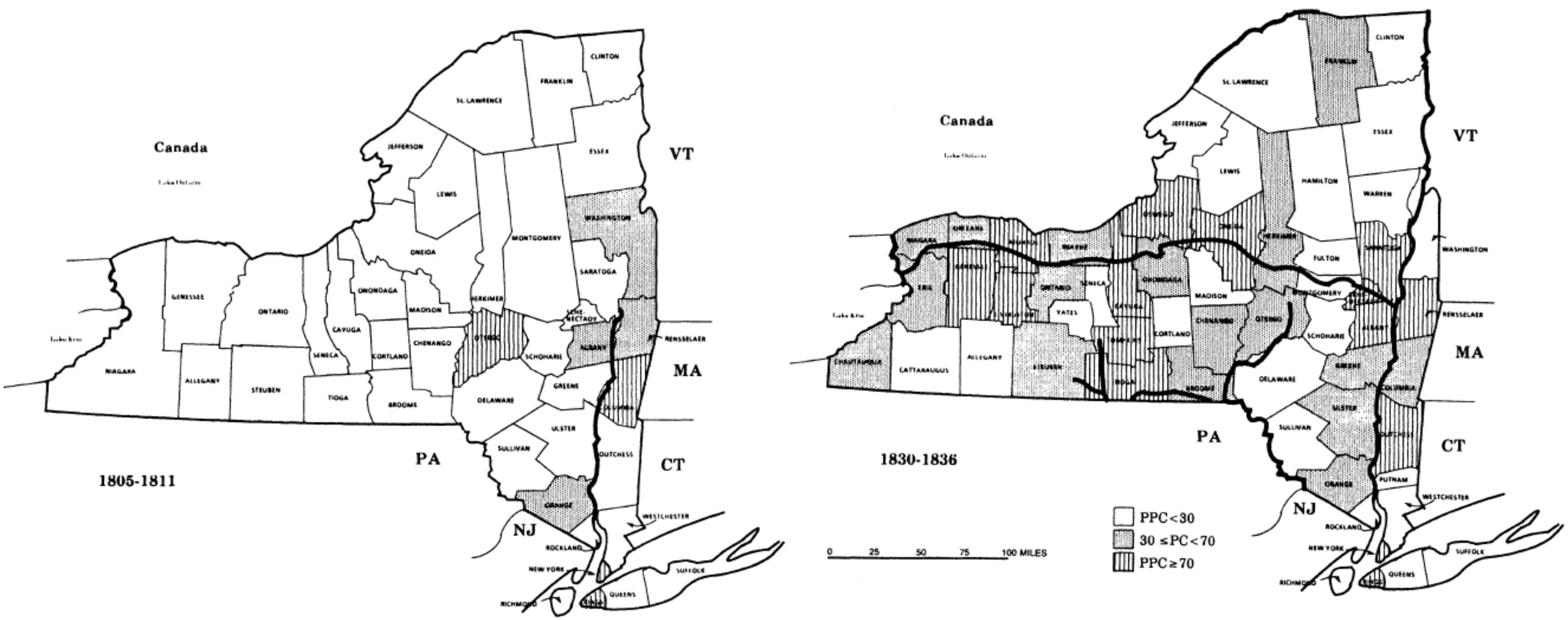
- Looking at the cross-sectional variation in patenting activity.

- A relationship with waterways could suggest a role for the growth of markets.

FIGURE 4

LEVELS OF INVENTIVE ACTIVITY IN NEW YORK, 1805–1811 AND 1830–1836

1805-1811 1830-1836

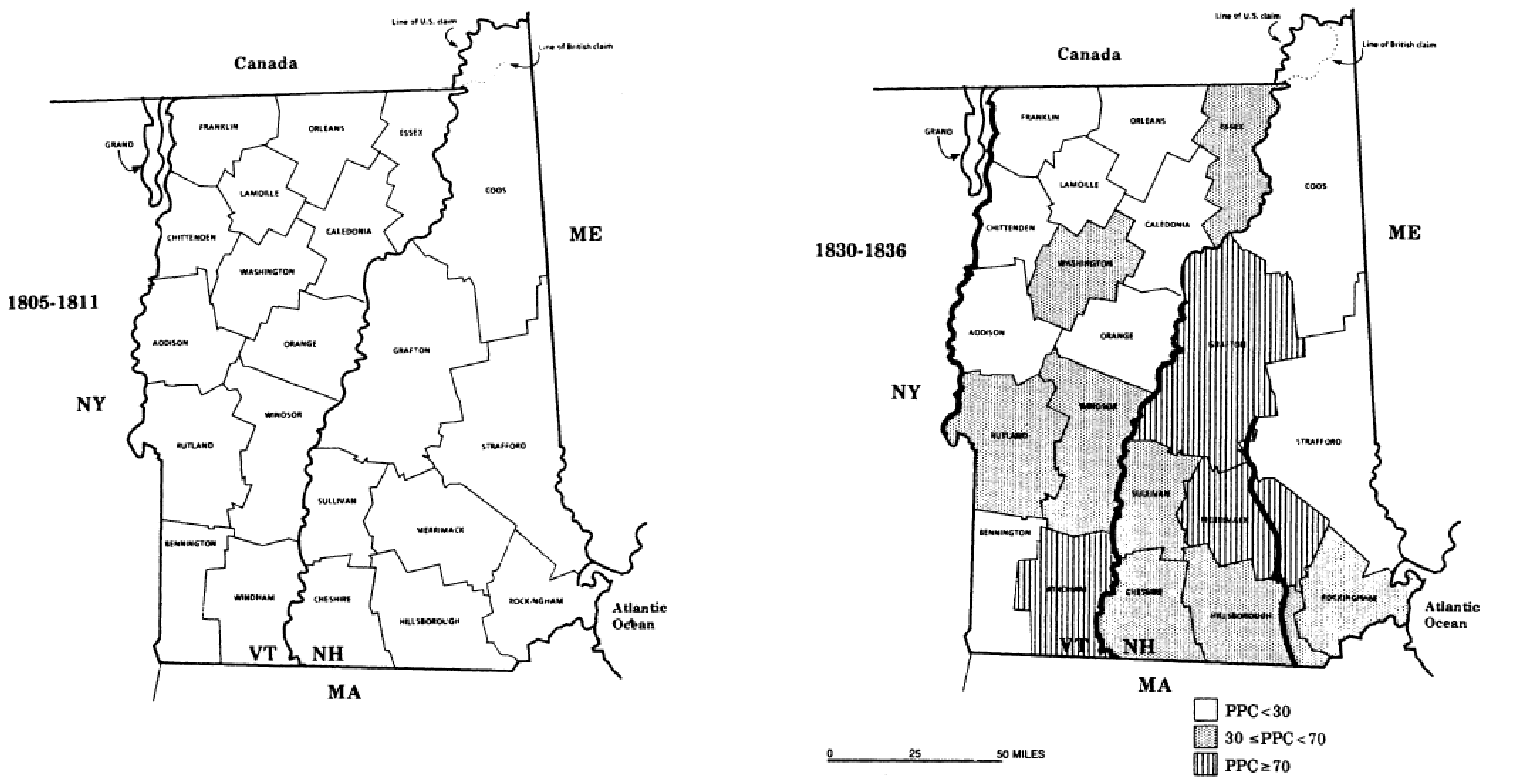


From: Sokoloff, “Inventive Activity in Early Industrial America”

FIGURE 5

LEVELS OF INVENTIVE ACTIVITY, NEW HAMPSHIRE AND VERMONT
1805–1811 AND 1830–1836

1805-1811 1830-1836



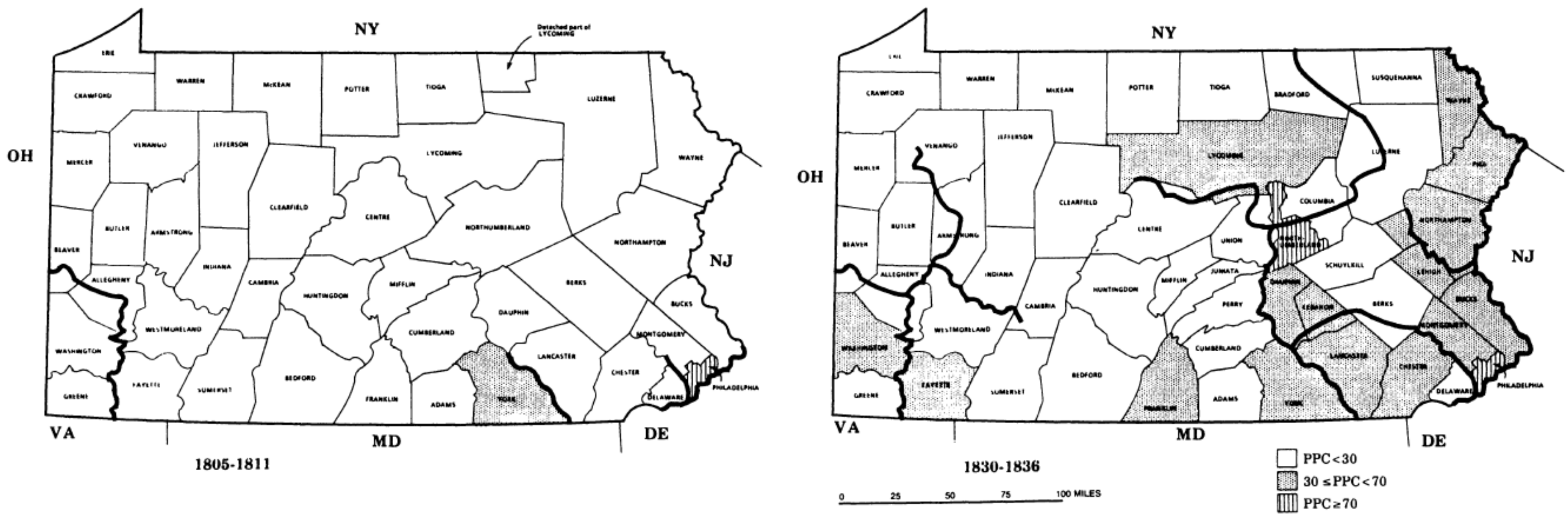
From: Sokoloff, “Inventive Activity in Early Industrial America”

FIGURE 3

LEVELS OF INVENTIVE ACTIVITY IN PENNSYLVANIA, 1805–1811 AND 1830–1836

1805-1811

1830-1836



From: Sokoloff, “Inventive Activity in Early Industrial America”

TABLE 5

CROSS-SECTIONAL REGRESSIONS OF PATENTS PER CAPITA ON COUNTY CHARACTERISTICS: 1805–1811, 1823–1829, AND 1830–1836

	Dependent Variable: Log (Annual Patents Per Million Residents)		
	1805–1811	1823–1829	1830–1836
Constant	1.397	1.724	2.429
	(4.61)	(5.98)	(8.21)
Log $\left(\frac{\text{Manufacturing Labor Force}}{\text{Agricultural Labor Force}}\right)$	0.173	0.093	0.180
	(1.21)	(0.79)	(1.58)
State Dummies			
Northern New England	0.166	0.707	1.001
	(0.41)	(2.12)	(3.04)
Southern New England	2.041	1.826	1.489
	(5.46)	(5.75)	(4.47)
New York	0.891	1.535	0.669
	(2.45)	(5.69)	(2.56)
Delaware or New Jersey	−0.173	−0.400	−0.716
	(−0.35)	(−0.93)	(−1.62)
Urbanization Dummies			
Urban	−0.252	−0.198	−0.096
	(−0.74)	(−0.74)	(−0.38)
Metropolitan	2.205	1.831	1.183
	(3.51)	(3.65)	(2.49)
Transportation Dummies			
Located on Navigable River or Canal	0.725	0.573	0.873
	(2.26)	(2.18)	(3.13)
Located on Ocean	−0.155	−0.426	−0.051
	(−0.39)	(−1.12)	(−0.13)
R^2	0.44	0.42	0.35
N	132	174	174

From: Sokoloff, “Inventive Activity in Early Industrial America”

Interpretation of the Cross-Section Evidence

- Sokoloff emphasizes growth of markets leading to higher returns to inventive activity.
- Alternative supply-side stories?

Evaluation of Sokoloff?

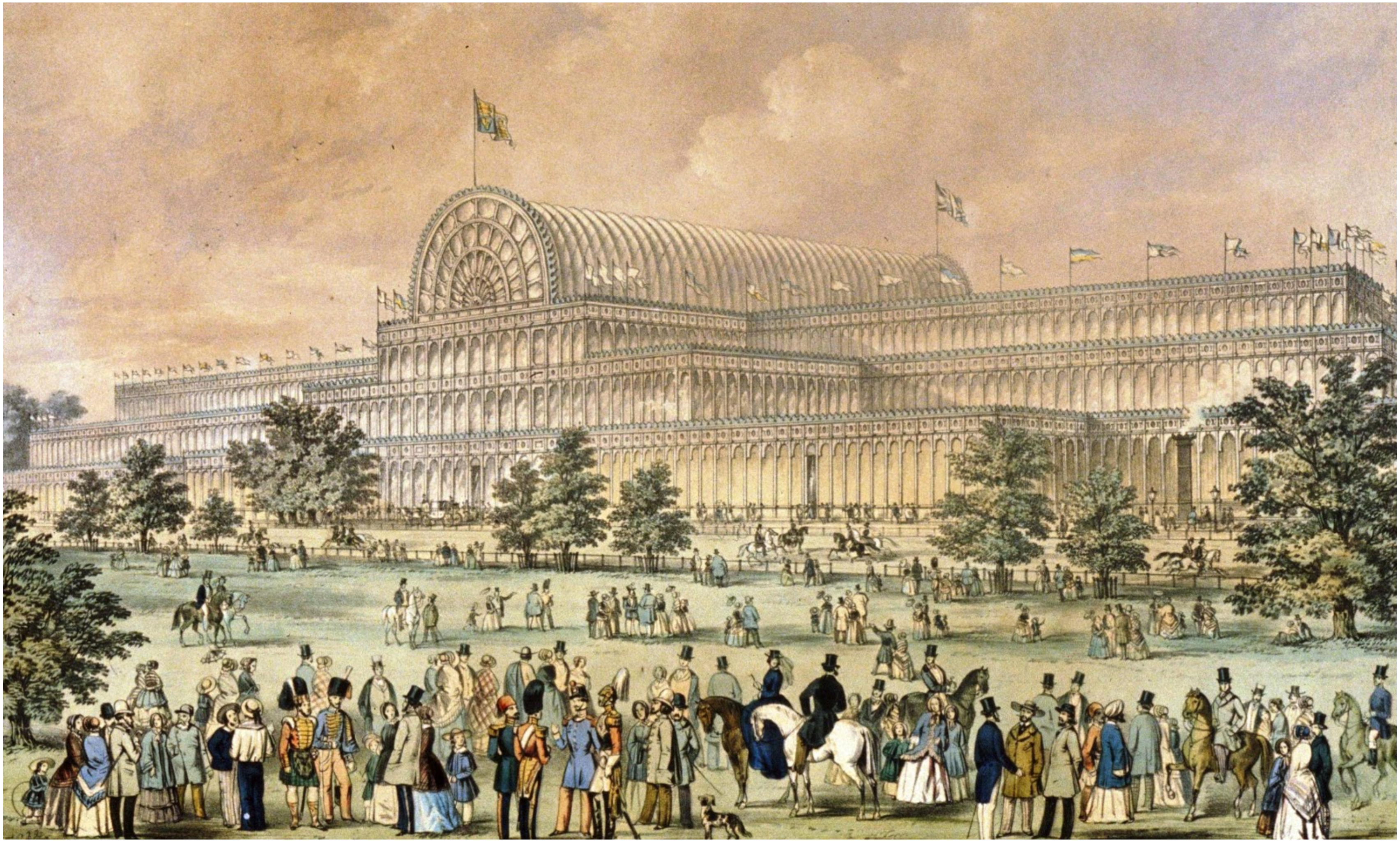
III. Petra Moser

"How Do Patent Laws Influence Innovation? Evidence from Nineteenth-Century World's Fairs"

Issue Moser Investigates

- Do patent laws change the *composition* of innovation?

Crystal Palace Exhibition of 1851



Crystal Palace Exhibition of 1851

Centennial Exhibition of 1876

Centennial Exhibition of 1876

Exhibition Data

- From two World's Fairs: 1851, 1876
- Source: Exhibition catalogs
- What information is provided on each invention?
- Strengths of the data, particularly relative to patent records?
- Potential weaknesses?

TABLE 1—STATISTICS ON THE WORLD'S FAIRS OF 1851 AND 1876

	Exhibition	
	Crystal Palace	Centennial
Location	London	Philadelphia
Year	1851	1876
Countries		
Total	40	35
N. Europe	12	10
Exhibitors		
Total	17,062	30,864
N. Europe	11,610	6,482
Visitors	6,039,195	9,892,625
Area (in acres)	25.7	71.4

From: Moser, "How Do Patent Laws Influence Innovation?"

First Issue: How Much Was Patenting Used in Various Industries?

- This is a way of identifying how patent laws (or lack of them) may skew the direction of invention.

TABLE 2—PATENTING RATES ACROSS INDUSTRIES IN 1851

	Patenting rate	
Industry of use	Britain	US
Mining	5.0%	5.8%
Chemicals	5.1%	4.0%
Food processing	7.9%	4.3%
Machinery	20.4%	36.4%
Scientific instruments	9.7%	14.9%
Textiles	6.9%	6.0%
Manufactures	10.1%	13.5%
Total	11.1%	14.2%

Notes: Patenting rates measure the share of exhibits that are patented. For Britain, innovations with patents are identified as exhibits whose description in the *Official Catalogue* (1851) refers to at least one patent. For the United States, innovations are matched with lists of all patents reported in the *Annual Report of the United States Patent Office* between 1841 and 1851.

From: Moser, "How Do Patent Laws Influence Innovation?"

Second Issue: What Is the Relationship between Patent Laws and Composition of Exhibitions?

TABLE 3—COUNTRY CHARACTERISTICS

	Patent length		Population		GDP		Primary education	
Country	1851	1876	1851	1876	1851	1876	1851	1876
Austria	15	15	3,950	4,730	6,563	9,395	389	426
Bavaria	15	—	4,521	—	6,673	—	—	—
Belgium	15	20	4,449	5,303	8,042	14,849	549	582
Britain	14	14	25,601	30,662	60,479	107,661	555	680
Denmark	0	5	1,499	1,973	2,549	4,008	—	—
France	15	15	36,350	38,221	60,685	84,014	515	737
Germany	—	15	—	24,023	—	—	—	732
Netherlands	15	0	3,095	3,822	5,844	52,805	541	639
Prussia	12	—	16,331	—	24,105	—	730	—
Saxony	12	—	1,894	—	2,796	—	—	—
Norway & Sweden	15	—	4,875	—	5,993	—	615	—
Norway	—	3	—	1,803	—	2,650	—	658
Sweden	—	3	—	4,363	—	8,006	—	568
Switzerland	0	0	2,379	2,750	1,986	5,787	—	759
Württemberg	10	—	1,745	—	2,575	—	—	—

From: Moser, “How Do Patent Laws Influence Innovation?”

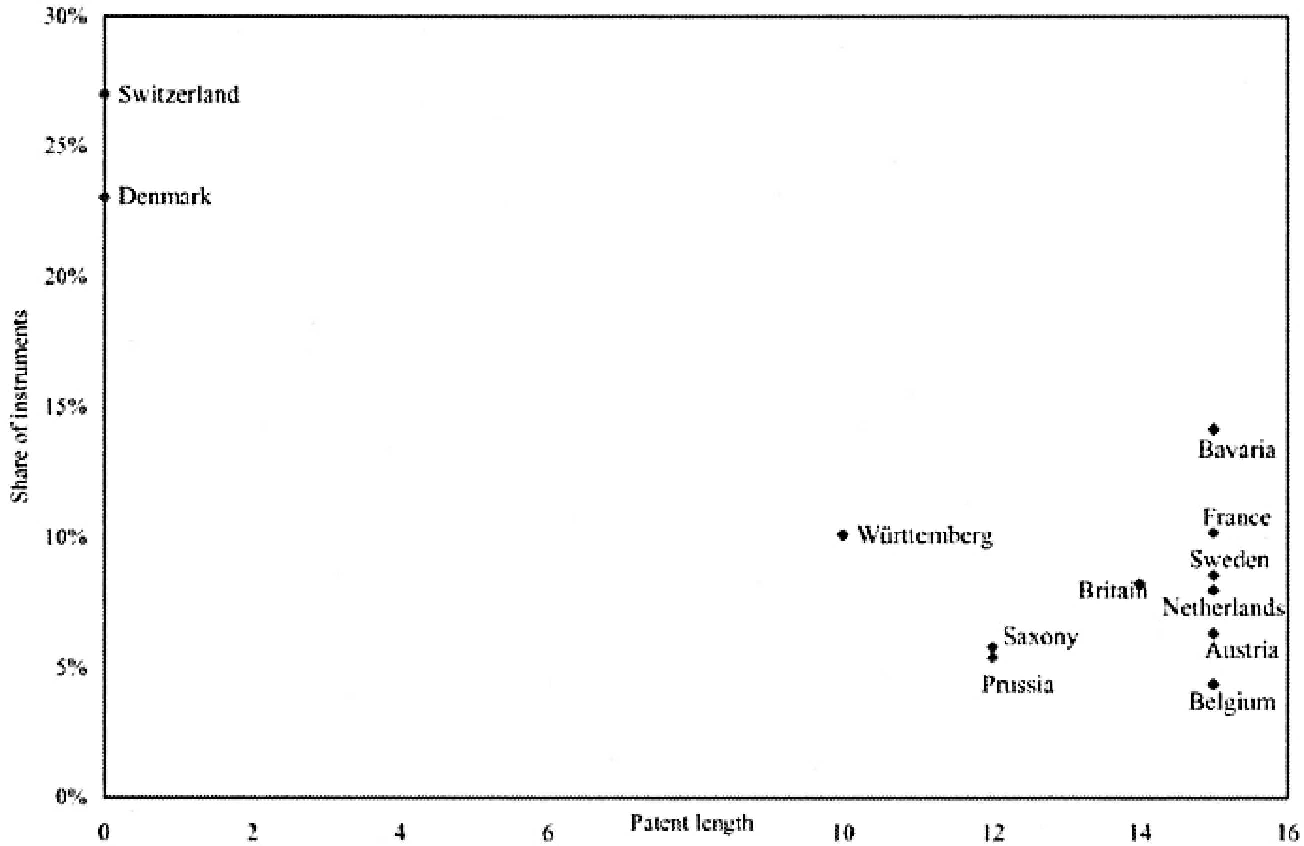
TABLE 4—CHI-SQUARE TEST OF THE HOMOGENEITY OF DISTRIBUTIONS

	1851		1876	
Industry categories	Seven	Ten	Seven	Ten
No patent protection	18.22	23.46	68.15	78.51
	(6)	(9)	(6)	(9)
Short and medium patent lives	89.16	91.09	55.70	67.59
	(12)	(18)	(12)	(18)
Patent length exceeds 12 years	768.83	802.68	237.27	265.91
	(54)	(36)	(24)	(36)
All countries	1349.99	1395.22	639.72	693.50
	(66)	(99)	(54)	(81)

- The mean of the distribution is equal to the number of degrees of freedom.
- The variance is equal to two times the number of degrees of freedom.

From: Moser, "How Do Patent Laws Influence Innovation?"

Figure 1. Shares of Exhibits in Scientific Instruments against Patent Length in 1851



From: Moser, “How Do Patent Laws Influence Innovation?”

Multinomial Logit Estimation

- Unit of observation is now individual exhibits (have about 14,000).
- Think of an inventor choosing to innovate in one of 7 industries.
- Key RHS variable is a dummy equal to 1 if the country the inventor is from ***doesn't*** have a patent law.
- Other controls as well.

Table 5—Multinomial Logit Regressions

	(1) 1851 and 1876	(2) 1851 and 1876	(3) 1851 only	(4) 1876 only	(5) 1851 and 1876	(6) (excl. Switzerland)
Mining						
No patent laws	−1.8171	−1.5864	−2.1358	−1.1898	−1.2505	−1.8636
	(0.4996)	(0.4058)	(0.7379)	(0.4971)	(0.4024)	(0.6289)
Chemicals						
No patent laws	0.4573	0.2674	0.0441	0.4981	0.2916	0.4094
	(0.3272)	(0.2591)	(0.6315)	(0.3085)	(0.2528)	(0.3819)
Food processing						
No patent laws	1.6874	1.4607	0.4947	1.7711	1.1626	1.9918
	(0.2499)	(0.1805)	(0.4687)	(0.2334)	(0.1723)	(0.2813)
Machinery						
No patent laws	0.6709	0.5385	0.1055	0.8235	0.9710	0.3944
	(0.2565)	(0.1893)	(0.3073)	(0.2570)	(0.1850)	(0.3089)
Instruments						
No patent laws	2.4863	2.3773	2.2218	2.5962	2.3000	1.2958
	(0.2560)	(0.1733)	(0.2275)	(0.2677)	(0.1667)	(0.3687)
Textiles						
No patent laws	1.3350	1.1660	0.9741	1.3625	1.0243	0.7340
	(0.2194)	(0.1440)	(0.1881)	(0.2224)	(0.1397)	(0.2856)
Exhibits	14,221	14,935	10,792	4,143	14,935	14,025
Countries	16	22	12	10	22	15

From: Moser, "How Do Patent Laws Influence Innovation?"

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Textiles	6.9%	6.0%
Manufactures	10.1%	13.5%
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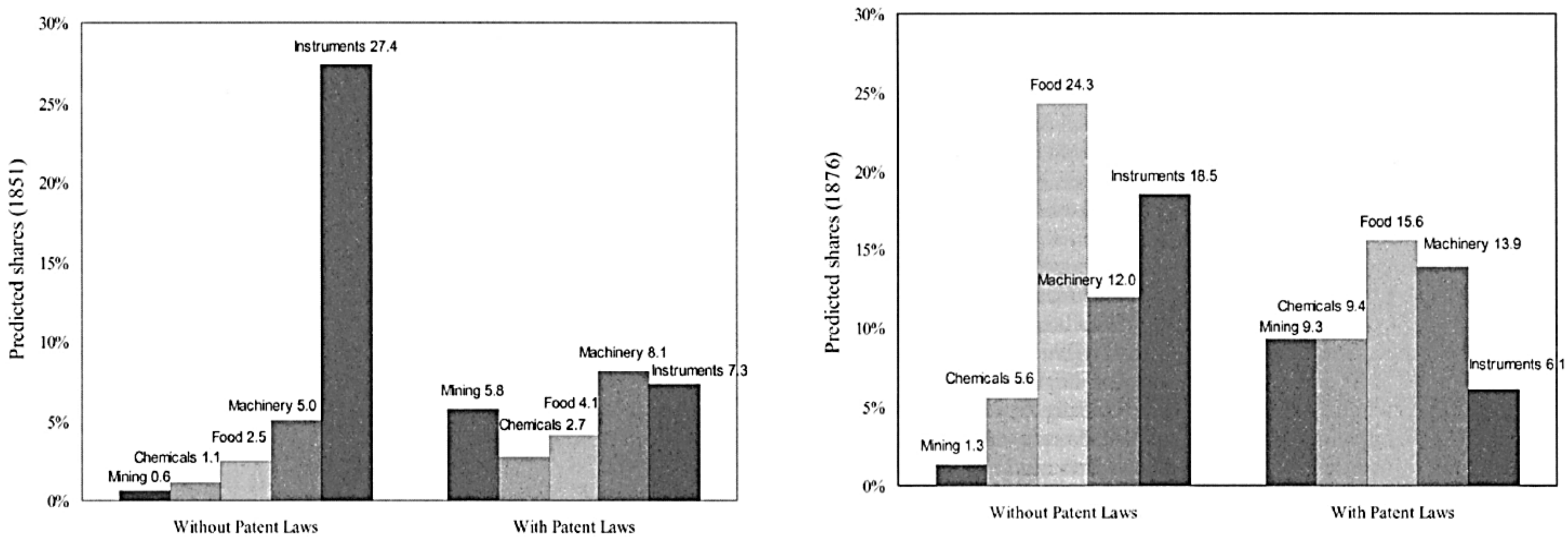
Notes: Patenting rates measure the share of exhibits that are patented. For Britain, innovations with patents are identified as exhibits whose description in the *Official Catalogue* (1851) refers to at least one patent. For the United States, innovations are matched with lists of all patents reported in the *Annual Report of the United States Patent Office* between 1841 and 1851.

From: Moser, "How Do Patent Laws Influence Innovation?"

Figure 2. Predicted Industry Shares, 1851 and 1876



From: Moser, “How Do Patent Laws Influence Innovation?”

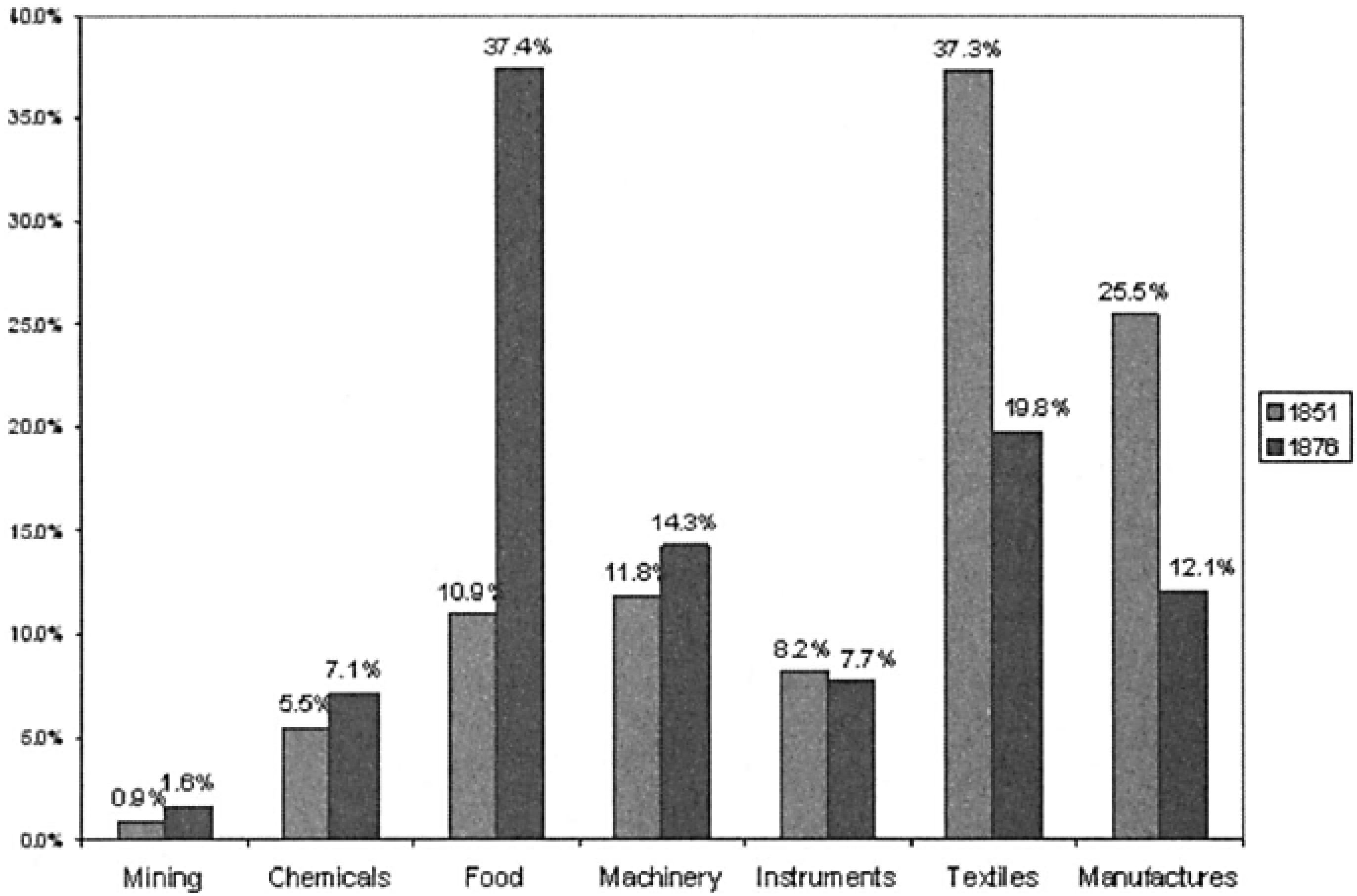
Causation

- Moser wants to interpret evidence as showing that lack of patenting skews investment toward instruments and processed foods.
- But, are there other explanations?
  - Small sample; perhaps there were idiosyncratic factors.
  - Perhaps there is path dependence. Switzerland started making watches for a random reason and then continued to innovate in that area.
  - Perhaps there is reverse causation.

The Netherlands as a Natural Experiment

- Abolished their patent laws between the two fairs.
- Moser says for relatively exogenous reasons.
- What happens to composition of innovation?

FIGURE 3. DUTCH INNOVATIONS ACROSS INDUSTRIES BEFORE AND AFTER THE ABOLITION OF PATENT LAWS IN 1869



From: Moser, "How Do Patent Laws Influence Innovation?"

Evaluation of Moser?

IV. Peter Thompson

"How Much Did the Liberty Shipbuilders Learn? New Evidence for an Old Case Study"

Learning-by-Doing

- Innovation as a side-effect of production.
- Production makes it easier to innovate – like an outward shift in the “supply curve” of innovation.
- May have implications involving externalities, amplification mechanisms, and endogenous growth.

Liberty Ships as a Case Study

- Liberty ships were viewed as a relatively homogenous commodity produced in large quantity with few changes in production processes (other than ones resulting from learning-by-doing).

- Previous evidence from Liberty ships was important in shaping views about learning-by-doing.

An Economics 210A Field Trip?

From: tripadvisor.com

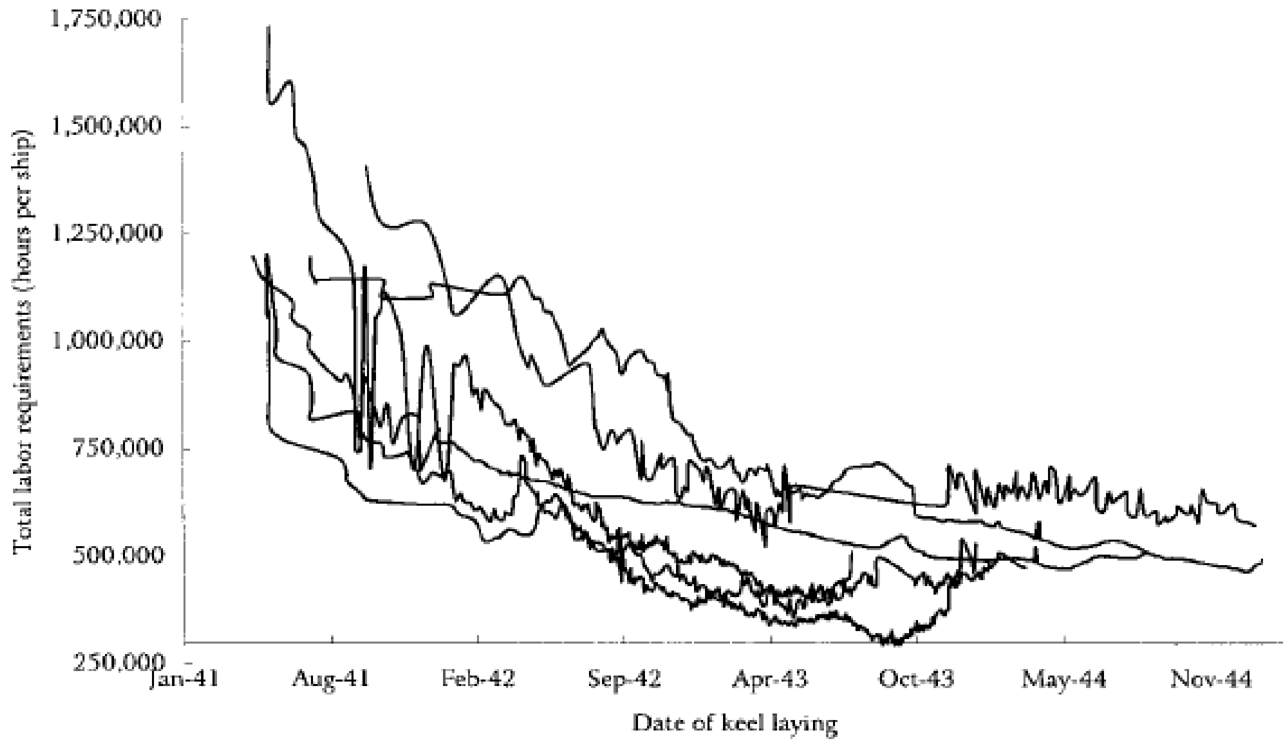


FIG. 1.—Standard Liberty ships labor productivity, six yards. The six yards are those for which capital data are available and that form the focus of study in this paper. See Searle (1945), Lane (1951), or Lucas (1993) for graphs of other yards. All ships delivered incomplete or modified are excluded.

From: Thompson, "How Much Did the Liberty Shipbuilders Learn?"

Previous Estimates

$$\ln y_{it} = A + \lambda t + \alpha \ln W_{it} + \beta \ln L_{it} + \gamma \ln Y_{it} + \varepsilon_{it},$$

where:

- *i* indexes shipyards and *t* indexes time;
- *y* is output;
- *W* is “ways” (loosely speaking, construction berths);
- *L* is person-hours;
- Y_{it} is cumulative output at yard *i* before period *t*.

Argote, Beckman, and Epple (1990) find $\hat{\gamma} = 0.44$.

Thompson's Concerns

- Increases in capital over time.
- Reductions in quality over time.

Suggestive Evidence of the Importance of Capital

- About two-thirds of the overall investment done after shipbuilding had started.

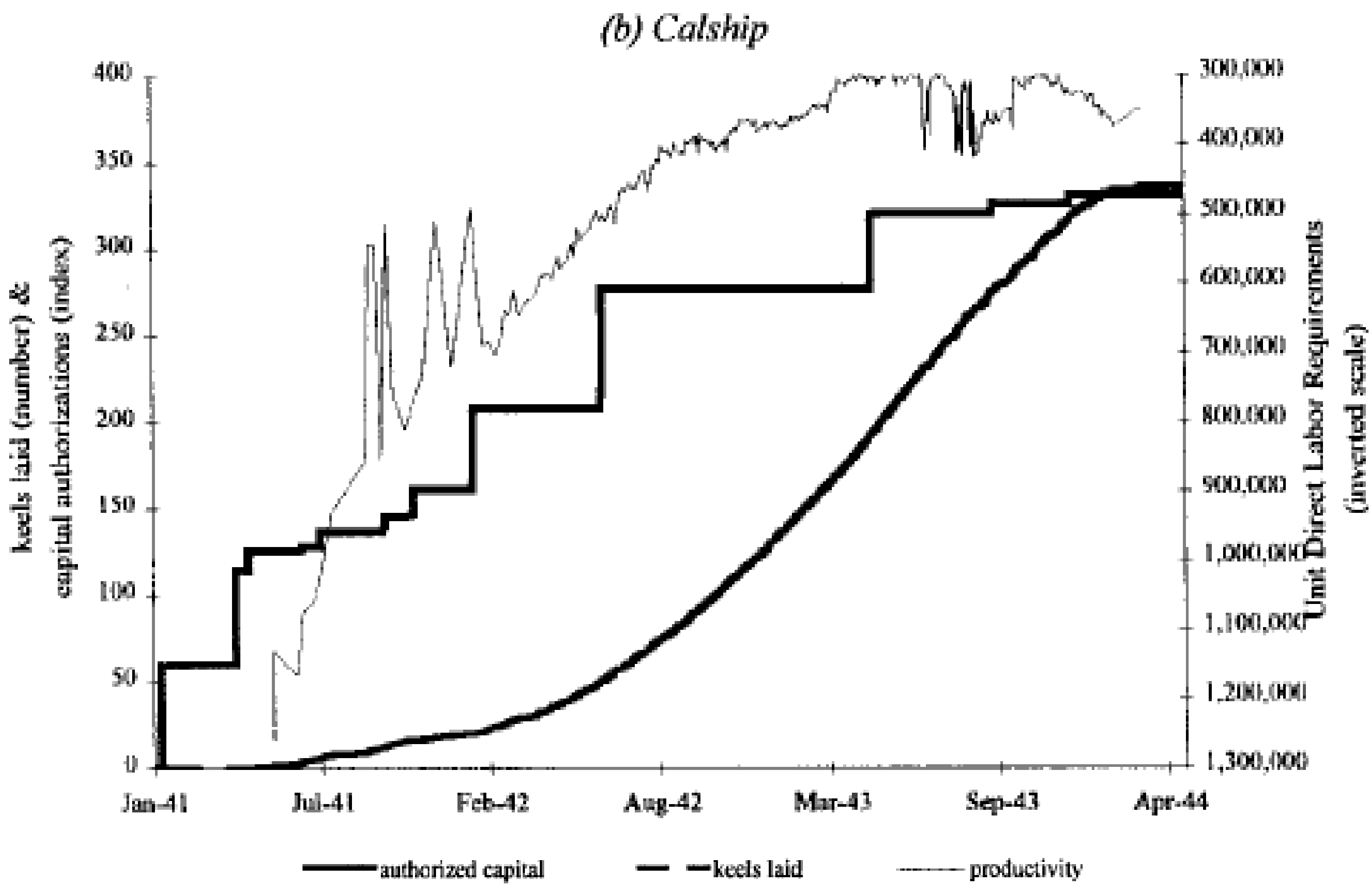


FIG. 3.—Capital, experience, and unit labor requirements, six yards

From: Thompson, "How Much Did the Liberty Shipbuilders Learn?"

Suggestive Evidence of the Importance of Capital

- About two-thirds of the overall investment done after shipbuilding had started.
- Anecdotal evidence of the importance of capital.
- There were large differences in capital across shipyards, and yards with more capital were more productive.

TABLE 1

FACILITIES PER WAY FOR SEVEN YARDS

	Crane Capacity (Tons per Way)	Equipment (Thousands of Dollars per Way)	Prefabrication Plant (Thousands of Square Feet per Way)
	A. Four Yards with Above-Average Productivity in the 12th Round		
Calship	34.3	679	27.7
North Carolina	44.7	765	30.2
Oregon	46.5	689	66.4
Permanente	40.0	593	53.7
Four-yard average	41.4	682	44.5
	B. Three Yards with Below-Average Productivity in the 12th Round		
Bethlehem-Fairfield	34.0	811	33.4
New England	22.4	579	17.2
Todd-Houston	24.7	286	32.7
Three-yard average	27.0	558	27.7

SOURCE.— Fischer (1948, table 1).

NOTE.—Productivity comparisons are made for the twelfth round of the ways. Planners at the USMC typically thought in terms of "rounds of the ways." The first ship produced on a particular way belongs to the first round, the second ship to the second round, and so on. It has long been standard practice to compare productivity across yards by averaging over all ships built in a yard at a particular round of the ways, even though the dates on which each yard reached that round varied.

From: Thompson, "How Much Did the Liberty Shipbuilders Learn?"

Another Economics 210A Field Trip?

From: wikipedia.org

Thompson's Estimation

$$\ln y_{it} = A_i + \alpha \ln K_{it} + \beta \ln L_{it} + \gamma \ln E_{it} + \varepsilon_{it},$$

where:

- *K* is capital;
- *E* is experience;
- The rest of the notation is the same as before.

Some Measurement Issues

- From authorized capital spending to the capital stock.

- For K, Thompson uses either the estimated capital stock or the estimated capital stock times estimated capital utilization.

- For E, Thompson uses either cumulative output before period t or cumulative labor-hours before period t.

Is OLS OK?

- <u>Perhaps</u> this is a (rare!) case where it's reasonable.

TABLE 2
SURE PRODUCTION FUNCTION ESTIMATES (EXPERIENCE PROXY: CUMULATIVE OUTPUT)

	RAPPING (1)	ARGOTE ET AL. (2)	DEPENDENT VARIABLE: LOG MONTHLY OUTPUT IN SHIP EQUIVALENTS (3)	(4)	(5)	(6)
Log experience (cumulative output)	.110 (.013)	.44 (.03)	.493 (.025)	.481 (.027)	.291 (.045)	.263 (.037)
Log authorized ways	.293 (.096)	1.15 (.05)	...	...	...	...
Log operating ways	...	...	...	.274 (.236)	...	...
Log capital, K_{it}	...	...	...	...	.743 (.180)	.780 (.154)
Capacity utilization weight, $w_{it} = (6 + S_{it})/7$	...	...	...	...	...	.780 (.154)
Log labor hours	1.11 (.032)	.18 (.04)	.414 (.061)	.422 (.061)	.414 (.057)	.253 (.088)
Wald tests (p-values):						
Col. 3	...	...	...	.656	.000	.000
Col. 4	...	...	...	...	.000	.000
Adjusted R^2	.967	.990	.925	.922	.919	.711
Observations	48	337	182	182	182	149

From: Thompson, "How Much Did the Liberty Shipbuilders Learn?"

TABLE 3
SURE Production Function Estimates (Experience Proxy: Cumulative Employment)

	Dependent Variable: Log Monthly Output in Ship Equivalents			
	(3)	(4)	(5)	(6)
Log experience (cumulative labor hours)	.359 (.040)	.355 (.038)	.228 (.038)	.208 (.050)
Log operating ways	...	−.278 (.299)	...	...
Log capital, K_{it}	...	...	1.040 (.127)	1.117 (.165)
Capacity utilization weight, $w_{it} = (6 + S_{it})/7$	...	...	...	1.117 (.165)
Log labor hours	.542 (.074)	.566 (.072)	.462 (.065)	.343 (.086)
Wald tests (p-values):				
Col. 3		.902	.001	.003
Col. 4	...	...	.001	.004
Lowest adjusted R^2	.905	.901	.98	.716
Observations	177	177	177	149

From: Thompson, "How Much Did the Liberty Shipbuilders Learn?"

An Alternative to Regressions to Find the Role of Increases in *K/L*: "Liberty Ship Growth Accounting" – Initial Steps

- Assume that by late in the war, $\mathrm{MPK}/r = MPL/w$ (where *r* is the user cost of capital).
- Assume Cobb-Douglas production, $Y_{it} = A_{it}{K_{it}}^{\alpha}{L_{it}}^{1-\alpha}$.
- Algebra yields: $\frac{\alpha}{1-\alpha} = \frac{r_{it}K_{it}}{w_{it}L_{it}}$.

"Liberty Ship Growth Accounting" – Implementation

- Find *r* , *K*, *w*, and *L* late in the war.

- Infer α.

- Calculate the implied series for $\ln A_{it}$.

- Use this as the dependent variable in regressions (in the extreme, with only a constant and a measure of experience on the right-hand side).

“Liberty Ship Growth Accounting” – Advantages and Disadvantages Relative to Finding Capital’s Contribution by OLS?

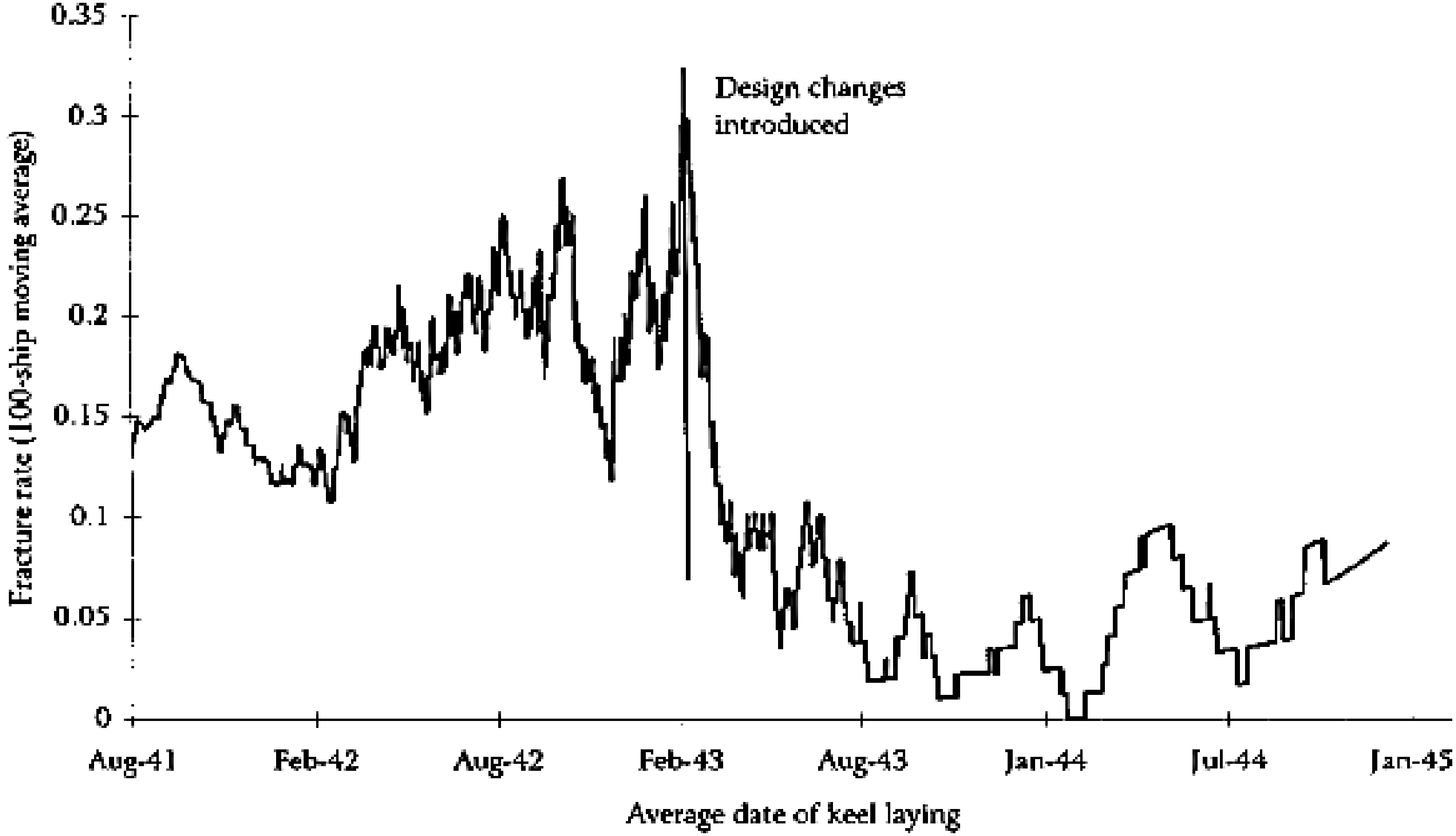


FIG. 6.—Observed fracture rates. The figure was constructed by ordering all ships, irrespective of yard, by date of keel laying. The fracture rate is a moving 100-ship window measuring the fraction of all the ships within the window that eventually produced fractures.

From: Thompson, "How Much Did the Liberty Shipbuilders Learn?"

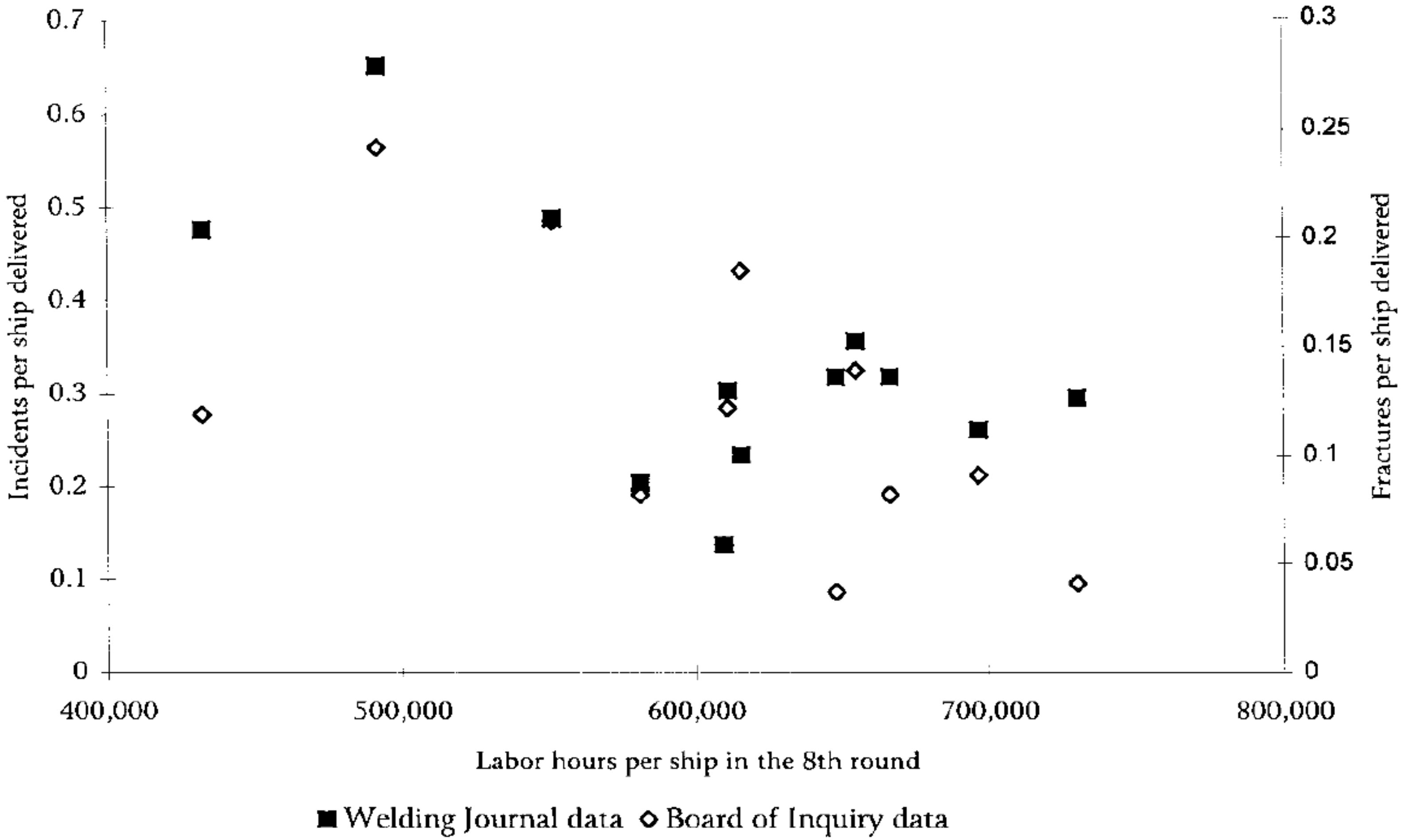


FIG. 7.—Fracture rates and productivity

From: Thompson, "How Much Did the Liberty Shipbuilders Learn?"

Importance of Quality Adjustment

"Even with these upper limits, the effects of quality adjustment on the productivity numbers are modest. …The unadjusted productivity increase is 122 percent and the adjusted productivity increase is no less than 113 percent; thus the raw data contain a measurement error equivalent to no more than 6 percent of measured productivity growth."

Conclusion

- Thompson's view: "it does seem reasonable to draw one conclusion from the Liberty ship program that is likely to resonate elsewhere: in a case study that is widely viewed as one of the cleanest examples of learning by doing on record, the real causes of productivity growth have turned out to be more complex and more diverse than economists have long believed to be the case."

- Do you agree?