Patents to Products:
Innovation and Firm Performance*

David Argente  Salomé Baslandze  Douglas Hanley  Sara Moreira

** PRELIMINARY AND INCOMPLETE **

Abstract

What do standard patent-based innovation measures capture? Using the unique
match of firms’ patenting activities and their product introduction in the con-
sumer goods sector, we study the relationship between patents and innovation.
Our current results indicate that both at the extensive margin and the intensive
margin, patents (and citations-adjusted patents) are strongly associated with
higher product introduction as well as product destruction and hence larger re-
allocation at the firm level. We provide additional evidence that this association
is at least partly causal. Firms that are patenting also introduce products of
higher quality, enjoy larger sales and hold more diverse set of products. We try
to disentangle the effect of patents on product versus process innovation, distinc-
tion that has been hard to measure from standard data sources. We find that
the effect of patenting on product creation is larger for smaller firms, while the
process innovation seems more pronounced in larger firms. Textual analysis of
patents and product descriptions sheds additional light on the exact transmission
of innovation embedded in the patents into specific product creation.

Keywords: Innovation, patents, product creation, productivity.

JEL Codes: O3, O4

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*Argente: University of Chicago (e-mail: dargente@uchicago.edu); Baslandze: Einaudi Institute for
Economics and Finance (e-mail: salome.baslandze@eief.it); Hanley: University of Pittsburgh (doughan-
ley@pitt.edu); Moreira: Northwestern University (e-mail: sara.moreira@kellogg.northwestern.edu).
1 Introduction

Since the seminal works by Griliches (1981, 1990), a large literature has developed that has been using patents and related patent-based measures as the primary proxies for innovation activities of the firms and the economy as a whole. However, what and how much really patent-based innovation measures capture is still an open question. Important effort in the literature to validate the patent metrics has been to show that patents and patent citations are positively related to firm’s market value, firm’s labor productivity or TFP, or firm’s resources spent on R&D. However, due to the lack of the systematic data on “real” innovation by the firms, it has been hard to evaluate success of standard patent-based metrics in measuring innovation. In this paper, we provide a new evidence on the relationship between patents and “real” innovation based on the unique match of firms’ patenting activities and their product introduction in the consumer goods sector. Specifically, we try to understand if patents or various quality-adjusted patent metrics predict product creation at the firm level. What kind of product improvements various types of patents lead to? Do patents relate more to process or product innovation? Does this relationship vary by firm size or other firm characteristics?

Our work is the first to combine firms detailed information at the product level from the Nielsen Retail Measurement Services (RMS) with information about the firms’ patenting activities derived from the USPTO. This match provides an opportunity to link patents at the firm level with specific products of a firm. Textual analysis of patents and product descriptions sheds additional light on the exact transmission of innovation embedded in the patents into specific product creation. Though this part of the project is still a work in progress, here, we present evidence using total patents and products and their characteristics.

We present our analysis in the successive three steps. First, we analyze the extensive margin of patenting. We show the across-firms comparison of firms that patent relative to non-patenting firms, as well as within-firms analysis of outcomes after firm starts patenting. Second, on the intensive margin, we analyze the effect of various intensive measures of patenting and patent quality on patenting firms’ outcomes. And finally, we are able to disentangle the effect of patents on product versus process innovation, distinction that has been hard to measure from standard data sources.

Our current results indicate that both at the extensive margin and the intensive margin, patents (and citations-adjusted patents) are strongly associated with higher product introduction as well as product destruction and hence larger reallocation at the firm level. Using synthetic control methodology (Abadie et al., 2010), we provide additional evidence that this association is at least partly causal. In addition, we find that firms that are patenting also introduce products of higher quality, enjoy larger sales and hold more diverse set of products. While we can explicitly measure the effect of patents on product innovation, we designate the residual effect of patents on firm-level productivity (TFP) as process innovation. We find that the effect of patenting on product creation is larger for smaller firms, while the process innovation seems more pronounced in larger firms.
Innovation

- Economists see innovation as key for economic growth

- Patents (and related measures) are the most widely proxy for innovations since Griliches (1990)

- Product entry is often referred as key mechanism through which innovation translates into economic growth (Aghion and Howitt, 1992; Grossman and Helpman, 1991; Aghion et al., 2014)
Questions

- How do patents relate to new product entry?
- How much product innovation do we miss out by just looking at patents?
- What aspects of economic activity do patent/product entry statistics actually capture?
Measuring innovation using patents

**Advantages:**
- Universe of patents spanning many years and all sectors
- Rich patent characteristics
- Comparability across firms and countries

**Disadvantages:**
- Not all innovations are patented (how much?)
- Different underlying phenomena.
- Strategic patenting
- Patents vary greatly in their technical and economic significance
  - How should we aggregate patent quantity then (citations, claims, etc)?
How about product introduction?

**Advantages:**
- Meaningful quality changes always result in new products
- Rich set of characteristics (including price and quantity)
- Products can be weighted by economic significance
- Allows to identify the portfolio of products of firms
- Measurement available at high frequencies

**Disadvantages:**
- Only available for a few sectors
- Mostly available for recent years
What do we do in this paper?

1. Build unique dataset that allows us to measure patent and product portfolios of firms;
2. Aggregate statistics;
   - Using firms’ total portfolios:
     3. Product innovation and extensive margin of patenting;
     4. Product innovation and intensive margin of patenting;
     5. Product vs process innovation;
   - Using specific patents - products match:
     ...results coming soon.
What is a product?

- A "product" is uniquely identified by a 12-digit number called Universal Product Code (UPC), which is the finest level of disaggregation at the product level
  - Approximately 300 thousand on average every quarter
  - Examples: a 31-ounce bag of Tide Pods Detergent, a 7-ounce bag of Pringles Select Potato Crisps Bold Crunch Jalapeno Ranch
Baseline product-level dataset

- **Source**
  - Nielsen Retail Measurement Services scanner dataset 2006-2015
  - 40,000 food, drug and mass merchandising stores (90 retail chains)
  - $220 billion of transactions/year, representing roughly 30 percent of total U.S. expenditures on food and beverages
  - Report weekly sales and volume for every UPC with positive sales generated by point-of-sales systems.

- **Our product dataset**
  - Combines all sales at national and annual level
  - **Baseline sample excludes** private label UPCs, UPCs without at least one transaction/quarter, UPCs from Alcohol and General Merchandise
  - **Period** 2006 – 2015
  - **Entry** is the first year in which we observe sales of a product
Baseline firm-product dataset

Matching firm and products
- GS1 codes are part of the UPC code (first 6 or 10 digits of the code)
- GS1 US Company Prefix Company (the source of barcodes)
  information on the parent company

Our firm-product dataset
- Our combined dataset allows us to identify the portfolio of Consumer
  Package Goods products of each firm at a annual level
- Firm Entry is first year of sales of the first product(s) by a firm
Patent Data

- United States Patent Office (USPTO) distributed through the Bulk Data Storage System:
  - all applications (granted or not)
  - 10 million patent applications (6 million granted) for 1975–2015

- We merge this data with Nielsen Data:
  - Assign filing firm to each patent;
  - New company name cleaning and standardization algorithm (building on NBER + Akcigit et al (2016));
  - Track corporate reorganizations using Thomson Reuters M&A.
Consumer packaged goods sector (CPG)

- 6-10% of GDP
- 13% of firms in CPG patent vs 6% of manufacturing firms in the US patent (Graham et al, 2015)
Augmented Dataset

- To obtain information on R&D and Productivity:
  - We merge our firm-product dataset with the **Compustat** database, using the names of the firm provided by GS1 US
  - Result:
    343 publicly traded companies, corresponding to 39% and 17% of revenue and products in our baseline firm-product dataset
  - Representativity:
    Captures larger firms when compared to our baseline firm-product dataset, but is very representative of Compustat firms.
## Summary Statistics by Patenting Status, Baseline dataset

- Descriptive statistics for pooled sample of firms, 2007–2015, all departments, accounts for M&A

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### Summary Statistics by Patenting Status, Augmented Dataset

- Descriptive statistics for pooled sample of firms in Compustat, 2007–2015, all departments, accounts for M&A

<table>
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<tr>
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<td>average quarterly entry rate</td>
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<td>number of different modules, max quarterly levels</td>
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</table>
Product creation by firms with and without patents

- By exploring cross-sectional variation in the average characteristics of firms in the period 2007–2015 we observe that:
  - Product creation occurs mostly in high revenue firms.
  - Patenting is a "large-firms business".
  - However, even within large firms almost half of new product innovations do not come from patenting firms.

Share of new products by revenue decile
Product creation by patenting firms: the intensive margin

- The link between new product introduction and new patents is not very strong if we exclude large revenue firms
Product creation by patenting firms: the intensive margin

- Even among high revenue firms there is substantial heterogeneity
Product creation: the intensive and extensive margins

To capture changes associated with a switch in status from being a nonpatentee to a patentee:

\[
\ln N_{j,t+k} = \beta(k) dP_{j,t} + \alpha_j + \gamma_{t+k} + u_{j,t+k}, \quad k = -3, \ldots, 0, \ldots, 4
\]

where \(\ln N_{j,t+k}\) is number of new products (log) \(j\) in \(t+k\), \(dP_{j,t}\) is a dummy that takes value 1 after a firm gets its first patent.

**NOTE:** The following graphs should be read as follows: Firms that become patentees in \(t=0\), change product creation by \(\beta\) percent in \(t=-3,\ldots,4\). So values before zero, mean that product creation changes prior to becoming a patentee. A significant estimated effect on product creation after 3 and 4 years may indicate that the effect is persistent (as opposed to temporary).
Product creation and becoming a first-time patentee

- The number of new products (logs) changes with the patenting status

While this makes sense. Unfortunately, it is not robust to the alternative specifications. And it is not robust in a subsample of departments.
Product creation and becoming a first-time patentee

► When we use an alternative approach, and consider the effect of the first patent

Dummy after 1st patents

Vertical bands represent +/- 1.65 * St. Error of each point estimate

Dummy with 1st patent

Vertical bands represent +/- 1.65 * St. Error of each point estimate
Product creation and becoming a first-time patentee

The revenue of new products (logs) does not show a pattern consistent with the number of new products.
Product creation and becoming a first-time patentee

Quality of entrant products

Dummy after 1st patents

Dummy with 1st patent
Product creation and becoming a first-time patentee

Total revenue (logs)

**Dummy after 1st patents**

**Dummy with 1st patent**

*Vertical bands represent +/- 1.65 * St. Error of each point estimate*
Product creation and becoming a first-time patentee

Change total revenue (logs)

Dummy after 1st patents

Vertical bands represent +/- 1.65 * St. Error of each point estimate

Dummy with 1st patent

Vertical bands represent +/- 1.65 * St. Error of each point estimate
Product creation and becoming a first-time patentee

Total number of products (logs)

**Dummy after 1st patents**

**Dummy with 1st patent**

selected sample  robustness non-weighted
Product creation and becoming a first-time patentee
Change in total number of products (logs)

Dummy after 1st patents

Dummy with 1st patent
Product creation: the intensive and extensive margins

To capture changes associated with a switch in status from being a nonpatentee to a patentee:

$$\ln N_{j,t+k} = \beta(k) dP_{j,t} + \alpha_j + \gamma_{t+k} + u_{j,t+k}, \ k = -3, \ldots, 0, \ldots, 4$$

where $\ln N_{j,t+k}$ is number of new products (log) $j$ in $t + k$, $dP_{j,t}$ is a dummy that takes value 1 after a firm gets its first patent.

To capture changes associated changes in the number granted patents:

$$\ln N_{j,t+k} = \beta(k) \ln P_{j,t} + \alpha_j + \gamma_{t+k} + u_{j,t+k}, \ k = -3, \ldots, 0, \ldots, 4$$

where $\ln N_{j,t+k}$ is number of new products (log) $j$ in $t + k$, $\ln P_{j,t}$ is number of granted patents (log).
Product creation among patenting firms: intensive margin

- There is positive and significant relationship between new patents and new product introduction
- An increase in patents in $t$ is followed by an increase in new products in $t$ and $t + 1$
Product creation among patenting firms: intensive margin

- This is robust to both patent applications and granted patents
- Effect larger on granted patents

![Graph showing the relationship between the number of patents granted and non-granted and the number of patents granted. The graph includes a legend indicating that red dots represent the number of patents granted, and blue circles represent the number of patents granted and non-granted. Vertical bands represent ±1.65 * St. Error of each point estimate.]

Additional notes:
- Selected sample
- By type
- Longer period
- Accounting for zeros N and P
- Zeros N
- Robustness non-weighted
- Robustness sample
Product creation among patenting firms: intensive margin

- The positive association is robust to different proxies for patenting intensivity/quality.
Product creation among patenting firms: intensive margin

- The positive association is also present when we use the stock approach.
Product creation among patenting firms: intensive margin

- There is a positive association between increase in revenue from entrant products and increase in number of patents granted.
Product creation among patenting firms: intensive margin

- There is a weak and noisy effect on the relative price of entrant products at entry
Product creation among patenting firms: intensive margin

- The nature of the correlation between the total revenue and the number of granted patents changes around the time of patenting.
Product creation among patenting firms: intensive margin

- The growth rate of revenue

![Graph showing the growth rate of revenue](image_url)
Some innovations may be directed towards improvement of production processes. Patents can capture both.

Can we use the residual variation in patents after controlling for product introduction as capturing process innovation?
### Process versus Product Innovation

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<thead>
<tr>
<th>VARIABLES</th>
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<td>N</td>
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</table>
Where are we going next?

GOAL: match products or groups of products with patents HOW?

- At the product level, we have the product descriptions, augmented with external sources such as product information databases and Wikipedia
- On the patents side, we have titles, abstracts, technology codes (US and IPC), as well as the full text of the patent
Matching products to patents

Let a generic patent be \( a \in \mathcal{A} \) and a generic product (or product group) be \( b \in \mathcal{B} \).

- Option 1: Simple comparison of word usage between \( a \) and \( b \) using a text similarity metric. Each document can be represented by a word frequency vector. Comparing the distance between two vectors produces a number between 0 and 1 for each pair of documents. All that is needed is then a distance cutoff value that determines which pairs constitute a match.
Matching products to patents

Let a generic patent be $a \in \mathcal{A}$ and a generic product (or product group) be $b \in \mathcal{B}$.

- Option 2: Uses machine learning (ML). A matching here can be formulated as a rule $f : \mathcal{A} \times \mathcal{B} \rightarrow \{0,1\}$. We can use ML methods to learn the functions $f$ using human generated training data. The document representation used can be either a general "word2vec" representation or the aforementioned frequency vectors, which discard information on word order.
  - Current toolkit: (1) a recursive neural network (RNN) to handle variable length text data, (2) word embedding to reduce the dimensionality of the text data, (3) dropout and validation to prevent overfitting with a high dimensional model.