The Recent Creativity Decline: Evidence from US Patents

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Boston University

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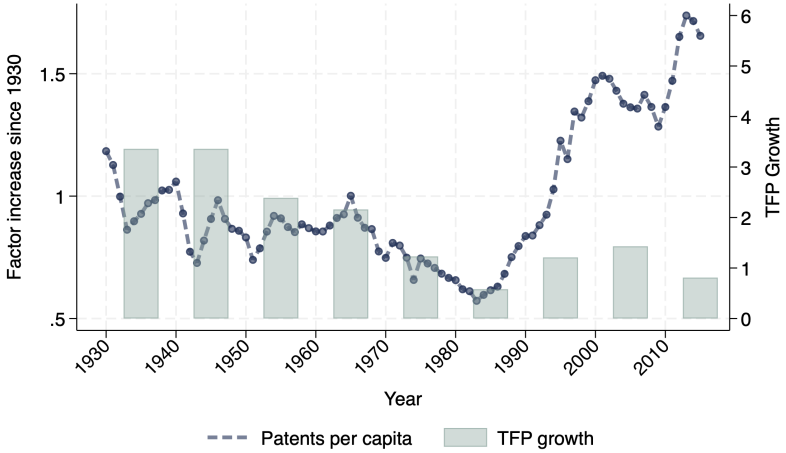
Recent Rise in Patenting Not Reflected in Aggregate Productivity Growth



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.
  - Also explains the increase in patents.

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Patent Creativity: Share of New Technical Two-word Combinations

- Full text of patents filed by US inventors between 1930 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.**

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

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  - Normalize such that sample average $= 1$.
  - **Label top 10% as creative.**

Example: What Makes a Patent Creative?

United States Patent [19]

Wolff

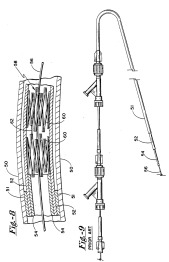
[54] **ARTICULATED STENT**

[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:
   - Firms that spend more R&D dollars per patent file more creative patents. link
   - Creative patents cite more recent academic papers and less past patents. link
2. Creative patents receive higher and more persistent citations than derivative patents. link
3. Creative patents are associated with higher patent valuation. link

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Fact 1: Creative Patents Associated with Higher TFP Growth

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

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

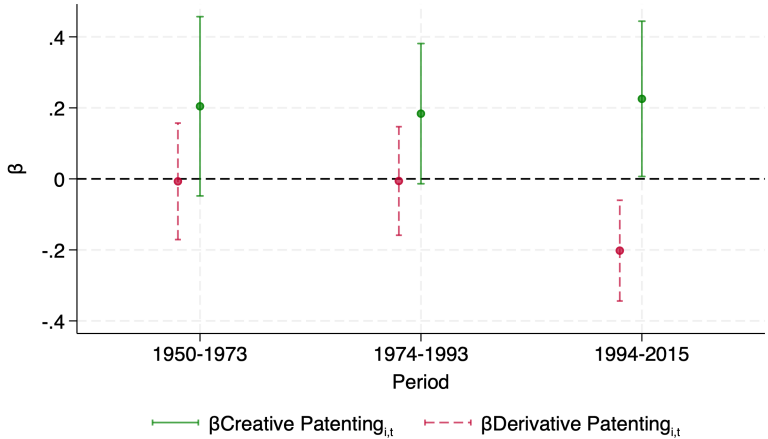
Fact 1: Creative Patents Associated with Higher TFP Growth

	(Sales/Emp) Growth$_{i,t}$ (5-year differences, in pct.)				
	(1)	(2)	(3)	(4)	(5)
ihs(creative patents$_{i,t}$)		0.162**		0.237***	0.196***
		(0.074)		(0.075)	(0.074)
ihs(derivative patents$_{i,t}$)			–0.063	–0.127**	
			(0.051)	(0.052)	
ihs(patents$_{i,t}$)	–0.054				
	(0.051)				
ihs(derivative patents - cite wt.$_{i,t}$)					–0.057
					(0.046)
N	36,027	36,027	36,027	36,027	36,027
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 1,805 manufacturing firms which file patents for at least 10 years between 1950-2015.

TFP Binscatter Dynamics Comparison against other measures

Fact 1: Creative Patents Associated with Higher TFP Growth



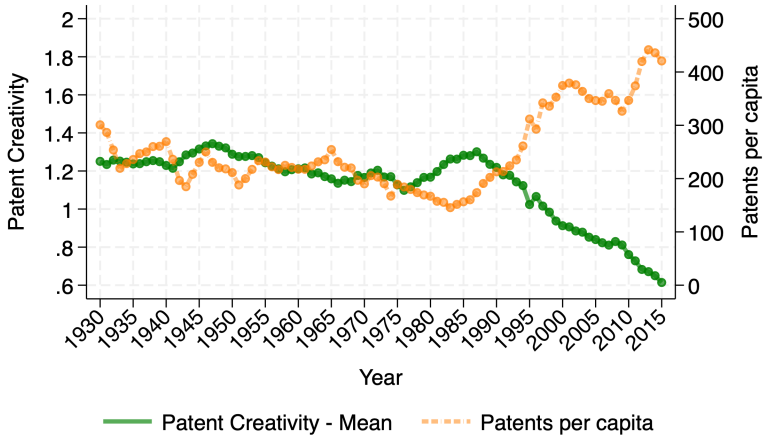
TFP | Binscatter | Dynamics | Comparison against other measures | Detailed table

Fact 1: TFP Growth at the 2-digit Industry Level

	TFP Growth$_{n,t}$ (5-year differences, in pct.)			
	(1)	(2)	(3)	(4)
log(patents$_{i,t}$)	0.140			
	(0.414)			
log(creative patents$_{i,t}$)		0.955***	2.195***	1.987***
		(0.323)	(0.529)	(0.540)
log(derivative patents$_{i,t}$)			–2.057***	
			(0.677)	
log(derivative patents - cite wt.$_{i,t}$)				–1.459**
				(0.608)
N	864	862	862	862
Year FE	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y

2-digit SIC manufacturing industries. Standard errors are robust.

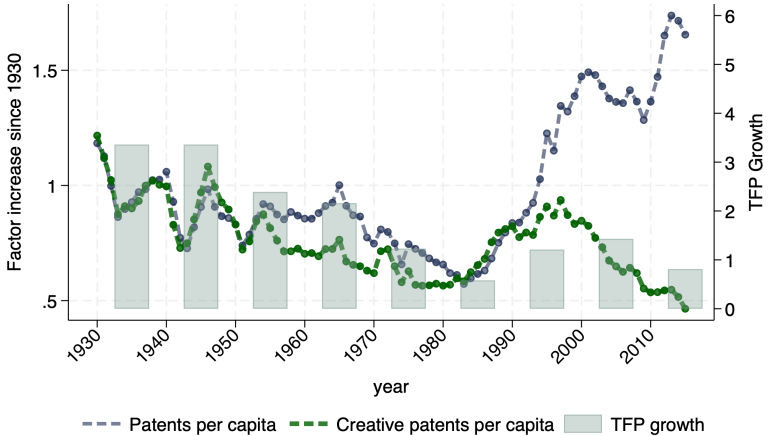
Fact 2: The Creativity Decline



All patent numbers are per year and in per capita terms. Patents filed by US inventors between 1930 and 2018 are included in the sample.

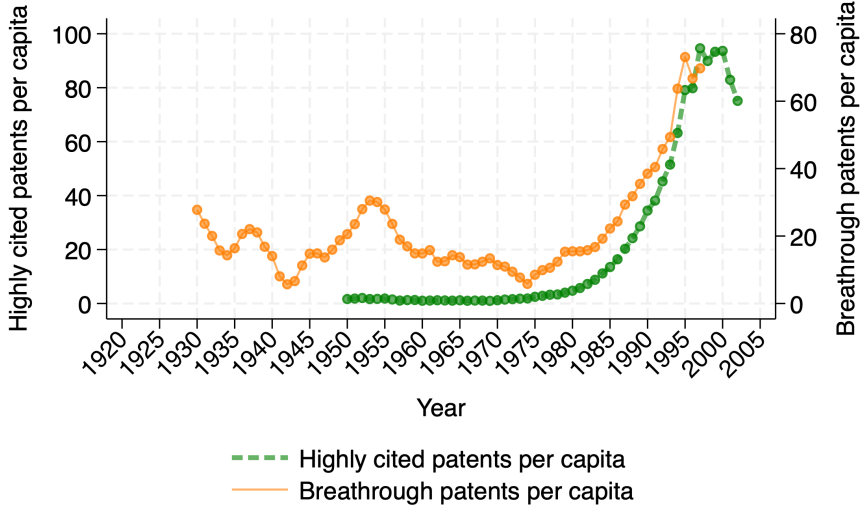
- Average share of creative technical bigrams: 14% (1981) vs 7% (2015).

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



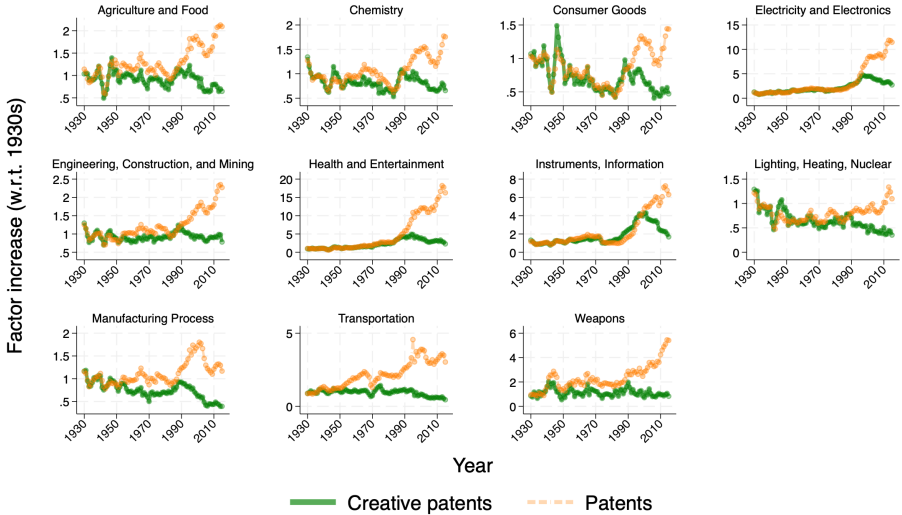
All patent numbers are per year and in per capita terms. Patents filed by US inventors between 1950 and 2015 are included in the sample.

Fact 2: Influential Patents have Increased



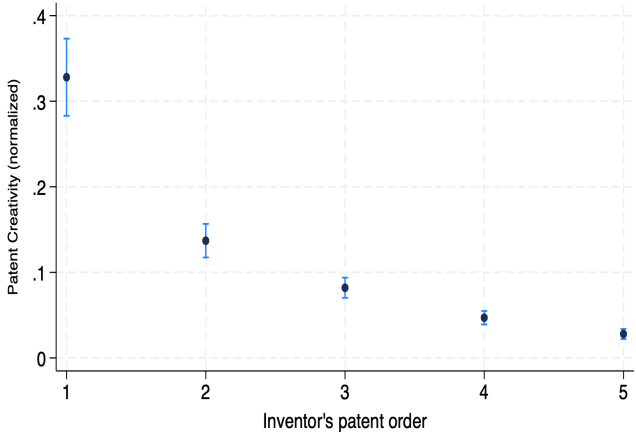
All patent numbers are per year and in per capita terms. Patents filed by US inventors between 1981 and 2018 are included in the sample.

Fact 2: Decoupling across patent classes



Fact 3: Creativity Declines over the Life-cycle

$$\text{Patent Creativity}_p = \alpha_0 + \sum \beta_k \{\text{Order}_p == k\} + \chi_p + \epsilon_p$$ 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

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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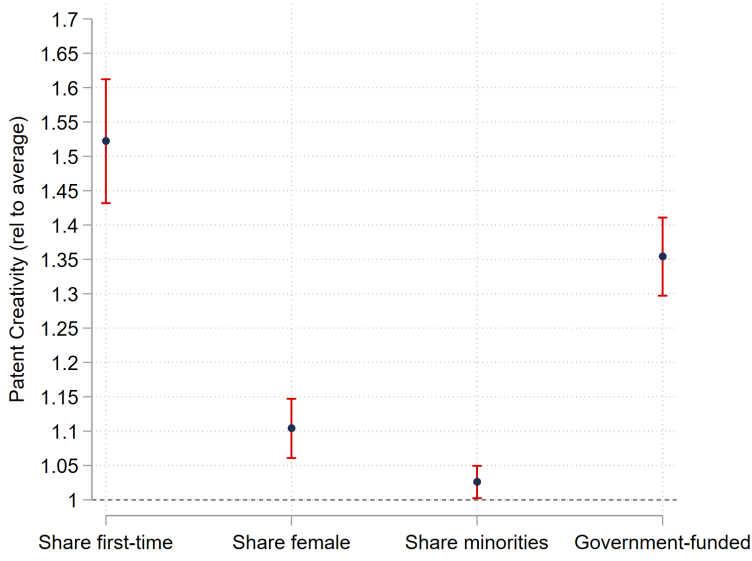
Model Overview: Two Types of Innovators

- 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.

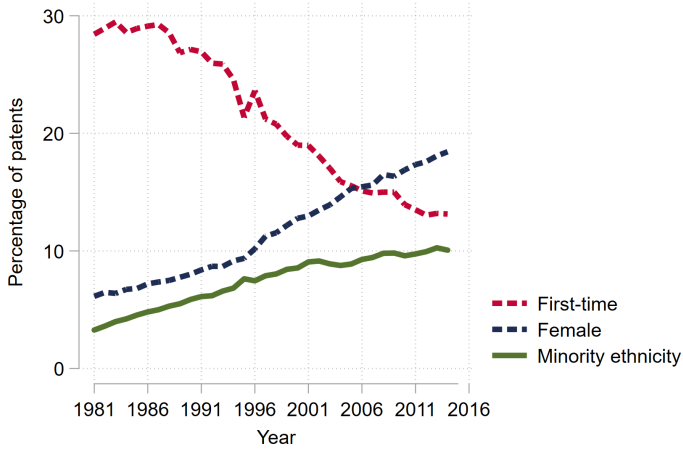
Results - Declining population growth

	(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



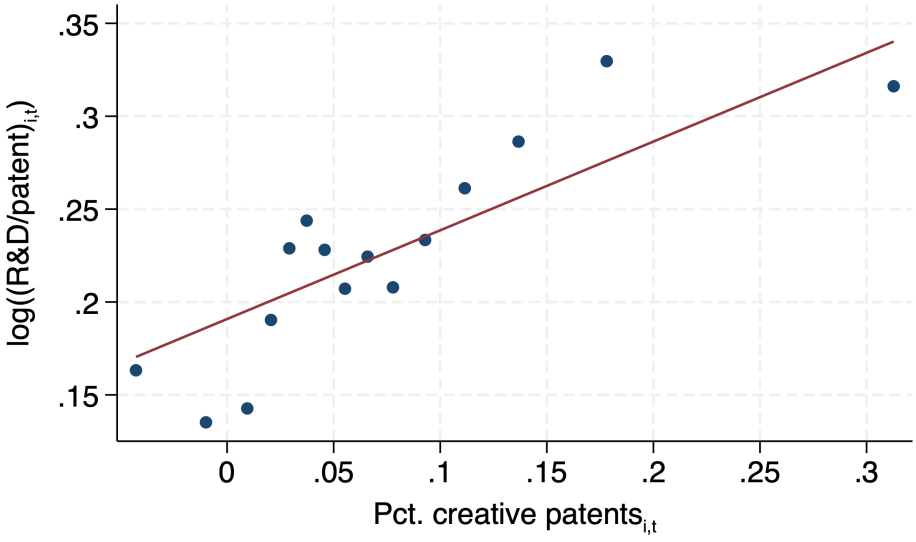
- Model estimates increase in inclusion leads a 3.75% increase in productivity growth.

Conclusion

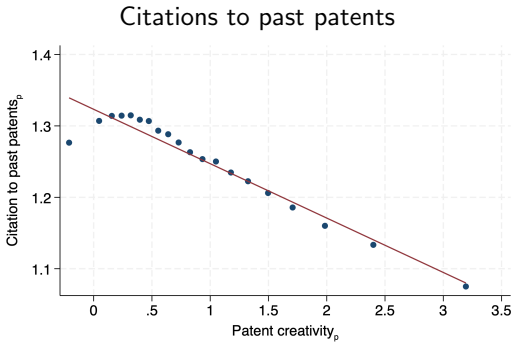
Develop a new text-based measure of patent creativity.

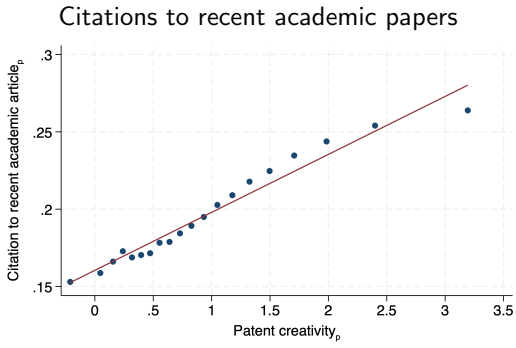
- Creativity captures an important new dimension of innovations.
- **The Creativity Decline:** Document a decline in creative patents.
- **Creativity and Firm level TFP:** Creative patents are associated with firm level TFP growth.
- **Creativity life-cycle:** For inventors, creativity declines over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

R&D and firm patenting

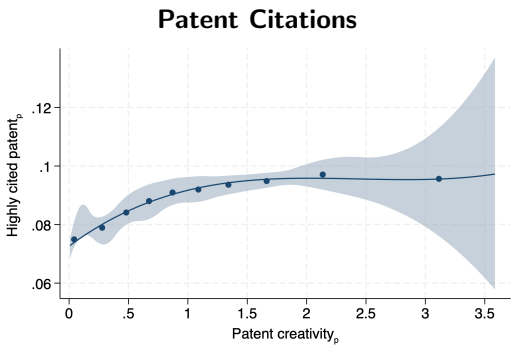


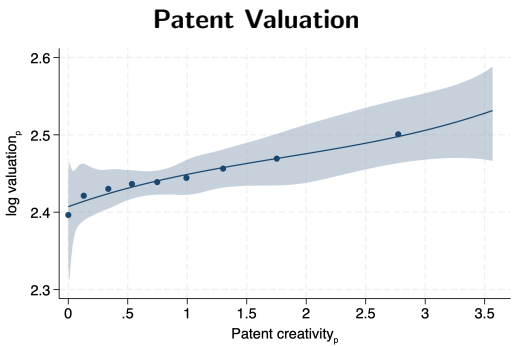
Citations to previous patents and academic papers



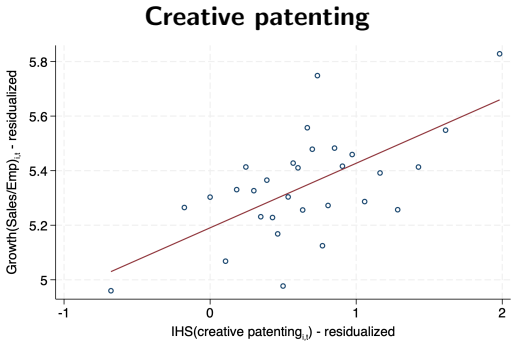


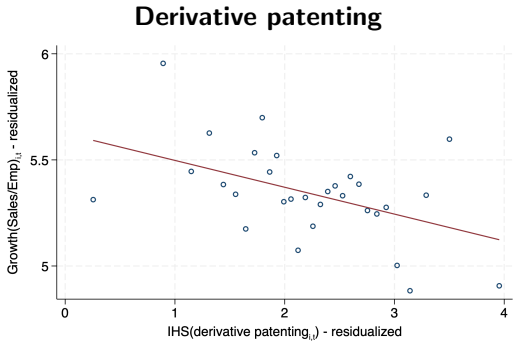
Patent citations and valuation



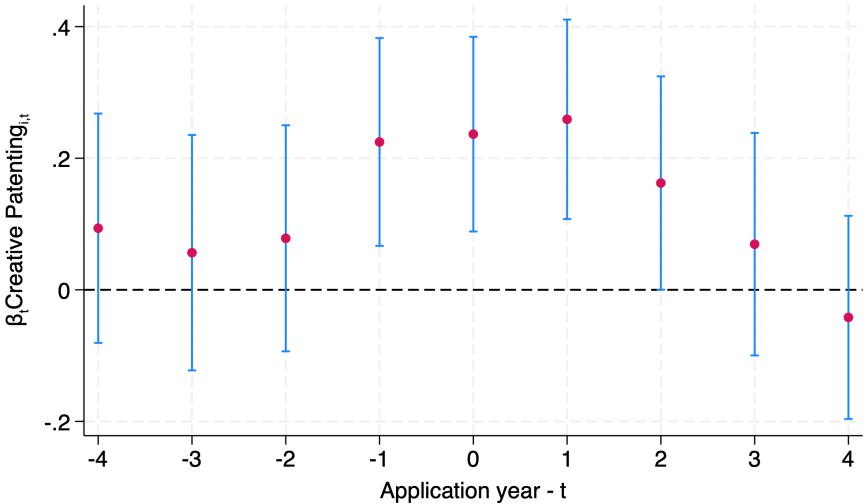


Creative, Derivative Patents and TFP Growth: Binscatter





Creative, Derivative Patents and TFP Growth: Binscatter



Creative Patents and TFP Growth: Comparison

	(Sales/Emp) Growth$_{i,t}$ (5-year differences, in pct.)			
	(1)	(2)	(3)	(4)
ihs(creative patents$_{i,t}$)	0.307***	0.282**	0.217**	0.272***
	(0.108)	(0.110)	(0.097)	(0.098)
ihs(top 10 pct.$_{i,t}$ - KSW (2021))	–0.039			
	(0.113)			
ihs(top 10 pct.$_{i,t}$ - bck sim. KPST (2021))		0.019		
		(0.118)		
ihs(top 10 pct.$_{i,t}$ - new unigrams)			0.117	
			(0.106)	
ihs(top 10 pct.$_{i,t}$ - # of claims)				0.018
				(0.089)
R^2	0.259	0.259	0.216	0.216
N	20,414	20,414	24,803	24,803

Creative Patents and TFP Growth: Comparison

	TFP Growth$_{i,t}$ (5-year differences, in pct.)				
	(1)	(2)	(3)	(4)	(5)
ihs(creative patents$_{i,t}$)		0.206***		0.235***	0.208***
		(0.061)		(0.063)	(0.061)
ihs(derivative patents$_{i,t}$)			0.013	–0.049	
			(0.045)	(0.046)	
ihs(patents$_{i,t}$)	0.021				
	(0.045)				
ihs(derivative patents - cite wt.$_{i,t}$)					–0.003
					(0.041)
N	34,623	34,623	34,623	34,623	34,623