Market Value and Patent Citations: A First Look

Bronwyn H. Hall
UC Berkeley, Oxford Univ., and NBER
(joint work with Adam Jaffe and Manuel Trajtenberg)

Introduction

**Question:** how to value intangible knowledge assets?
**One answer:** relate measures of economic value (profit, market value, consumer willingness-to-pay) to measures of innovation (R&D spending, patent counts, ...)

**Difficulties:**
- R&D spending an input to innovation, not an output
- R&D not broken down by technology field
- Patents add very little additional info in the presence of R&D

Our Questions

1. Do the number of cites received by patents help to explain “value” in the presence of
   a. Patent counts themselves
   b. R&D spending
2. What is the timing? Is current market value better explained by past cites received or future cites not yet received?
3. Are self-citations more or less valuable than other citations?

Might citations be useful?

- R&D capital is an important explanatory variable for market value (in US and UK, $R^2 \approx 0.25$). Patents also matter, but are much less important, add little in presence of R&D (Griliches, Hall, Pakes 1987).
- WHY? Patent value distribution is very skew
- Citations have been used to proxy for spillovers and to describe research trajectories (Jaffe, Trajtenberg, and Henderson 1993, Ham 1998, etc.). Limited evidence that they correspond to anything “economic.”
- Correlations with firm market value can help to validate the use of citations in economic analysis.

Outline

- What are patent citations?
- The context: previous research on innovation valuation (very briefly)
- How do we use citations?
  - Measurement and modeling issues
  - Results
  - Future research

What are patent citations?

Somewhat like Citations in a Research Paper:
- References to prior technology, either patents or other scientific literature on which the current patent builds or which it uses
- Some added by the USPTO examiner (the "referee")
- Some added after the fact (not used by inventor)
- Some added to avoid infringement (limit scope, defense against suits)
- Some added for “teaching” (like survey articles)
(See Jaffe, Trajtenberg, Fogarty inventor survey, NBER)
Some facts about citations

- Prior work finds more valuable patents are cited more.
- One quarter of patents receive no citations.
- 0.01% receive more than one hundred citations.
- Lag distribution is skew to the left with a mode at about 3.5 years. Most cites happen by 10 years, but there can be long lags (30 years).
- Number included per patent has increased recently with advent of computerized search.

Early evidence using patent citations to predict value

- Trajtenberg (1990) - consumer welfare for CAT scanners and citations
- Klock and Shane (1995) - market value of citation weighted patents in semiconductors
- Austin (1993) - event studies on citation-weighted biotech patents
Recent work on citation value

- Sampat (1998) and Ziedonis (1998) - correlating university licensing revenue with citations. (reverse regression)
- Harhoff, Narin, Scherer, and Vopel (1997) - German inventions patented in the U.S. Expected discounted profits correlated with citations.

Our data and variables

- Variables: capital stock, leverage, sales or earnings growth, market value (debt plus equity), innovation measures:
  - R&D stock
  - Patent stock
  - Citation-weighted patent stock (i.e., Cite stock)
- All stocks constructed with 15% depreciation.
- Citations corrected for truncation.

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Constructing knowledge stocks

\[ K_t = (1 - \delta)K_{t-1} + R_t \]

where \( K_t \) = knowledge stock at end of period \( t \)
\( R_t \) = flow of R&D or patents during \( t \)
\( \delta \) = depreciation rate of \( K \), usually = 15%

Note: if \( R \) grows at a constant rate \( g \) over time,
\[ K_t \approx \frac{R_t}{(\delta + g)} \]

=> Low coefficient on \( K \) or \( R \) may imply \( \delta \gg 0.15 \)

Hedonic regression for market value

Practice(2): (without using \( \log(1 + x) \approx x \))

\[ \log Q_t = \log q_t + \log(1 + \gamma K_t/A_t) + \alpha d(K_t = 0) \]

where \( Q_t = V_t / A_t \) (market to book or Tobin’s \( Q \))

Interpretation:
\( q_t \) = Premium or discount for the absence of \( K \) assets.
\( q \) = overall market level (approximately one).
\( \gamma \) = Relative shadow value of \( K \) assets (=1 if depreciation correct, investment strategy optimal, and no adjustment costs).
1. Basic results

- Year-by-year specification compares the different K measures (Figure 4) – horse race.
- Exploration of the functional form using pooled data, constant coefficients (Tables 2, 3, and 4).

**Conclusion:** R&D stock has the highest explanatory power for market value, but citation-weighted patent stocks are significantly more related to value than ordinary patent stocks.

2. Exploration of cites variable

- Table 3 - include stock of R&D, patents per R&D, and cites per patent. Cites per patent are more important than patent yield itself:
  Increase of one cite per patent is associated with an increase of 3-4% in market value

- Table 5 - break up cites per patent into five ranges: 0 to 4, 4 to 6, 6 to 10, 10 to 20, over 20
  Only the latter three categories are positive; the other two are zero – 50-75% boost to market value if citations per patent average above 20!

3. Timing of the relationship

- **Two separate cite-weighted patent stocks**
  - Pre and post the date of market value measure.
  - Past stock is slightly negative in the presence of the total stock, which implies future citations are what matter.
- **Orthogonal decomposition** - unpredictable citations have a higher coefficient than predictable, both are positive.
4. Self citations

- Self cites = citations to patents owned by the same firm.
  - More valuable => owning a technology trajectory, cumulativeness is valuable
  - Less valuable => cite whatever is at hand, does not necessarily signify any value

- Measures
  - Share of citations that are self cites
  - Self cites/patent – highly skew distribution
  - Dummy for zero self cites

Table 4 (excerpt)
Splitting Citation Stocks into Past and Future
U.S. Manufacturing 1979-88

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cite Stock/A</td>
<td>0.117 (.006)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Past Cite Stk/A</td>
<td>-0.056 (.019)</td>
<td>0.162 (.008)</td>
<td>0.106 (.005)</td>
</tr>
<tr>
<td>Pred. Cite Stk/A</td>
<td>0.159 (.008)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unpred. Cite Stk/A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D(P=0)</td>
<td>0.204 (.012)</td>
<td>0.202 (.012)</td>
<td>0.202 (.012)</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.140</td>
<td>0.145</td>
<td>0.145</td>
</tr>
<tr>
<td>Standard error</td>
<td>0.740</td>
<td>0.737</td>
<td>0.737</td>
</tr>
</tbody>
</table>

Dep. Var.: logQ

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Table 6 (excerpt)
Self-Citations and Market Value
U.S. Manufacturing Firms 1979-88

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K/Assets</td>
<td>1.203 (.056)*</td>
<td>1.385 (.078)*</td>
<td>1.081 (.069)*</td>
</tr>
<tr>
<td>D(K=0)</td>
<td>0.017 (.017)</td>
<td>0.072 (.019)*</td>
<td>0.009 (.018)</td>
</tr>
<tr>
<td>Pat stock/K</td>
<td>0.032 (.008)*</td>
<td>0.015 (.006)*</td>
<td></td>
</tr>
<tr>
<td>Citations per patent</td>
<td>0.017 (.086)</td>
<td>0.015 (.066)</td>
<td></td>
</tr>
<tr>
<td>Self citations per patent</td>
<td>0.028 (.015)*</td>
<td>0.014 (.017)*</td>
<td></td>
</tr>
<tr>
<td>Log (S) = log(sales)-mean</td>
<td>-.0480 (.0059)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log (S)*Self cites per patent</td>
<td>.0258 (.0057)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D(no self citations)</td>
<td>0.161 (.051)*</td>
<td>0.127 (.047)*</td>
<td></td>
</tr>
<tr>
<td>Log (S)*D(no self)</td>
<td>-.079 (.065)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chi-squared versus col. (1) 622.6 815.4
Degrees of freedom 4 7
Chi-squared per d.f. 155.7 116.5

Answers to our questions

1. Do the number of cites received by patents help to explain “value” in the presence of
   a. Patent counts themselves - yes
   b. R&D spending - yes
2. What is the timing? Is current market value better explained by past cites received or
   future cites not yet received? - future cites
3. Are self-citations more or less valuable than other citations? - more valuable
Questions for further work

- Controlling for field - citations and/or patents
- How far into the future does the market see citations?
- Generality - is it worth more or less? Does it depend on the firm?