The Creativity Decline: Evidence from US Patents

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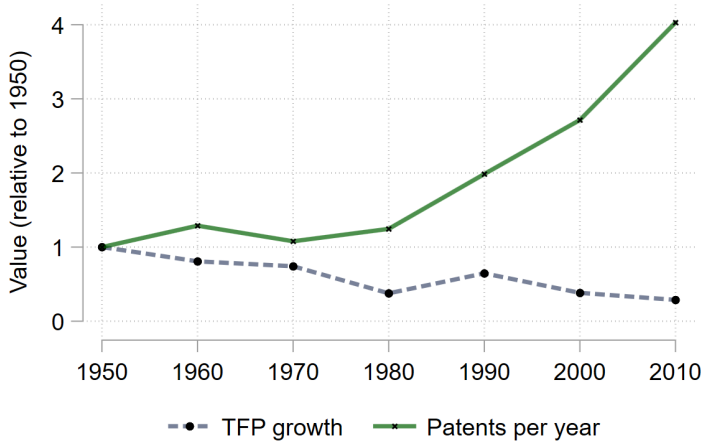
Puzzle: Rise in Patenting Not Reflected in Aggregate Productivity Growth



Notes: Productivity denotes BEA Non Farm Total Factor productivity; USPTO patents by US inventors. 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. **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.
2. **Creativity and Firm level TFP**: Only creative patents associated with firm level TFP growth and returns.
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 and stock returns.

- **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), 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);

  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

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Quantitative Analysis

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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.**

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

.

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

Example: What Makes a Patent Creative?

United States Patent [19]

Wolff

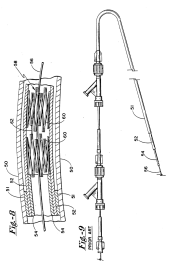
[54] **ARTICULATED STENT**

[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 biocompatable material. A second embodiment uses a stent of a previous invention made up of a number or 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 citations than derivative patents.
3. Grants of creative (not derivative patents) associated with higher stock returns.

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Validation: Creative Patents Receive Higher Citations

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

	Citations (normalized)		
	All (1)	First 5 years (2)	5-10 years (3)
Creative Patent$_p$	0.237***	0.147***	0.236***
	(0.022)	(0.015)	(0.020)
R^2	0.022	0.033	0.015
N	890,275	890,275	890,275
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.

Validation: Only Creative Patent Grants associated with Stock Returns

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

	Stock Returns$_{i,t}$ (in pct., weekly)		
	(1)	(2)	(3)
IHS(creative patents$_{i,t}$)	0.093***	0.085***	0.082***
	(0.022)	(0.026)	(0.025)
IHS(derivative patents$_{i,t}$)		0.009	
		(0.013)	
IHS(derivative patents$_{i,t}$ - citation weighted)			0.014
			(0.013)
R^2	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, in a week with creative patent grant firms experience a .11 basis point higher stock return.

Details | Creativity cut-offs | Placebo | Measure variations | KPSS | Firm Fixed Effects

Validation: Versus Other Measures of Patent Originality

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

	Stock Returns$_{i,t}$*100 (weekly)		
	(1)	(2)	(3)
IHS(creative patents$_{i,t}$)	0.104***	0.076***	0.073***
	(0.034)	(0.023)	(0.022)
IHS(original patents$_{i,t}$ - backward similarity, Kelly et al. (2021))	−0.057		
	(0.064)		
IHS(original patents$_{i,t}$ - citations HHI, Hall et al. (2001))		0.014	
		(0.042)	
IHS(original patents$_{i,t}$ - # claims, Lanjouw and Schankerman (2004))			0.029
			(0.041)
R^2	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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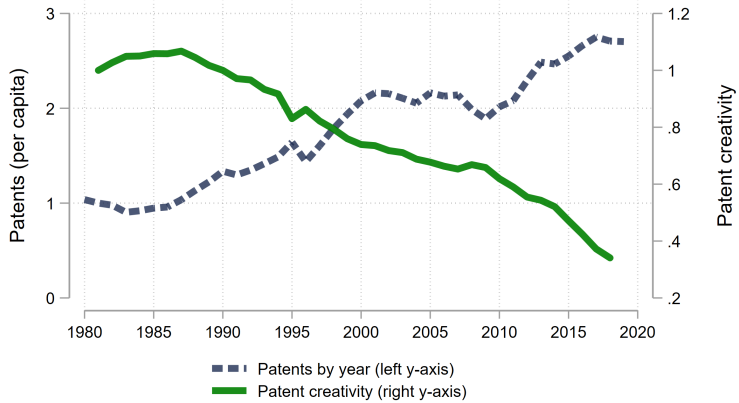
Measurement

Empirical Findings

Quantitative Analysis

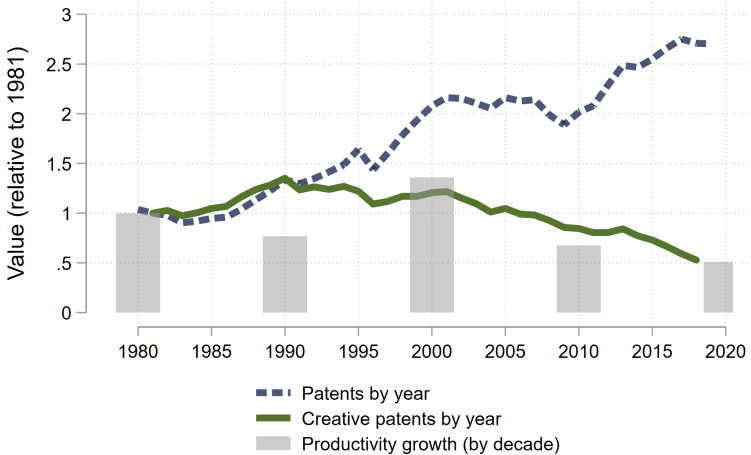
Fact 1: The Creativity Decline



Number of patents per year per capita. Patents filed by US inventors between 1981 and 2018 are included in the sample.

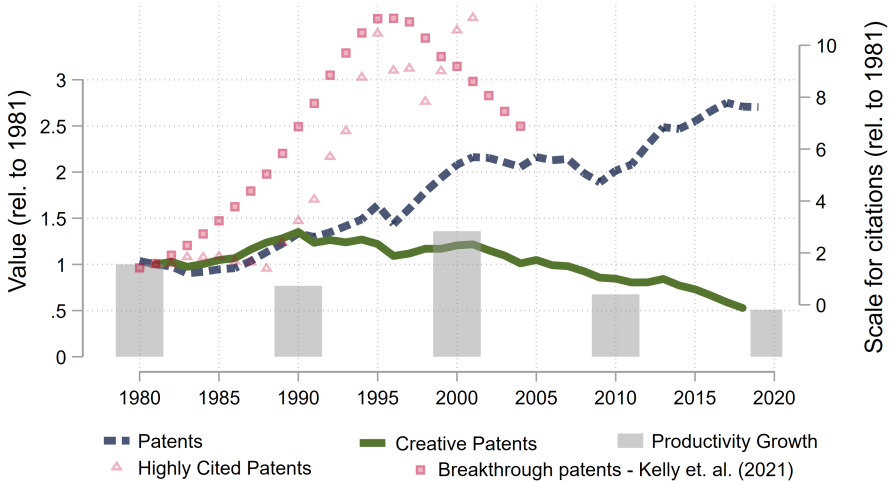
- Percentage of creative bigrams in patents: 14% (1981) and 7% (2015).

Fact 1: Creativity Decline Strong Enough to Overturn the Rise in Patents



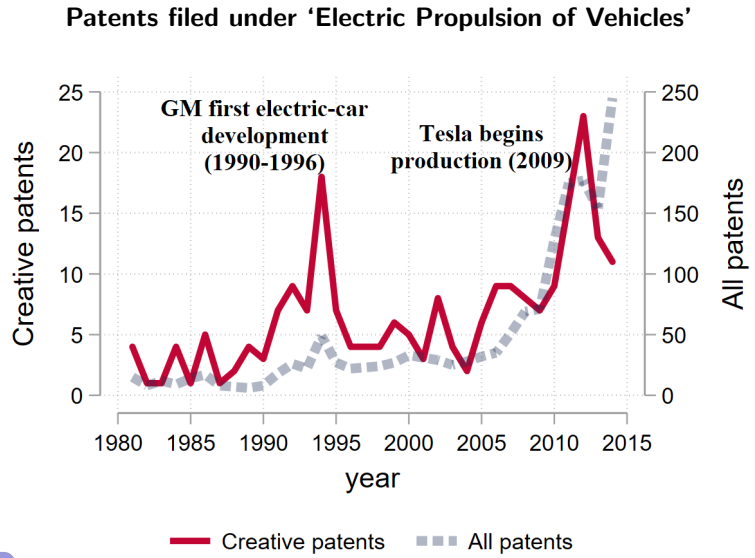
All patent numbers are per year and in per capita terms. Patents filed by US inventors between 1981 and 2018 are included in the sample.

Fact 1: 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 1: Multiple Waves of Creativity within Product Categories



Other industry examples

Fact 1: 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 2: Creative Patents Associated with Higher TFP Growth

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

- 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 $log(TFP)$.

Fact 2: Creative Patents Associated with Higher TFP Growth

	TFP Growth$_{i,t}$ (5-year differences, in pct.)					
	(1)	(2)	(3)	(4)	(5)	(6)
IHS(# creative patents$_{i,t}$)		0.234***	0.169*		0.215**	0.211**
		(0.078)	(0.098)		(0.104)	(0.102)
IHS(# derivative patents$_{i,t}$)			0.078		–0.095	
			(0.083)		(0.106)	
IHS(# patents$_{i,t}$)	0.164**			0.014		
	(0.067)			(0.101)		
IHS(# derivative patents - cite wt.$_{i,t}$)						–0.087
						(0.091)
R^2	0.012	0.012	0.012	0.005	0.005	0.005
N	19,020	19,020	19,020	19,012	19,012	19,012
Year FE	Y	Y	Y	Y	Y	Y
Firm FE	N	N	N	Y	Y	Y

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

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

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Year FE	Y	Y	Y	Y	Y	Y
Firm FE	N	N	N	Y	Y	Y

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

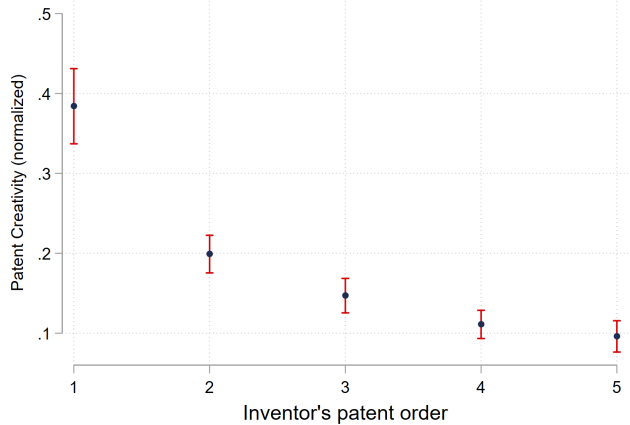
Fact 2: TFP Growth at the Industry Level

	TFP Growth$_{n,t}$ (5-year differences)					
	(1)	(2)	(3)	(4)	(5)	(6)
IHS(# creative patents$_{n,t}$)		2.450***	3.781***		3.261**	7.108***
		(0.416)	(0.722)		(1.486)	(2.150)
IHS(# derivative patents$_{n,t}$)			–1.493**			–6.027***
			(0.621)			(1.544)
IHS(# patents$_{n,t}$)	2.047***			–3.908***		
	(0.415)			(1.219)		
Partial R^2	0.105	0.156	0.166	0.035	0.014	0.094
N	414	414	414	414	414	414
Year FE	N	N	N	Y	Y	Y
Industry FE	N	N	N	Y	Y	Y

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

Fact 3: Creativity Declines over the Life-cycle

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

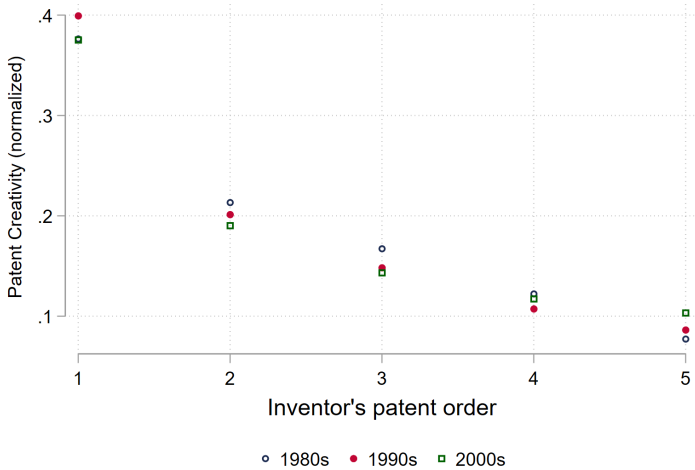


Controls for technology class and year fixed effects. Standard errors are clustered by technology class. Inventors with at least 5 patents.

Stock return regression | Recent academic citations | More lifetime patents

Fact 3: Life-cycle Consistent over time

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



Stock return regression | Recent academic citations | More lifetime patents

Summary of Empirical Facts

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

Next, growth model which takes (2) + (3) and rationalizes (1) 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

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

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

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

- Φ_C: Distribution of creative technologies, Φ_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**:

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

– μ_C: drift, ν: 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**: $V_N^E - \eta_E \frac{W}{P} \geq 0$

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

- 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 Ω_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* Ω_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 Ω_C: better pool of technologies available for imitation.

- Creativity (Ω_C) is increasing in population growth (g_L):

Calibration

#	Moment	Value
I	Aggregate productivity growth	1.48%
II	Pct. innovators	9.82%
III	Pct. creative innovators	12.53%
Fact 2(a)	Creative entrepreneur's TFP growth	0.17%
Fact 2(b)	Creative excess valuation	14.81%
Fact 3	Pct. creative first-time patents	23.74%
Fact 3	Pct. creative fifth patent	11.23%

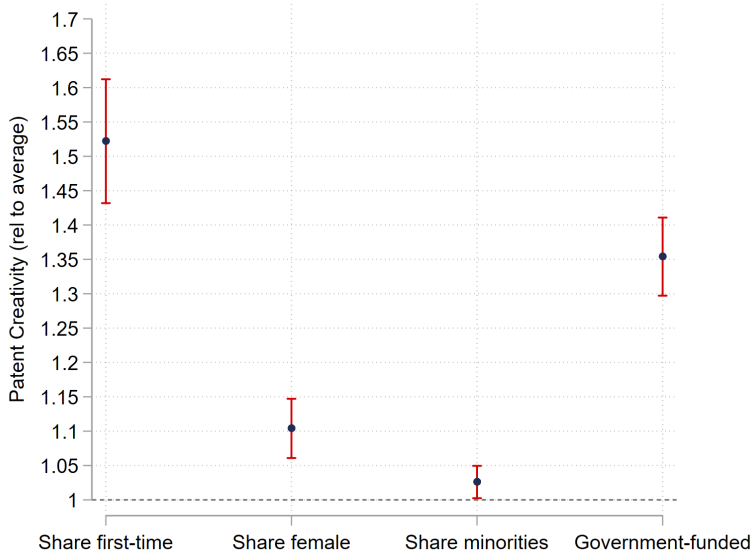
Parameter	Value
Imitation cost (η)	6.55
Entry cost (η_E)	10.87
Creative-derivative transition probability (α)	0.14
Drift of *creative* GBM (μ)	0.0017
Volatility of *creative* GBM (ν)	0.038
Creativity probability (entrants)(p_c^E)	0.37
Creativity probability (existing)(p_c)	0.18

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

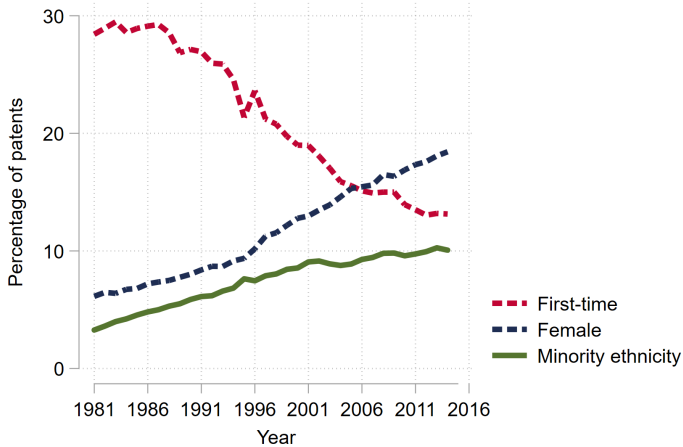
Results - Declining population growth

	(1) 1980	(2) 2010	(3)	(4)	(5)
	g_L: 2.3%	g_L: 0.7%	Chg. in Model	Chg. in Data	Pct. Explained
Prod. Growth (g_m)	1.48%	1.21%	-20%	-66%	30%
Pct. Creative Innovators (Ω_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



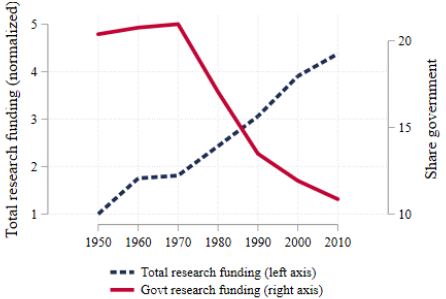
Concluding Remarks: Changing Compositions into Patenting



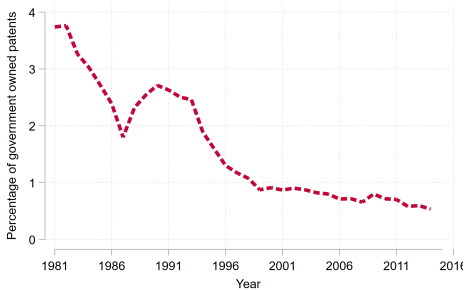
- Model estimates increase in inclusion leads a 3.75% increase in productivity growth.

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.

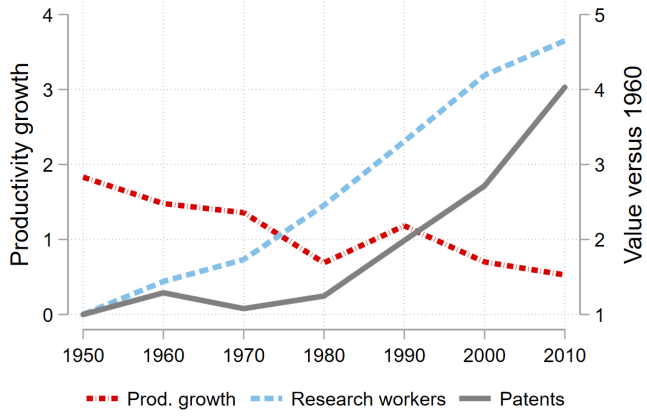
Conclusion

Develop a new text-based measure of patent creativity.

- Creativity captures an important new dimension of innovations.
- **The Creativity Decline:** Document a decline in creative patents.
- **Creativity and Firm level TFP:** Only creative patents are associated with firm level TFP growth.
- **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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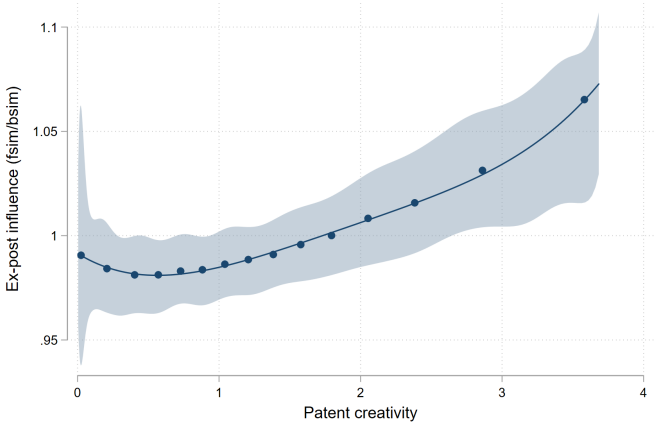
Details: Influence and creativity



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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)*

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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 ≥ 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***	0.049***	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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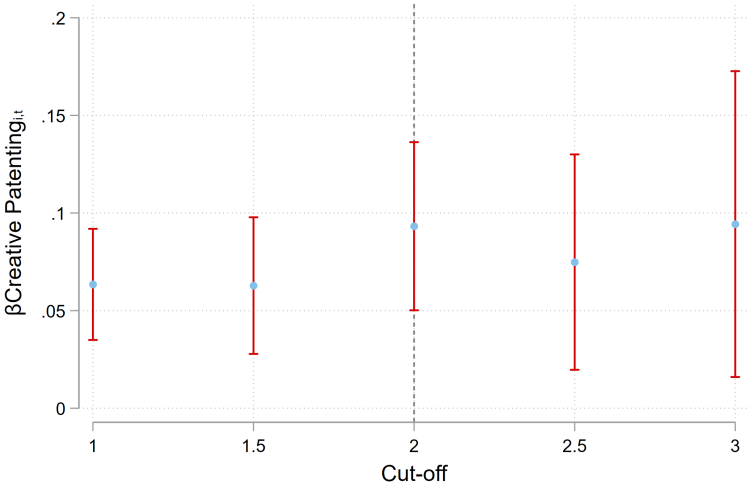
Validation: Extended table

	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)
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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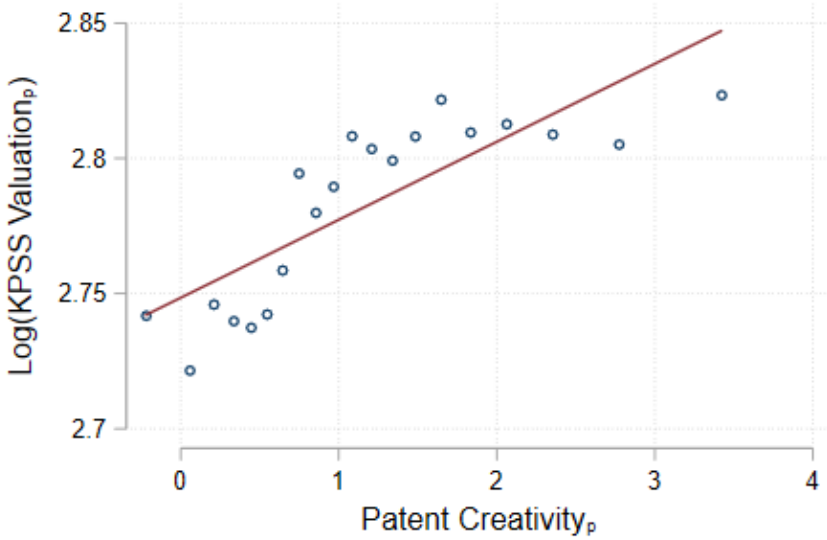
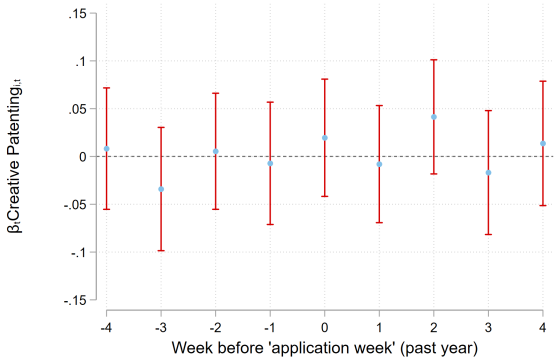
Creative Patents are more Valuable - KPSS measure



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

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

	Stock Returns$_{i,t}$ (in pct., weekly)		
	(1)	(2)	(3)
ihs(creative patents$_{i,t}$)	0.072**	0.073**	0.068**
	(0.030)	(0.030)	(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.

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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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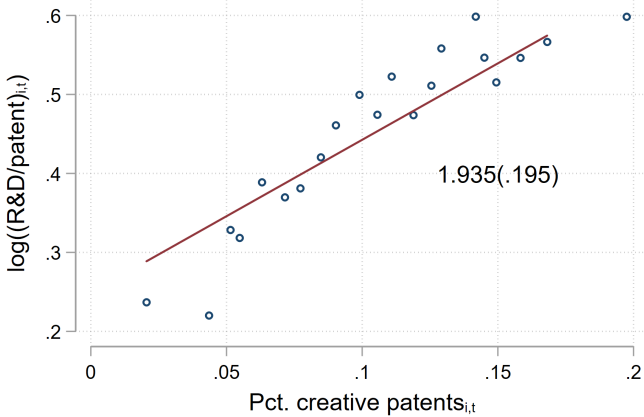
Validation: R&D Expenditure and Creative Patenting



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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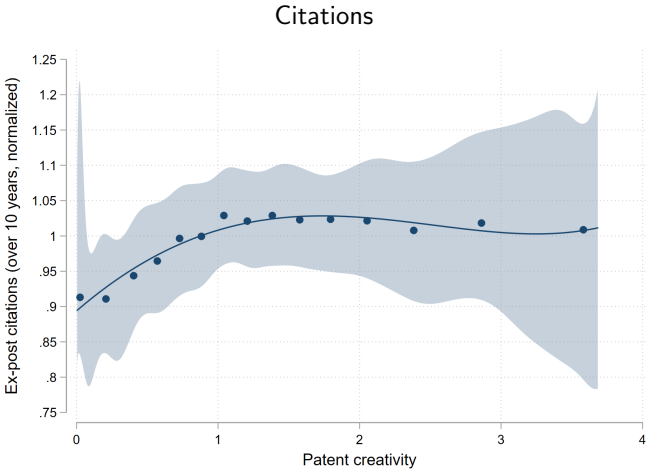
Validation: *Patent creativity* and citations



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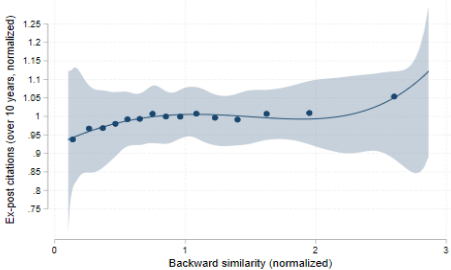
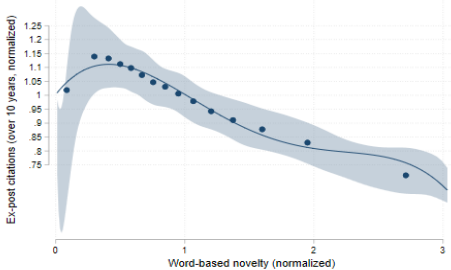
Not the same pattern for other used measure of novelty with words

Backword similarity with words



Word-based novelty



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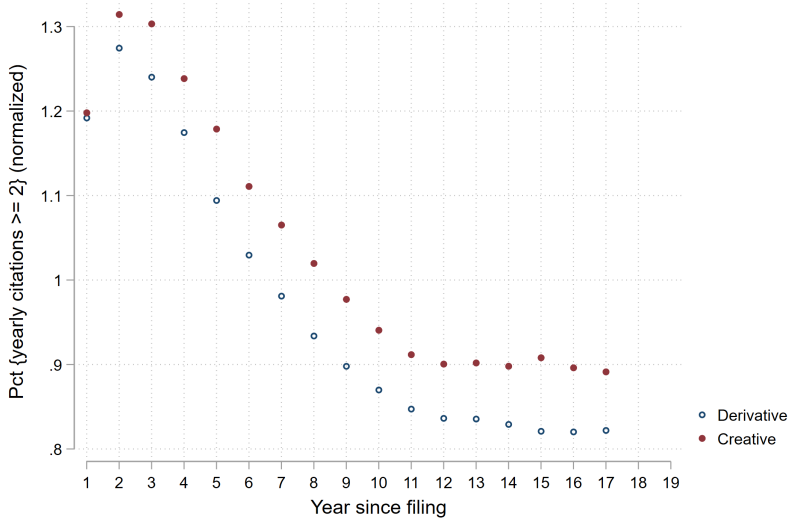
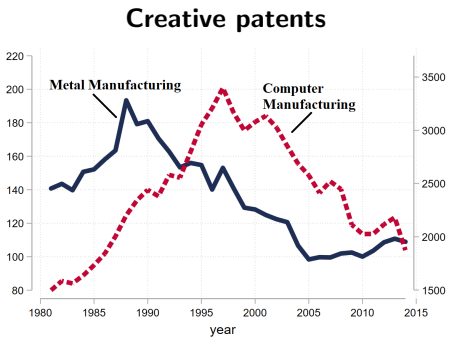
- Reason: 'Machine' and 'Learning' are not new words, but 'MRNA Vaccine' is a new bigram.

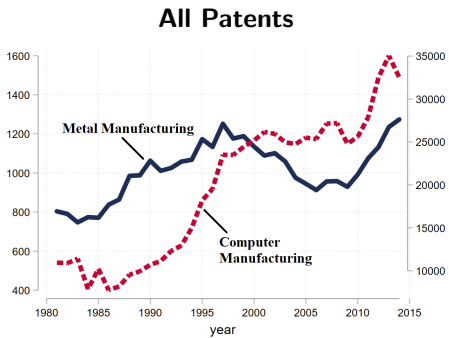
Validation: Citation patterns of *creative* and *derivative* patents



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

Example industry patterns: creative and all patents



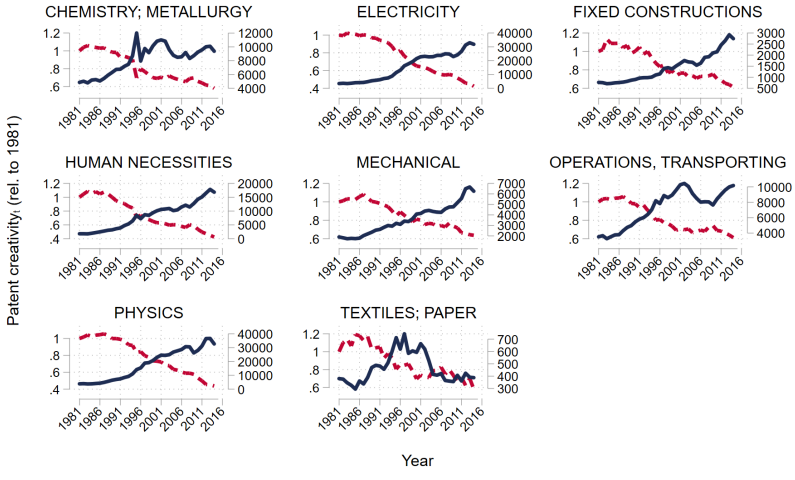


- Distinct patterns in creative and overall patenting across industries.

back

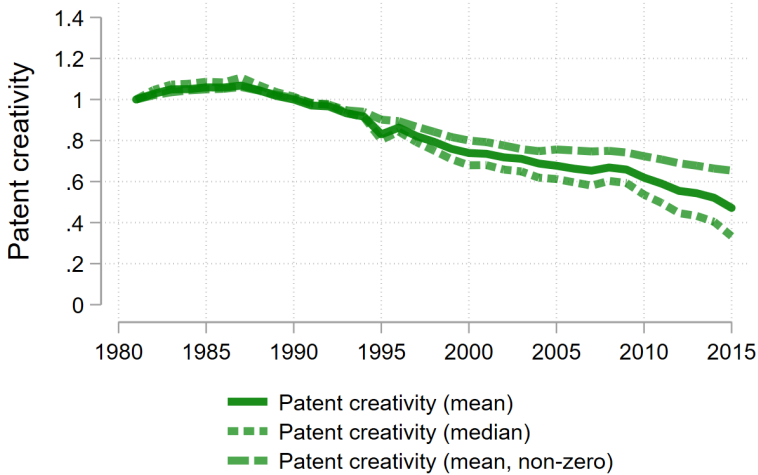
Details: Patent creativity by technology class

Figure: *PatentCreativity* by year for each technology class

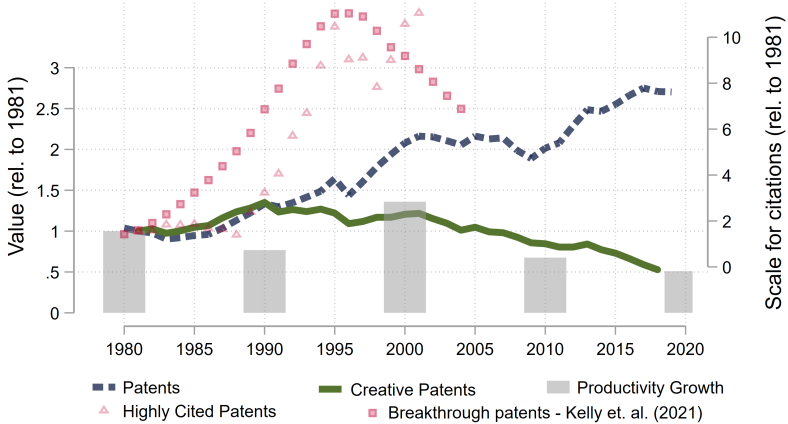


Decline in creativity: other summary statistics

Figure: Distribution of patent creativity



Highly cited or influential patents



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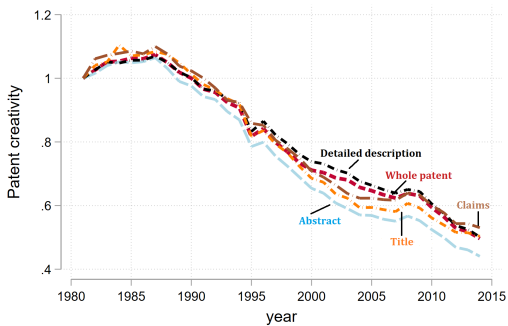
Check 1/3: Increasing patent lengths

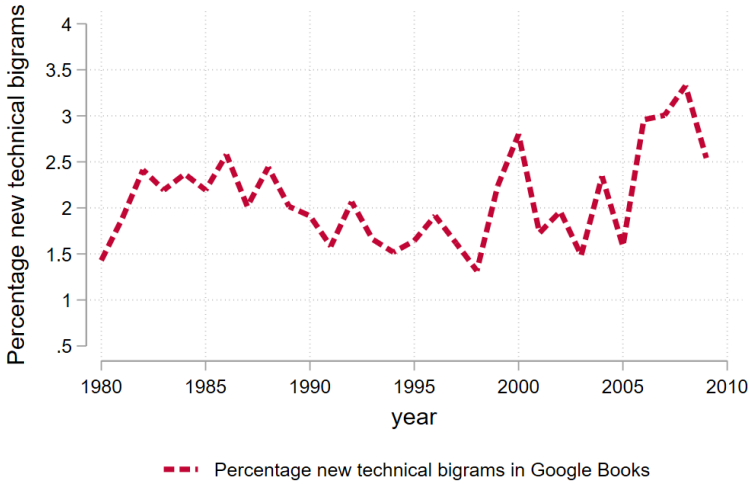
- Increasing patent lengths could be driving the decline in patent creativity.
- Average patent in 1981 contains 3,757 words versus 9,501 words in 2014.
- Increase in length almost entirely driven by detailed description section (2,420→8,112).
- Length of patent titles (9→10) and abstracts (102→98) have 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: Creativity in Google Books



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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 -

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

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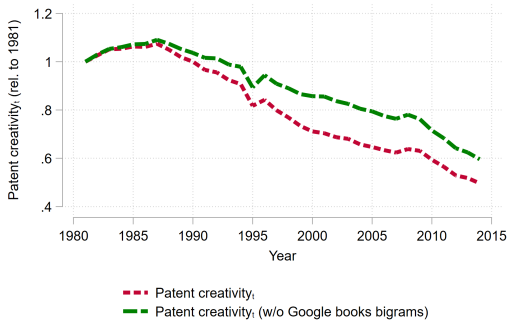
Figure: *PatentCreativity* w/o language trends



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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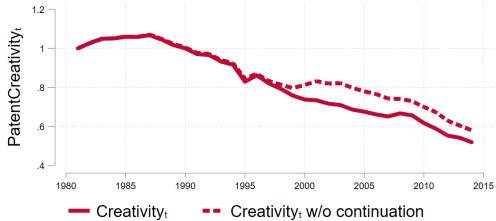
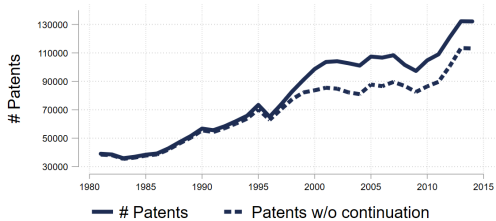
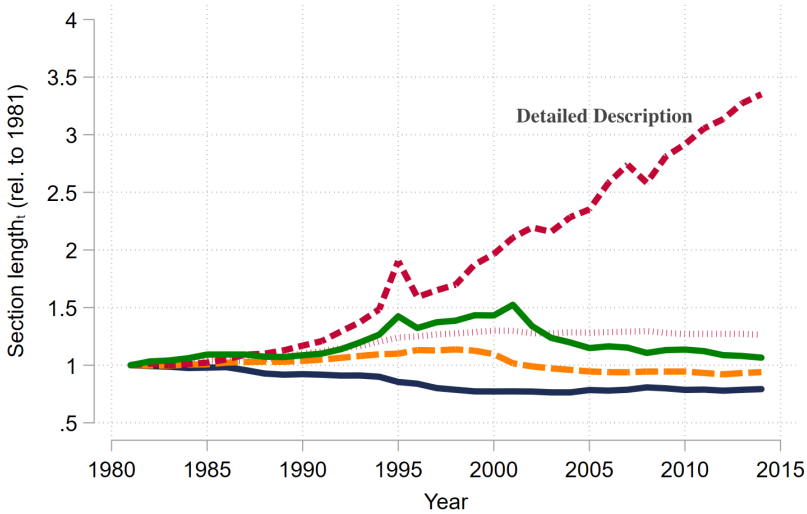




Details: Lengths of patent sections



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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

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$_{i,t}$ (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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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

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)
lhs(creative patents$_{i,t}$)	0.093***		0.077***
	(0.022)		(0.030)
lhs(new-entry patents$_{i,t}$)		0.072***	0.026
		(0.020)	(0.028)
R^2	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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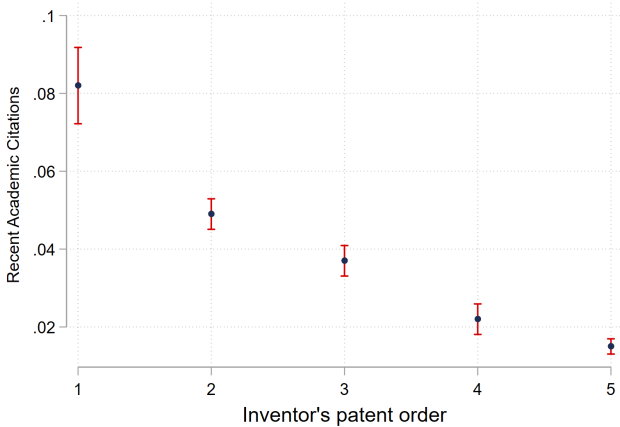
Robustness: Recent Academic Citations - a Similar Pattern



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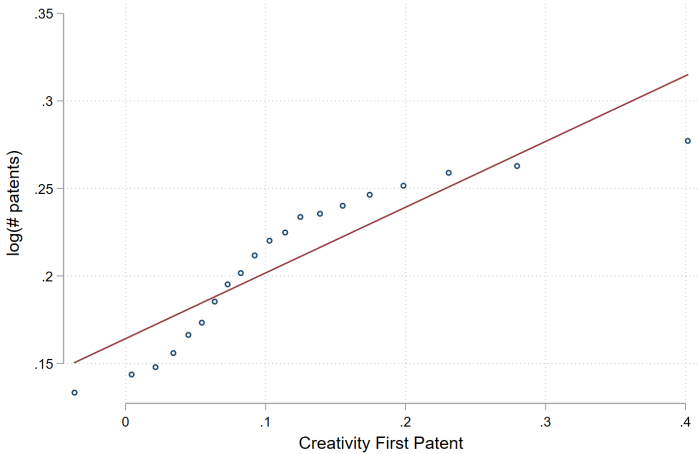
Robustness: Inventors with Creative First Patent File more Patents



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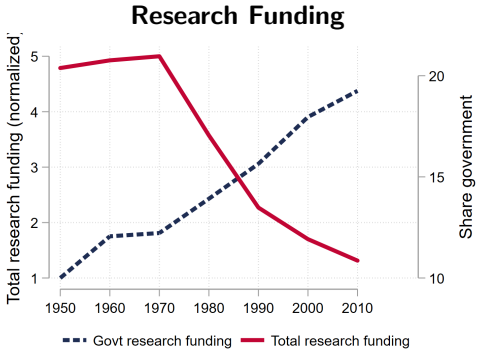
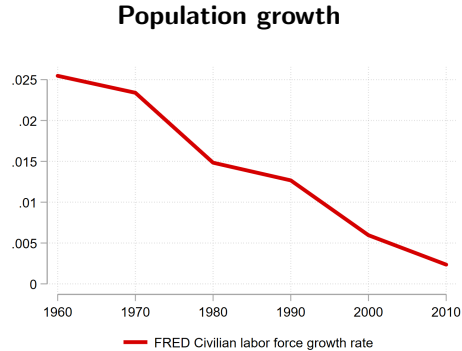
Aggregate patterns in demographics and research funding





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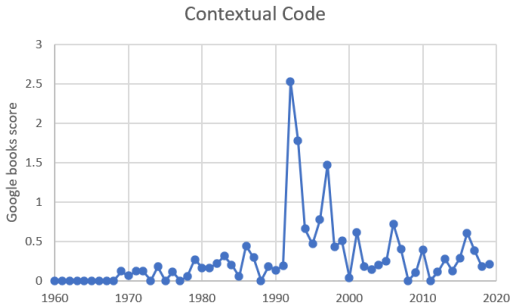
Google ngram example



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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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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.