# The creativity decline: Evidence from US patents

*Job market paper*

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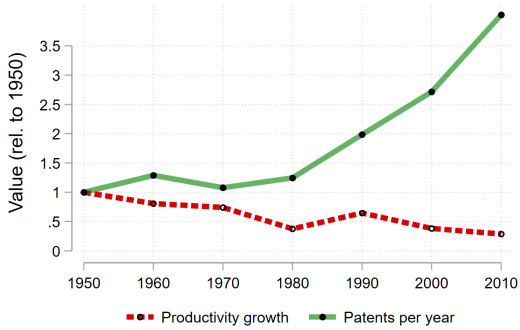
September 27, 2022

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




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

R&D

This paper,

- Argue that these patterns explained by declining creativity in US patenting.
- Partly driven by changing composition of inventors towards less creative ones.

# A new text-based measure to distinguish creative from derivative patenting

Patent creativity: share of new technical two-word combinations in a patent.

Empirical findings:

1. The creativity decline: Average patent in 2010 is **half** as creative as a patent in 1980.
2. Only creative and not derivative patents are associated with market returns and productivity growth.
3. Patent creativity declines sharply with inventor tenure.
4. Women and minorities in patenting file more creative patents.

# Model: composition of inventors into aggregate creativity and growth

- Accounts for social benefit of creative innovations with rich structure on spillovers.
- Model matches groups of innovators into creative and derivative using empirical moments.
- Productivity growth depends on share of creative innovators.

Results:

- Rationalizes 40% of the creativity decline and 32% of the slowdown with falling US pop. growth.
- Immigration and increasing participation of women improves creativity and growth.
- Government R&D subsidies can improve creativity of inventions and boost prod. growth.

# 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);

  → Explain slowdown: declining creativity from falling pop. growth and changing composition of inventors.

- **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 creativity

Model

# Table of Contents

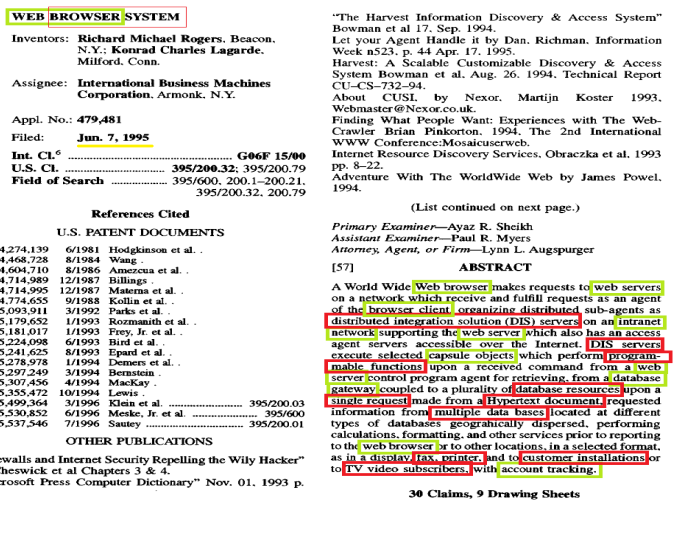
# PatentCreativity: Share of new technical two-word combinations

- Full text (title, abstract, description, claim) of patents filed by US inventors (1976-2018).
- 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)
- $\textit{Patent creativity}_p = \frac{\#\text{ creative technical bigrams}_p}{\#\text{ technical bigrams}_p}$. Normalized such that sample average is 1.

# PatentCreativity: Share of new technical two-word combinations

- Full text of patents filed by US inventors (1976-2018).
- Decompose text into two word combinations - bigrams.
- Remove bigrams in colloquial language: Remaining 'technical bigrams'.
  - Using Corpus of Historical American English
- Classify bigram as creative if not in any patent from previous 5 years.
- $\textit{Patent Creativity}_p = \frac{\#\text{ creative technical bigrams}_p}{\#\text{ technical bigrams}_p}$. Normalized such that sample average is 1.
- Ex-ante/backward looking measure unlike citations/influence (Kelly et al., 2021).

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



**United States Patent** [19]

**Rogers et al.**

[11] **Patent Number: 5,793,964**

[45] **Date of Patent: Aug. 11, 1998**

[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.**[6] ..... **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**

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*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.

**30 Claims, 9 Drawing Sheets**

# 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 disclaimer.

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

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

(51) **Int. Cl.**[7] ..... **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

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*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.

**20 Claims, 3 Drawing Sheets**

# Validation: Management more likely to talk about new products when filing creative patents (1/3)

- 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)*

Details

Table: New product introductions in EC

| | # earnings with 'new product introductions'$_{i,t}$ | |
|---|---|---|
| | (1) | (2) |
| ihs(creative patenting$_{i,t}$) | 0.058*** | 0.049*** |
| | (0.018) | (0.018) |
| ihs(derivative patenting$_{i,t}$) | | 0.026 |
| | | (0.016) |
| $R^2$ | 0.561 | 0.561 |
| N | 12,342 | 12,342 |
| Year FE | Y | Y |
| Firm FE | Y | Y |

Patent is creative if patent creativity $\geq 2$. Standard errors are clustered by firm.

# Validation: Only creative patenting associated with stock returns (2/3)

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

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

  - $r_{i,t}$ 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).
  - $creativepatenting_{i,t}$ granted to firm $i$ in time $t$.
  - Controls for CAPM betas and past R&D spend.
- Additional creative patent $\leftrightarrow$ +3.1% return.

Details | Creativity cut-offs | Placebo | Measure variations

Table: Returns and creative patenting

| | Stock Returns$_{i,t}$*100 (weekly) | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| ihs(creative patenting$_{i,t}$) | 0.093*** | 0.085*** | 0.082*** |
| | (0.022) | (0.026) | (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** | 0.005* | 0.005* |
| | (0.003) | (0.003) | (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.

# Validation: versus other measures of originality (2/3)

| | Stock Returns$_{i,t}$*100 (weekly) | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4)) |
| ihs(creative patents$_{i,t}$) | 0.100*** | 0.087*** | 0.083*** | 0.088*** |
| | (0.038) | (0.026) | (0.027) | (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 (3/3)

- Management more likely to talk about new products when filing creative patents.
- Only creative and not derivative patenting associated with stock returns.
- 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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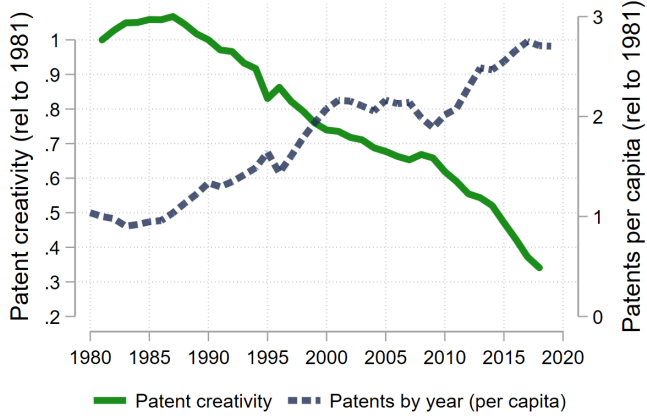
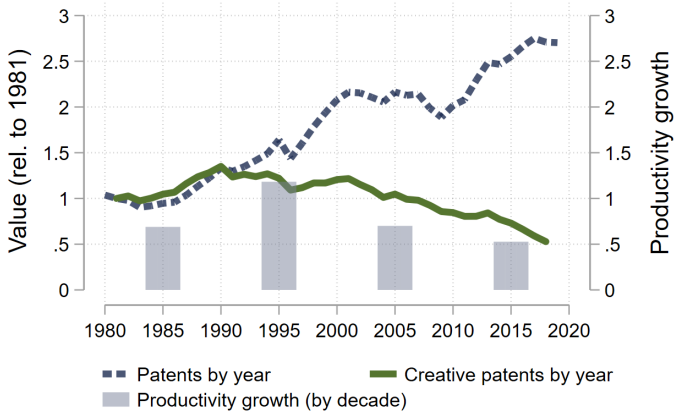
# Creativity decline - Average patent creativity has halved




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

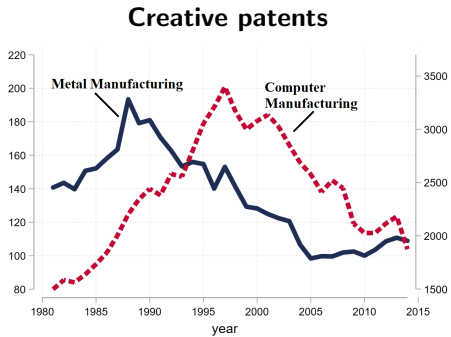


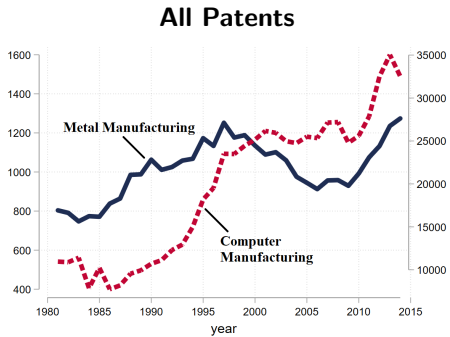

Notes: Productivity → BEA TFP; Patent is creative if patent creativity $> 2$.

- Rise in patents entirely driven by derivative patents.

By technology class Distribution

# Example industry patterns: creative and all patents




- Distinct patterns in creative and overall patenting across industries.

# 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
  - Patents use only about 7% of all technical bigrams in Google books.
- 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

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

- 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 NAICS-4 digit industries with 10x coefficients. link

Investment and Labor Productivity | Employment and sales growth | Comparison against other measures

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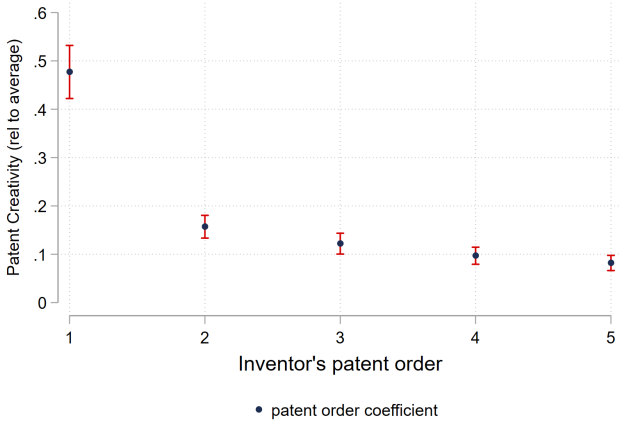
# Empirical evidence: Creativity drops as inventors' patent more

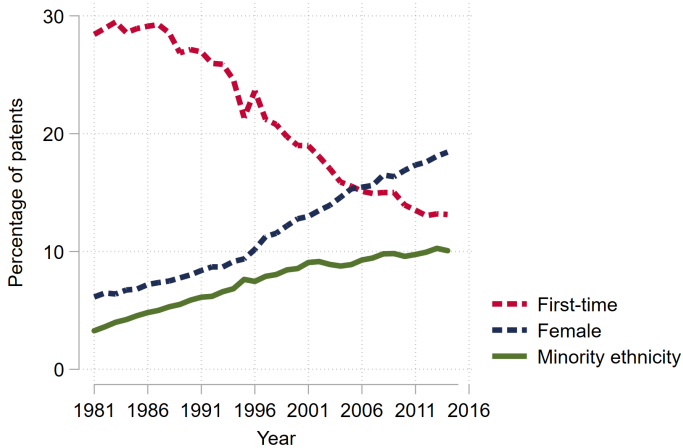



Coefficient by decade:inventor | Stock return regression

# Empirical evidence: Patent creativity for women and minorities

| | Patent creativity$_p$ | | | |
|---|---|---|---|---|
| Female author$_p$ | 0.136*** | 0.035 | | |
| | (0.022) | (0.022) | | |
| Female author$_p$ * First patent$_p$ | | 0.214*** | | |
| | | (0.042) | | |
| Minority author$_p$ | | | 0.046*** | 0.046*** |
| | | | (0.012) | (0.015) |
| Minority author$_p$ * First patent$_p$ | | | | –0.032 |
| | | | | (0.042) |
| Constant | 0.982*** | 0.872*** | 0.987*** | 0.868*** |
| | (0.002) | (0.007) | (0.002) | (0.008) |
| *PartialR*$^2$ | 0.001 | 0.052 | 0.000 | 0.051 |
| $R^2$ | 0.068 | 0.116 | 0.068 | 0.115 |
| 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 |

# Changing compositions into patenting



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

So far,

1. Patent creativity has been declining.
2. Only creative patenting predicts firm-level productivity growth.
3. New-entrants, women and ethnic minorities have a creative advantage.

Rest of the talk, a growth model:

- Maps composition of inventor groups into share of creative inventors.
- Calculates aggregate productivity growth using a rich structure on spillovers of creative innovations while matching private benefit in the data.
- Perform counterfactuals.

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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.

# Households and production (standard)

**Household**

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

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

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

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

**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**[1]:

$$rV_D(t,Z) = \Pi(t,Z) + \underbrace{\max\left(V_N(t) - V_D(t,Z) - \eta\frac{W(t)}{P(t)}, 0\right)}_{\text{abandon and search}} ...$$

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

- Cut-off rule: abandon if $Z \leq M(t)$

[1] *Perla and Tonetti (2014)* - $p_C = 0$

# Creative innovators - explosive stochastic process

- **Creative State**:

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

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

- Heavy tail of technologies along the BGP.

# Entrants - a similar choice to existing entrepreneurs

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

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

- 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?

- Maps composition of innovators into prod. growth.

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

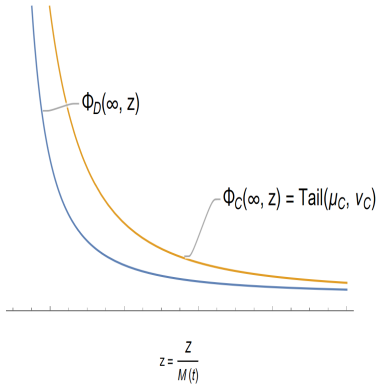
where pct. creative innovators $\Omega_C = \frac{p_C^E g_L + p_C S_N}{g_L + \alpha}$

- Higher creativity leads to a better pool of technologies available for immitation.

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

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

Figure: Densities



# Calibration

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

| # | Moment | Value |
|---|---|---|
| 1. | Aggregate productivity growth (MFP) | 1.48% |
| 2. | Pct. Innovators/Managers | 9.82% |
| 3. | Pct. creative first-time patents | 23.74% |
| 4. | Pct. creative fifth patent | 11.23% |
| 5. | Pct. creative | 12.53% |
| 6. | Creative entrepreneur's TFP growth | 0.17% |
| 7. | Creative excess valuation | 14.81% |

| Parameter | Value |
|---|---|
| Creativity probability (existing)($p_c$) | 0.18 |
| Creativity probability (entrants)($p_c^E$) | 0.37 |
| Creative-derivative transition probability ($\alpha$) | 0.14 |
| Drift of *creative* GBM ($\mu$) | 0.0017 |
| Volatility of *creative* GBM ($\nu$) | 0.038 |
| Adoption cost ($\eta_S$) | 6.55 |
| 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.

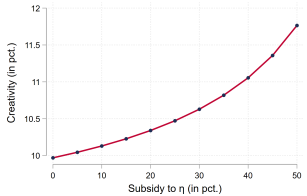
# Results - Declining population growth

| | (1) 1960 | (2) 1980* | (3) 2010 | (4) Chg. in Model | (5) Chg. in Data | (6) Pct. Explained |
|---|---|---|---|---|---|---|
| | 2.5% | 2.3% | 0.7% | | | |
| 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% | - | - |

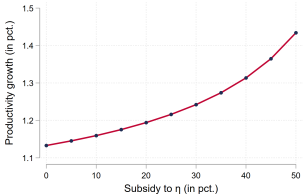
- Model estimates about 3-4% increase in productivity growth because of inclusion of women and minorities.

# What if government subsidizes $\eta$

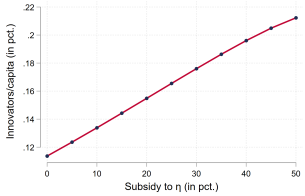
**Panel A: Pct. Creative**




**Panel B: Productivity Growth**



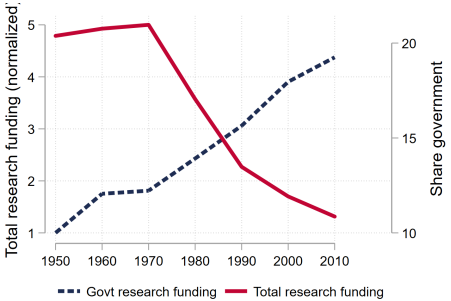

**Panel C: Innovators per capita**



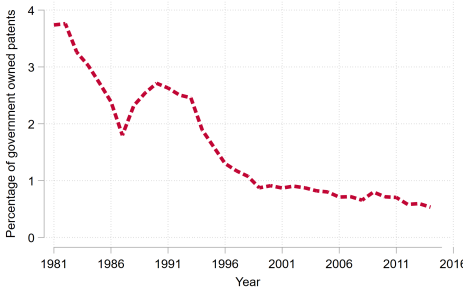
# Government subsidies to research have been decreasing

- Government owned patents are 52% more creative than other patents. link
- Doubling research expenditure (in 2010), increases creativity and productivity growth by about 5%.

**Panel A**
**Government and private R&D funding**




**Panel B**
**Pct. govt. owned patents**

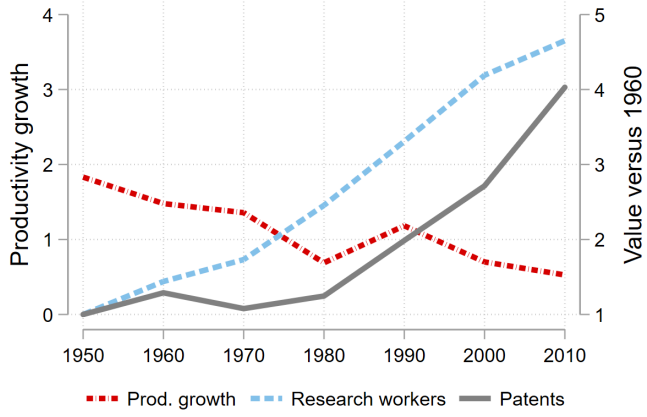


# Conclusion

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 is productivity and market valuations.
- In a model, I show that 40% of the decline in creativity is driven by falling population growth.
- Increasing government R&D support can boost creativity and productivity growth.

# Details: Productivity, research expenditure and patents




*Notes:*

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# 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*** | 0.049*** | 0.012 | 0.007 |
| | (0.018) | (0.018) | (0.009) | (0.010) |
| ihs(derivative patenting$_{i,t}$) | | 0.026 | | 0.016** |
| | | (0.016) | | (0.008) |
| $R^2$ | 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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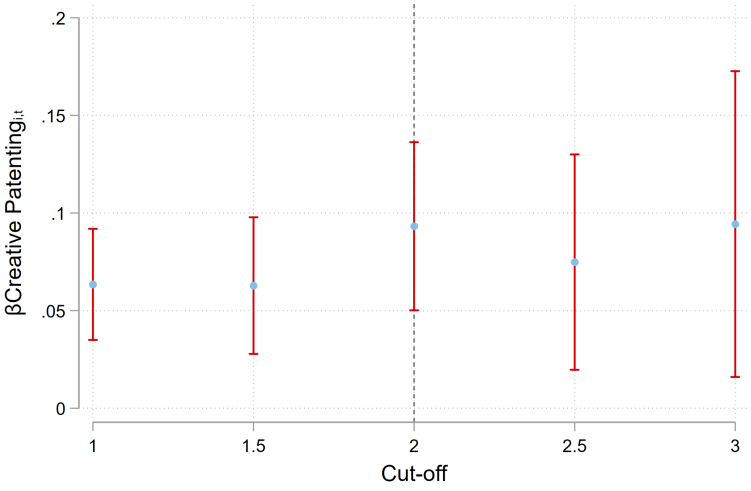
# Validation: Extended table

| | Stock Returns$_{i,t}$ (weekly) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| ihs(creative patenting$_{i,t}$) | 0.161*** | 0.093*** | 0.085*** | 0.082*** | 0.083*** |
| | (0.022) | (0.022) | (0.026) | (0.025) | (0.026) |
| ihs(derivative patenting$_{i,t}$) | | | 0.009 | | |
| | | | (0.013) | | |
| ihs(derivative patenting$_{i,t}$ - cite wt.) | | | | 0.014 | |
| | | | | (0.013) | |
| ihs(derivative patenting$_{i,t}$ - f/b) | | | | | 0.011 |
| | | | | | (0.013) |
| ihs(R&D spending$_{i,t}$) | | 0.006** | 0.005* | 0.005* | 0.005* |
| | | (0.003) | (0.003) | (0.003) | (0.003) |
| Beta$_i$ | | 0.270*** | 0.270*** | 0.270*** | 0.270*** |
| | | (0.015) | (0.015) | (0.015) | (0.015) |
| $R^2$ | 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.

back

# Robustness: Cut-offs for creative patents

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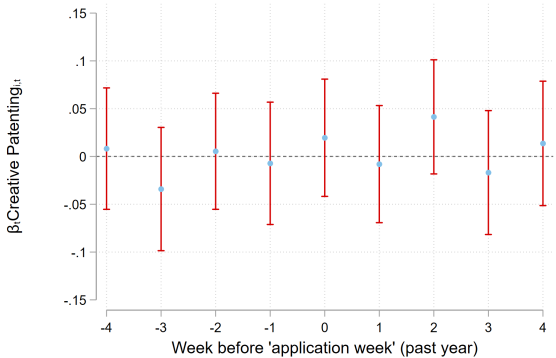
# Robustness: Placebo

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

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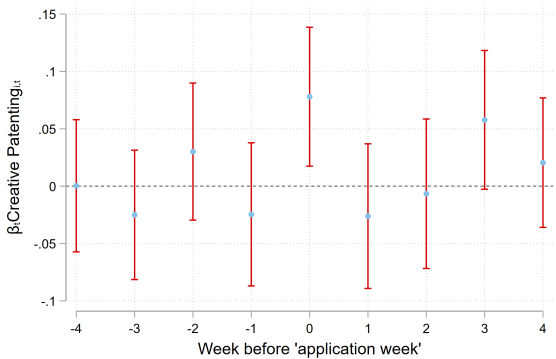
# Robustness: Placebo

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

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# Validation: Other variations of the measure

| | Stock Returns$_{i,t}$ (weekly)*100 | | | | | | |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| lhs(creative patenting$_{i,t}$) | 0.093*** | | | | | | |
| | (0.022) | | | | | | |
| 1{creative patenting $> 0$}$_{i,t}$ | | 0.106*** | | | | | |
| | | (0.028) | | | | | |
| lhs(total patent creativity$_{i,t}$) | | | 0.042*** | | | | |
| | | | (0.010) | | | | |
| lhs(creative patenting$_{i,t}$ - using title) | | | | 0.069*** | | | |
| | | | | (0.020) | | | |
| lhs(creative patenting$_{i,t}$ - using abstract) | | | | | 0.070*** | | |
| | | | | | (0.020) | | |
| lhs(creative patenting$_{i,t}$ - using desc.) | | | | | | 0.078*** | |
| | | | | | | (0.021) | |
| lhs(creative patenting$_{i,t}$ - using claims) | | | | | | | 0.070*** |
| | | | | | | | (0.021) |
| $R^2$ | 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.

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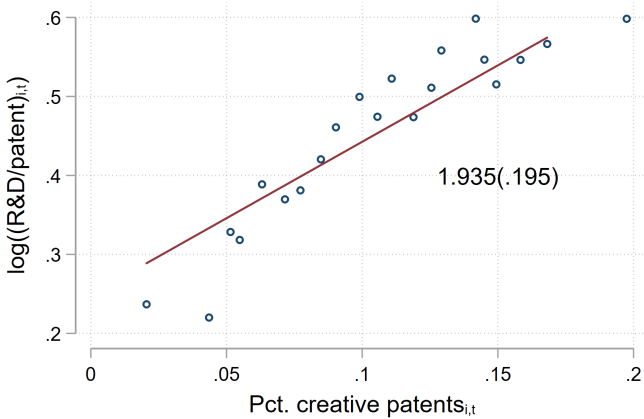
# Validation: R&D Expenditure and Creative Patenting




*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.

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# Validation: Creative patents and academic citations

| | Patent creativity | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| $1\{\text{Cites academic paper}\}_p$ | 0.337*** | 0.236*** | |
| | (0.051) | (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*** | 0.939*** | 0.932*** |
| | (0.039) | (0.008) | (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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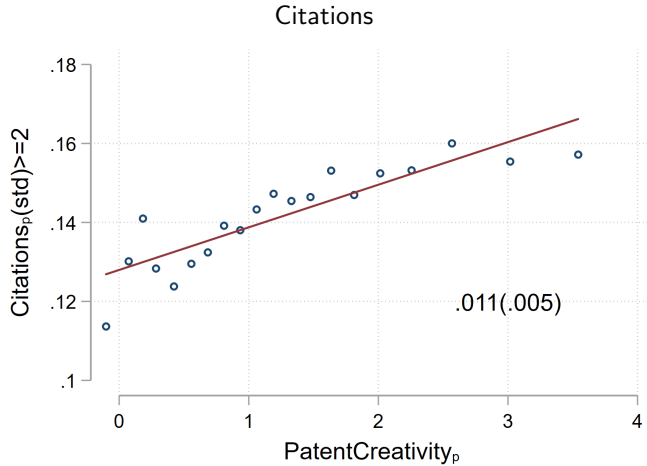
# Validation: *Patent creativity* and citations




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

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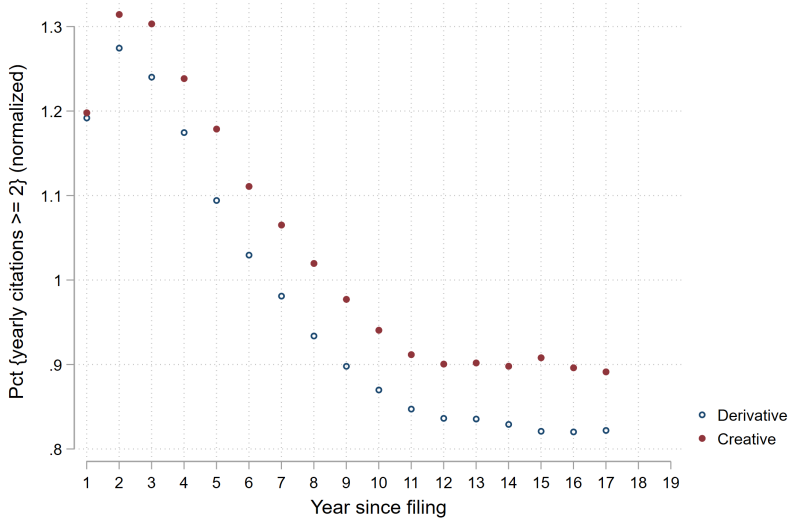
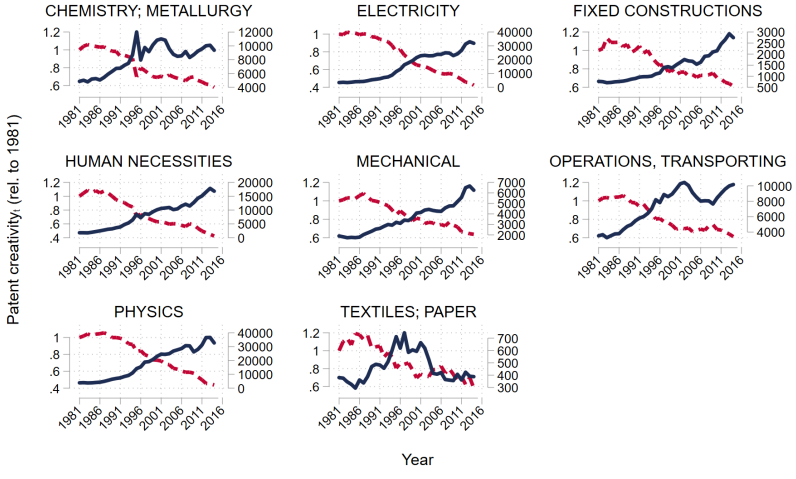
# Validation: Citation patterns of *creative* and *derivative* patents




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

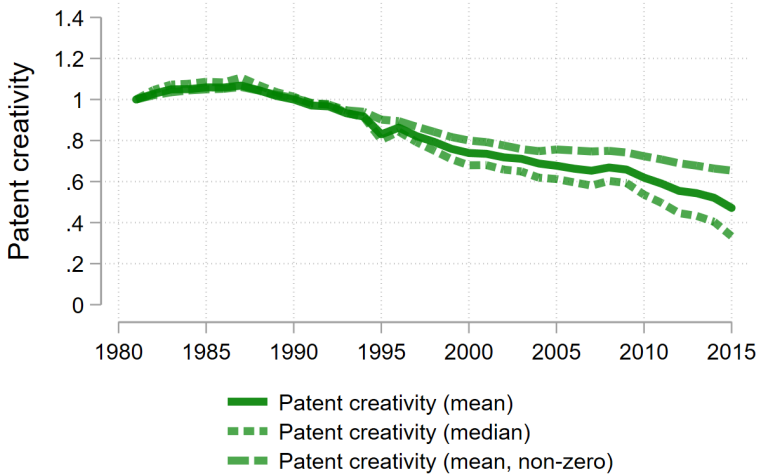
# Details: Patent creativity by technology class

Figure: *PatentCreativity* by year for each technology class

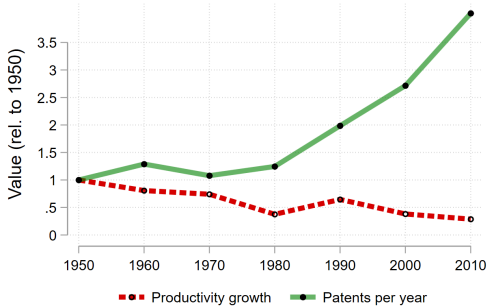


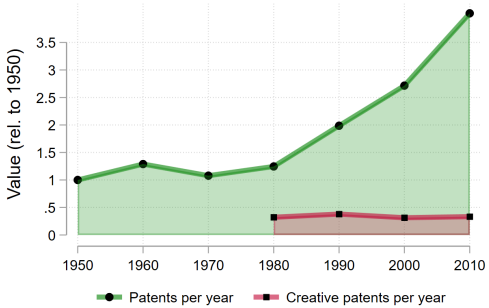
# Decline in creativity: other summary statistics

Figure: Distribution of patent creativity



# Details: Patents, Creative patents and productivity growth

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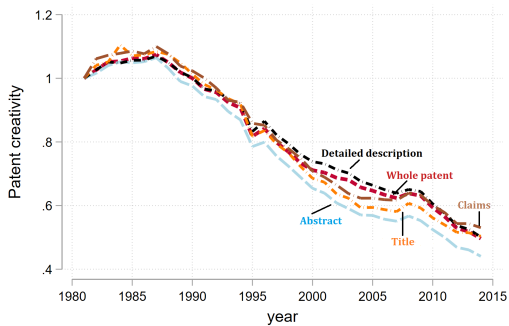
# Check 1/3: Increasing patent lengths

- 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→8,112).
- Length of patent titles (9→10) and abstracts (102→98) have largely remained the same.
- Pct. patents with titles which contain at least one creative bigram have decreased from 24% to 14%.

Figure: *PatentCreativity* calculated using different patent sections




Section lengths back

# 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 -

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

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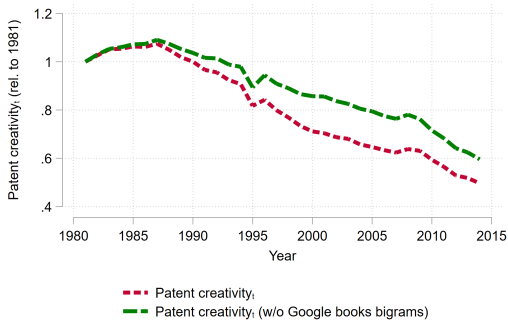
Figure: *PatentCreativity* w/o language trends



# 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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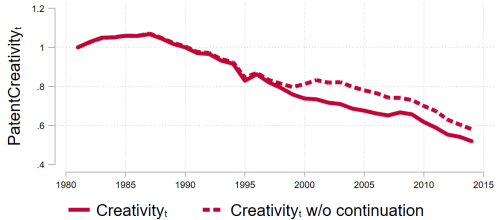
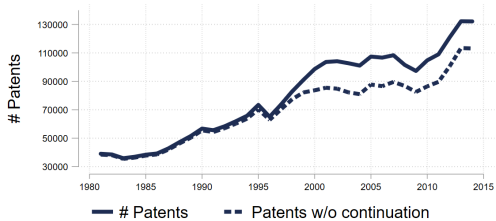
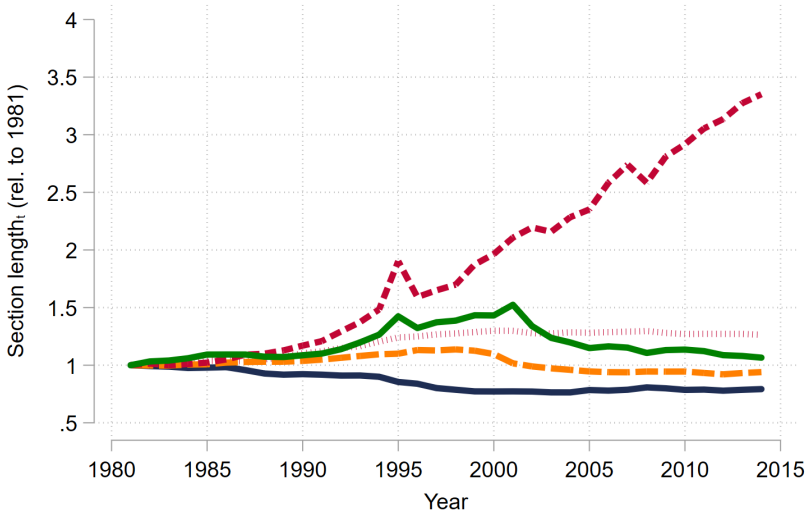


# Details: Lengths of patent sections

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# Creative patenting, labor productivity and investment rates

| | *LaborProd* (1) | *Growth**100 (2) | *InvestmentRate**100 (3) | (4) |
|---|---|---|---|---|
| ihs(CreativePatenting$_{i,t}$) | 0.214* | 0.214* | 0.223*** | 0.223*** |
| | (0.116) | (0.116) | (0.085) | (0.085) |
| ihs(DerivativePatenting$_{i,t}$) | –0.166 | –0.166 | 0.037 | 0.037 |
| | (0.119) | (0.119) | (0.075) | (0.075) |
| $R^2$ | 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$_{i,t}$ (5-year differences, in pct.) | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| ihs(creative patents$_{i,t}$) | | 0.268* | | 0.221 |
| | | (0.154) | | (0.181) |
| ihs(original patents$_{i,t}$ - bck sim.) | –0.047 | –0.145 | | |
| | (0.158) | (0.168) | | |
| ihs(non-original patents$_{i,t}$ - bck sim.) | –0.019 | –0.099 | | |
| | (0.129) | (0.140) | | |
| ihs(original patents$_{i,t}$ - cites HHI) | | | –0.252 | –0.297* |
| | | | (0.182) | (0.179) |
| ihs(non-original patents$_{i,t}$ - cites HHI) | | | 0.026 | –0.061 |
| | | | (0.166) | (0.195) |
| $R^2$ | 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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# Industry level productivity growth

Table: Patent Creativity and Industry-level TFP Growth

| | TFP Growth$_{i,t}$ (5-year differences) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| ihs(patents$_{i,t}$) | –3.190*** | | | | |
| | (1.062) | | | | |
| ihs(creative patenting$_{i,t}$) | | 1.920*** | 1.674** | 2.203* | 6.278*** |
| | | (0.737) | (0.677) | (1.294) | (1.947) |
| ihs(derivative patenting$_{i,t}$) | | | –2.773*** | | –5.812*** |
| | | | (0.925) | | (1.359) |
| Partial $R^2$ | 0.041 | 0.019 | 0.059 | 0.007 | 0.097 |
| N | 506 | 506 | 506 | 506 | 506 |
| Year FE | N | N | N | Y | Y |
| Industry FE | Y | Y | Y | Y | Y |

*Notes*: Standard errors are clustered by industry.

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# Creative patenting, and employment and sales growth

| | *EmpGrowth**100 | | *SalesGrowth**100 | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| ihs(CreativePatents$_{i,t}$) | 0.586*** | 0.586*** | 0.716*** | 0.716*** |
| | (0.153) | (0.153) | (0.197) | (0.197) |
| ihs(DerivativePatents$_{i,t}$) | 1.145*** | 1.145*** | 0.942*** | 0.942*** |
| | (0.162) | (0.162) | (0.214) | (0.214) |
| $R^2$ | 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$_p$ | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| | Full | 1980s | 1990s | 2000s |
| First-time patent$_p$ | 0.434*** | 0.429*** | 0.441*** | 0.420*** |
| | (0.026) | (0.033) | (0.025) | (0.030) |
| $R^2$ | 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: First-time inventor patent creativity

| | Stock returns$_{i,t}$*100 | | | |
|---|---|---|---|---|
| | (1) OLS | (2) OLS | (3) OLS | (4) IV |
| lhs(creative patents$_{i,t}$) | 0.093*** | | 0.077*** | 0.121*** |
| | (0.022) | | (0.030) | (0.036) |
| lhs(new-entry patents$_{i,t}$) | | 0.072*** | 0.026 | |
| | | (0.020) | (0.028) | |
| $R^2$ | 0.075 | 0.075 | 0.075 | 0.000 |
| N | 1,816,951 | 1,816,951 | 1,816,951 | 1,816,951 |
| Year FE | Y | Y | Y | Y |
| Controls | Y | Y | Y | Y |

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# Robustness: Patent creativity of govt. funded patents

| | Patent creativity$_p$ | | | |
|---|---|---|---|---|
| | (1) Full | (2) 1980s | (3) 1990s | (4) 2000s |
| Government owned patent$_p$ | 0.529*** | 0.545*** | 0.465*** | 0.543*** |
| | (0.038) | (0.042) | (0.033) | (0.041) |
| *Partial*$R^2$ | 0.004 | 0.008 | 0.004 | 0.003 |
| $R^2$ | 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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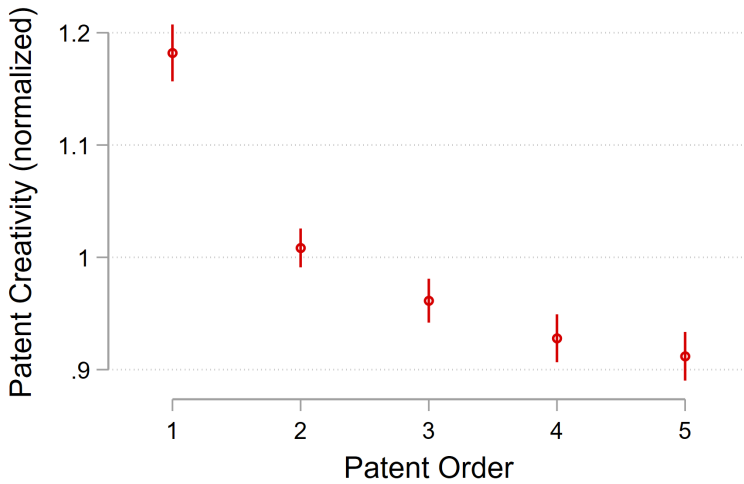
# Robustness: First-time inventor patent creativity

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# Patent creativity by degrees of govt. involvement

| | Patent creativity$_p$ | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Government owned$_p$ | 0.529*** | | | |
| | (0.038) | | | |
| Government funded$_p$ | | 0.348*** | | |
| | | (0.029) | | |
| Cites govt owned patent$_p$ | | | –0.007 | |
| | | | (0.010) | |
| Cites govt funded patent$_p$ | | | | –0.011*** |
| | | | | (0.002) |
| *PartialR*$^2$ | 0.004 | 0.007 | 0.000 | 0.001 |
| $R^2$ | 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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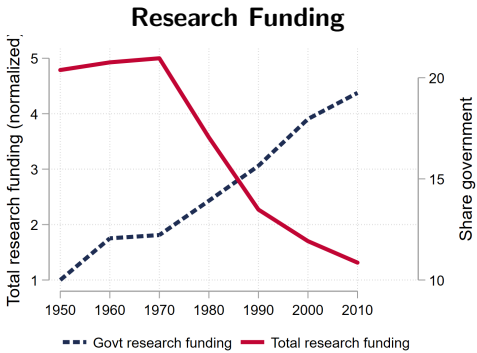
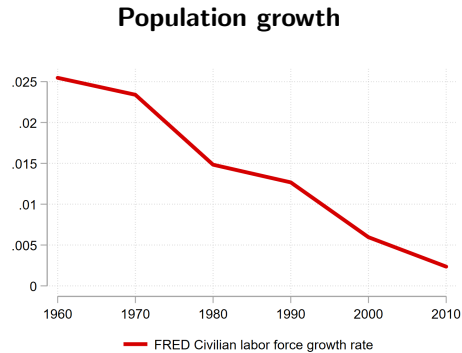
# Aggregate patterns in demographics and research funding

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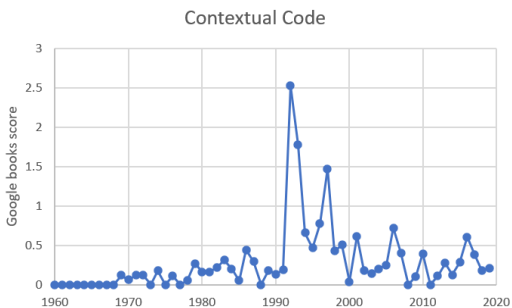
# Google ngram example

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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**

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(List continued on next page.)

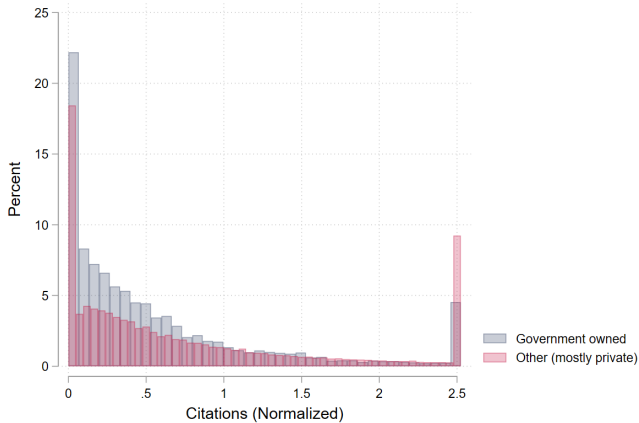
*Primary Examiner*—Sue Lao
(74) *Attorney, Agent, or Firm*—Gary S. Williams; Pennie & Edmonds LLP

(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.

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