Crisis Innovation

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Motivation

How do crises affect innovative activity?

Theoretically ambiguous

- **Bad**: "missing generation" of highly productive entrants (Gourio et al. 2016)
- **Good**: more efficient organizational forms/projects; increase in creativity (Schumpeter 1942; Caballero et al., 1994; Manso et al., 2019)

Empirical evidence is mixed

- **Bad**: Exposed firms have lower quantity and quality of innovation (Nanda and Nicholas 2014; Huber 2018)
- **Good**: Aggregate data show increase in important innovations (Field 2003; Kelly et al. 2019)

Empirical Challenges

1. **Firm-level vs. aggregate estimates**
   - Identification vs. Reallocation (key feature)

2. **Long-run effects w/ slow moving firm dynamics**
   - Reallocation may need time
   - 1/3rd of patents filed in 1920 cited 50+ years later (Lamoreaux et al. 2009)

3. **Current innovative activity geographically concentrated**
   - Especially true for technological entrepreneurship
   - Meaningful variation today in crises difficult

Empirical Challenges: Our Approach

DiD: Variation in severity of Great Depression, compare patenting before/after

1. **Firm-level vs. aggregate estimates**
   - County-level w/ universe of US patents 1900–2015
   - Bank distress (and housing wealth) for severity
   - Captures local reallocation in period when county = closer to GE

2. **Long-run effects w/ slow moving firm dynamics**
   - Create new measure of tech entrepreneurship w/ unassigned patents
   - 80+ years of post crisis outcomes including citations of future patents
   - Longitudinally matched inventor data to examine reallocation

3. **Current innovative activity geographically concentrated**
   - In 1920s predominant form of patenting was outside the firm
   - Ecosystems supporting tech entrepreneurship ubiquitous across U.S.

Summary of Findings

1. **Quantity of innovation falls for entrepreneurs, but not firms**
   - Causes total decline
2. **Reallocation of innovation into firms**
   - No significant departures of inventors out of distressed areas
   - Observe inventors moving into firms
3. **Quality of innovation rises a lot**
   - Increase in average citations/patent
4. **Surprising resilience of innovation**

Setting and Data

Data Sources

- **Bank Distress**
  - Annual county-level active & suspended banks/deposits, 1920–36 (FDIC)
  - *Bank Distress*$_c$ = 1 if county more than 1 suspension 1930–33 (mean = 71%)
- **Patents**
  - Universe of USPTO-approved patents: 9 million over 1830–2015
  - Filing and grant date
  - Inventors' name and their location, assignee's name (if assigned)
  - Citations by future patents: 1911–2015
  - Patent technology classification (e.g. electricity)
- **Complete count US Censuses of 1910, 1920, 1930, 1940**
  - Match 70% ($\sim$500K) of US inventors in 1905–1944 patents
  - Get demographic, geographic, and socio-economic data
  - Create longitudinal individual-level data over 1905–1944

Innovation inside vs. outside firms

Two main organizational forms for innovation (Lamoreaux, Sokoloff, 2005; Nicholas, 2010)

1. **Firms**
   - Main organizational form today (87%–1990s)
   - Patents assigned to firms
   - Commercialize innovation internally
2. **Independent inventors (i.e., entrepreneurial innovation)**
   - Main organizational form 100 years ago (78%–1900s)
   - Patents unassigned or assigned to inventor/other individual
   - Financed with local wealthy capital
   - Either sell patents to big firms or commercialize in own startups

Firm Patent Example: General Electric's Light Bulb

A. SWAN.
INCANDESCENT LAMP.
APPLICATION FILED JUNE 7, 1905.

905,478. Patented Dec. 1, 1908.

Fig. 1.

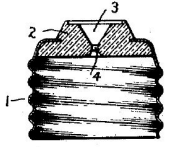
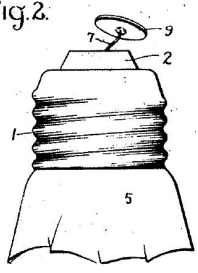
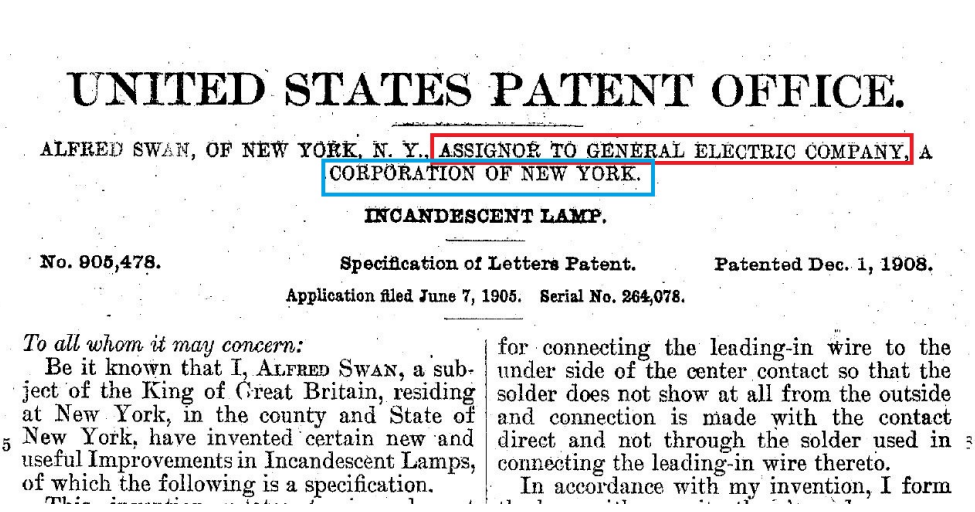


Fig. 2.



Firm Patent Example: General Electric's Light Bulb



UNITED STATES PATENT OFFICE.

ALFRED SWAN, OF NEW YORK, N. Y., ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

INCANDESCENT LAMP.

No. 905,478. Specification of Letters Patent. Patented Dec. 1, 1908.

Application filed June 7, 1905. Serial No. 264,078.

To all whom it may concern:

Be it known that I, ALFRED SWAN, a subject of the King of Great Britain, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Incandescent Lamps, of which the following is a specification.

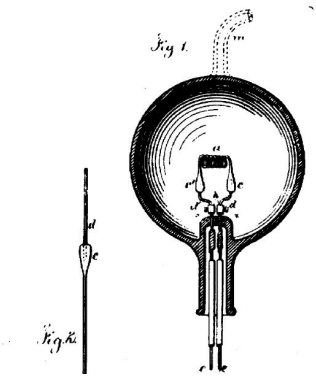
for connecting the leading-in wire to the under side of the center contact so that the solder does not show at all from the outside and connection is made with the contact direct and not through the solder used in connecting the leading-in wire thereto.

In accordance with my invention, I form

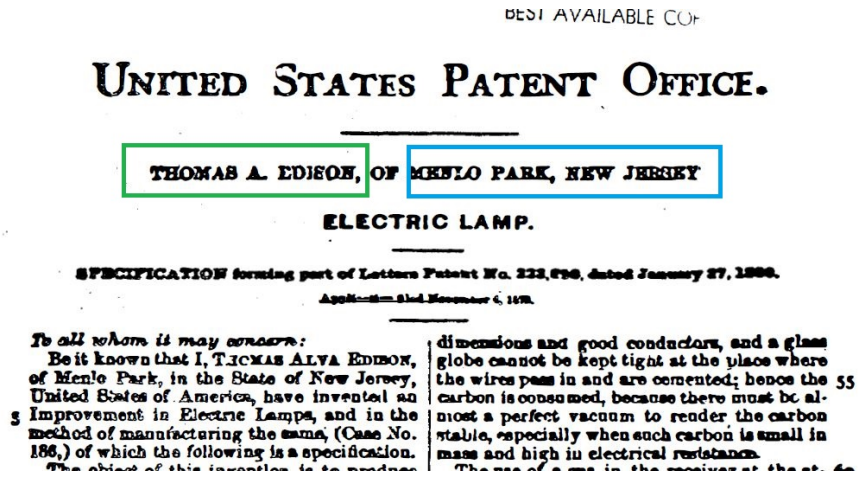
Independent Patent Example: Thomas Edison's Light Bulb

T. A. EDISON.
Electric-Lamp.

No. 223,898. Patented Jan. 27, 1880.



Independent Patent Example: Thomas Edison's Light Bulb



BEST AVAILABLE COPY

UNITED STATES PATENT OFFICE.

THOMAS A. EDISON, OF MENLO PARK, NEW JERSEY

ELECTRIC LAMP.

SPECIFICATION forming part of Letters Patent No. 223,898, dated January 27, 1880.

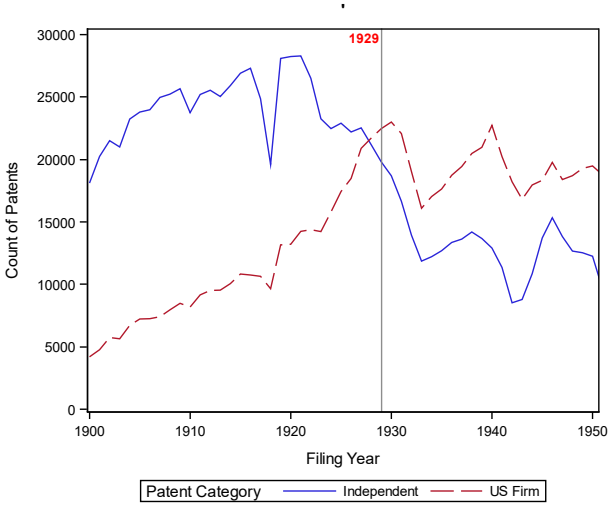
Application filed November 4, 1879.

To all whom it may concern:

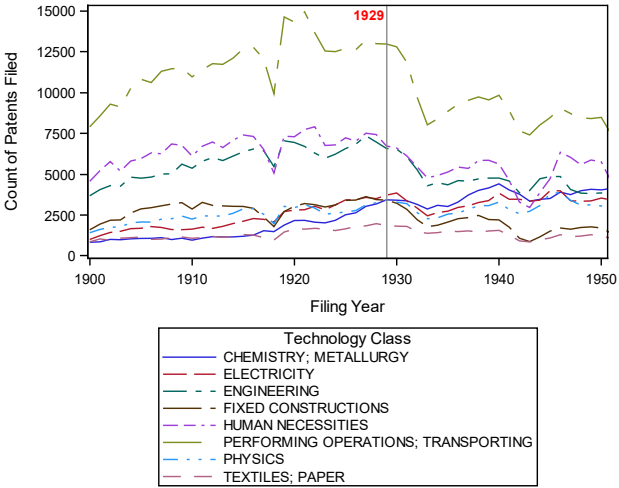
Be it known that I, THOMAS ALVA EDISON, of Menlo Park, in the State of New Jersey, United States of America, have invented an Improvement in Electric Lamps, and in the method of manufacturing the same, (Case No. 186,) of which the following is a specification.

dimensions and good conductors, and a glass globe cannot be kept tight at the place where the wires pass in and are cemented; hence the carbon is consumed, because there must be almost a perfect vacuum to render the carbon stable, especially when such carbon is small in mass and high in electrical resistance.

U.S. Patents 1900-1950



Independent Patents by Technology Class 1900-1950



Empirical Setting

Difference-in-Difference around the Great Depression

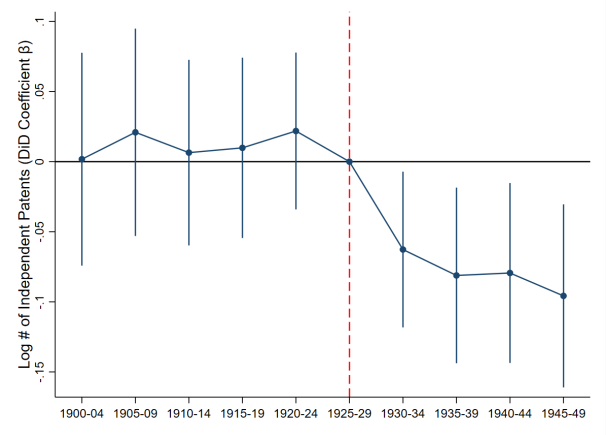
$$Ln(Innovation)_{cst} = \beta \textbf{Bank Distress}_{\textbf{c}} \times \textbf{Post 1929}_{\textbf{t}} + \lambda_c + \gamma_{st} + \gamma' X_{cst} + \epsilon_{cst}$$

- Indices: c – county, s – state, t – time (5-year or decade)
- *Innovation* – county-level patenting: all, firm, or independent
- *Bank Distress* – equals 1 if county has at least one suspended bank over 1930–33
- *Post 1929* – equals 1 for observations starting in 1930
- λ_c – county fixed effects
- γ_{st} – state-by-time
- X - controls (e.g., population)

Patenting Behavior in Aftermath of Great Depression

Independent Patenting Following Great Depression

$$Ln(\#IndependentPatents)_{cst} = \lambda_c + \gamma_{st} + \sum \beta_t \mathbb{1}_t BankDistress_c + \epsilon_{cst}$$



Firms vs. Independents

- Independent declines, but county-level firms don't
- Differs from studies with firm-level data (Nanda and Nicholas 2014, Huber 2019)
- Results aren't inconsistent! We measure local GE effects capturing reallocation

	(1) Ln(# Total Patents+1)	(2) Ln(# Firm Patents+1)	(3) Ln(# Ind. Patents+1)
BankDistress X After1929	-0.105***	0.016	-0.127***
	(-3.42)	(0.60)	(-4.47)
StateXTime FE	Y	Y	Y
County FE	Y	Y	Y
Start Decade	1910	1910	1910
End Decade	1940	1940	1940
Adj R-Sq	0.903	0.896	0.895
Obs	11,900	11,900	11,900

Identification

Identification concerns:

- Omitted variable: technology demand or county characteristics
- Reverse causality: technological entrepreneurship falls, bringing down banks

Identification

Identification concerns:

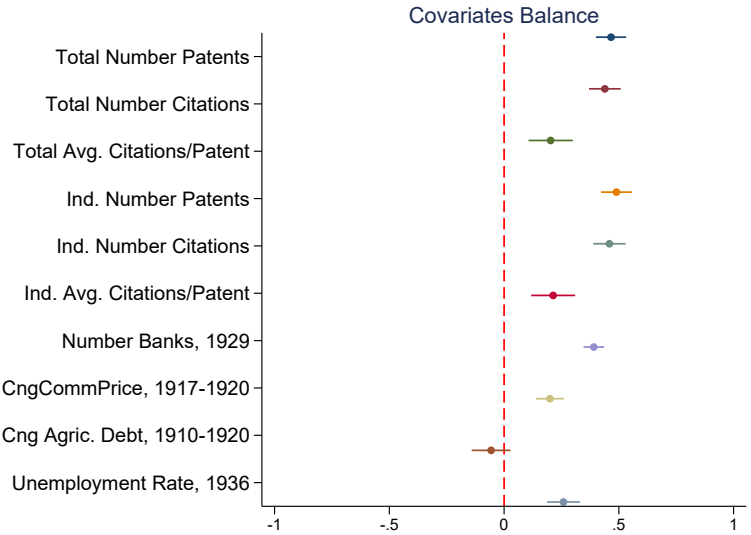
- **Omitted variable: technology demand or county characteristics**
- Reverse causality: technological entrepreneurship falls, bringing down banks

Declines Occur Within Every Major Technology Class

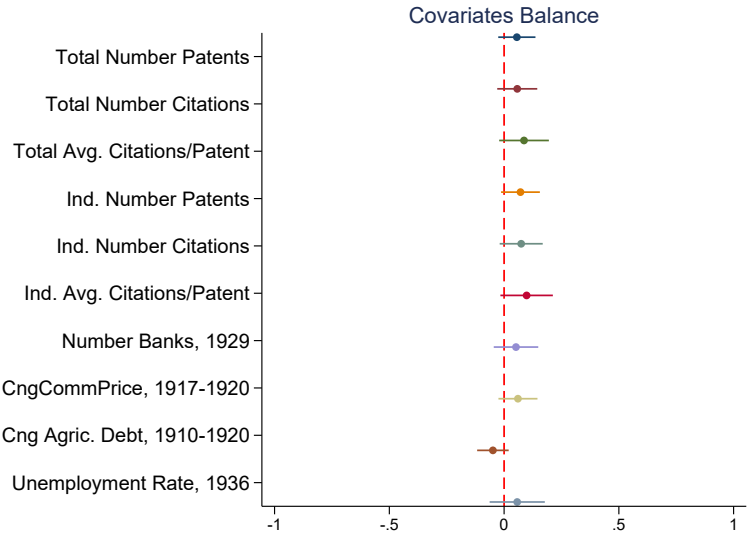
- Reshape patenting data into county-time-technology class panel
- Column 1: same specification as before
- Column 2: add technology-state-time fixed effects
- Column 3–7: main specification by biggest technology classes

	Ln(# Independent Patents+1)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
BankDistress X After1929	-0.140***	-0.140***	-0.142***	-0.156***	-0.151***	-0.148***	-0.101***
	(-8.78)	(-8.72)	(-5.63)	(-5.79)	(-6.65)	(-6.01)	(-5.30)
StateXTime FE	Y	Y	Y	Y	Y	Y	Y
County FE	Y	Y	Y	Y	Y	Y	Y
TechnologyXStateXTime FE	N	Y	N	N	N	N	N
Technology	All	All	A	B	E	F	G
Start Decade	1910	1910	1910	1910	1910	1910	1910
End Decade	1940	1940	1940	1940	1940	1940	1940
Adj R-Sq	0.733	0.830	0.842	0.859	0.789	0.823	0.804
Obs	59,500	59,500	11,900	11,900	11,900	11,900	11,900

Co-variate Balance (20s)



Co-variate Balance (20s) adjusting for population



Robust to various controls

	Ln(# Independent Patents+1)				
	(1)	(2)	(3)	(4)	(5)
BankDistress X After1929	-0.082***	-0.089***	-0.125***	-0.126***	-0.069**
	(-2.78)	(-3.04)	(-4.34)	(-4.40)	(-2.34)
Ln(Population, 1920) X After1929	-0.092***				-0.097***
	(-6.00)				(-5.14)
$<$6 Banks, 1929 X After1929		0.134***			0.042
		(4.92)			(1.33)
Chg Retail Sales, X After1929			-0.041		-0.009
			(-0.64)		(-0.15)
Unemployment, 1936 X After1929				-0.498	2.792
				(-0.31)	(1.49)
StateXTime FE	Y	Y	Y	Y	Y
County FE	Y	Y	Y	Y	Y
Start Decade	1910	1910	1910	1910	1910
End Decade	1940	1940	1940	1940	1940
Adj R-Sq	0.896	0.895	0.892	0.895	0.893
Obs	11,792	11,900	11,764	11,892	11,676

Robust to matching

- Nearest Neighbor matching: state, population, and 1920 ind. patenting

	Ln(# Independent Patents+1)		Ln(# Firm Patents+1)	
	(1)	(2)	(3)	(4)
BankDistress X After1929	-0.128***	-0.130***	-0.019	-0.046
	(-3.02)	(-3.05)	(-0.49)	(-1.10)
StateXTime FE	Y	Y	Y	Y
County FE	Y	Y	Y	Y
Controls	N	Y	N	Y
Start Decade	1910	1910	1910	1910
End Decade	1940	1940	1940	1940
Adj R-Sq	0.832	0.835	0.802	0.801
Obs	3,836	3,712	3,836	3,712

Identification

Identification concerns:

- Omitted variable: technology demand or county characteristics
- **Reverse causality: technological entrepreneurship falls, bringing down banks**

Alternative Shock from WWI to Local Wealth

- 42% of business owners had substantial local land ownership
- WWI agricultural price shock predicts 1930s bank failures

(Alston et al. 1994; Rajan and Ramcharan 2015; Jaremski and Wheelock 2018)

- Not subject to reverse causality concerns

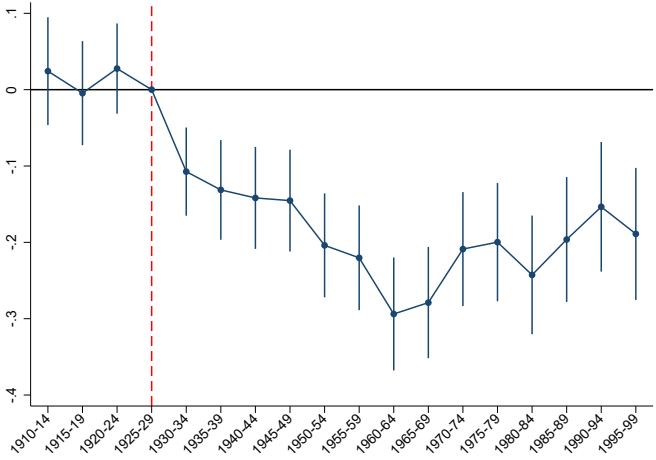
	(1) BankDistress X After1929	(2) Ln(# Ind. Patents+1)	(3) Ln(# Total Patents+1)
CngCommPrice, 1917-1920 X After1929	0.029*** (6.53)	-0.050*** (-7.79)	-0.043*** (-6.26)
StateXTime FE	Y	Y	Y
County FE	Y	Y	Y
Start Decade	1910	1910	1910
End Decade	1940	1940	1940
Adj R-Sq	0.767	0.897	0.905
Obs	11,316	11,316	11,316

Intertemporal Substitution Concerns

- Patenting isn't free
- Maybe distressed county independents still invent, but delay filing till crisis abates?
- If so expect recovery (and short-run spike) in independent patenting after 1930s....

But Decline in Independent Patenting Never Reverses ("hysteresis")

$$Ln(\#IndependentPatents + 1)_{cst} = \lambda_c + \gamma_{st} + \sum \beta_t \mathbb{1}_t BankDistress_c + \epsilon_{cst}$$



Caused “missing generations” of highly productive entrants?

Or

Increase in allocative efficiency?

1) No (Short-run) Changes in Local Stock of Inventors

- Match inventors across US censuses covering 100% of population
- No evidence of cross-county migration out of distressed areas

	(1) Move County	(2) Move County	(3) Move County
Bank Distress	0.003 (0.30)		
Bank Distress %		0.026 (1.30)	
Bank Distress $>$ Med			-0.002 (-0.21)
State FE	Y	Y	Y
Patent Pre	Y	Y	Y
Controls	Y	Y	Y
Adj R-Sq	0.030	0.030	0.030
Obs	66,693	66,693	66,693

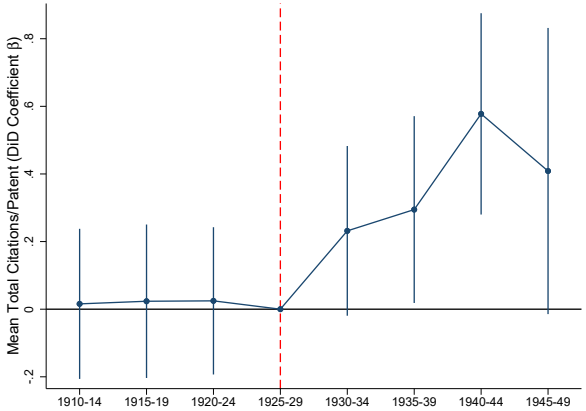
2) Harder-hit Counties See Inventor Migration into Firms

- Inventors who were independent in 1910-1920 move into firms in 1930s
- Cross-organizational (not cross-county) migration

	Patent Within Firm = 1		
	(1)	(2)	(3)
Bank Distress %	0.078**	0.096**	0.090**
	(2.00)	(2.42)	(2.27)
State FE	Y	Y	Y
County Controls	N	Y	Y
Individual Controls	N	N	Y
Adj R-Sq	0.020	0.021	0.027
Obs	5,295	5,294	5,294

3) Overall Patent Quality Improves

$$Ln(\#Citations/\#Patents+1)_{cst} = \lambda_c + \gamma_{st} + \sum \beta_t \mathbb{1}_t BankDistress_c + \epsilon_{cst}$$



- Primarily driven by decline in low citation patents

Conclusion

What Do We Learn?

Bad:

1. Great Depression caused substantial declines in tech entrepreneurship
2. Hysteresis suggests strong persistence in disruptions to innovation "ecosystems"

Good:

1. Strong resilience of innovation (cross-organizational migration)
2. Opportunity for improved allocative efficiency (avg. patent quality rises)

Conclusion:

1. Crises can be both destructive and creative forces for innovation

"depressions are not simply evils, which we might attempt to suppress, but . . . forms of something which has to be done, namely, adjustment to . . . change."

- Schumpeter (1934)

Thank you!