

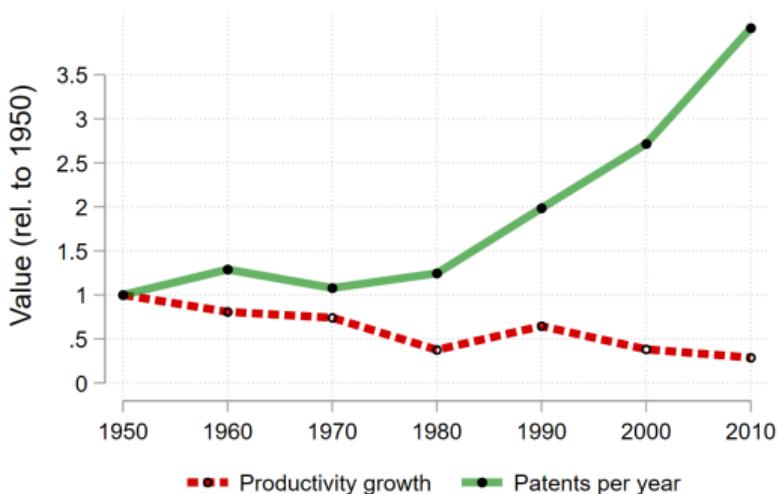
# The creativity decline: Evidence from US patenting

*Job market paper*

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# Patent puzzle: Rise in patenting does not reflect in productivity growth



Notes: Productivity → BEA MFP; USPTO patents by US inventors. Data points by decade.

This paper,

- ▶ Argue that these patterns explained by declining **creativity** in US patenting.
- ▶ Declining creativity partly driven by declining population growth and reducing government support for creative innovations.

## Summary

- ▶ Develop a new text-based measure: patent creativity, to distinguish creative from derivative patenting.
  - ▶ Share of new two-word combinations in a patent.
- ▶ Empirical findings:
  1. Average patent in 2010 is about **half** as creative as a patent in 1980.
  2. At the firm level, productivity growth and market returns associated with **only** creative, not derivative patenting.
  3. Patents by younger inventors and patents receiving government support are **50%** more creative than others.
- ▶ Build a model which fits cross-sections of creativity data, and rationalizes the decline in creativity and productivity growth with falling population growth and government R&D.
  - ▶ Explains about **half** of the decline in creativity and **40%** of slowdown in productivity growth.
  - ▶ Driven by creative advantages of entrants and government subsidized innovations.

## Related literature

- ▶ **Measurement** - Olley and Pakes (1996), Levinsohn and Petrin (2003); Lerner and Seru (2022); Akcigit and Kerr (2018), Acemoglu et al. (2018); Kelly et al. (2021), Hall et al. (2001), Watzinger and Schnitzer (2019), Lanjouw and Schankerman (2004);
  - Creative patenting, the only ex-ante measure which predicts firm level productivity growth.
- ▶ **Role of age and government in innovation** - Acemoglu et al. (2014), Galenson and Weinberg (2000); Galenson and Weinberg (2001); Jones (2010), Jones and Weinberg (2011); Howell (2017), Lerner (1996), Bloom et al. (2002), De Rassenfosse et al. (2019);
  - Micro evidence: patents by younger inventors or funded by govt. are significantly more creative.
- ▶ **Slowdown in research productivity and growth** - Gordon (2012), Bloom et al. (2020); Syverson (2017), Byrne et al. (2016); Aghion et al. (2019), De Ridder (2019), Corhay et al. (2020), Akcigit and Ates (2020), Akcigit and Ates (2021); Jones (2020), Peters and Walsh (2021), Hopenhayn et al. (2018), Karahan et al. (2019);
  - Slowdown partly explained declining creativity from ageing and lack of government support for R&D.
- ▶ **Innovation and diffusion models** - Kortum (1997), Luttmer (2007); Lucas Jr and Moll (2014), Perla and Tonetti (2014), Benhabib et al. (2021), Luttmer (2012);
  - Develop and quantify a model of creativity with subsequent diffusion.

# Overview

Measurement

The creativity decline

Creativity and productivity growth

Drivers of declining creativity

Model

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## Measurement

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## PatentCreativity: Share of new technical two-word combinations

- ▶ Full text (title, abstract, description, claim) of patents filed by US inventors (1976-2014).
- ▶ Decompose text into two word combinations - bigrams. (7,445/patent)
- ▶ Remove bigrams in magazines/articles using Corpus of Historical American English.
  - ▶ Remaining 'technical bigrams' (423/patent).
- ▶ Classify bigram as creative if not in any patent from previous 5 years. (44/patent)
- ▶  $\text{Patent creativity}_p = \frac{\# \text{ creative technical bigrams}_p}{\# \text{ technical bigrams}_p}$ . Normalized such that sample average is 1.

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# Examples: 'Web browser' IBM patent (patent creativity: 3.1, top 2%)

**United States Patent [19]**  
**Rogers et al.**

[54] **WEB BROWSER SYSTEM**

[75] Inventors: **Richard Michael Rogers, Beacon, N.Y.; Konrad Charles Lagarde, Milford, Conn.**

[73] Assignee: **International Business Machines Corporation, Armonk, N.Y.**

[21] Appl. No.: **479,481**

[22] Filed: **Jun. 7, 1995**

[51] Int. Cl.<sup>6</sup> ..... **G06F 15/00**

[52] U.S. Cl. ..... **395/200.32; 395/200.79**

[58] Field of Search ..... 395/600, 200.1-200.21, 395/200.32, 200.79

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,274,139	6/1981	Hodgkinson et al.
4,468,728	8/1984	Wang .
4,604,710	8/1986	Amezua et al. .
4,714,989	12/1987	Billings .
4,714,995	12/1987	Materma et al. .
4,774,655	9/1988	Kollin et al. .
5,093,911	3/1992	Parks et al. .
5,179,652	1/1993	Rozmanith et al. .
5,181,017	1/1993	Frey, Jr. et al. .
5,224,098	6/1993	Bird et al. .
5,241,625	8/1993	Epard et al. .
5,278,978	1/1994	Demers et al. .
5,297,249	3/1994	Bernstein .
5,307,456	4/1994	MacKay .
5,355,472	10/1994	Lewis .
5,499,364	3/1996	Klein et al. .... 395/200.03
5,530,852	6/1996	Meske, Jr. et al. .... 395/600
5,537,546	7/1996	Sautay ..... 395/200.01

OTHER PUBLICATIONS

'Firewalls and Internet Security Repelling the Wily Hacker' by Cheswick et al Chapters 3 & 4.  
'Microsoft Press Computer Dictionary' Nov. 01, 1993 p. 209.

[11] Patent Number: **5,793,964**  
[45] Date of Patent: **Aug. 11, 1998**

"The Harvest Information Discovery & Access System" Bowman et al 17. Sep. 1994.

Let your Agent Handle it by Dan. Richman. Information Week n523, p. 44 Apr. 17. 1995.

Harvest: A Scalable Customizable Discovery & Access System Bowman et al. Aug. 26. 1994. Technical Report CU-CS-732-94.

About CUSL by Nexor. Martijn Koster 1993. Webmaster@Nexor.co.uk.

Finding What People Want: Experiences with The Web-Crawler Brian Pinkerton. 1994. The 2nd International WWW Conference:Mosaicuserweb.

Internet Resource Discovery Services. Obraczka et al. 1993 pp. 8-22.

Adventure With The WorldWide Web by James Powell. 1994.

(List continued on next page.)

Primary Examiner—Ayaz R. Sheikh

Assistant Examiner—Paul R. Myers

Attorney, Agent, or Firm—Lynn L. Augspurger

[57] **ABSTRACT**

A World Wide Web browser makes requests to web servers on a network which receive and fulfill requests as an agent of the browser client organizing distributed sub-agents as distributed integration solution (DIS) servers on an intranet network supporting the web server which also has an access agent servers accessible over the Internet. DIS servers execute selected capsule objects which perform programmable functions upon a received command from a web server control program agent for retrieving, from a database gateway coupled to a plurality of database resources upon a single request made from a Hypertext document, requested information from multiple data bases located at different types of databases geographically dispersed, performing calculations, formatting, and other services prior to reporting to the web browser or to other locations, in a selected format, as in a display, fax, printer, and to customer installations or to TV video subscribers, with account tracking.

# Examples: Derivative ‘Web browser’ patent (creativity: 0.35, bottom 25%)

(12) **United States Patent**  
Himmel et al.

(10) Patent No.: **US 6,453,342 B1**  
(45) Date of Patent: \*Sep. 17, 2002

(54) **METHOD AND APPARATUS FOR  
SELECTIVE CACHING AND CLEANING OF  
HISTORY PAGES FOR WEB BROWSERS**

(75) Inventors: **Maria Azua Himmel; Herman  
Rodriguez**, both of Austin, TX (US)

(73) Assignee: **International Business Machines  
Corporation**, Armonk, NY (US)

(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 0 days.

This patent is subject to a terminal dis-  
claimer.

(21) Appl. No.: **09/204,922**

(22) Filed: **Dec. 3, 1998**

(51) Int. Cl.<sup>7</sup> ..... **G06F 15/167**

(52) U.S. Cl. ..... **709/213; 709/216; 711/135**

(58) Field of Search ..... 709/230, 231,  
709/213, 216; 711/135, 136, 139

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,774,660 A	6/1998	Brendel et al.	.....	395/200
5,787,470 A	7/1998	DeSimone et al.	.....	711/214

6,070,184 A \* 5/2000 Blount et al. .... 709/200  
6,269,403 B1 \* 7/2001 Andrs ..... 709/231  
6,314,492 B1 \* 11/2001 Allen et al. ..... 711/135

OTHER PUBLICATIONS

Cache tag ver. 1.4 http://coldjava.hypermart.net/servlets/  
cachetag No date.\*

Claa ClearCache http://www.nada.kth.se/projects/prup98/  
web\_proxy/doc/rabbit/meta/ClearCache No date.\*

\* cited by examiner

*Primary Examiner*—Mehmet B. Geckil

(74) Attorney, Agent, or Firm—Duke W. Yee; Jeffrey S.  
LaBaw

(57) **ABSTRACT**

A method and apparatus in a **data processing** system for  
**selectively caching** **web information** in a cache for a  
browser. **Web content** is first retrieved by the browser during  
a **browsing session**. The **web content** is parsed for an  
indication of how the page should be stored. The **web**  
**content** is then stored using the indication. For example,  
retrieved **web content** may be parsed for an indication that  
the **web content** is to be removed after the **browsing session**  
**terminates**. Responsive to identifying the indication, the **web**  
**content** is cleared from the cache in response to the **browsing**  
**session terminating**.

## Examples: General motor co. creative and derivative patent

Figure: Planar micro motor with bifilar micro coils  
- Filed: 1993; Patent creativity: 4.4

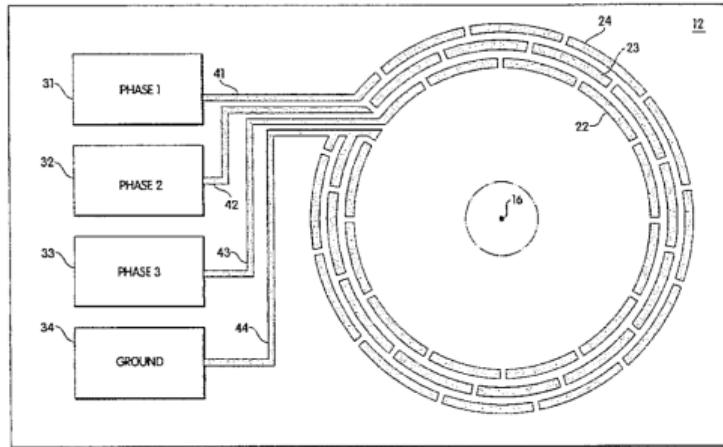
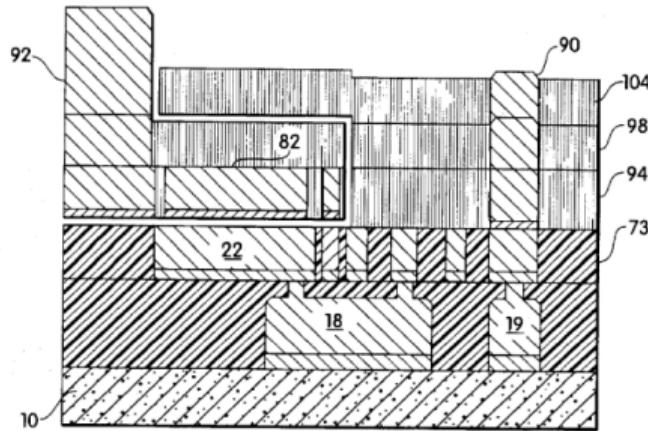


Figure: Self assembly fabrication method for planar micro motor - Filed: 1994;  
Patent Creativity: 1.2



# Examples: Microsoft files a ‘continuation patent’

- ▶ Patent 1: Method and system for displaying internet shortcut icons on the desktop.  
Filed: 1995, Patent creativity: 4.24.

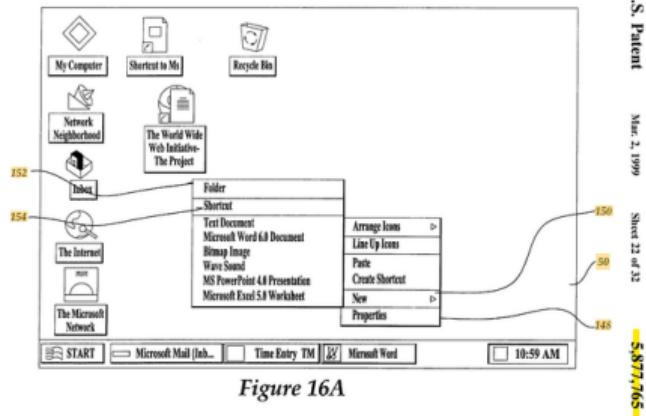


Figure 16A

- ▶ Patent 2: Automatically activating a browser with internet shortcuts on the desktop. Filed: 1999, Patent Creativity: 0

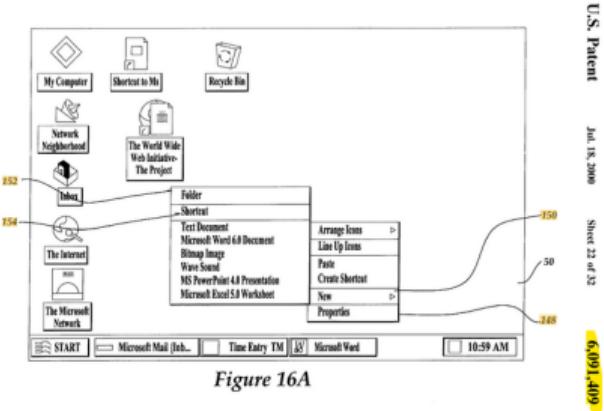


Figure 16A

*"This application (now pat no. 6,091,409) is a continuation application under 37 C.F.R. 1.53(b) claiming priority from U.S. patent application Ser. No. 08/526,314, which is a Continued Prosecution Application ... which claimed the priority filing date of the parent U.S. patent application Ser. No. 08/526,314, which was filed on Sep. 11, 1995, now U.S. Pat. No. 5,877,765."*

# Validation: Management more likely to talk about new products when filing creative patents

- ▶ 68,497 earnings conference calls for about 3,195 patenting firms between 2002-19.
- ▶ Count synonyms of ‘new product introductions’.
- ▶ Example: “*We continue to put our cash to good use the reinvestment in our business through research and development has resulted in a significant number of new product introductions that have dramatically expanded our served addressable market.*” - *Micrel Semiconductor (2010)*

Table: New product introductions in EC

	# earnings with 'new product introductions' <sub>i,t</sub>	
	(1)	(2)
ihs(creative patenting <sub>i,t</sub> )	0.058*** (0.018)	0.049*** (0.018)
ihs(derivative patenting <sub>i,t</sub> )		0.026 (0.016)
<i>R</i> <sup>2</sup>	0.561	0.561
N	12,342	12,342
Year FE	Y	Y
Firm FE	Y	Y

Details

# Validation: Only creative patenting associated with stock returns

- ▶ Rights to new products/features are indicative of higher future profits.
- ▶ Specification:

$$r_{i,t} = \alpha + \beta \text{ ihs(creative patenting}_{i,t}\text{)} \\ + \chi_{i,t} + \epsilon_{i,t}$$

- ▶  $r_{i,t}$  are weekly stock returns,
- ▶  $i$  is one of 4,139 listed firms,
- ▶  $t$  is a week between 1991-2010,
- ▶ Creative if Patent creativity > 2 ( $\sim 20\%$  of patents).
- ▶  $\text{creative patenting}_{i,t}$  granted to firm  $i$  in time  $t$ .
- ▶ Controls for CAPM betas and past R&D spend.
- ▶ Additional creative patent  $\leftrightarrow +3.1\%$  return.

Table: Returns and creative patenting

	Stock Returns $_{i,t}^*$ 100 (weekly)		
	(1)	(2)	(3)
ihs(creative patenting $_{i,t}$ )	0.093*** (0.022)	0.085*** (0.026)	0.082*** (0.025)
ihs(derivative patenting $_{i,t}$ )		0.009 (0.013)	
ihs(derivative patenting $_{i,t}$ - cite wt.)			0.014 (0.013)
ihs(R&D spending $_{i,t}$ )	0.006** (0.003)	0.005* (0.003)	0.005* (0.003)
$R^2$	0.075	0.075	0.075
N	1,816,951	1,816,951	1,816,951
Time FE	Y	Y	Y

Standard errors are clustered by firm.

Details Creativity cut-offs Placebo Measure variations

## Validation: versus other measures of originality

	Stock Returns $_{i,t}^*$ 100 (weekly)			
	(1)	(2)	(3)	(4)
ihs(creative patents $_{i,t}$ )	0.100*** (0.038)	0.087*** (0.026)	0.083*** (0.027)	0.088*** (0.023)
ihs(original patents $_{i,t}$ - bck sim)	0.023 (0.060)			
ihs(original patents $_{i,t}$ - cites HHI)		0.011 (0.042)		
ihs(original patents $_{i,t}$ - academic citations)			0.015 (0.022)	
ihs(original patents $_{i,t}$ - # claims)				0.024 (0.041)
$R^2$	0.062	0.073	0.075	0.075
N	1,214,194	1,706,247	1,816,951	1,816,951
Time FE	Y	Y	Y	Y

Standard errors are clustered by firm.

## Other validation exercises

- ▶ Firms which spend more R&D dollars per patent file more creative patents. [link](#)
- ▶ Creative patents receive higher and more persistent ex-post citations. [higher](#) [persistent](#)
- ▶ Creative patents cite more recent academic papers. [link](#)

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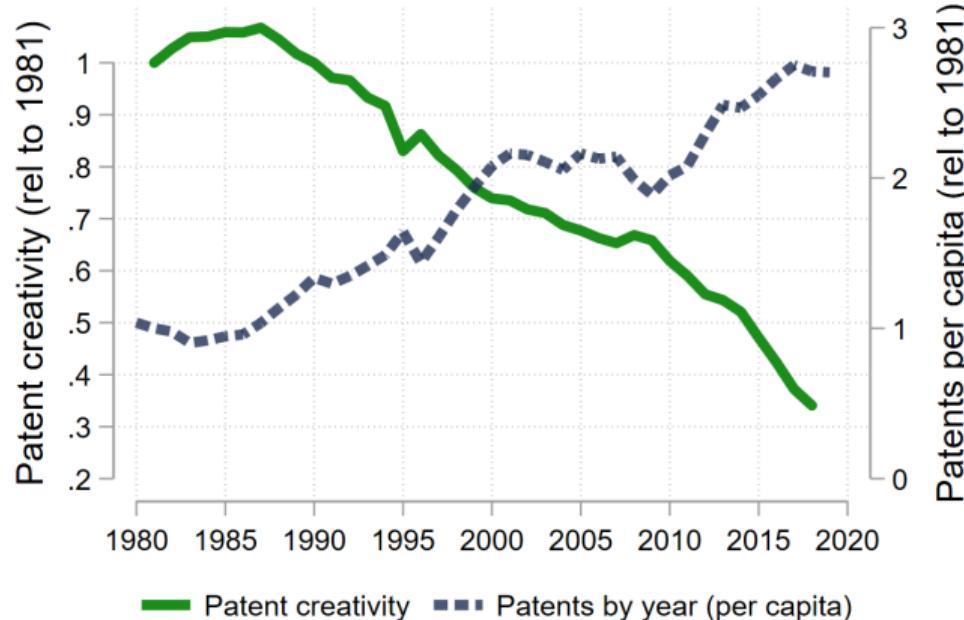
The creativity decline

Creativity and productivity growth

Drivers of declining creativity

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## Creativity decline - Average patent creativity has halved

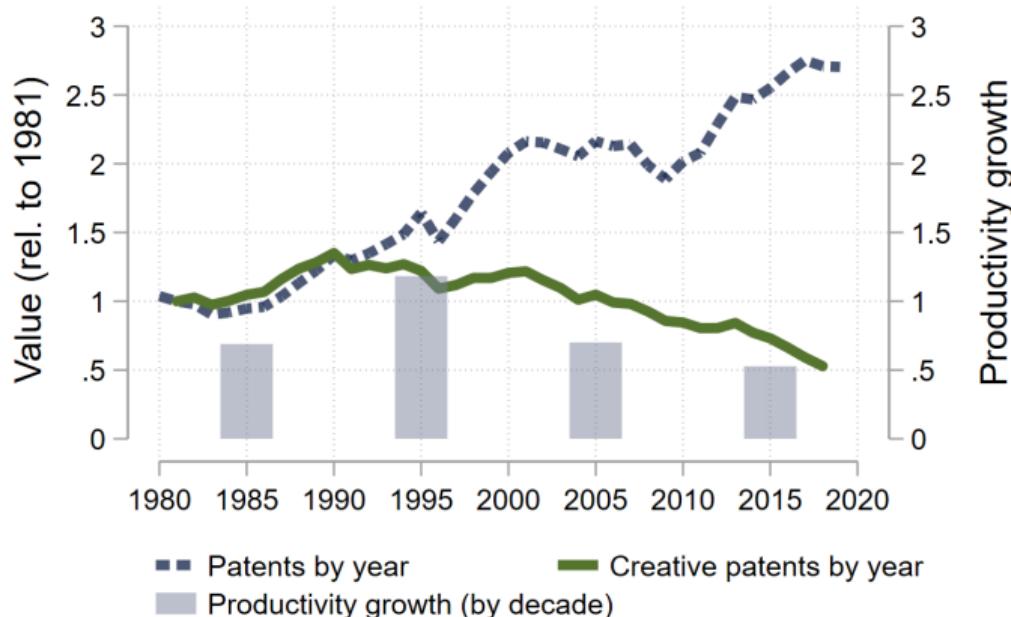


By technology class

Distribution

- ▶ In 1981, 14% of technical bigrams are creative on average across patents which falls to about 7% in 2015.

## Creativity decline strong enough to overturn the rise in patents

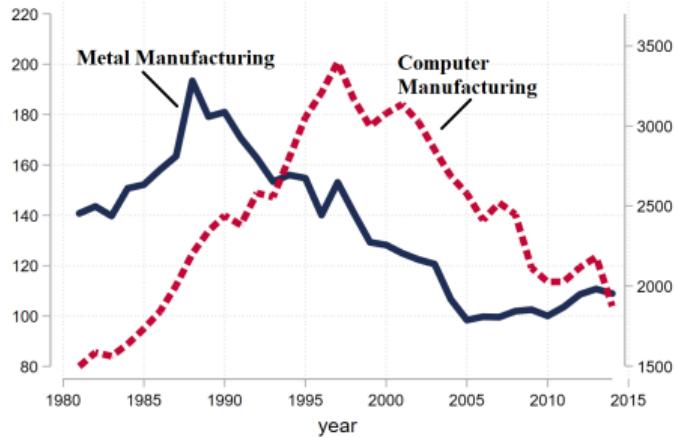


Notes: Productivity → BEA TFP; Patent is creative if patent creativity > 2.

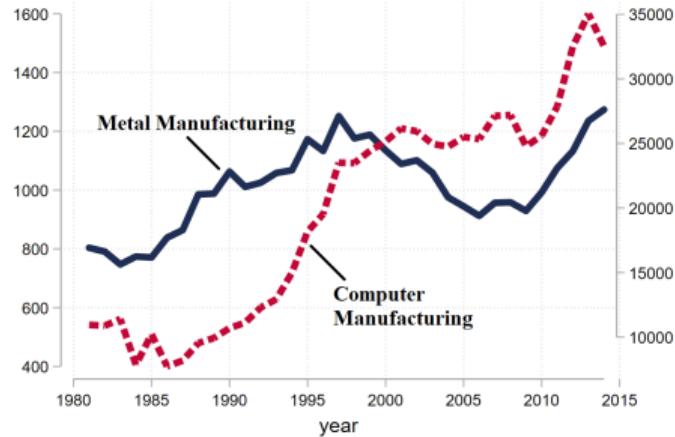
- ▶ Rise in patents entirely driven by derivative patents.

## Example industry patterns: creative and all patents

### Creative patents

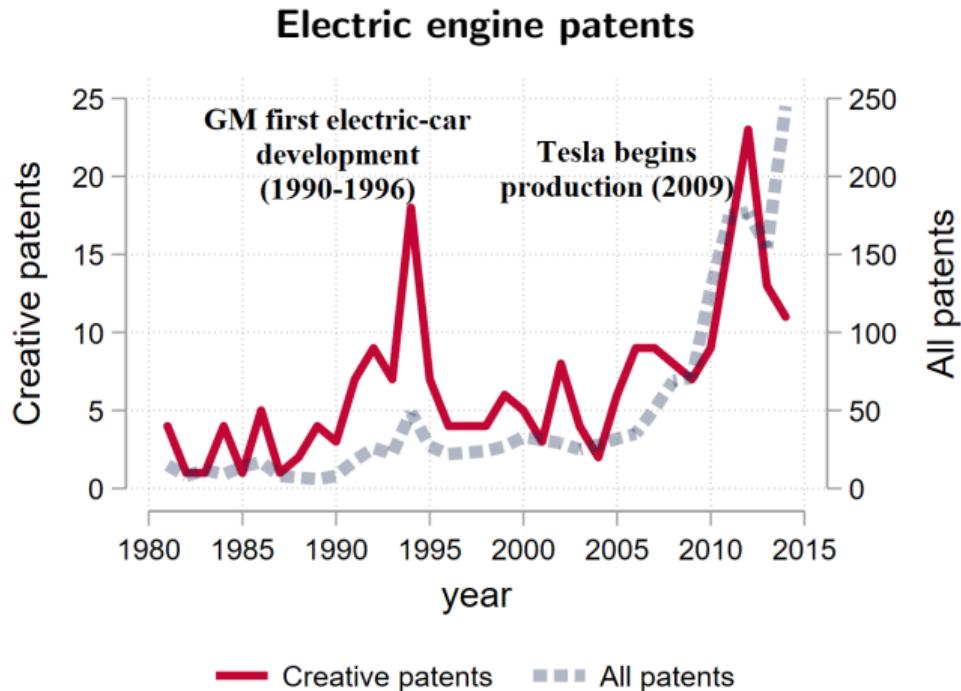


### All Patents



- ▶ Distinct patterns in creative and overall patenting across industries.

## Example product category: Electric engine patents



- ▶ Recent peak in creative electric-engine patents accompanied by more derivative patents.

## Perform checks to ensure the decline in creativity of innovations

- ▶ Increasing patent lengths: Calculate creativity using different sections and just patent titles. [link](#)
- ▶ Convergence in language: Exclude bigrams in Google books (database of 8 million books) and recalculate creativity. [link](#)
- ▶ Heavily litigated (continuation) patenting accounts for only about 10% of decline in creativity. [link](#)

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## Creative patenting and firm level TFP growth

$$\Delta^5 \log(TFP)_{i,t} = \alpha + \beta_1 Ihs(CreativePatenting)_{i,t} + \beta_2 Ihs(R\&D)_{i,t-1} + \chi_{i,t} + \delta_i + \delta_t + \epsilon_{i,t}$$

- ▶ TFP calculated using Olley and Pakes (1996) method.
- ▶  $\Delta^5 \log(TFP)_{i,t}$  is 5-year differences in  $\log(TFP)$ .
- ▶ Patent is creative if Patent creativity > 2 ( $\sim 20\%$  of patents).
- ▶  $\chi_{i,t}$  are polynomial controls for firm age.
- ▶ Standard errors are clustered by firm.
- ▶ Sample of 1,194 manufacturing firms which file at least 10 patents during 1991-2014.

# Creative patenting and firm level TFP growth

	TFP Growth $_{i,t}$ (5-year differences, in pct.)			
	(1)	(2)	(3)	(4)
ihs(creative patents $_{i,t}$ )	0.179*	0.221**	0.217**	
	(0.101)	(0.105)	(0.103)	
ihs(derivative patents $_{i,t}$ )		-0.093		
		(0.107)		
ihs(patents $_{i,t}$ )	0.018			
	(0.102)			
ihs(derivative patents - cite wt. $_{i,t}$ )			-0.083	
			(0.091)	
$R^2$	0.235	0.235	0.235	0.235
N	18,832	18,832	18,832	18,832
Year FE	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y

- ▶ An additional creative patent is associated with 0.17% increase in TFP growth.
- ▶ Similar results for labor productivity and investment rate. [link](#)

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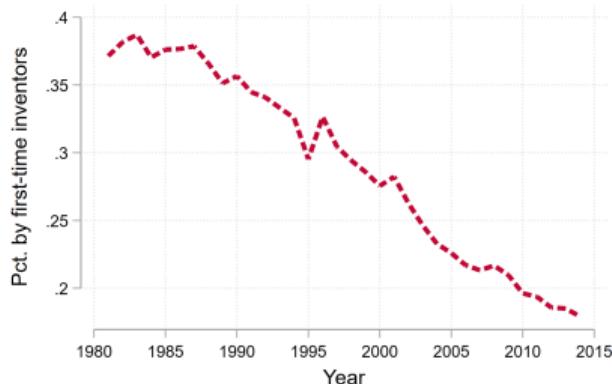
Model

# Declining aggregate population growth and government-involvement

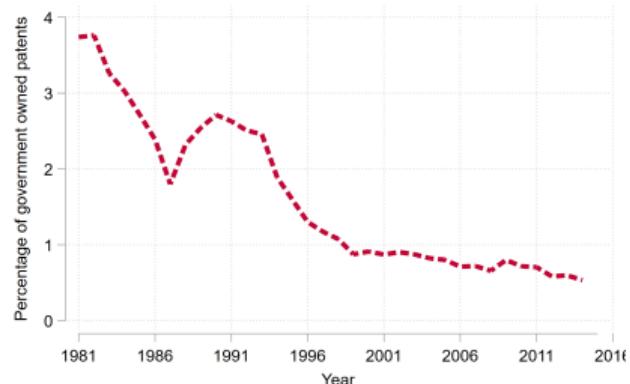
Offer two explanations for declining creativity:

- ▶ Working population growth rate has declined from 2.5% (1950s) to 0.7% (2010s).
- ▶ Government's share of total R&D spend has declined from 20%(1950s) to 10%(2010s). [figures](#)

Pct. patents by first-time inventors

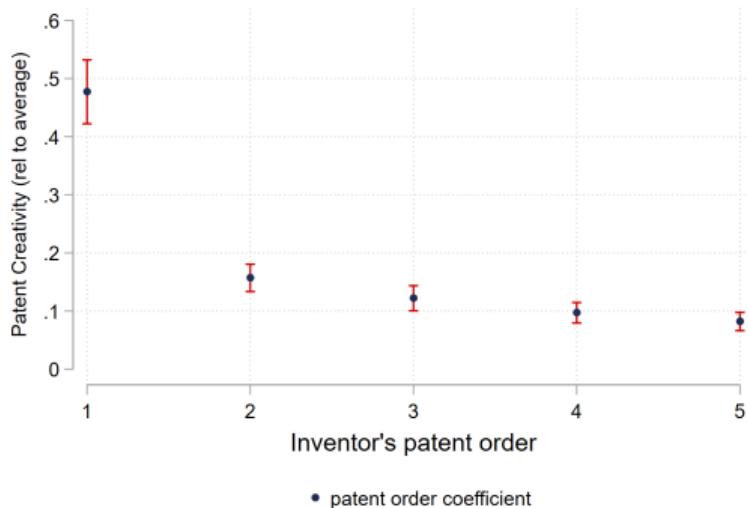


Pct. government owned patents



# Empirical evidence: Creativity drops as inventors patent more

$$\text{Patent Creativity}_p = \alpha + \sum_i \beta_i 1\{\text{Order}_p = i\} + \delta_\tau + \delta_t$$



- ▶ A link between youth and creative innovations.

Coefficient by decade:inventor

Coefficient by decade:govt.

Other types of government involvement

## Empirical evidence: Lesser drop for government funded patents

$$\text{Patent Creativity}_p = \alpha + \sum_i \beta_i \mathbf{1}\{\text{Order}_p = i\} + \sum_i \beta_{i,g} \mathbf{1}\{\text{Order}_p = i, \text{Govt funded}_p = 1\} + \delta_\tau + \delta_t$$



- ▶ Government funds more ex-ante creative than derivative innovations.

Coefficient by decade:inventor

Coefficient by decade:govt.

Other types of government involvement

Failures mechanism

## What are the aggregate consequences of declining population growth and government support for novel research?

So far,

- ▶ Within firm productivity benefits of creative innovations.
- ▶ Cross-sectional creative advantage of younger and government-funded patents.

Rest of the talk, a growth model:

- ▶ Account for larger benefits of creative innovations through subsequent diffusion.
- ▶ Entrants and government funded research have creative advantages → Cross-sectional.
- ▶ Perform counterfactuals with changing pop. growth and government funding.

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## Model overview: Perla and Tonetti (2014) + creative state

- ▶ Representative household with population growth.
- ▶ Entrepreneurs/innovators produce varieties; operate in creative or derivative state.
- ▶ **Derivative state:** stick to current technology or abandon it and pay fixed cost to search for different one. When searching:
  - ▶ Randomly assigned a technology (Perla and Tonetti, 2014) or **move to the creative state**.
- ▶ **Creative state:** productivity follows Geometric Brownian motion.
  - ▶ Results in a pareto tail of productivities. (Luttmer, 2007)
  - ▶ At some point, move to derivative state at random.
- ▶ Free entry: Entrants search more likely lead to creative state than existing innovators.
- ▶ Govt. subsidizes fixed cost of search for entrants and abandoning existing firms.

## Households and production (standard)

Household

$$\bar{U}(t) = \int_t^\infty U(C(\tilde{t})) \exp^{-\rho(\tilde{t}-t)} d\tilde{t}$$

s.t.       $C(t) \leq \frac{W(t)}{P(t)} (L_p(t) + L_E(t) + L_\chi(t)) + \Pi_t$

$$\frac{\dot{L}}{L} = g_L$$

$$C(t) = \left( \int_{\Omega(t)} Q(t, v)^{\frac{\sigma-1}{\sigma}} dv \right)^{\frac{\sigma}{\sigma-1}}$$

Production (each instant)     $Q(v) = Z(v)L(v)$

$$\Pi(Z) = \frac{1}{\sigma} \left( Z \frac{P}{\bar{\sigma} W} \right)^{\sigma-1} \frac{Y}{P}$$

## Derivative innovators - stick to current or abandon

### ► Derivative State<sup>1</sup>:

$$rV_D(t, Z) = \Pi(t, Z) + \max \left( V_N(t) - V_D(t, Z) - \eta \frac{W(t)}{P(t)}, 0 \right) \dots$$

abandon and search

$$V_N(t) = p_C \underbrace{\int V_C(t, Z') d\Phi_C(Z')}_{\text{Move to creative}} + (1 - p_C) \underbrace{\int V_D(t, Z') d\Phi_D(Z')}_{\text{Allocated another randomly}}$$

- Cut-off rule: abandon if  $Z \leq M(t)$
- Govt subsidizes  $\eta$ .

---

<sup>1</sup>Perla and Tonetti (2014) -  $p_C = 0$

# Creative innovators - explosive stochastic process

## ► Creative State:

$$\text{GBM: } \frac{dZ_t}{Z_t} = \left( \mu_C + \frac{\nu^2}{2} \right) dt + \nu dW_t \quad \text{if } Z > M(t)$$

$$rV_C(t, Z) = \Pi(t, Z) + \underbrace{\left( \mu_C + \frac{\nu^2}{2} \right) Z \partial_Z V_C(t, Z) + \frac{\nu^2}{2} Z^2 \partial_Z^2 V_C(t, Z)}_{\text{GBM}} \\ + \underbrace{\alpha(V_D(Z, t) - V_C(t, Z)) \dots}_{\text{Derivative shock}}$$

## Entrants - a similar choice to existing entrepreneurs

► **Entry:**  $V_N^E - (\eta + \eta_E) \frac{W}{P} \geq 0$

$$V_N^E(t) = p_C^E \underbrace{\int V_C(t, Z') d\Phi_C(Z')}_{\text{Move to creative}} + (1 - p_C^E) \underbrace{\int V_D(t, Z') d\Phi_D(Z')}_{\text{Allocated another randomly}}$$

- Entrants have an advantage in realizing the creative state:  $p_C^E > p_C$ .
- Along BGP, rate of entry = population growth. ( $g_L$ ).

# What drives creativity and growth along the BGP?

- ▶ Prop 1: Higher rate of entry/population growth and higher rate of 'abandonment and search' leads to higher share of creative innovators (agg creativity).

$$\Omega_C = \frac{p_C^E g_L + p_C S_N}{g_L + \alpha}$$

- ▶ Prop 2: Higher creativity leads to a better pool of technologies available for imitation.

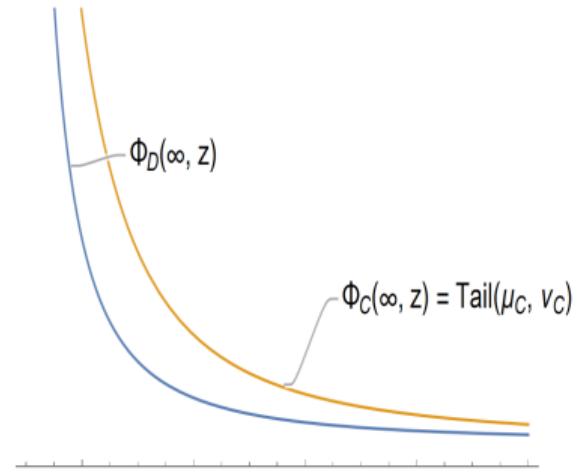
$$\Phi_D(\infty, z) = \zeta(\Omega_C) \Phi_C(\infty, z) + (1 - \zeta(\Omega_C)) \Phi_D(t=0, z)$$

$\zeta(\Omega_C)$  is increasing in  $\Omega_C$ .

- ▶ Prop 3: If  $p_C^E \gg p_C$ , then:

$$g_m = \frac{\alpha(1 - p_C)}{\alpha_D p_C} \cdot \frac{\Omega_C}{(1 - \Omega_C)}$$

Figure: Densities



$$z = \frac{Z}{M(t)}$$

## Calibration

- ▶ Match seven moments from patent creativity and aggregate data from the 1980s, to calibrate seven parameters.

#	Moment	Value	Parameter	Value
1.	Aggregate productivity growth (MFP)	1.48%	Creativity probability (existing)( $p_c$ )	0.18
2.	Pct. Innovators/Managers	9.82%	Creativity probability (entrants)( $p_c^E$ )	0.37
3.	Pct. creative first-time patents	23.74%	Creative-derivative transition probability ( $\alpha$ )	0.14
4.	Pct. creative fifth patent	11.23%	Drift of creative GBM ( $\mu$ )	0.0017
5.	Pct. creative	12.53%	Volatility of creative GBM ( $\nu$ )	0.038
6.	Creative entrepreneur's TFP growth	0.17%	Adoption cost ( $\eta_S$ )	6.55
7.	Creative excess valuation	14.81%	Entry cost ( $\eta_E$ )	4.32

- ▶ Initial derivative pareto tail parameter: 4.99 (Perla, Tonetti and Waugh (2021)).
- ▶ Elasticity of substitution: 3.17.
- ▶ Aggregate productivity growth and pct. creative is matched to 1980.

## Results - Declining population growth

	(1) 1960	(2) 1980*	(3) 2010	(4)	(5)	(6)
	2.5%	2.3%	0.7%	Chg. in Model	Chg. in Data	Pct. Explained
Prod. Growth	1.51%	1.48%	1.21%	-20.01%	-65.95%	30.34%
Pct. Creative	12.74%	12.53%	10.42%	-16.87%	-42.86%	39.36%
Innovators per capita	9.29%	9.82%	16.12%	73.50%	348.94%	21.06%
Weight - creative technologies	81.44%	73.47%	21.54%	-73.55%	-	-
Adopters	5.51%	5.52%	5.40%	-2.02%	-	-
Avg. creative valuation	9.292	9.515	13.419	44.41%	-	-
Avg. derivative valuation	7.912	7.782	5.489	-30.62%	-	-

## Results - Declining R&D subsidy

	(1)	(2)	(3)	Chg. in Model	Chg. in Data	(6) Pct. Explained
	1960	1980*	2010			
Prod. Growth	20%	19%	10%	-6.09%	-65.95%	9.24%
Pct. Creative	12.61%	12.53%	12.12%	-3.24%	-42.86%	9.06%
Innovators per capita	10.04%	9.82%	8.57%	-14.68%	348.94%	-4.21%
Weight - creative technologies	73.65%	73.47%	73.10%	-0.75%	-	-
Adopters	5.62%	5.52%	5.05%	-10.03%	-	-
Avg. creative valuation	9.336	9.515	10.574	13.26%	-	-
Avg. derivative valuation	7.673	7.782	8.443	10.03%	-	-

## Results - Both declining population growth and subsidy

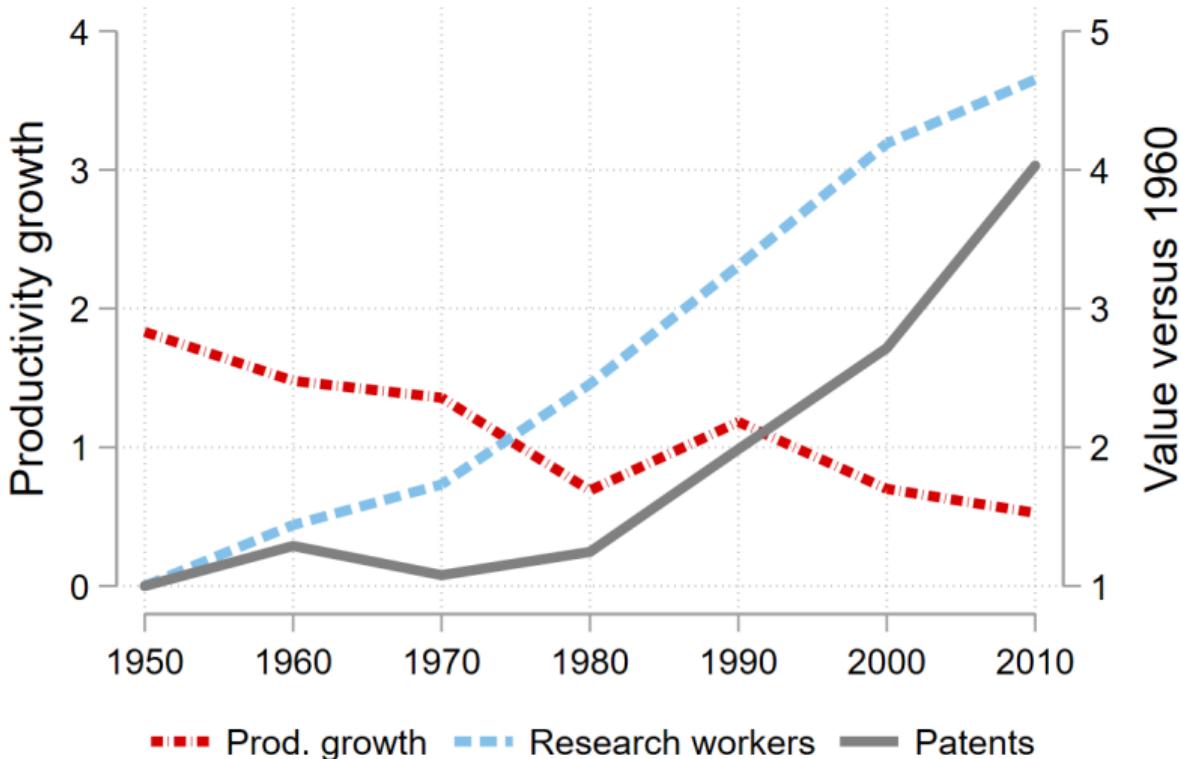
	(1) 1960	(2) 1980*	(3) 2010	(4)	(5)	(6)
	↔			Chg. in Model	Chg. in Data	Pct. Explained
Prod. Growth	1.53%	1.48%	1.16%	-23.78%	-65.95%	36.06%
Pct. Creative	12.82%	12.53%	10.15%	-19.01%	-42.86%	44.35%
Innovators per capita	9.50%	9.82%	13.59%	43.04%	348.94%	12.33%
Weight of creative technologies	81.83%	73.47%	23.32%	-71.51%	-	-
Adopters	5.61%	5.52%	5.12%	-8.73%	-	-
Avg. creative valuation	9.120	9.515	15.230	67.00%	-	-
Avg. derivative valuation	7.799	7.782	5.707	-26.82%	-	-

## Conclusion

Rise in patenting and a slowdown in productivity growth can be explained by a decrease in patent creativity.

- ▶ Develop a new text-based measure of patent creativity.
- ▶ Patent creativity has halved over the last three decades.
- ▶ Creative and NOT derivative patenting is associated with improvements in productivity and market valuations.
- ▶ In a model, I show that half of the decline in creativity is driven by ageing and decreasing government support for R&D.

## Details: Productivity, research expenditure and patents



Notes:

## Validation: Management discussions detailed table

	# earnings w/ 'new product' bigrams $_{i,t}$	# earnings w/ 'new design' bigrams $_{i,t}$		
	(1)	(2)	(3)	(4)
ihs(creative patenting $_{i,t}$ )	0.058*** (0.018)	0.049*** (0.018)	0.012 (0.009)	0.007 (0.010)
ihs(derivative patenting $_{i,t}$ )		0.026 (0.016)		0.016** (0.008)
R <sup>2</sup>	0.561	0.561	0.510	0.510
N	12,342	12,342	12,342	12,342
Year FE	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y

- ▶ Example: “We continue to put our cash to good use the reinvestment in our business through research and development has resulted in a significant number of new product introductions that have dramatically expanded our served addressable market.” - Micrel Semiconductor (2010)

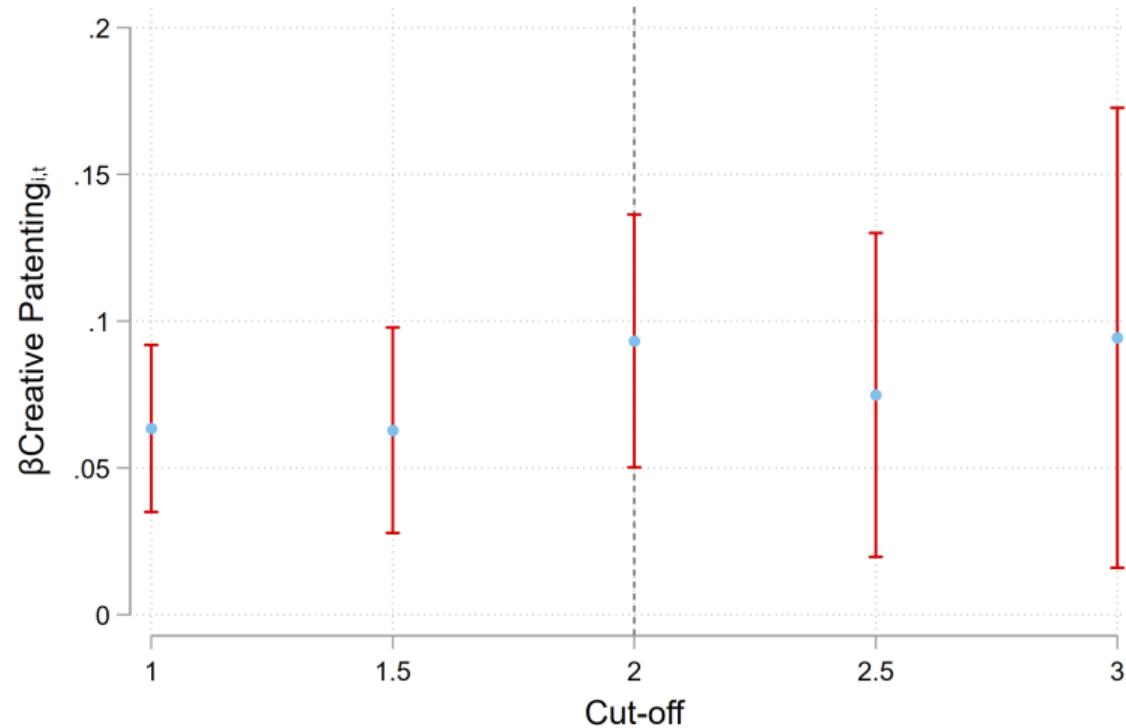
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## Validation: Extended table

	Stock Returns <sub>i,t</sub> (weekly)				
	(1)	(2)	(3)	(4)	(5)
ihs(creative patenting <sub>i,t</sub> )	0.161*** (0.022)	0.093*** (0.022)	0.085*** (0.026)	0.082*** (0.025)	0.083*** (0.026)
ihs(derivative patenting <sub>i,t</sub> )			0.009 (0.013)		
ihs(derivative patenting <sub>i,t</sub> - cite wt.)				0.014 (0.013)	
ihs(derivative patenting <sub>i,t</sub> - f/b)					0.011 (0.013)
ihs(R&D spending <sub>i,t</sub> )		0.006** (0.003)	0.005* (0.003)	0.005* (0.003)	0.005* (0.003)
Beta <sub>i</sub>		0.270*** (0.015)	0.270*** (0.015)	0.270*** (0.015)	0.270*** (0.015)
R <sup>2</sup>	0.074	0.075	0.075	0.075	0.075
N	1,816,951	1,816,951	1,816,951	1,816,951	1,816,951
Time FE	Y	Y	Y	Y	Y

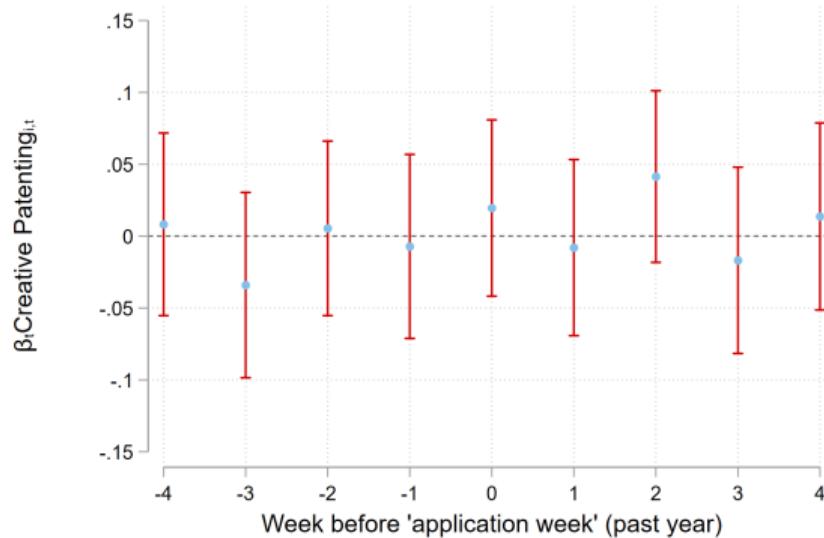
Standard errors are clustered by firm.

## Robustness: Cut-offs for creative patents



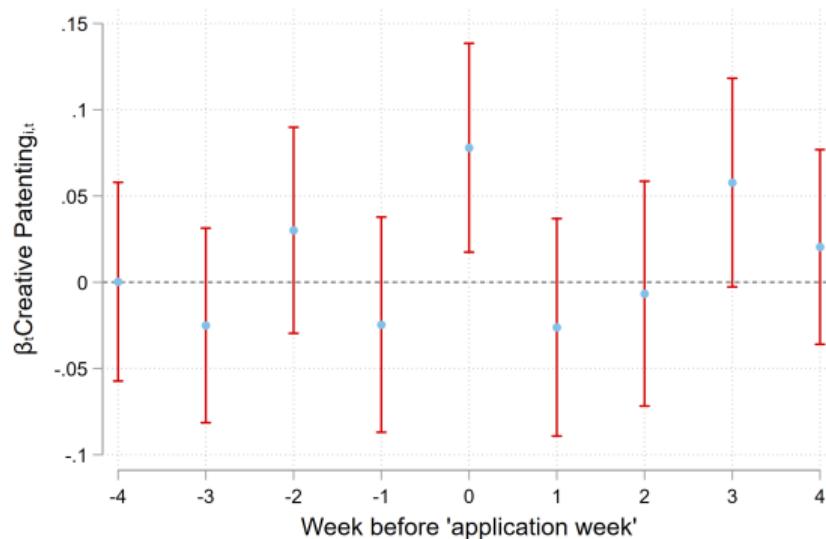
## Robustness: Placebo

$$r_{i,t}^{year-1} = \alpha + \sum_{\tau=-4}^4 \beta_\tau Ihs(\text{CreativePatenting}_{i,t-\tau}) + \chi_{i,t} + \delta_t + \epsilon_{i,t}$$



## Robustness: Placebo

$$r_{i,t} = \alpha + \sum_{\tau=-4}^4 \beta_\tau Ihs(\text{CreativePatenting}_{i,t-\tau}) + \chi_{i,t} + \delta_t + \epsilon_{i,t}$$

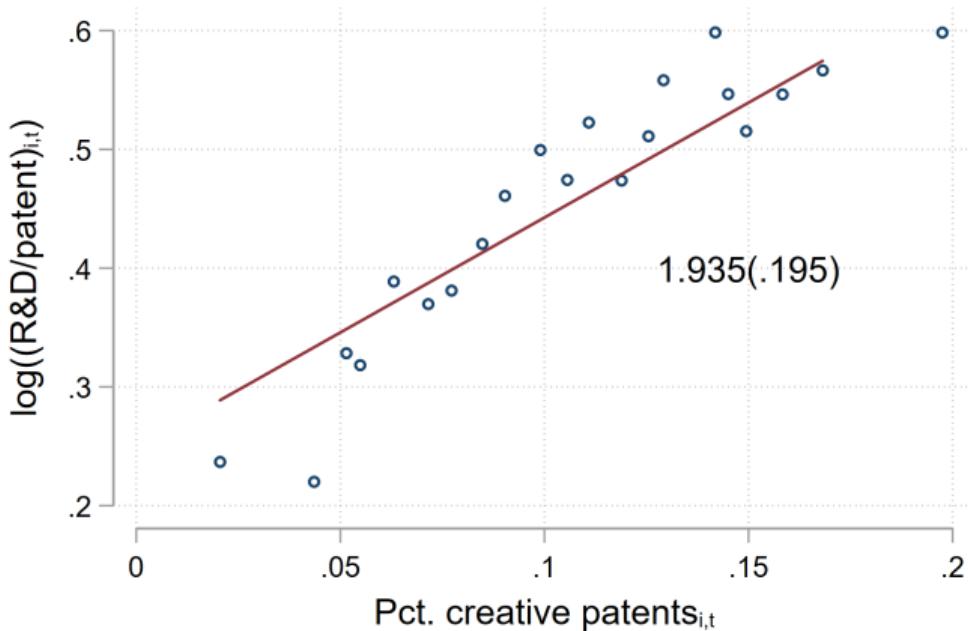


## Validation: Other variations of the measure

	Stock Returns <sub>i,t</sub> (weekly)*100						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ihs(creative patenting <sub>i,t</sub> )	0.093*** (0.022)						
1{creative patenting > 0} <sub>i,t</sub>		0.106*** (0.028)					
Ihs(total patent creativity <sub>i,t</sub> )			0.042*** (0.010)				
Ihs(creative patenting <sub>i,t</sub> - using title)				0.069*** (0.020)			
Ihs(creative patenting <sub>i,t</sub> - using abstract)					0.070*** (0.020)		
Ihs(creative patenting <sub>i,t</sub> - using desc.)						0.078*** (0.021)	
Ihs(creative patenting <sub>i,t</sub> - using claims)							0.070*** (0.021)
R <sup>2</sup>	0.075	0.075	0.075	0.075	0.075	0.075	0.075
N	1,816,951	1,816,951	1,816,951	1,816,951	1,816,951	1,816,951	1,816,951
Time FE	Y	Y	Y	Y	Y	Y	Y

Standard errors are clustered by firm.

## Validation: R&D Expenditure and Creative Patenting



Notes: The figure plots a binned scatter plot of  $\log$  of R&D expenditure per patent against average creativity per patent for a Compustat firm  $i$  at time  $t$ . Creativity per patent is calculated as the average creativity of the patents registered by a firm  $i$  at time  $t$ . The binscatter controls for 3-digit NAICS industry and year fixed effect. Standard errors are clustered by firm.

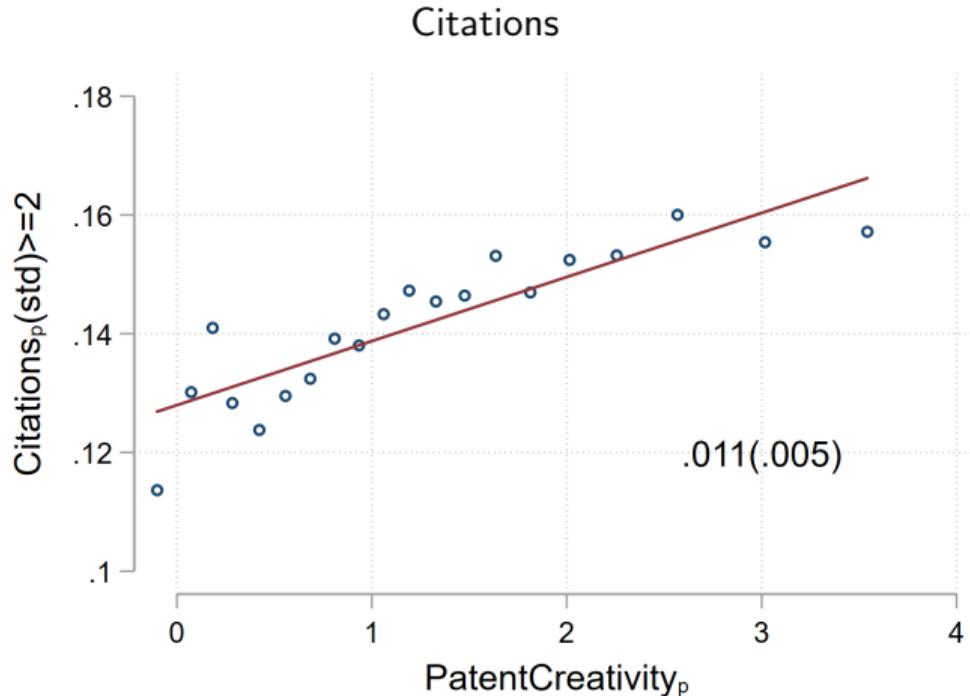
## Validation: Creative patents and academic citations

	Patent creativity		
	(1)	(2)	(3)
$1\{\text{Cites academic paper}\}_p$	0.337*** (0.051)	0.236*** (0.033)	
$1\{\text{Cites recent academic paper}\}_p$			0.359*** (0.033)
$1\{\text{Cites older academic paper}\}_p$			-0.026 (0.023)
Constant	0.913*** (0.039)	0.939*** (0.008)	0.932*** (0.009)
$R^2$	0.043	0.078	0.084
N	2,747,115	2,747,115	2,747,115

Notes: The table controls for technology class and year fixed effects. Standard errors are clustered by technology class.

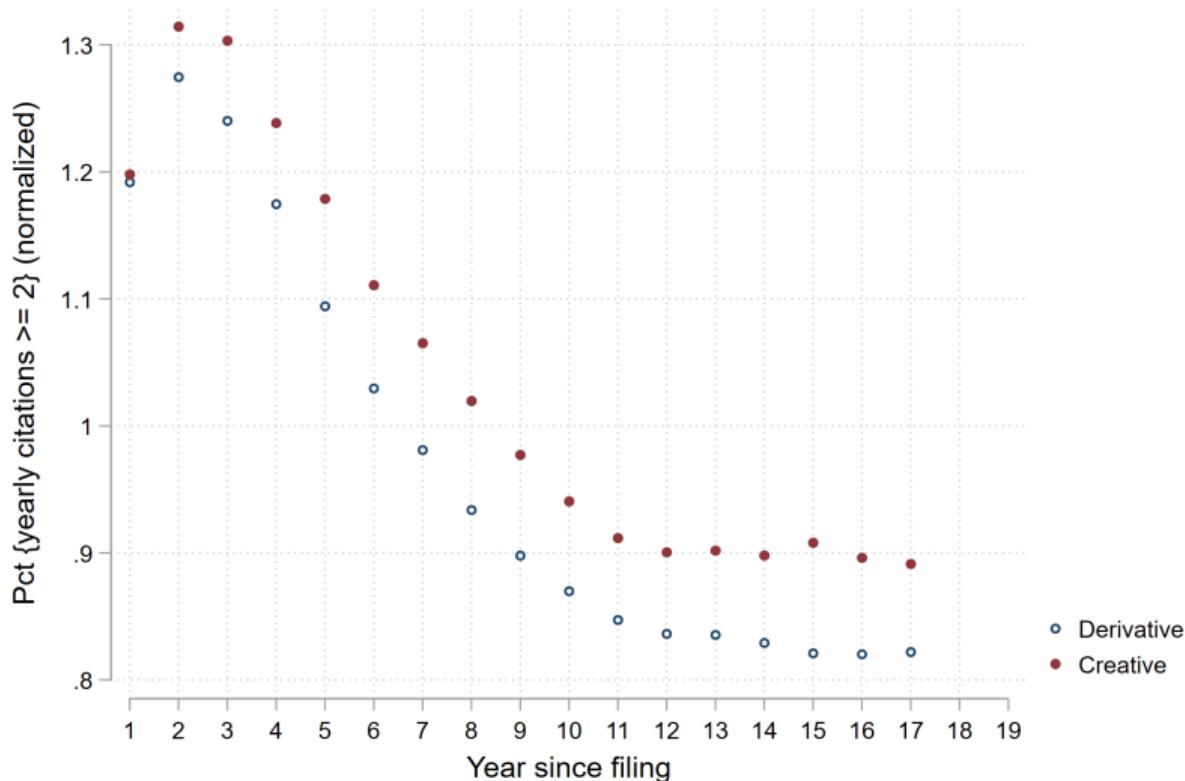
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## Validation: Patent creativity and citations



**Notes:** The figure plots a binned scatter plot of  $\text{patent creativity}_p$  against  $\text{citations}_p$ , while controlling for technology class and year fixed effects.

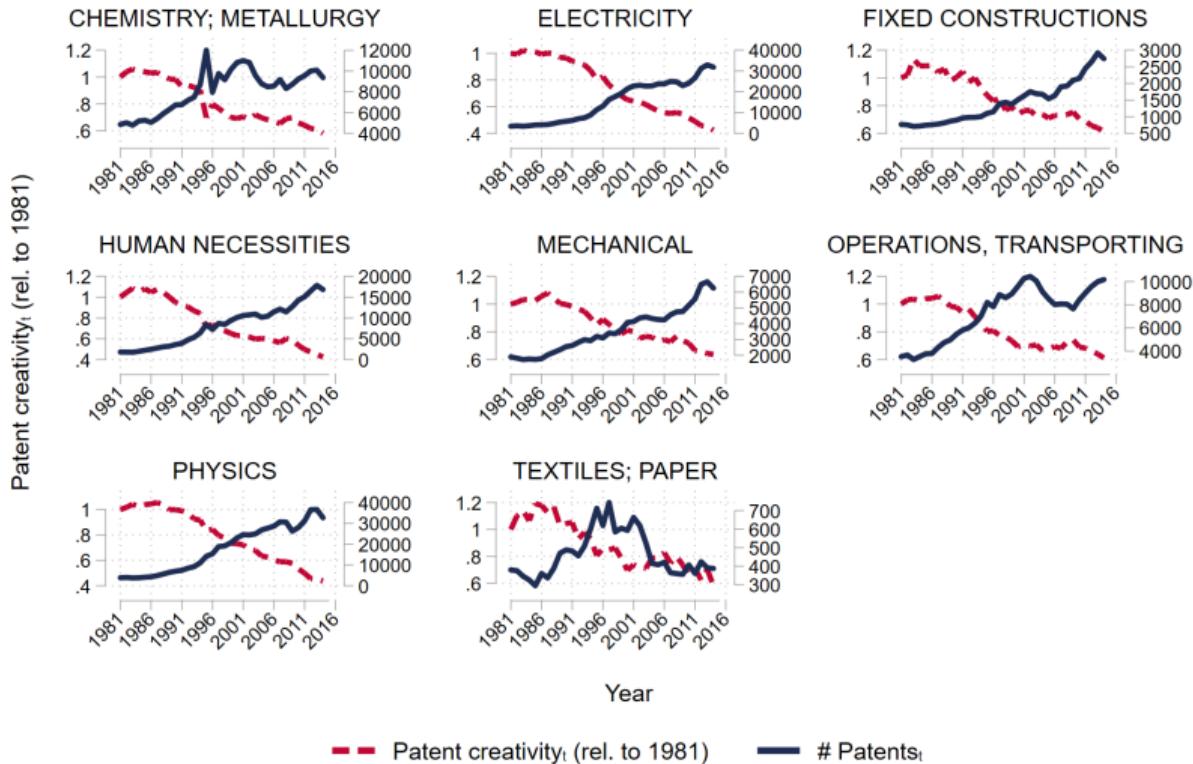
## Validation: Citation patterns of *creative* and *derivative* patents



Notes: The figure plots percentage of patents which receive more than two normalized

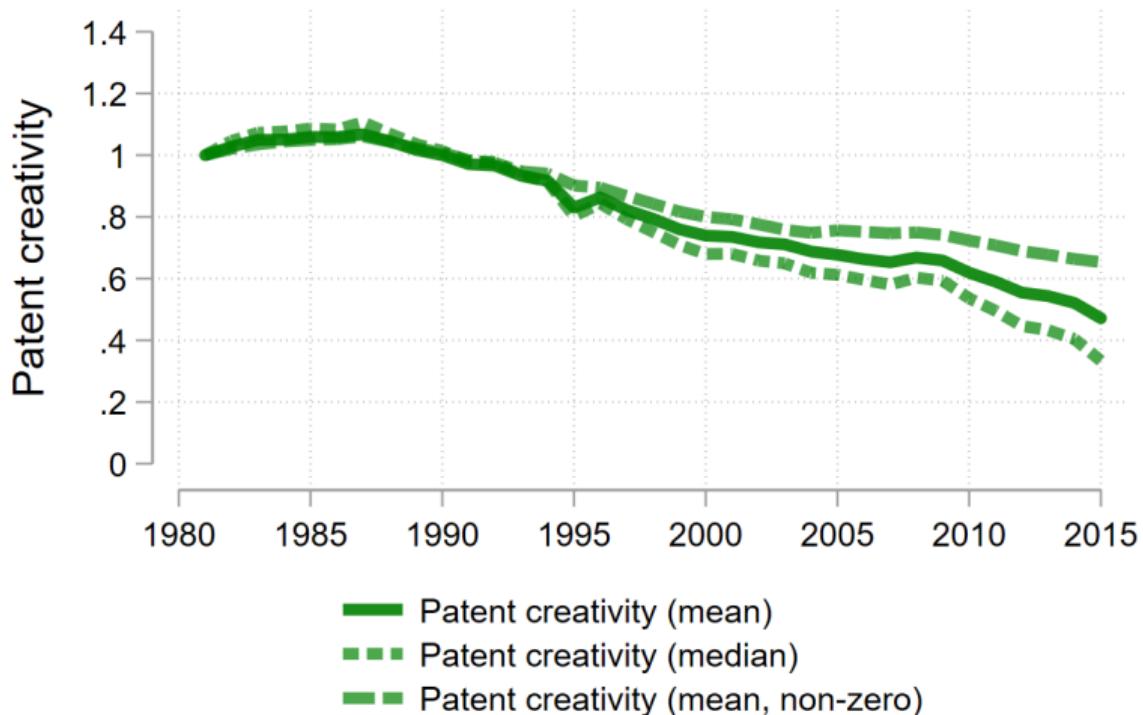
# Details: Patent creativity by technology class

Figure: *PatentCreativity* by year for each technology class

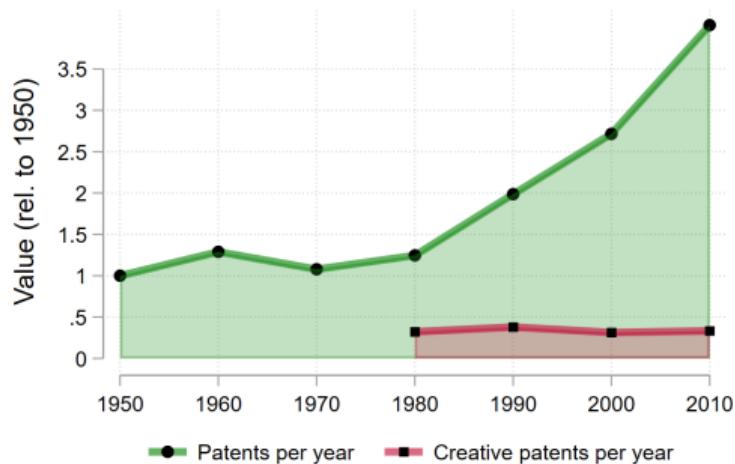
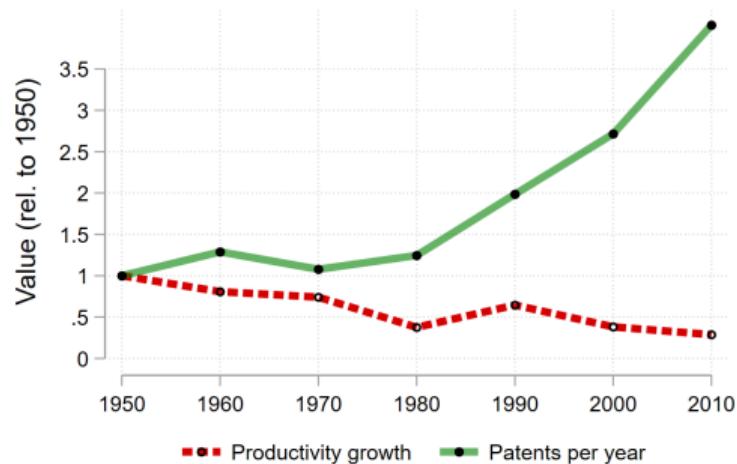


## Decline in creativity: other summary statistics

Figure: Distribution of patent creativity



## Details: Patents, Creative patents and productivity growth

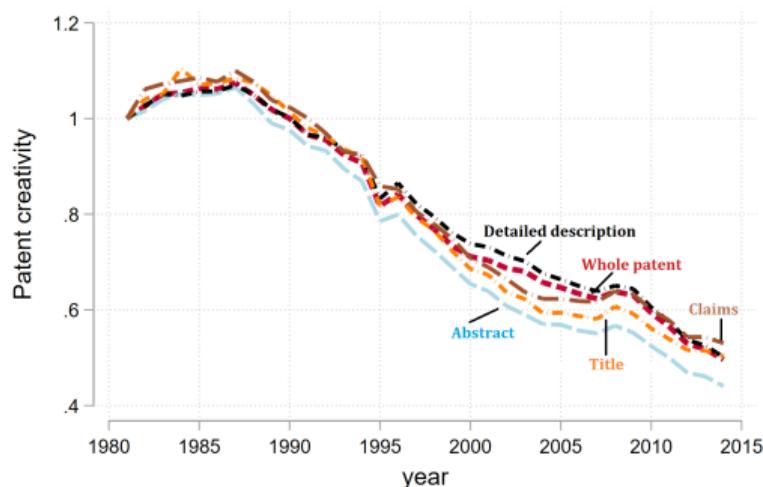


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## Check 1/3: Increasing patent lengths

- ▶ Increasing patent lengths could be driving the decline in patent creativity.
- ▶ Average patent in 1981 contains 3,757 words versus 9,501 words in 2014.
- ▶ Increase in length almost entirely driven by detailed description section ( $2,420 \rightarrow 8,112$ ).
- ▶ Length of patent titles ( $9 \rightarrow 10$ ) and abstracts ( $102 \rightarrow 98$ ) have largely remained the same.
- ▶ Pct. patents with titles which contain at least one creative bigram have decreased from 24% to 14%.

**Figure:** Patent Creativity calculated using different patent sections



[Section lengths](#)

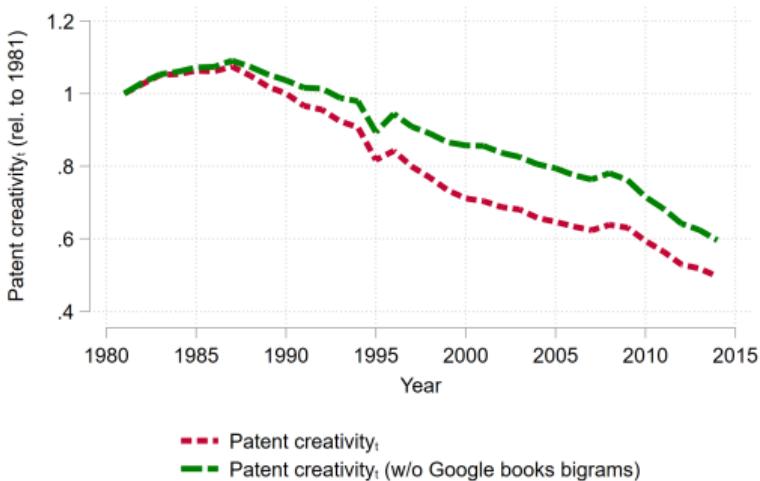
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## Check 2/3: Language trends

- ▶ Homogenization of language might be mis-labelled as lack of creativity.  
Example
- ▶ Google books (GB) - a collection of 8 million books published.
- ▶ Remove any technical bigram in patent mentioned in books published within five years before patent filing.
- ▶ Removes 71% of derivative technical bigrams and 12% of creative technical bigrams.
- ▶ Recalculate patent creativity as -

$$\frac{\text{creative technical bigrams w/o GB}}{\text{technical bigrams w/o GB}}$$

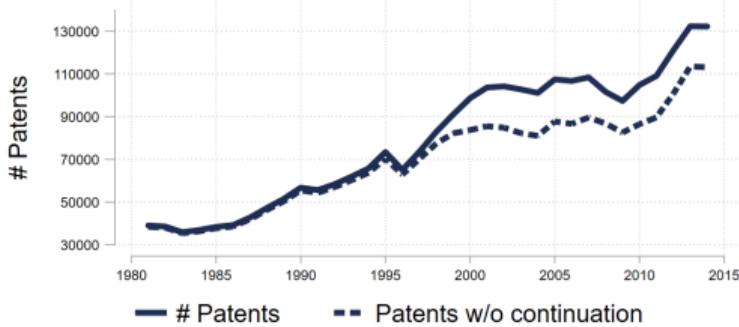
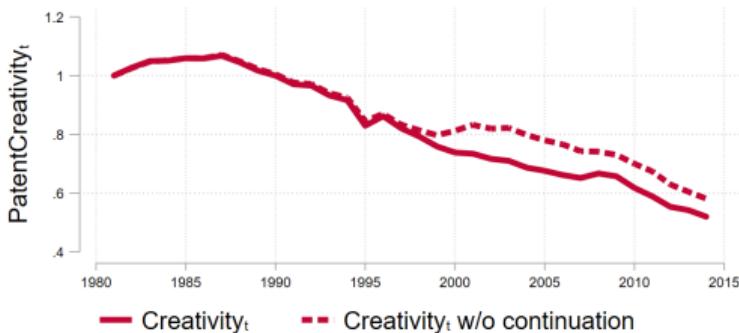
Figure: Patent Creativity w/o language trends



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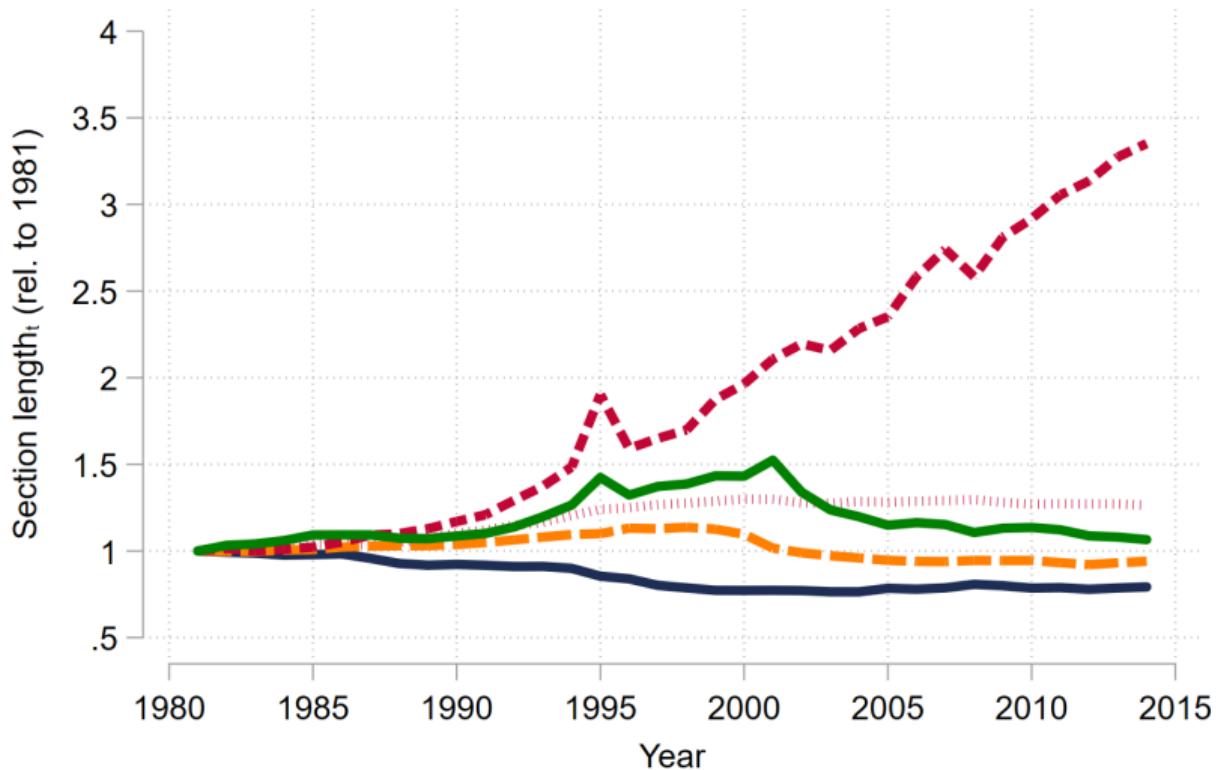
## Check 3/3: 'Continuation' (heavily litigated) patents

- ▶ 'Continuation' patents filed explicitly as minor changes over previous patents.
- ▶ About one-fourth as creative as other patents.
- ▶ Continuation patents account for half of the total litigated patents. Lemley and Moore (2004)
- ▶ Account for ~20% of the increase in patenting and ~11% of the decrease in creativity.



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## Details: Lengths of patent sections



# Creative patenting, labor productivity and investment rates

	<i>LaborProd</i>	<i>Growth*100</i>	<i>InvestmentRate*100</i>	
	(1)	(2)	(3)	(4)
ihs(CreativePatenting <sub>i,t</sub> )	0.214* (0.116)	0.214* (0.116)	0.223*** (0.085)	0.223*** (0.085)
ihs(DerivativePatenting <sub>i,t</sub> )	-0.166 (0.119)	-0.166 (0.119)	0.037 (0.075)	0.037 (0.075)
<i>R</i> <sup>2</sup>	0.212	0.212	0.377	0.377
N	19,571	19,571	23,070	23,070
Year FE	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y

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## TFP Growth: Comparison against other measures

	TFP Growth <sub>i,t</sub> (5-year differences, in pct.)			
	(1)	(2)	(3)	(4)
ihs(creative patents <sub>i,t</sub> )		0.268*		0.221
		(0.154)		(0.181)
ihs(original patents <sub>i,t</sub> - bck sim.)	-0.047	-0.145		
	(0.158)	(0.168)		
ihs(non-original patents <sub>i,t</sub> - bck sim.)	-0.019	-0.099		
	(0.129)	(0.140)		
ihs(original patents <sub>i,t</sub> - cites HHI)			-0.252	-0.297*
			(0.182)	(0.179)
ihs(non-original patents <sub>i,t</sub> - cites HHI)			0.026	-0.061
			(0.166)	(0.195)
R <sup>2</sup>	0.313	0.313	0.369	0.369
N	11,881	11,881	8,127	8,127
Year FE	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y

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## Creative patenting, and employment and sales growth

	<i>EmpGrowth*100</i>		<i>SalesGrowth*100</i>	
	(1)	(2)	(3)	(4)
ihs(CreativePatents $_{i,t}$ )	0.586*** (0.153)	0.586*** (0.153)	0.716*** (0.197)	0.716*** (0.197)
ihs(DerivativePatents $_{i,t}$ )	1.145*** (0.162)	1.145*** (0.162)	0.942*** (0.214)	0.942*** (0.214)
<i>R</i> <sup>2</sup>	0.426	0.426	0.379	0.379
N	19,724	19,724	20,679	20,679
Year FE	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y

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## Robustness: First-time inventor patent creativity

	Patent creativity <sub>p</sub>			
	(1) Full	(2) 1980s	(3) 1990s	(4) 2000s
First-time patent <sub>p</sub>	0.434*** (0.026)	0.429*** (0.033)	0.441*** (0.025)	0.420*** (0.030)
R <sup>2</sup>	0.099	0.083	0.082	0.052
N	5,641,924	465,570	1,387,335	3,789,019
Year FE	Y	Y	Y	Y
Technology Class FE	Y	Y	Y	Y

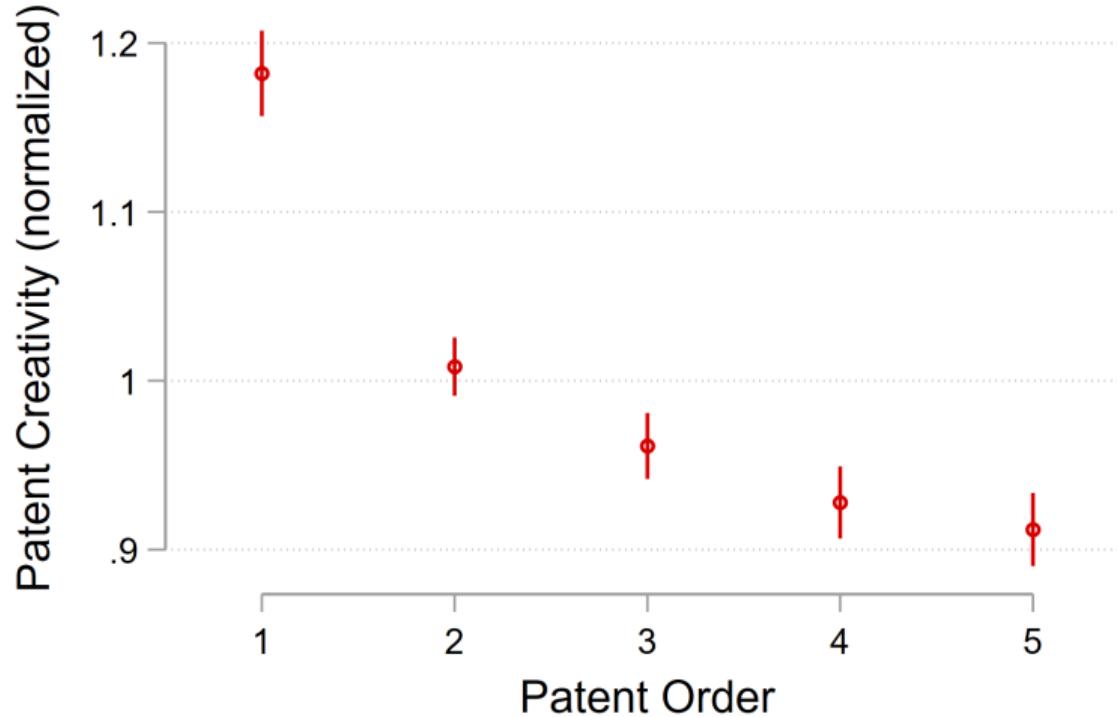
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## Robustness: Patent creativity of govt. funded patents

	Patent creativity <sub>p</sub>			
	(1) Full	(2) 1980s	(3) 1990s	(4) 2000s
Government owned patent <sub>p</sub>	0.529*** (0.038)	0.545*** (0.042)	0.465*** (0.033)	0.543*** (0.041)
<i>Partial R<sup>2</sup></i>	0.004	0.008	0.004	0.003
R <sup>2</sup>	0.071	0.052	0.047	0.014
N	1,780,168	189,835	443,453	711,730
Year FE	Y	Y	Y	Y
Technology Class FE	Y	Y	Y	Y

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## Robustness: First-time inventor patent creativity

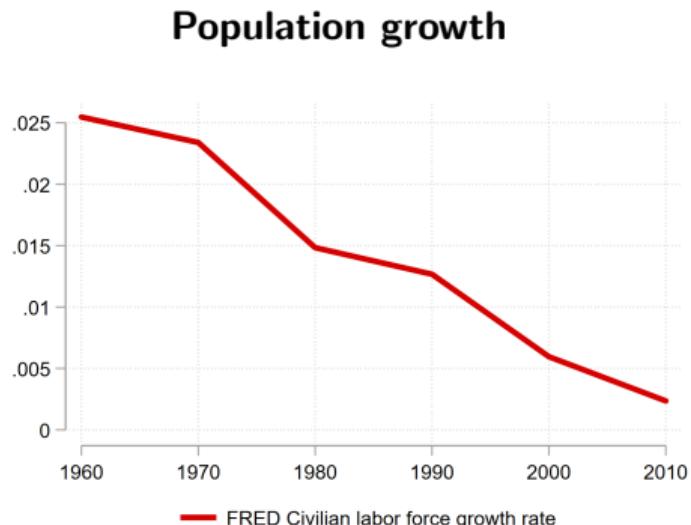
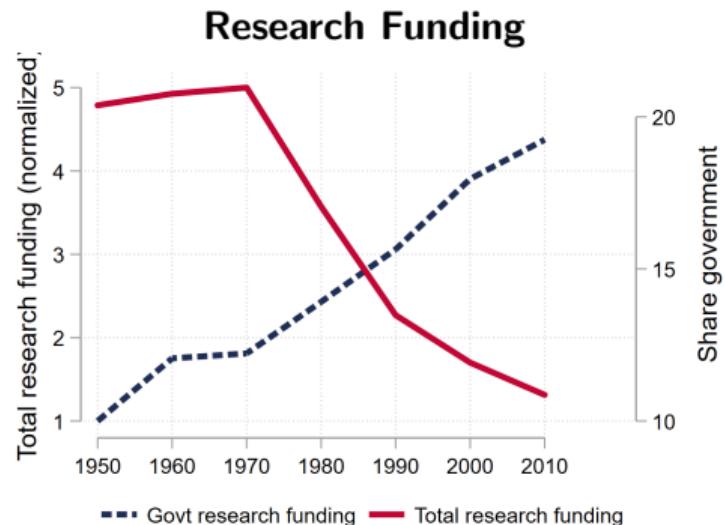


## Robustness: Patent creativity by degrees of govt. involvement

	Patent creativity <sub>p</sub>			
	(1)	(2)	(3)	(4)
Government owned <sub>p</sub>	0.529*** (0.038)			
Government funded <sub>p</sub>		0.348*** (0.029)		
Cites govt owned patent <sub>p</sub>			-0.007 (0.010)	
Cites govt funded patent <sub>p</sub>				-0.011*** (0.002)
<i>Partial R<sup>2</sup></i>	0.004	0.007	0.000	0.001
<i>R<sup>2</sup></i>	0.071	0.074	0.067	0.068
N	1,780,168	1,780,168	1,780,168	1,780,168
Year FE	Y	Y	Y	Y
Technology Class FE	Y	Y	Y	Y

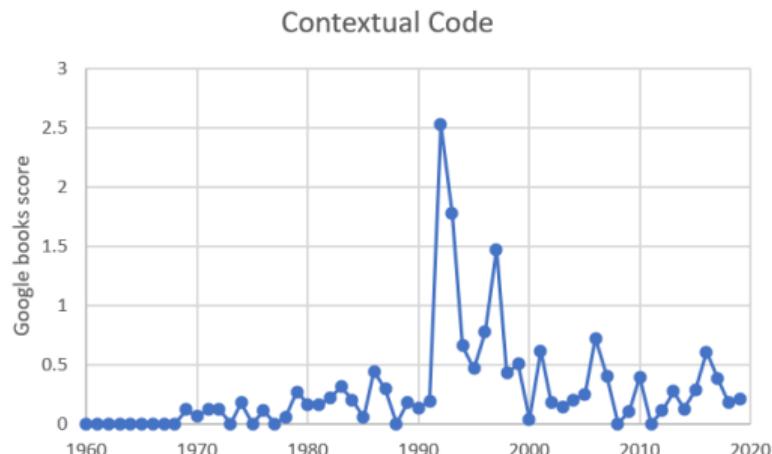
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# Aggregate patterns in demographics and research funding



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# Google ngram example



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(12) **United States Patent**  
Gosling

(10) Patent No.: US 6,618,754 B1  
(45) Date of Patent: \*Sep. 9, 2003

(54) **SYSTEM FOR TRANSMISSION OF EMBEDDED APPLICATIONS OVER A NETWORK**

(75) Inventor: James A. Gosling, Woodside, CA (US)

(73) Assignee: Sun Microsystems, Inc., Santa Clara, CA (US)

(\*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: 08/546,808

(22) Filed: Oct. 23, 1995

OTHER PUBLICATIONS

Object Linking & Embedding, Programmers Reference, Version 1.0, Microsoft Press, pp. 4-10, 1992.\*

Hardware-Software Co Design of Embedded System, Chiodo et al., IEEE Micro, pp. 26-36, Aug. 1994.\*

A. Laursen, et al, "Oracle Media Server: Providing Consumer Based Interactive Access to Multimedia Data", ACM, pp. 470-477, May, 1994.\*

James Gosling & Henry McGilton, "The Java Language Environment A White Paper", Oct. 1995, Sun Microsystems, pp. 1-88.\*

(List continued on next page.)

Primary Examiner—Sue Lao

(74) Attorney, Agent, or Firm—Gary S. Williams; Pennie & Edmonds LLP

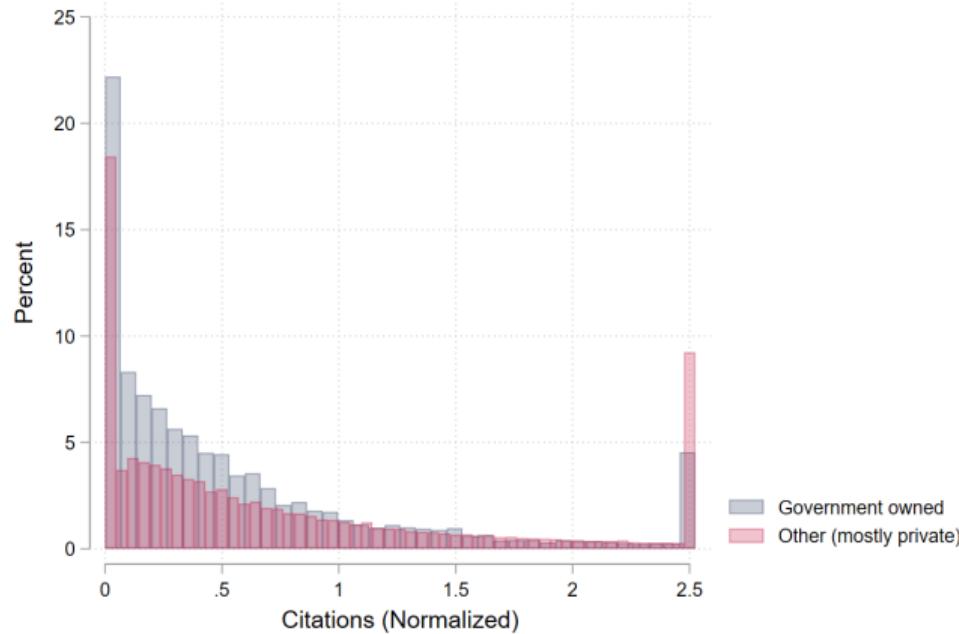
(57) **ABSTRACT**

A system and method for transmitting embedded applications over a network is disclosed, wherein a user of a

document in which the application was embedded. The executable programs should be of at least four types: (1) output code that, when executed, produces a visual or audible manifestation (e.g., graphical or sound simulations), (2) meta-knowledge code that can advise a user regarding legal interactions with the document in which the code fragment was embedded, (3) contextual code that can sense and indicate the processing context of the compound document in which the code fragment was embedded; and (4) handlers for embedded data.

# Government invests in more failed creative projects

Figure: Distribution of citations for creative patents



- ▶ Average government funded creative patent cited 32% less than other creative patents.