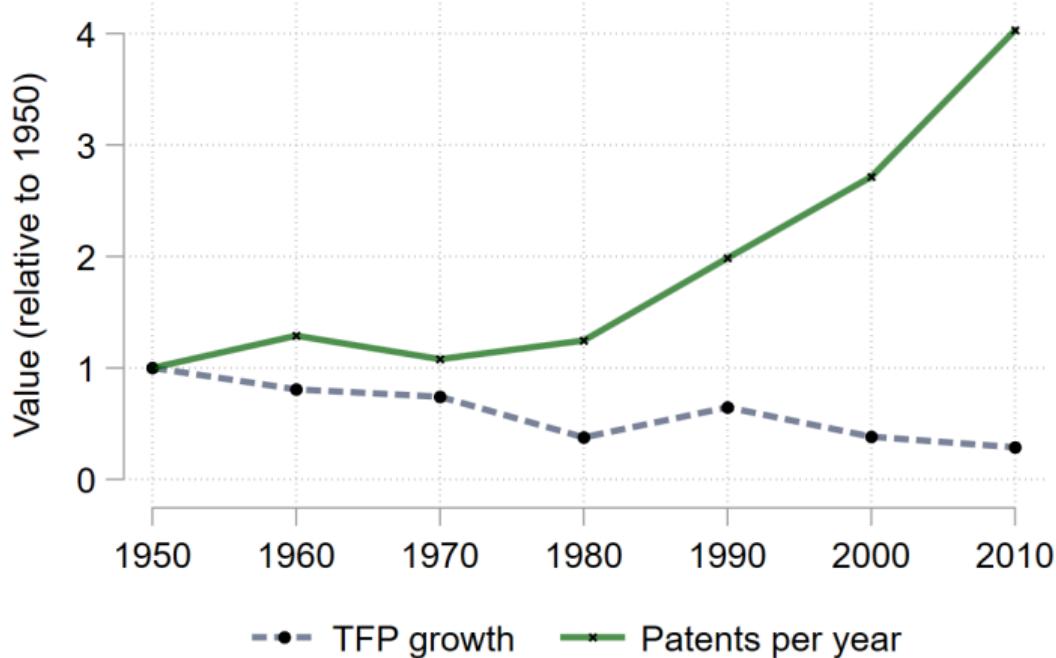


# The Creativity Decline: Evidence from US Patents

Aakash Kalyani  
Boston University

January 18, 2023

## Puzzle: Rise in Patenting Not Reflected in Aggregate Productivity Growth



Notes: Productivity denotes BLS Non Farm Total Factor productivity; USPTO patents by US inventors in per capita terms. Data points by decade.

# New Text-based Measure of Patent Creativity

## **Patent creativity** **share of new technical language**

- Share of new two-word combinations (e.g. 'cloud computing' in 2007)
- Captures degree to which a patent contains new products, processes, features.
- Backward looking measure - different from citations.

# Empirical Facts about Patent Creativity

1. **Creativity and Firm TFP:** Only creative patents associated with firm level TFP growth.
2. **The Creativity Decline:** Average patent in 2010 half as creative compared to 1980.
  - Observed increase in patents is entirely derivative.
  - Number of filed creative patents declining in line with TFP growth.
3. **The Creativity Life-cycle:** First patent by inventors tends to be their most creative one.

## Link Creativity Decline to Demographics

- Growth model with: 1. Creativity and diffusion, 2. Creativity life-cycle.
- Calibrate model to match new micro facts of patent creativity.
- Falling population growth accounts for one-third of decline in aggregate creativity and aggregate productivity growth.
  - Mechanism: changing composition of creative inventors through creativity life-cycle.

# Related Literature

- **Measurement** - Lerner and Seru (2022); Kelly et al. (2021), Hall et al. (2001), Watzinger and Schnitzer (2019),  
Lanjouw and Schankerman (2004);  
**New direct measure of creativity associated with TFP growth.**
- **Role of age 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);  
**Documents new creativity life-cycle for inventors.**
- **Slowdown in research productivity and growth** - Gordon (2012), Bloom et al. (2020); Syverson (2017), Park,  
Leahy and Funk (2023), Byrne et al. (2016); 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);  
**Lack of younger inventors links population growth and productivity growth.**
- **Innovation and diffusion models** - Kortum (1997), Luttmer (2007); Lucas Jr and Moll (2014), Perla and Tonetti  
(2014), Benhabib et al. (2021), Luttmer (2012);  
**Framework to link creative innovations to aggregate productivity growth.**

# Overview

Measurement

Empirical Findings

Quantitative Analysis

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Measurement

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Quantitative Analysis

## Patent Creativity: Share of New Technical Two-word Combinations

- Full text of patents filed by US inventors between 1976 and 2018 in US Patent Office.
- Decompose text into two word combinations - **bigrams**.
- Remove bigrams in colloquial language: keep only ‘technical bigrams’.
  - Corpus of Historical American English to exclude non-technical bigrams.
- **Classify bigram as creative if it does not appear in patents from previous 5 years.**

$$\text{Patent Creativity}_p = \frac{\text{creative technical bigrams}_p}{\text{technical bigrams}_p}$$

- Normalize such that sample average = 1.
- **Label top 20% as creative.**

# Example: What Makes a Patent Creative?

## United States Patent [19]

Wolff

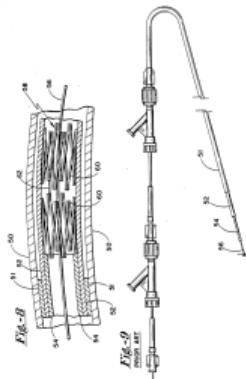
[54] ARTICULATED STENT

[75] Inventor: Rodney G. Wolff, Maple Grove, Minn.

[73] Assignee: Medtronic, Inc., Minneapolis, Minn.

[21] Appl. No.: 721,914

[22] Filed: Jun. 20, 1991



[57]

## ABSTRACT

In a first embodiment a number of stent segments are connected together by hinges welded in place to provide articulation between the stent segments. The hinges can be, among other shapes, either a straight wire or a coiled wire of biocompatible material. A second embodiment uses a stent of a previous invention made up of a number of wires welded together for the stent segments with connection between adjacent stents provided by having one of the wires of adjacent stents continue between these adjacent stents to provide a hinge action. In this embodiment the wire portion extending between the segments is ground to a smaller diameter than the wire of the stent segment itself, to provide the necessary hinge flexibility. This articulated stent made up of a number of individual stent segments, gives support for curved arteries, with the hinges between the segments providing both articulation and spacing between the stent segments. This articulated stent is tailored to match the curvature existing in the artery and is positioned at the site with the necessary preferred angular orientation using a previous catheter system.

- 46% of technical bigrams in the patent are creative.  
**Patent creativity - 4.84.**

# Is My Measure Capturing Creativity?

1. Correlations suggest creative patents are at the frontier:
  - Management talks about new products in earnings calls when filing creative patents. [link](#)
  - Firms that spend more R&D dollars per patent file more creative patents. [link](#)
  - Creative patents cite more recent academic papers. [link](#)
2. Creative patents receive higher and more persistent citations than derivative patents. [link](#)
3. Grants of creative (not derivative patents) associated with higher stock returns.

# Is My Measure Capturing Creativity?

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  - Creative patents cite more recent academic papers. [link](#)
2. Creative patents receive higher and more persistent citations than derivative patents. [link](#)
3. Grants of creative (not derivative patents) associated with higher stock returns.

# Validation: Only Creative Patent Grants associated with Stock Returns

$$r_{i,t} = \alpha + \beta \text{ IHS}(\text{creative patents}_{i,t}) + \chi_i + \delta_t + \epsilon_{i,t} \quad \text{where i: firm, t: time (week)}$$

	Stock Returns <sub>i,t</sub> (in pct., weekly)		
	(1)	(2)	(3)
IHS(creative patents <sub>i,t</sub> )	0.093*** (0.022)	0.085*** (0.026)	0.082*** (0.025)
IHS(derivative patents <sub>i,t</sub> )		0.009 (0.013)	
IHS(derivative patents <sub>i,t</sub> - citation weighted)			0.014 (0.013)
R <sup>2</sup>	0.075	0.075	0.075
N	1,816,951	1,816,951	1,816,951
Time FE	Y	Y	Y

IHS denotes inverse hyperbolic sine. Standard errors are clustered by firm. Controls for firm CAPM betas and past firm R& D expenditures.

- On average, an additional creative patent is associated with 11 basis point higher return.

## Validation: Versus Other Measures of Patent Originality

$$r_{i,t} = \alpha + \beta IHS(\text{creative patents}_{i,t}) + \chi_i + \delta_t + \epsilon_{i,t} \quad \text{where i: firm, t: time (week)}$$

	Stock Returns <sub>i,t</sub> *100 (weekly)		
	(1)	(2)	(3)
IHS(creative patents <sub>i,t</sub> )	0.104*** (0.034)	0.076*** (0.023)	0.073*** (0.022)
IHS(original patents <sub>i,t</sub> - backward similarity, Kelly et al. (2021))	-0.057 (0.064)		
IHS(original patents <sub>i,t</sub> - citations HHI, Hall et al. (2001))		0.014 (0.042)	
IHS(original patents <sub>i,t</sub> - # claims, Lanjouw and Schankerman (2004))			0.029 (0.041)
R <sup>2</sup>	0.062	0.075	0.075
N	1,214,662	1,816,951	1,816,951
Time FE	Y	Y	Y

Standard errors are clustered by firm. Observations vary due to data availability for other measures.

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## Fact 1: Creative Patents Associated with Higher TFP Growth

$$\Delta^5 \log(TFP)_{i,t} = \alpha + \beta_1 IHS(\text{Creative Patents})_{i,t} + \chi_{i,t} + \delta_i + \delta_t + \epsilon_{i,t}$$

- firm  $i$ , year  $t$
- TFP calculated by applying Olley and Pakes (1996) method on Compustat accounts.
- $\Delta^5 \log(TFP)_{i,t}$  is 5-year differences in  $\log(TFP)$ .
- $\chi_{i,t}$  denotes controls for polynomials of firm age, past R&D expenditures, and industry sales growth.

## Fact 1: Creative Patents Associated with Higher TFP Growth

	TFP Growth $_{i,t}$ (5-year differences, in pct.)				
	(1)	(2)	(3)	(4)	(5)
IHS(# patents $_{i,t}$ )	0.014 (0.101)				
IHS(# patents $_{i,t}$ - cite weighted $_{i,t}$ )		0.024 (0.090)			
IHS(# creative patents $_{i,t}$ )			0.172** (0.080)	0.215** (0.104)	0.211** (0.102)
IHS(# derivative patents $_{i,t}$ )				-0.095 (0.106)	
IHS(# derivative patents - cite weighted $_{i,t}$ )					-0.087 (0.091)
Partial R <sup>2</sup>	0.005	0.005	0.005	0.005	0.005
N	19,012	19,012	19,012	19,012	19,012
Year FE	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y

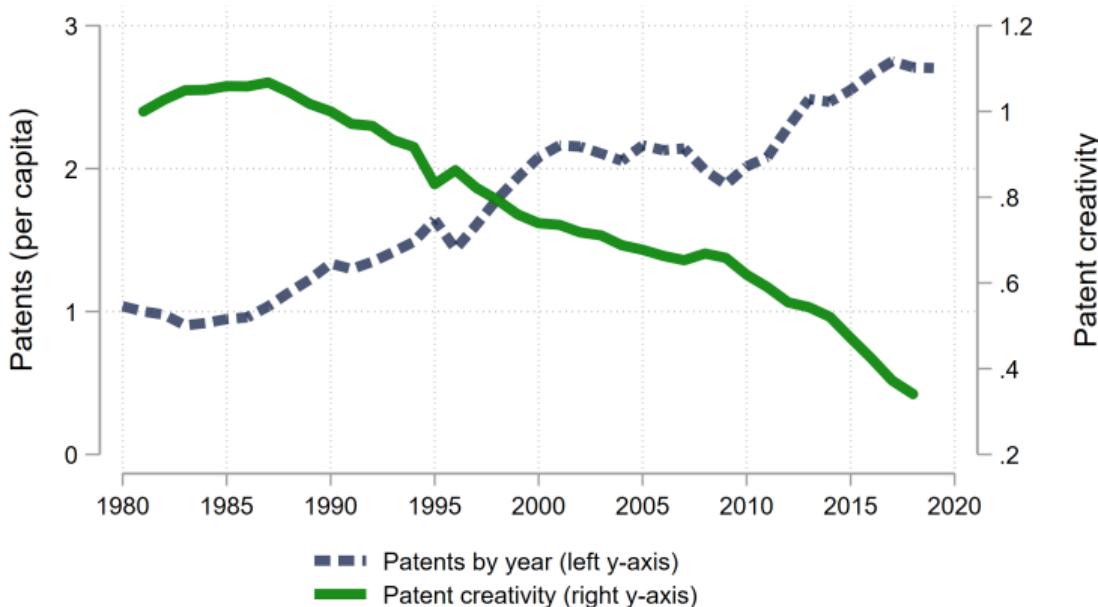
IHS denotes inverse hyperbolic sine. Standard errors are clustered by firm. Controls for past firm R& D expenditures, polynomials of firm age, industry sales growth. Sample of 1,194 manufacturing firms which file at least 10 patents.

## Fact 1: TFP Growth at the Industry Level

	TFP Growth <sub>n,t</sub> (5-year differences, in pct.)			
	(1)	(2)	(3)	(4)
IHS(# patents <sub>i,t</sub> )	-3.099*** (1.153)			
IHS(# patents <sub>i,t</sub> - cite weighted)		-3.345 (6.549)		
IHS(# creative patents <sub>i,t</sub> )			5.687*** (1.983)	9.805*** (2.838)
IHS(# derivative patents <sub>i,t</sub> )				-6.330*** (1.731)
Partial R <sup>2</sup>	0.020	0.000	0.039	0.125
N	299	299	299	299
Year FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y

Standard errors are clustered by industry. 4-digit NAICS manufacturing industries which file at least 1000 patents on average.

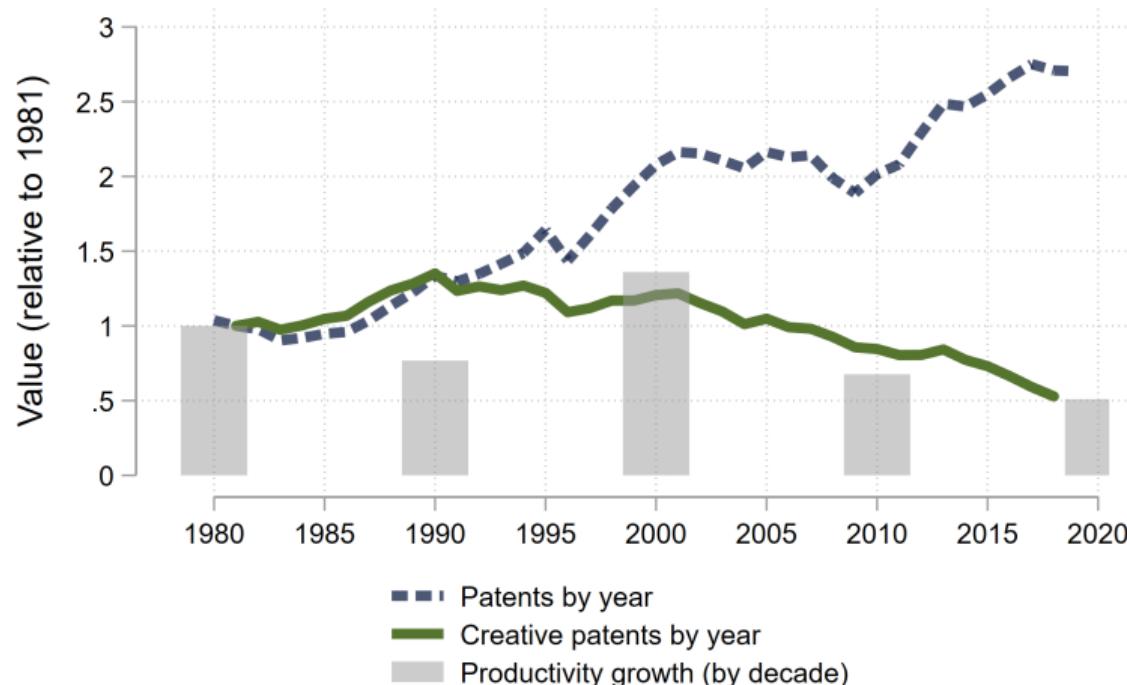
## Fact 2: The Creativity Decline



All patent numbers are per year and in per capita terms. Patents filed by US inventors between 1981 and 2018 are included in the sample.

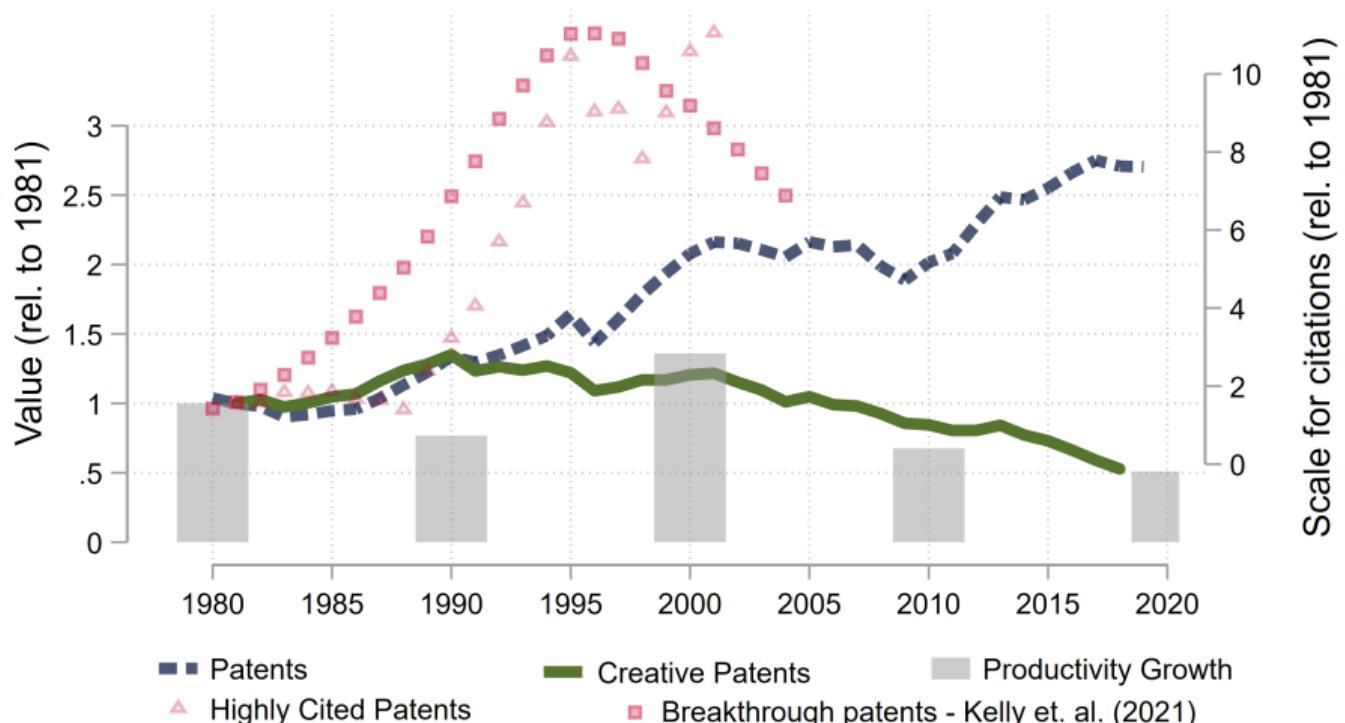
- Average share of creative technical bigrams: 14% (1981) vs 7% (2015).

## Fact 2: Creativity Decline Strong Enough to Overtake the Rise in Patents



All patent numbers are per year and in per capita terms. Patents filed by US inventors between 1981 and 2018 are included in the sample.

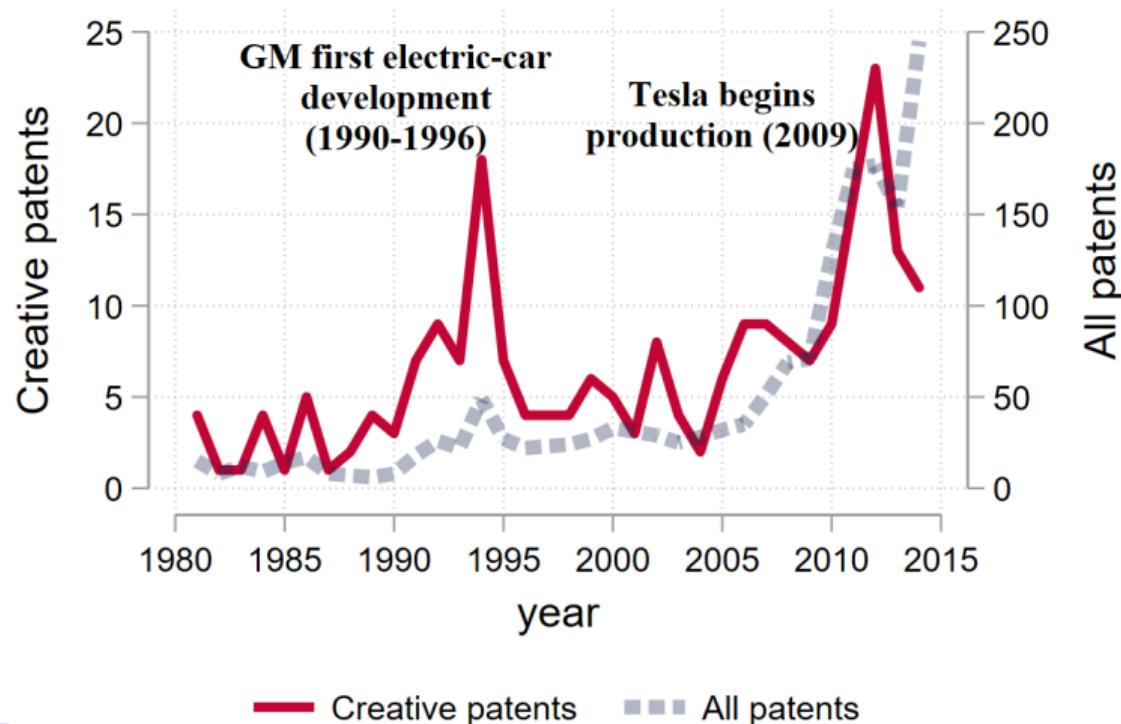
## Fact 2: Influential Patents have Increased



All patent numbers are per year and in per capita terms. Patents filed by US inventors between 1981 and 2018 are included in the sample.

## Fact 2: Multiple Waves of Creativity within Product Categories

### Patents filed under 'Electric Propulsion of Vehicles'



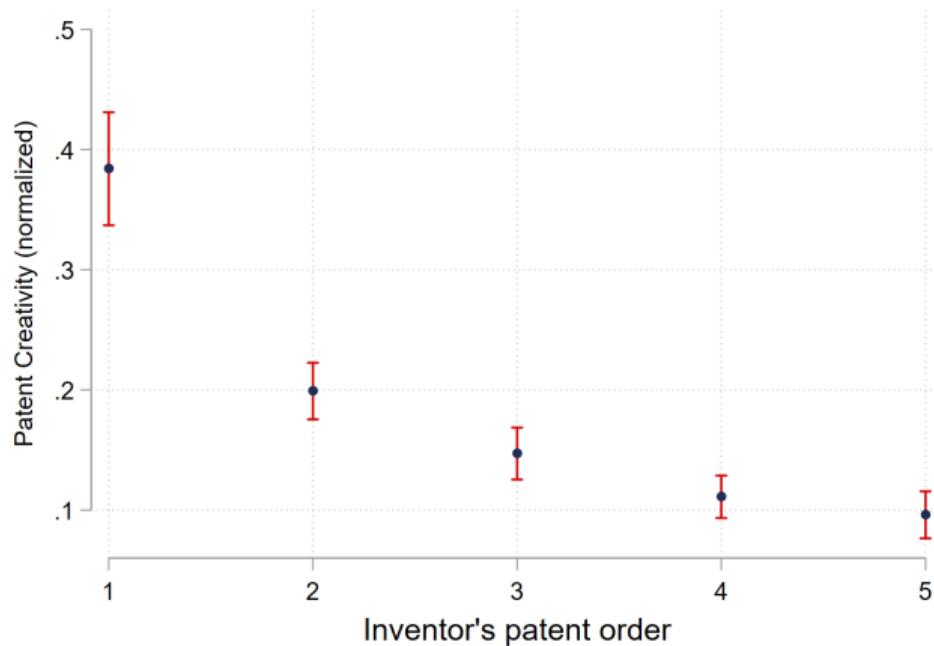
Other industry examples

## Fact 2: Robustness

- Creativity decline not due to **increasing patent lengths**.
  - Percentage of patents with creative bigrams in titles. [link](#)
- Creativity decline not due to **convergence in language**:
  - **Google Books Placebo:** Creativity not declining in Google books (8 million books). [link](#)
  - Patents use only about 7% of all technical bigrams in Google books.
  - Exclude bigrams in Google books; recalculate creativity. [link](#)
- **Heavily litigated (continuation) patenting** accounts for only 10% declining creativity.
  - [link](#)

## Fact 3: Creativity Declines over the Life-cycle

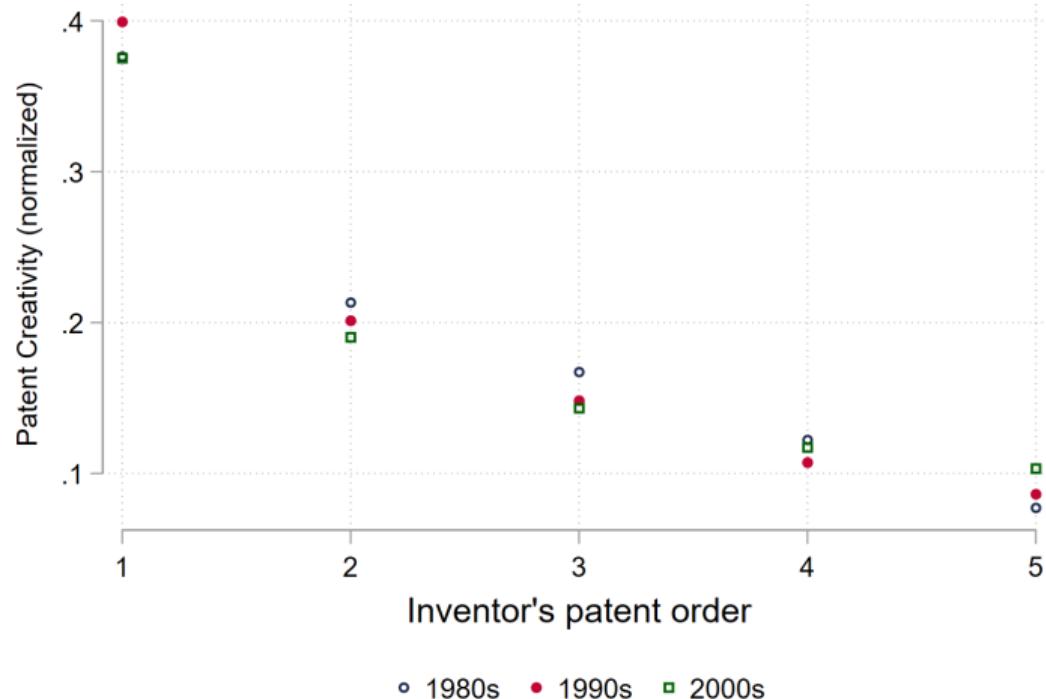
$$\text{Patent Creativity}_p = \alpha_0 + \sum \beta_k \{\text{Order}_p == k\} + \chi_p + \epsilon_p \quad \text{where } k: \text{inventor's order of patent}$$



Controls for technology class and year fixed effects. Standard errors are clustered by technology class. Inventors with at least 5 patents.

## Fact 3: Life-cycle Consistent over time

$$\text{Patent Creativity}_p = \alpha_0 + \sum \beta_k \{\text{Order}_p == k\} + \chi_p + \epsilon_p \quad \text{where } k: \text{inventor's order of patent}$$



## Summary of Empirical Facts

1. Creative patents are associated with firm level TFP.
2. The Creativity Decline
3. Creativity Life-cycle

Next, growth model which takes (1) + (3) and rationalizes (2) with changing demographics.

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## Model Overview: Two Types of Innovators

- Entrepreneurs/innovators produce varieties; operate in creative or derivative state.
- **Derivative state:** Make an imitation choice.
  - Stick to current technology or pay fixed cost to search for different one.
  - When searching, randomly assigned a technology (Perla and Tonetti, 2014) and new state **derivative or creative**.
- **Creative state:** Make technology improvements.
  - At some point, move to derivative state at random with their technology.
  - Improve the pool of technologies available for imitation.
- Entrants more likely to enter creative state than existing innovators.
  - Motivated by creativity life-cycle.

# Preferences and Technology

**Household**  $\bar{U} = \int_0^\infty U(C(t)) \exp^{-\rho t} dt$  **Utility**

s.t.  $C(t) \leq \frac{W(t)}{P(t)} (L_p(t) + L_E(t) + L_X(t)) + \Pi(t)$  **Budget constraint**

$\frac{\dot{L}(t)}{L(t)} = g_L$  **Population Growth**

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

**Production (flow)**  $Q(v) = Z(v)L(v)$  **Variety Production**

$\Pi(t, Z(v)) \propto Z(v)^{\sigma-1} \Lambda(t)$  **Profits**

## Derivative Innovators - Imitation Choice

- **Derivative State:**

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

abandon technology and search

$$V_N(t) = p_C \int V_C(t, Z') d\Phi_C(Z') + (1 - p_C) \int V_D(t, Z') d\Phi_D(Z')$$

Move to creative state      Allocated another technology randomly

- $\Phi_C$ : Distribution of creative technologies,  $\Phi_D$ : Distribution of derivative technologies.
- Cut-off rule: abandon if  $Z \leq M(t)$
- $V_C$  = Value of creative state, next..

# Creative Innovators - Make Productivity Improvements

- **Creative State:**

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

- $\mu_C$ : drift,  $\nu$ : volatility - parameters governing the creativity process.

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

- Pareto tail of technologies along the BGP.

## New Entry

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

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

- Entrants have an advantage in realizing the creative state:  $p_C^E > p_C$ .
- Along BGP, rate of entry = population growth. ( $g_L$ ).
  - Keeps innovators per capita ( $I/L$ ) constant.

# What Drives Creativity and Growth along the BGP?

Denote share of creative innovators as  $\Omega_C$ .

- Endogenous productivity distribution of derivative innovators:

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

$\zeta(\Omega_C)$  is increasing in  $\Omega_C$ .  $\text{Tail}(\Phi_C) = f(\mu_c, \nu)$

- Aggregate productivity growth:

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

- Higher  $\Omega_C$ : better pool of technologies available for imitation.
- Creativity ( $\Omega_C$ ) is increasing in population growth ( $g_L$ ):

# Calibration

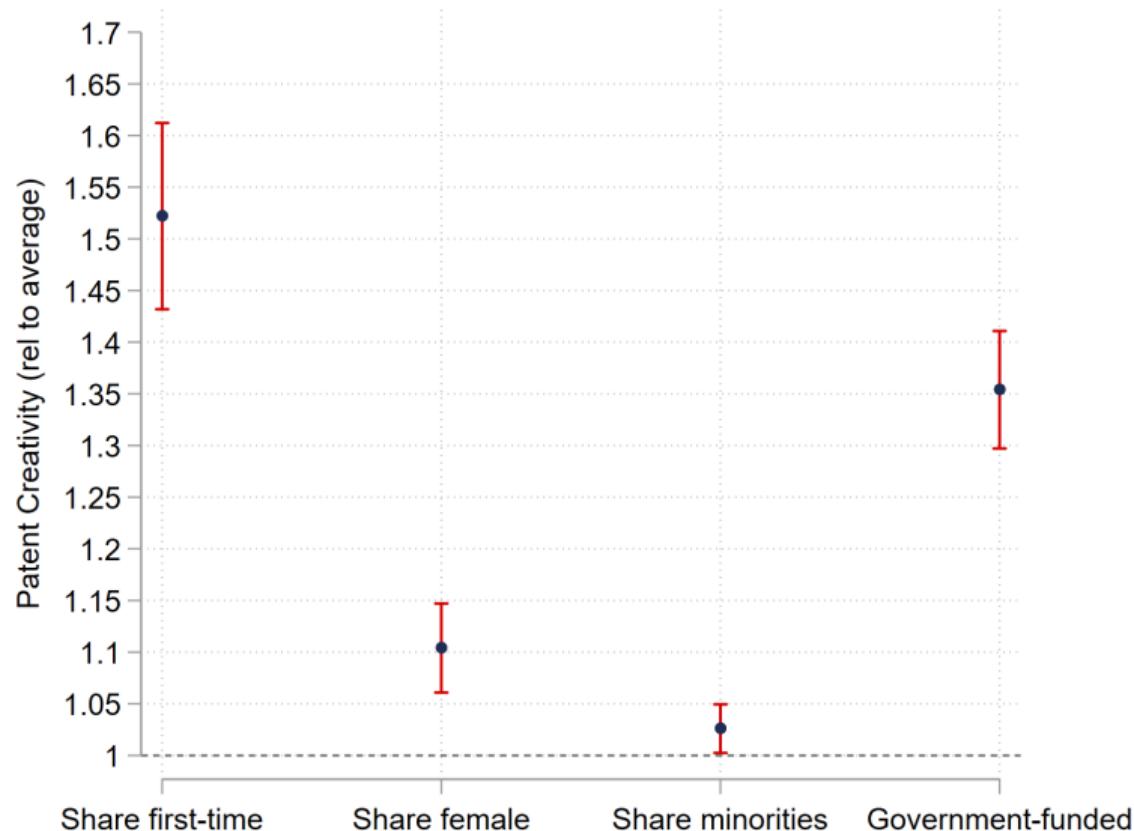
#	Moment	Value	Parameter	Value
I	Aggregate productivity growth	1.48%	Imitation cost ( $\eta$ )	6.55
II	Pct. innovators	9.82%	Entry cost ( $\eta_E$ )	10.87
III	Pct. creative innovators	12.53%	Creative-derivative transition probability ( $\alpha$ )	0.14
Fact 2(a)	Creative entrepreneur's TFP growth	0.17%	Drift of <i>creative</i> GBM ( $\mu$ )	0.0017
Fact 2(b)	Creative excess valuation	14.81%	Volatility of <i>creative</i> GBM ( $\nu$ )	0.038
Fact 3	Pct. creative first-time patents	23.74%	Creativity probability (entrants)( $p_c^E$ )	0.37
Fact 3	Pct. creative fifth patent	11.23%	Creativity probability (existing)( $p_c$ )	0.18

- Initial derivative pareto tail parameter: 4.99 (Perla, Tonetti and Waugh (2021)).
- Elasticity of substitution: 3.17. (Broda and Weinstein (2006))

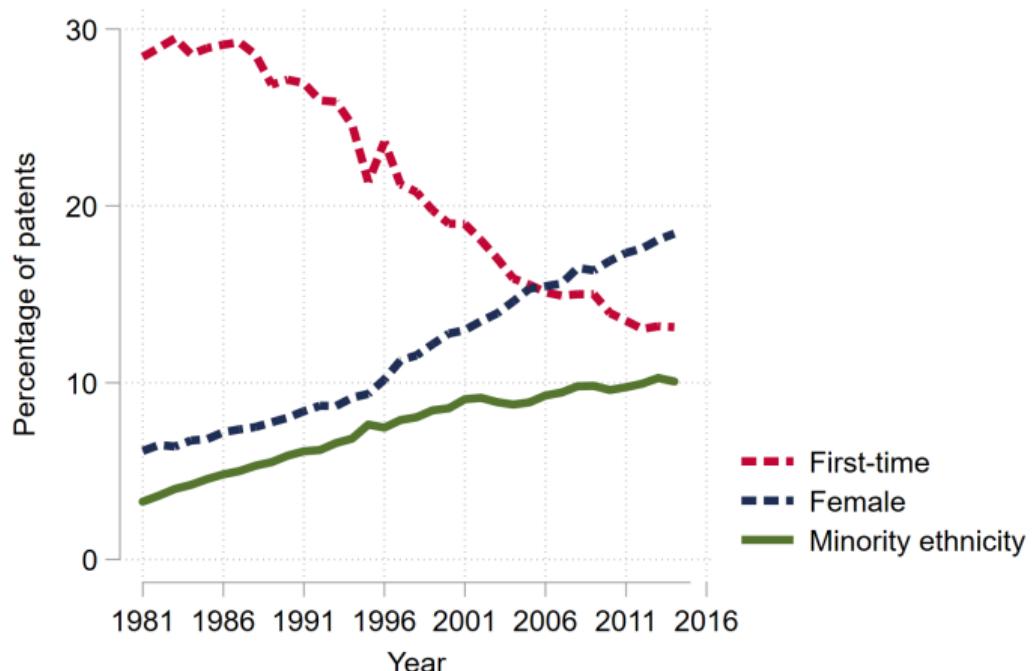
## Results - Declining population growth

	(1) 1980 $g_L$ : 2.3%	(2) 2010 $g_L$ : 0.7%	(3)	(4)	(5)
			Chg. in Model	Chg. in Data	Pct. Explained
Prod. Growth ( $g_m$ )	1.48%	1.21%	-20%	-66%	30%
Pct. Creative Innovators ( $\Omega_C$ )	12.53%	10.42%	-17%	-43%	39%
Innovators per capita ( $I/L$ )	9.82%	16.12%	73%	349%	21%
Mixture weight - $\tau(\Omega_C)$	73.47%	22%	-74%	-	-
Average $V_C(Z)$	9.515	13.419	44%	-	-
Average $V_D(Z)$	7.782	5.489	-31%	-	-

## Concluding Remarks: Other Drivers of Creativity



## Concluding Remarks: Changing Compositions into Patenting

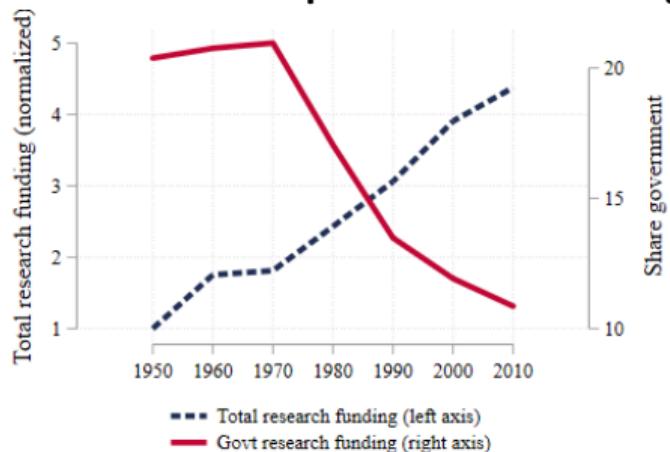


- Model estimates increase in inclusion leads a 3.75% increase in productivity growth.

# Concluding Remarks: Decreasing Government Research Subsidies

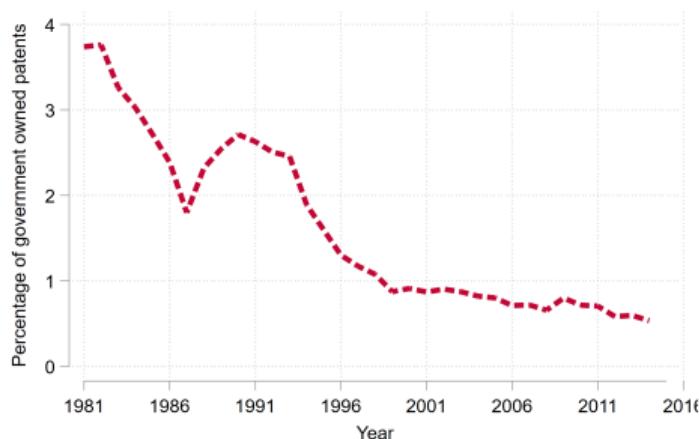
**Panel A**

## Government and private R&D funding



**Panel B**

## Pct. govt. owned patents



- Model estimates 5% decrease in productivity growth because of lack of government R&D.

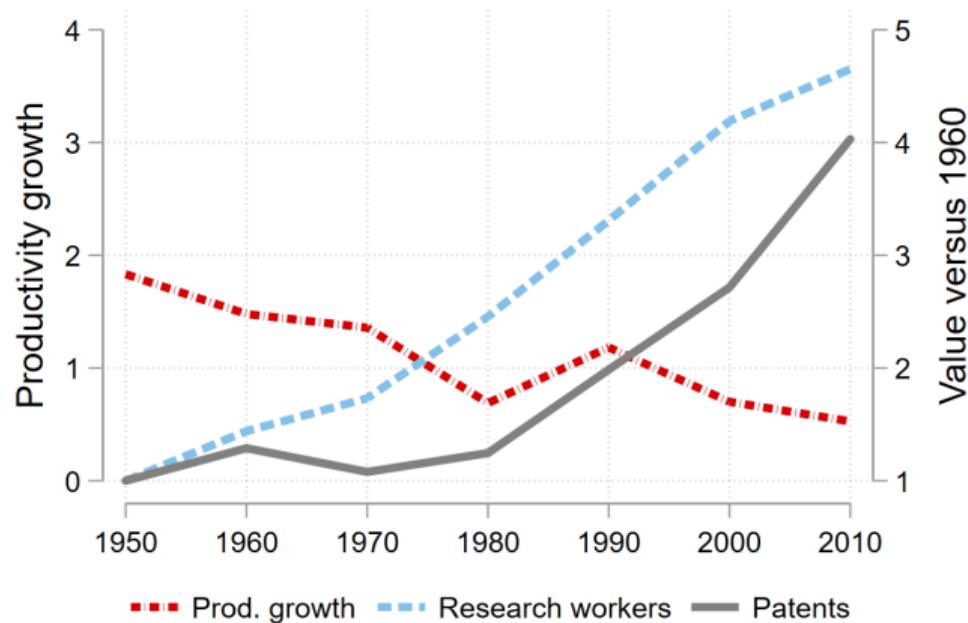
# Conclusion

Develop a new text-based measure of patent creativity.

- Creativity captures an important new dimension of innovations.
- **Creativity and Firm level TFP:** Creative patents are associated with firm level TFP growth.
- **The Creativity Decline:** Document a decline in creative patents.
- **Creativity life-cycle:** For inventors, creativity declines over the life-cycle.
- Third of the decline in creativity is driven by falling population growth.

**Future work:** to understand what makes inventors and firms **Creative!**

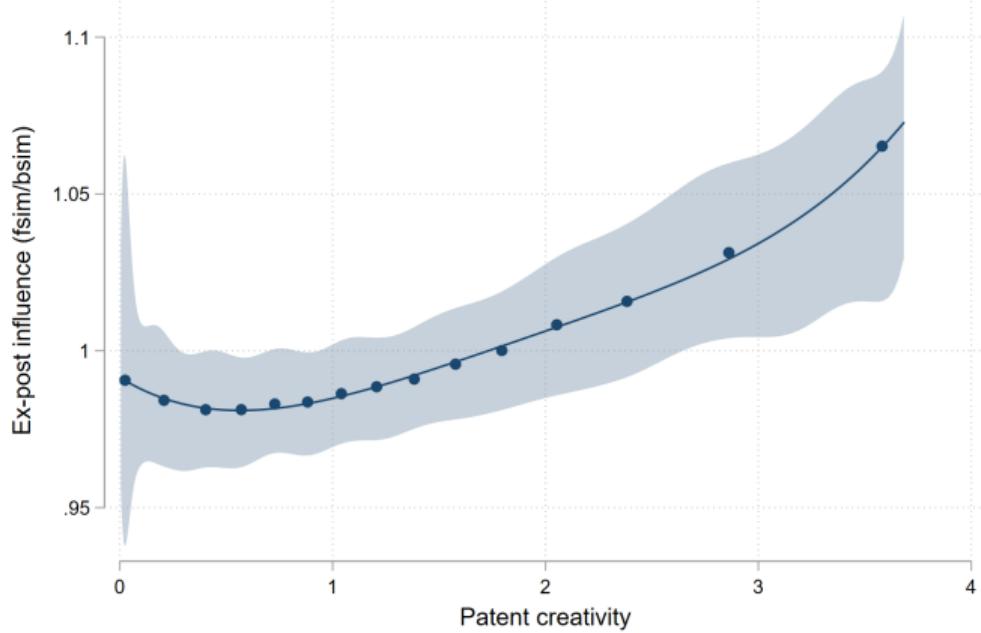
## Details: Productivity, research expenditure and patents



Notes:

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## Details: Influence and creativity



Notes:

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# 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

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

## 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 $_{i,t}$ (weekly)				
	(1)	(2)	(3)	(4)	(5)
ihs(creative patenting $_{i,t}$ )	0.161*** (0.022)	0.093*** (0.022)	0.085*** (0.026)	0.082*** (0.025)	0.083*** (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)
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.

back

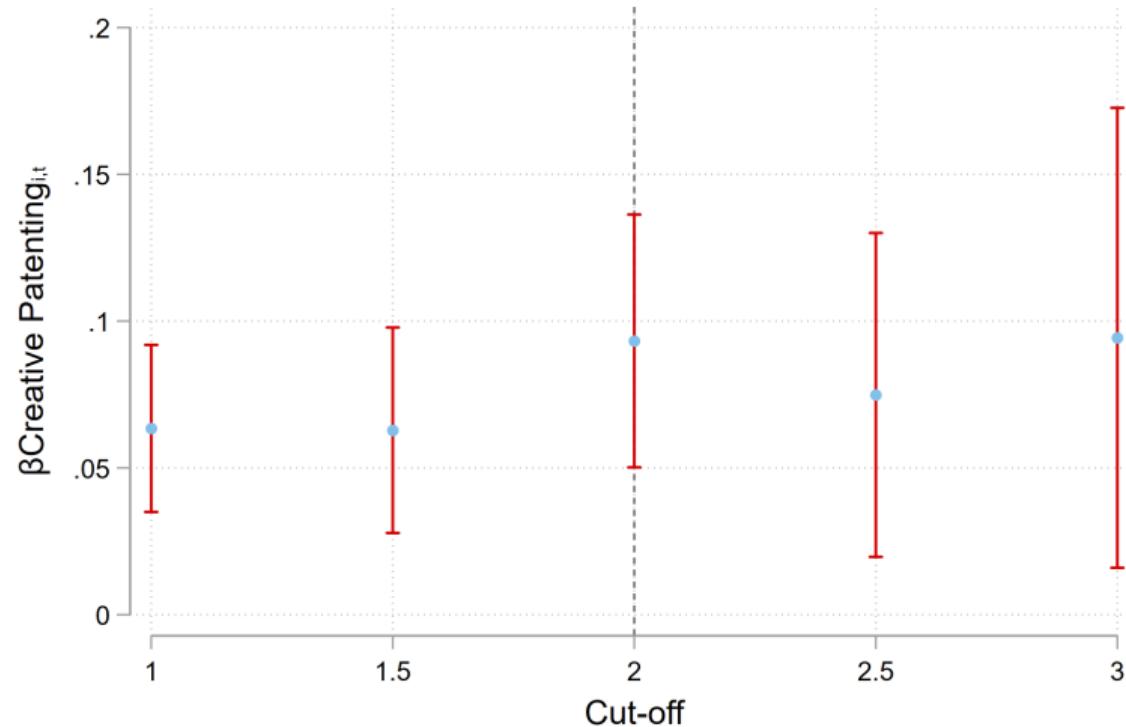
## Validation: Creative Patents Receive Higher Citations

$$Citations_p = \alpha + \beta Creative\ Dummy_p + \epsilon_p \quad \text{where } p: \text{ patent}$$

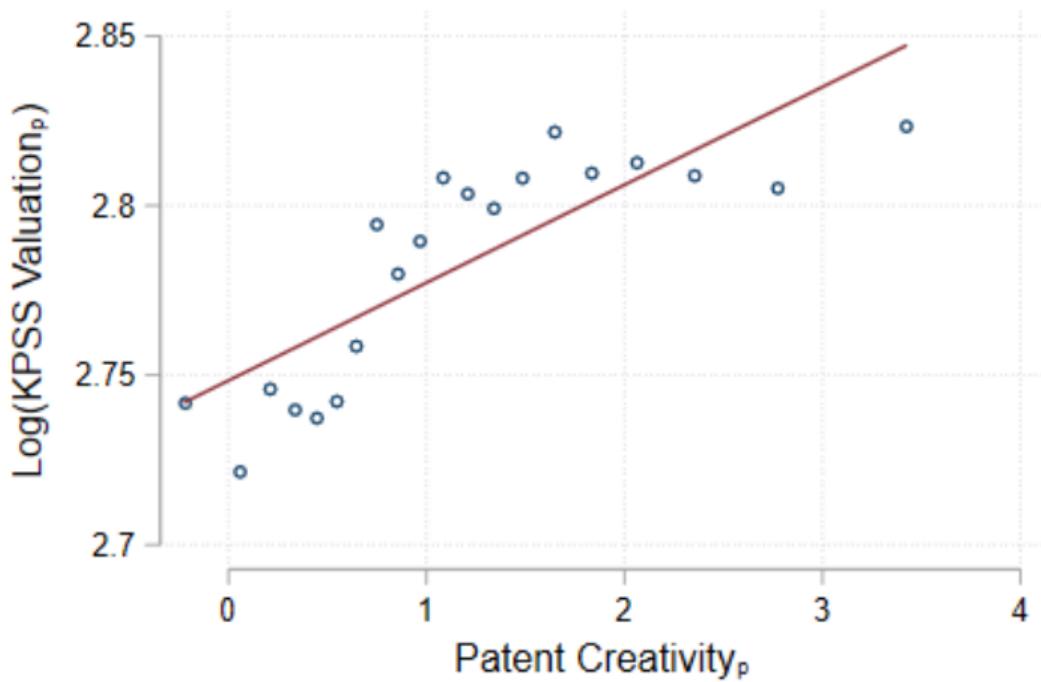
	Citations (normalized)		
	All (1)	First 5 years (2)	5-10 years (3)
Creative Patent <sub>p</sub>	0.237*** (0.022)	0.147*** (0.015)	0.236*** (0.020)
R <sup>2</sup>	0.022	0.033	0.015
N	890,275	890,275	890,275
Technology Class FE	Y	Y	Y
Filing Year FE	Y	Y	Y

Standard errors are clustered by technology class. Controls for filing year fixed effects. Includes patents for which at least 10 years of citations are observed.

## Robustness: Cut-offs for creative patents

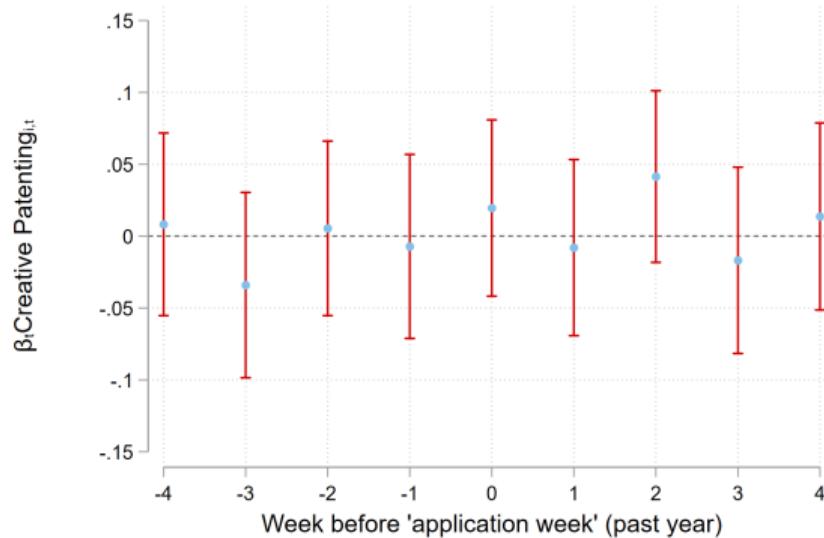


## Creative Patents are more Valuable - KPSS measure



## 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

$$r_{i,t} = \alpha + \beta \text{ IHS}(\text{creative patents}_{i,t}) + \chi_i + \delta_t + \epsilon_{i,t} \quad \text{where i: firm, t: time (week)}$$

	Stock Returns $_{i,t}$ (in pct., weekly)		
	(1)	(2)	(3)
ihs(creative patents $_{i,t}$ )	0.072** (0.030)	0.073** (0.030)	0.068** (0.030)
ihs(derivative patents $_{i,t}$ )		-0.007 (0.018)	
ihs(derivative patents $_{i,t}$ - cite wt.)			0.014 (0.016)
$R^2$	0.078	0.078	0.078
N	1,817,679	1,817,679	1,817,679
Time FE	Y	Y	Y
Firm FE	Y	Y	Y

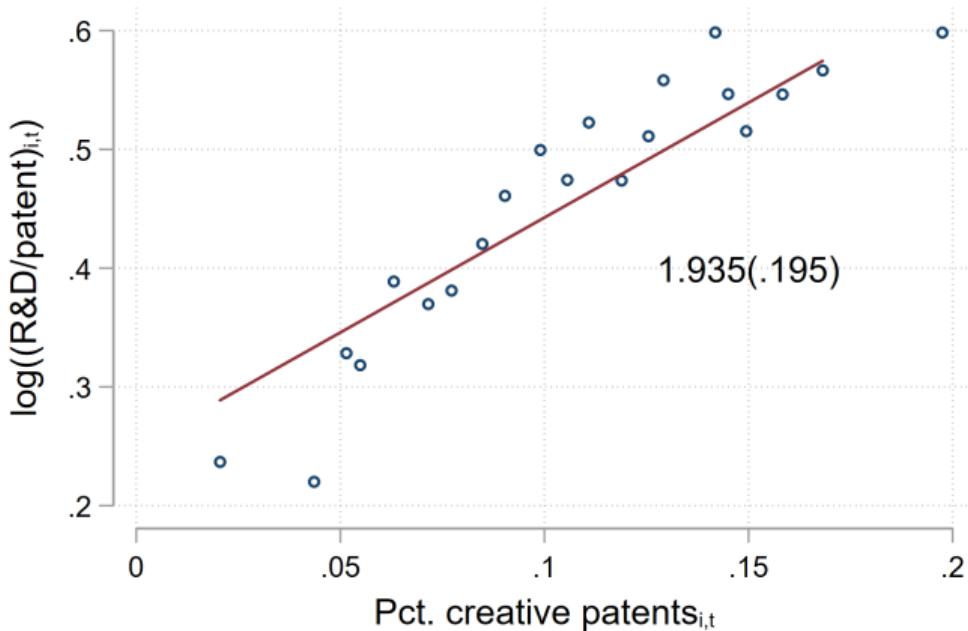
IHS denotes inverse hyperbolic sine. Standard errors are clustered by firm.

## 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  $\log(R&D)$  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

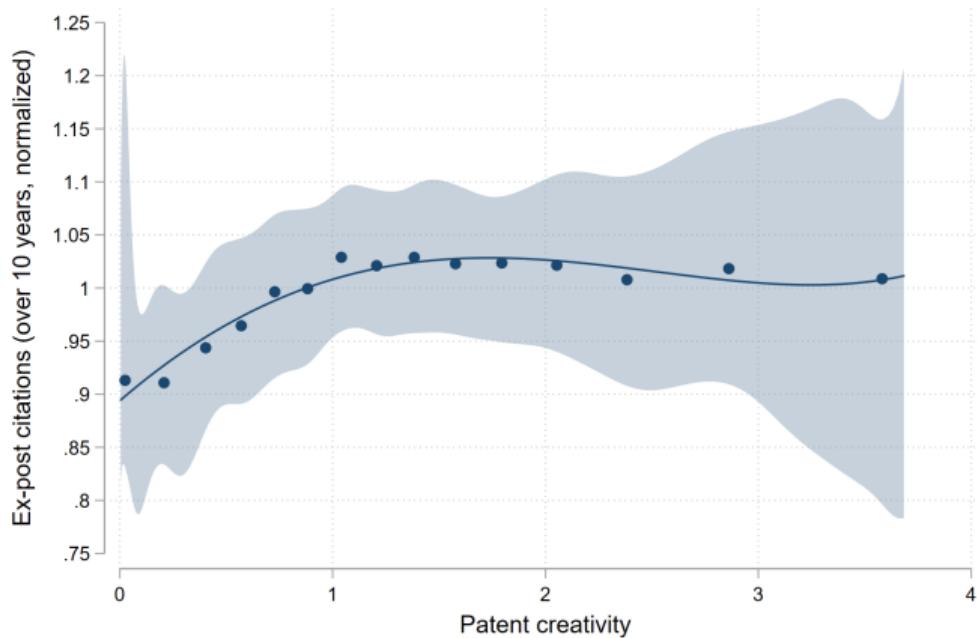
	Patent creativity		
	(1)	(2)	(3)
$1\{\text{Cites academic paper}\}_p$	0.337*** (0.051)	0.236*** (0.033)	
$1\{\text{Cites recent academic paper}\}_p$			0.359*** (0.033)
$1\{\text{Cites older academic paper}\}_p$			-0.026 (0.023)
Constant	0.913*** (0.039)	0.939*** (0.008)	0.932*** (0.009)
$R^2$	0.043	0.078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

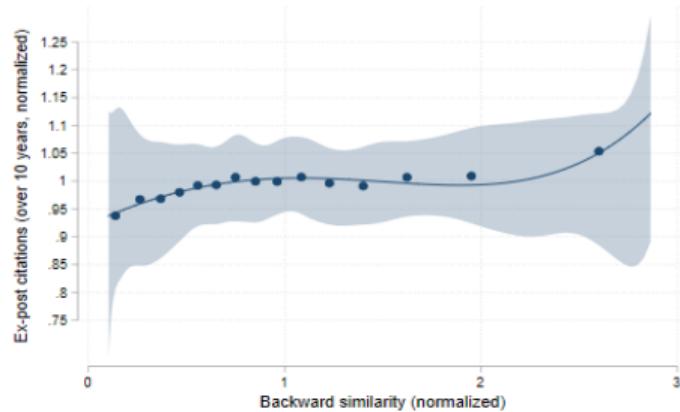
Citations



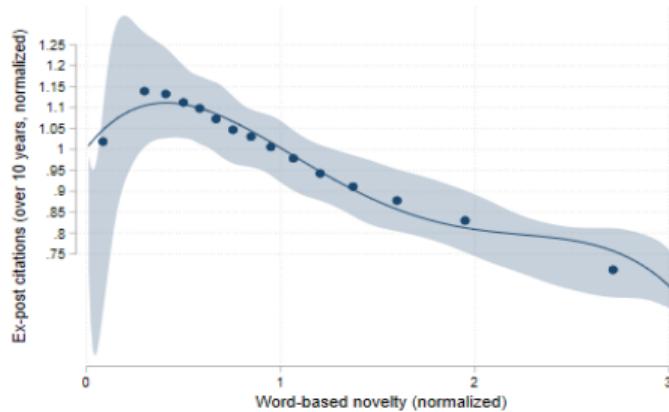
**Notes:** The figure plots a binned scatter plot of  $\text{patent creativity}_p$  against  $\text{citations}_p$ , while controlling for technology class and year fixed effects.

# Not the same pattern for other used measure of novelty with words

Backword similarity with words



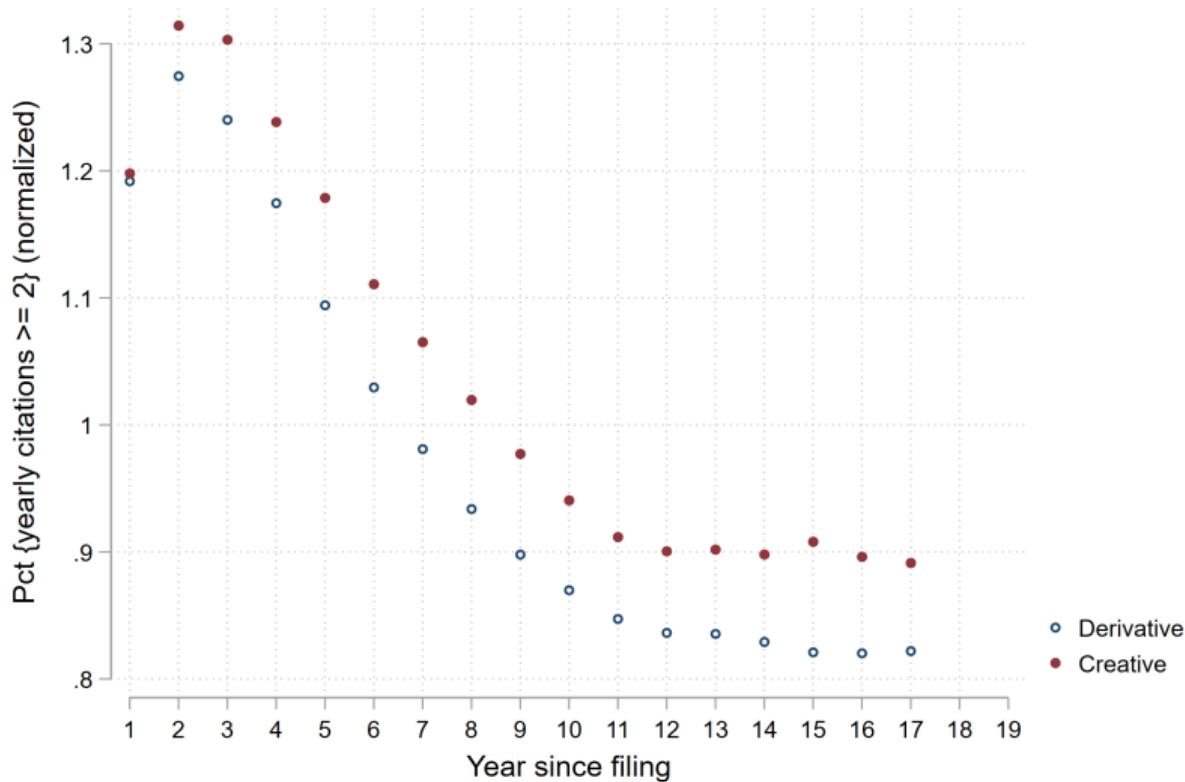
Word-based novelty



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- Reason: 'Machine' and 'Learning' are not new words, but 'MRNA Vaccine' is a new bigram.

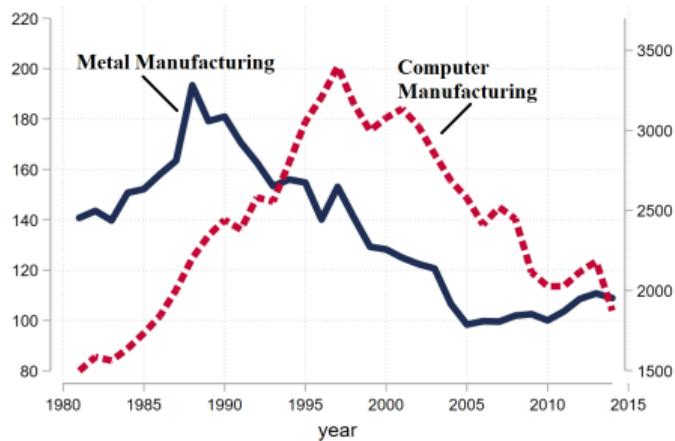
## Validation: Citation patterns of *creative* and *derivative* patents



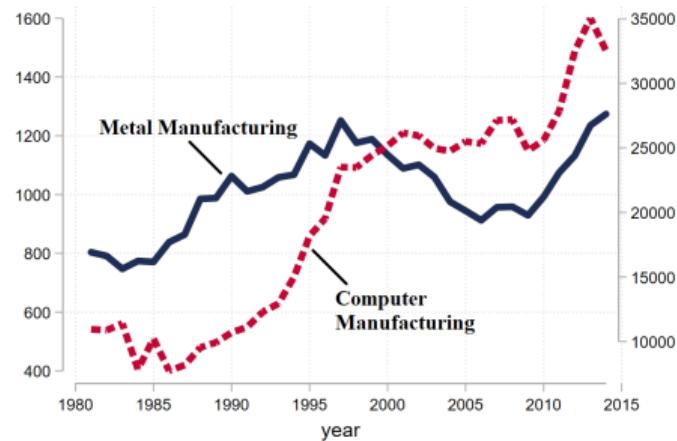
Notes: The figure plots percentage of patents which receive more than two normalized

# Example industry patterns: creative and all patents

## Creative patents



## All Patents

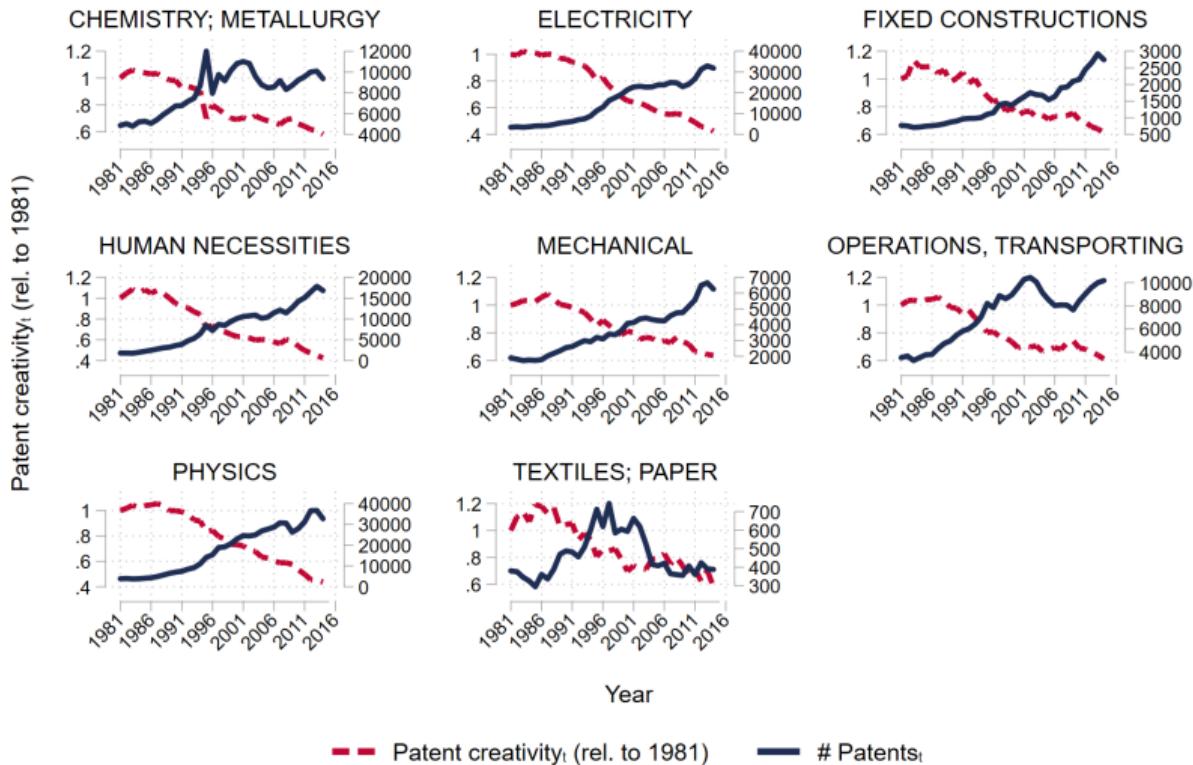


- Distinct patterns in creative and overall patenting across industries.

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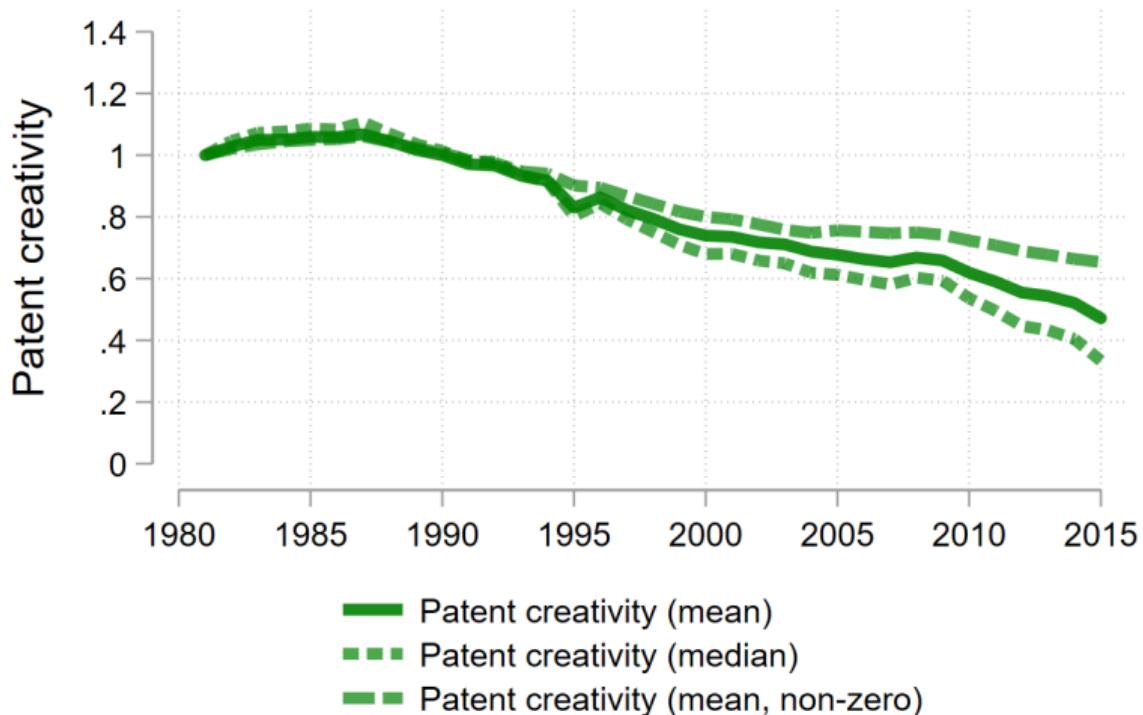
# Details: Patent creativity by technology class

Figure: *PatentCreativity* by year for each technology class

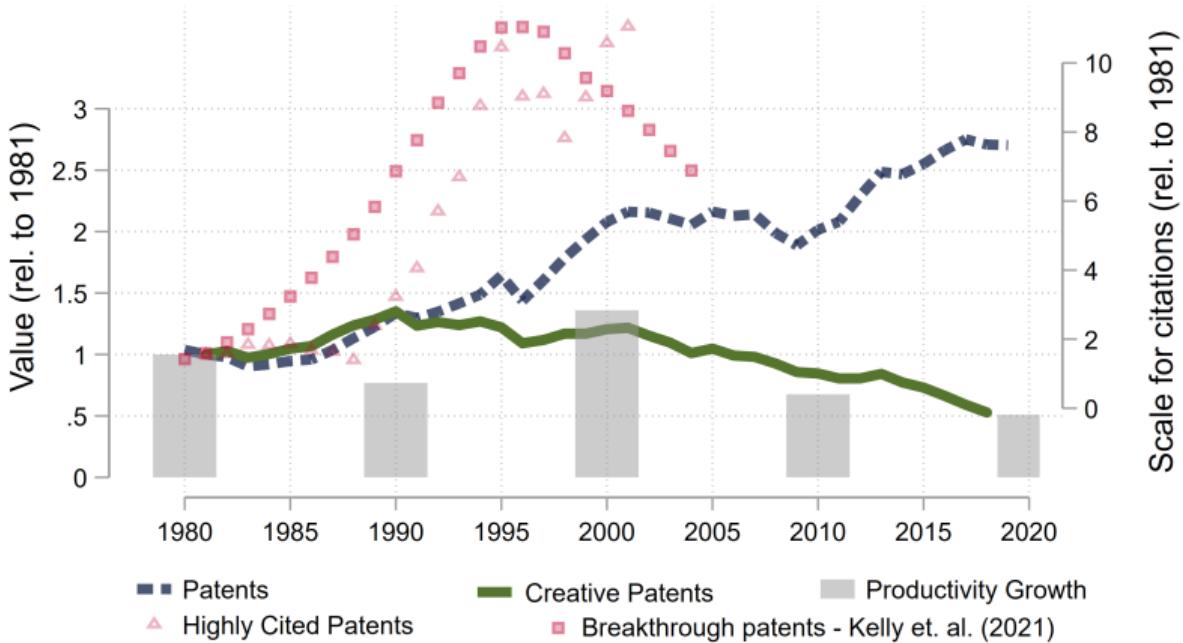


## Decline in creativity: other summary statistics

Figure: Distribution of patent creativity



# Highly cited or influential patents

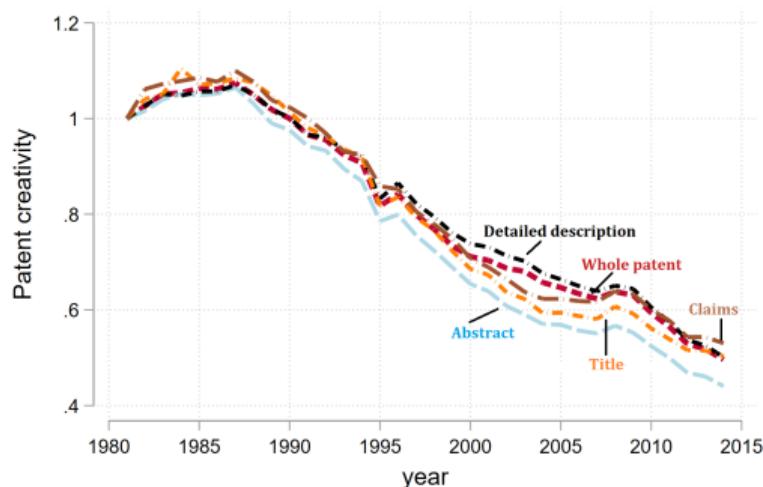


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## Check 1/3: Increasing patent lengths

- 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%.

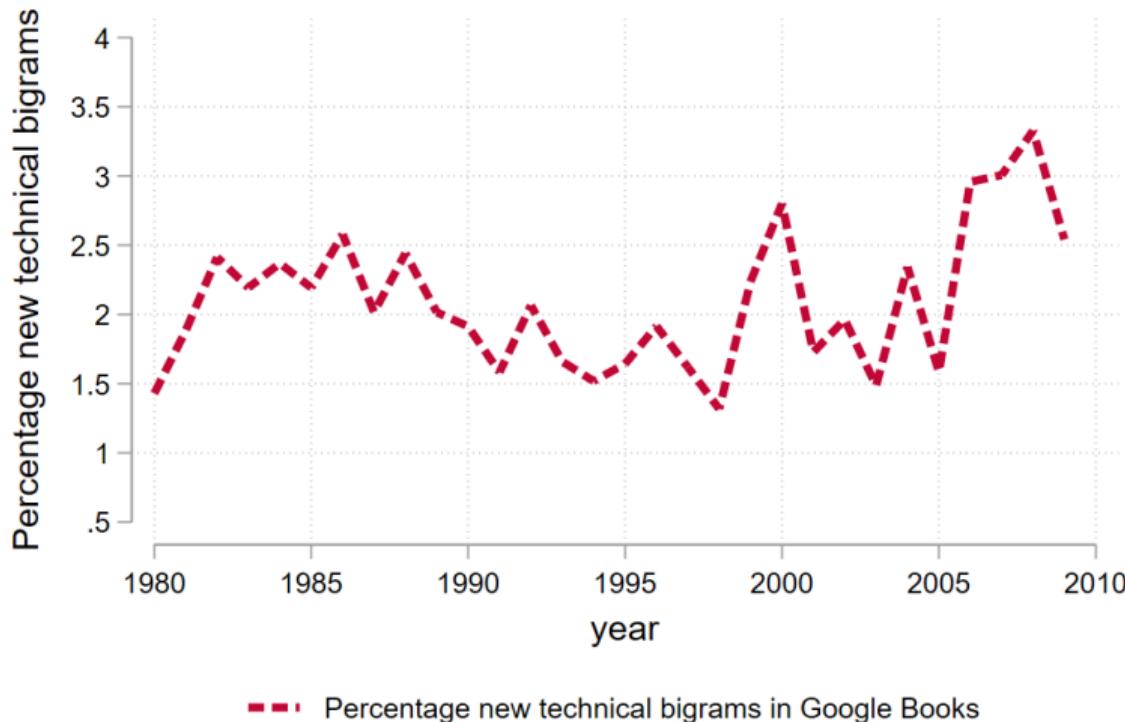
**Figure:** Patent Creativity calculated using different patent sections



[Section lengths](#)

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## Check 2/3: Creativity in Google Books

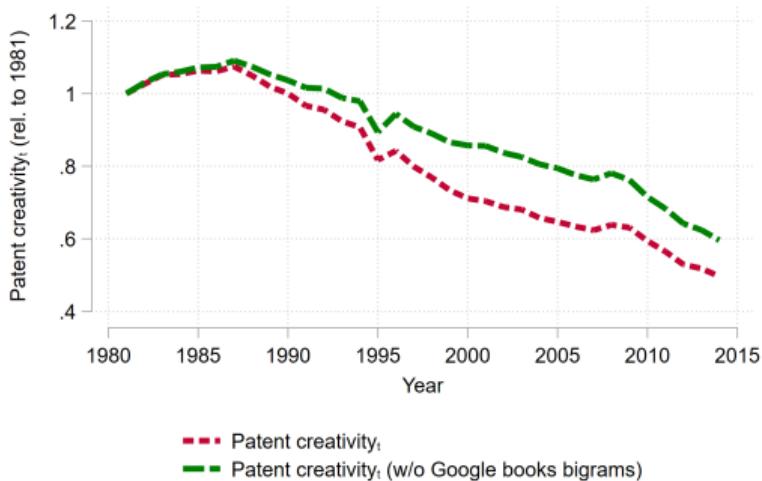


## Check 2/3: Language trends

- 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 -

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

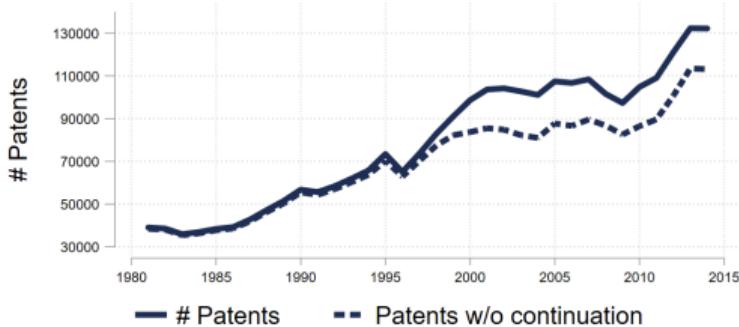
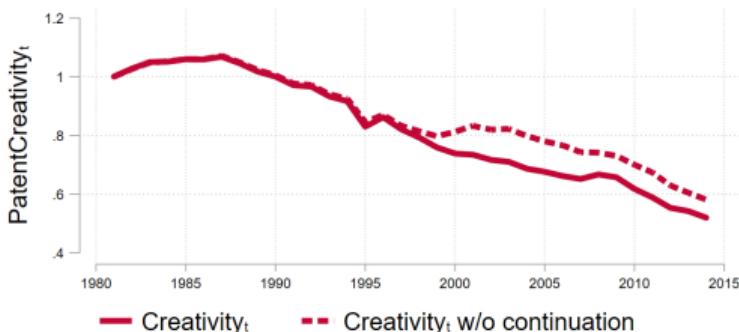
Figure: Patent Creativity w/o language trends



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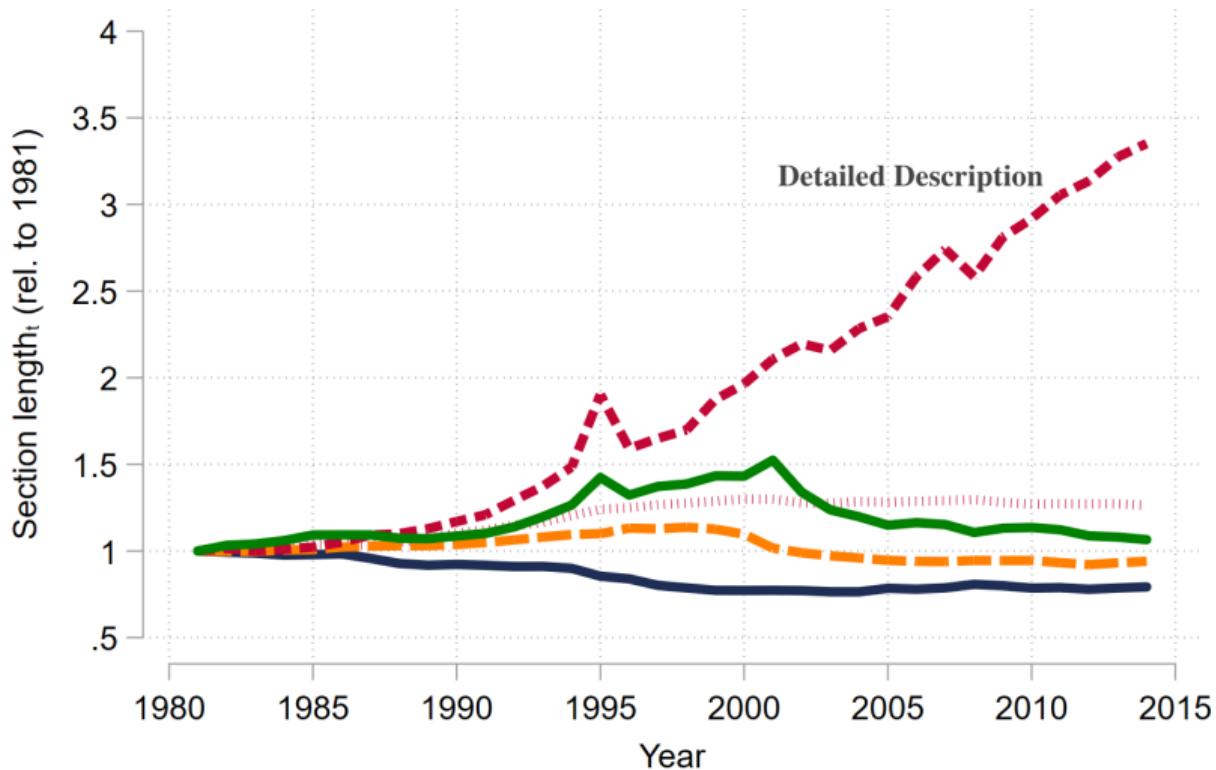
## Check 3/3: 'Continuation' (heavily litigated) patents

- '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

Standard errors are clustered by firm. Sample includes firms which file at least 10 patents in sample.

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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 <sub>i,t</sub> )	0.586*** (0.153)	0.586*** (0.153)	0.716*** (0.197)	0.716*** (0.197)
ihs(DerivativePatents <sub>i,t</sub> )	1.145*** (0.162)	1.145*** (0.162)	0.942*** (0.214)	0.942*** (0.214)
R <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

Standard errors are clustered by firm. Only includes firms which file at least 10 patents during my sample period.

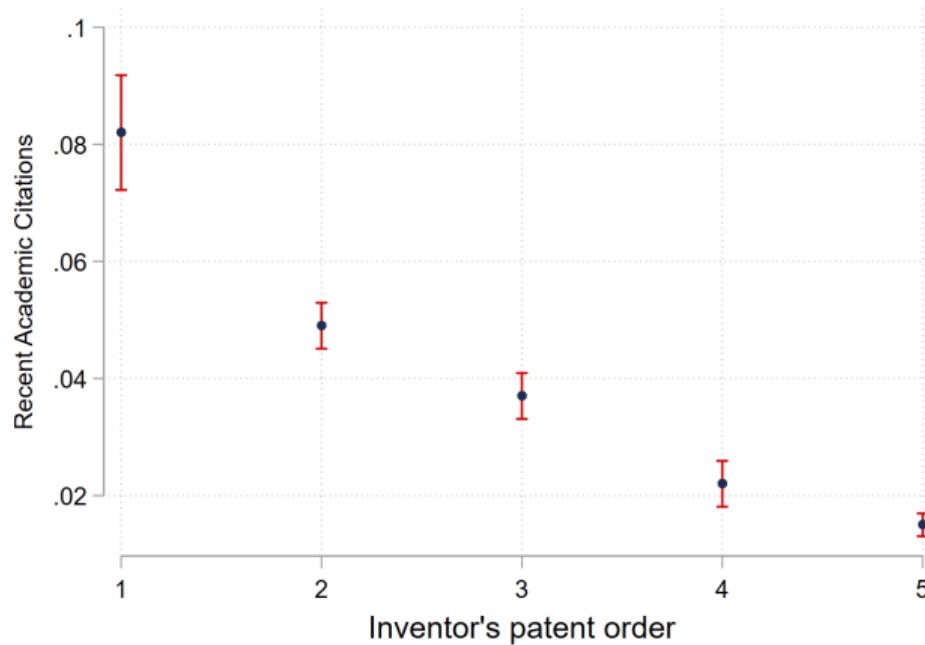
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## Robustness: First-time inventor patent creativity and stock returns

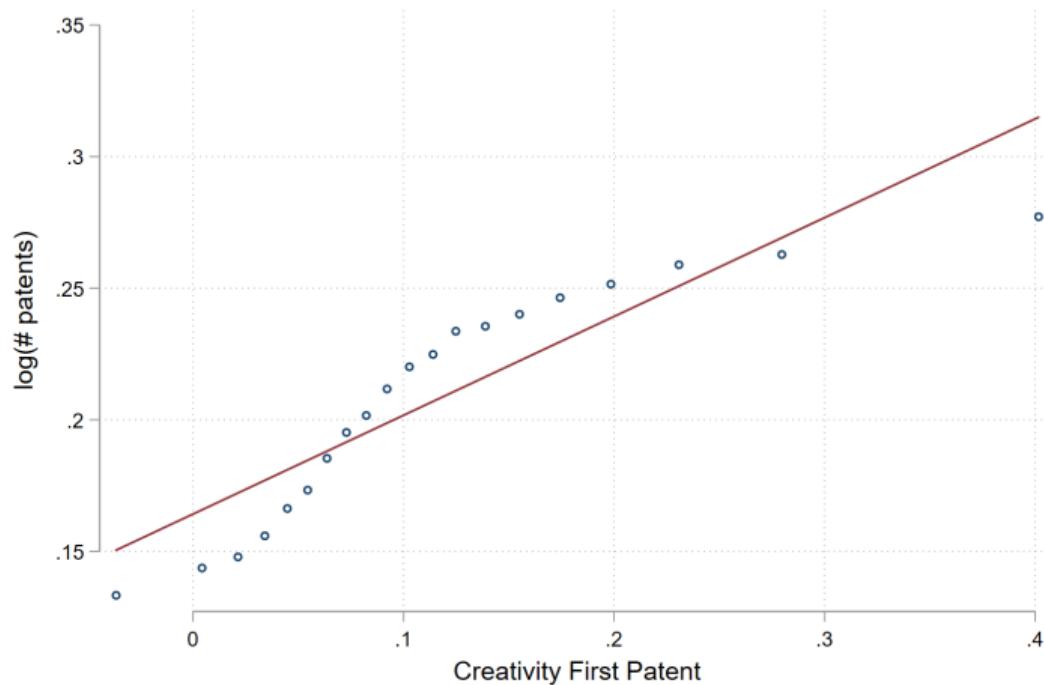
	Stock returns $_{i,t} * 100$		
	(1)	(2)	(3)
Ihs(creative patents $_{i,t}$ )	0.093*** (0.022)		0.077*** (0.030)
Ihs(new-entry patents $_{i,t}$ )		0.072*** (0.020)	0.026 (0.028)
R <sup>2</sup>	0.075	0.075	0.075
N	1,816,951	1,816,951	1,816,951
Year FE	Y	Y	Y
Controls	Y	Y	Y

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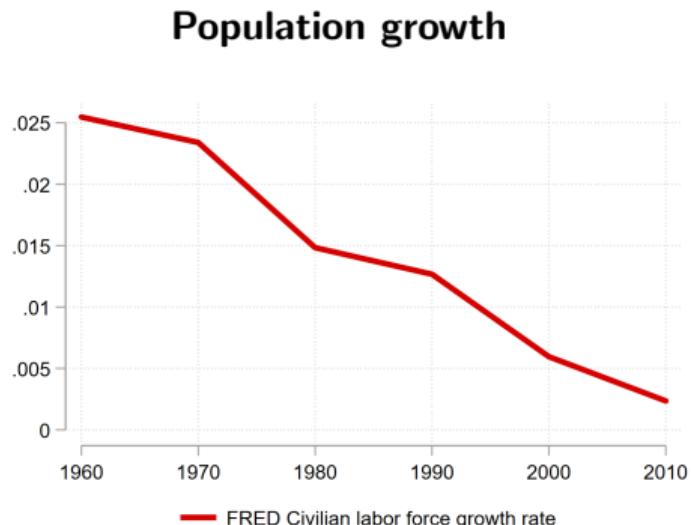
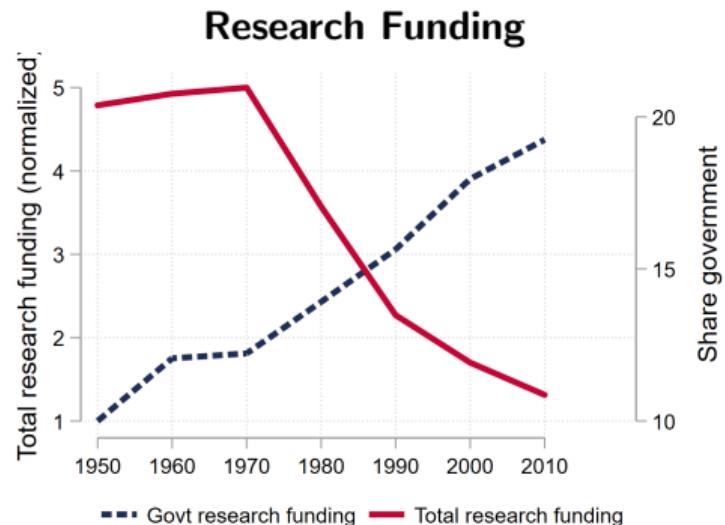
## Robustness: Recent Academic Citations - a Similar Pattern



## Robustness: Inventors with Creative First Patent File more Patents

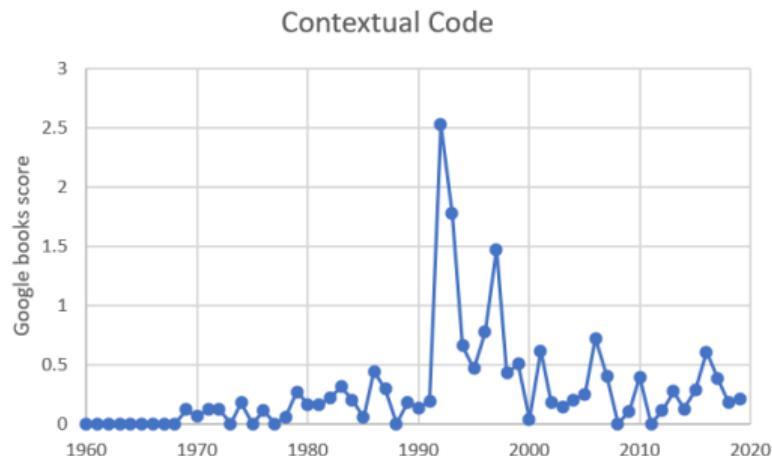


# Aggregate patterns in demographics and research funding



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# Google ngram example



(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.

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