The Recent Creativity Decline: Evidence from US Patents

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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


• 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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Measurement

Empirical Findings

Quantitative Analysis
Patent Creativity: Share of New Technical Two-word Combinations


- 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.

\[
Patent\ Creativity_{p} = \frac{creative\ technical\ bigrams_{p}}{technical\ bigrams_{p}}
\]

- Normalize such that sample average $= 1$.
- Label top 10% as creative.
Example: What Makes a Patent Creative?

- 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.
   - Creative patents cite more recent academic papers and less past patents.

2. Creative patents receive higher and more persistent citations than derivative patents.

3. Creative patents are associated with higher patent valuation.
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Measurement

Empirical Findings

Quantitative Analysis
Fact 1: Creative Patents Associated with Higher TFP Growth

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

- firm \( i \), year \( t \)
- TFPR calculated by applying some method on Compustat accounts.
- \( \Delta^5 \log(\text{TFPR})_{i,t} \) is 5-year differences in \( \log(\text{TFPR}) \).
- \( \chi_{i,t} \) denotes controls for polynomials of firm age, past R&D expenditures, and industry sales growth.
**Fact 1: Creative Patents Associated with Higher TFP Growth**

<table>
<thead>
<tr>
<th></th>
<th>(Sales/Emp) Growth(_{i,t}) (5-year differences, in pct.)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>ihs(creative patents(_{i,t}))</td>
<td>0.162**</td>
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<tr>
<td></td>
<td>(0.074)</td>
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<td>ihs(derivative patents(_{i,t}))</td>
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<td>ihs(patents(_{i,t}))</td>
<td>-0.054</td>
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<td></td>
<td>(0.051)</td>
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<td>ihs(derivative patents - cite wt.(_{i,t}))</td>
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<td></td>
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</tr>
<tr>
<td>N</td>
<td>36,027</td>
</tr>
<tr>
<td>Year FE</td>
<td>Y</td>
</tr>
<tr>
<td>Firm FE</td>
<td>Y</td>
</tr>
</tbody>
</table>

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.
Fact 1: Creative Patents Associated with Higher TFP Growth
### Fact 1: TFP Growth at the 2-digit Industry Level

<table>
<thead>
<tr>
<th></th>
<th>TFP Growth_{n,t} (5-year differences, in pct.)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>log(patents_{i,t})</td>
<td>0.140</td>
</tr>
<tr>
<td></td>
<td>(0.414)</td>
</tr>
<tr>
<td>log(creative patents_{i,t})</td>
<td>0.955***</td>
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<tr>
<td></td>
<td>(0.323)</td>
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<tr>
<td>log(derivative patents_{i,t})</td>
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<td>log(derivative patents - cite wt.__i,t)</td>
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<tr>
<td>N</td>
<td>864</td>
</tr>
<tr>
<td>Year FE</td>
<td>Y</td>
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<tr>
<td>Industry FE</td>
<td>Y</td>
</tr>
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</table>

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.

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

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

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

Empirical Findings

Quantitative Analysis
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

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

$g_L$: 2.3\%  \quad g_L$: 0.7\%
Concluding Remarks: Other Drivers of Creativity

![Graph showing the relationship between various factors and patent creativity](image-url)
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

\[ \log((\text{R&D/patent})_{i,t}) \]

vs

Pct. creative patents_{i,t}
Citations to previous patents and academic papers

Citations to past patents

Citations to recent academic papers
Patent citations and valuation

![Graphs showing Patent Citations and Patent Valuation](image)
Creative, Derivative Patents and TFP Growth: Binscatter

Creative patenting

Derivative patenting
Creative, Derivative Patents and TFP Growth: Binscatter
## Creative Patents and TFP Growth: Comparison

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<td>(0.108)</td>
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<td>ihs(top 10 pct.(_{i,t}) - KSW (2021))</td>
<td>–0.039</td>
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<td>(0.113)</td>
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<td>ihs(top 10 pct.(_{i,t}) - bck sim. KPST (2021))</td>
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<tr>
<td>ihs(top 10 pct.(_{i,t}) - new unigrams)</td>
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<td>ihs(top 10 pct.(_{i,t}) - # of claims)</td>
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<td>(R^2)</td>
<td>0.259</td>
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