R&D, innovation, and productivity

Bronwyn H. Hall

University of California at Berkeley, NBER, IFS London, NIESR London, and MPI Munich
R&D, innovation and productivity

Note the broader topic, given the importance of non-R&D based innovation for productivity

- Some facts about R&D/innovation
- Framework for interpreting results
- Brief summary of what we know
- Policies toward both R&D and innovation
  - How they differ
  - Are they effective?
R&D and innovation -> productivity

What are the mechanisms connecting R&D and innovation with aggregate productivity?

- Improvements within existing firms
  - Creation of new goods & services, leading to increased demand for firm’s products
  - Process and organizational innovation leading to efficiency gains in production
- Entry of more efficient firms
- Entry of firms on technology frontier
- Exit of less efficient firms
Measuring innovative activity

- Large literature using R&D flows or stocks as proxies for innovation input
  - Hall, Mairesse, Mohnen 2010 survey, *inter alia*
- Smaller literature using patents as a proxy for intermediate innovation output
- Both measures have well-known weaknesses, especially outside the manufacturing sector
- Recently more direct measures are available, thanks to CIS firm surveys
R&D vs innovation

- Not all innovative firms do formal R&D
- R&D-doing firms do not innovate every year (or even every 3 years)

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**Italian firms 1995-2006**

<table>
<thead>
<tr>
<th></th>
<th>Non-innovator</th>
<th>Innovator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does not do R&amp;D</td>
<td>30.9%</td>
<td>34.8%</td>
</tr>
<tr>
<td>Does R&amp;D</td>
<td>6.2%</td>
<td>34.3%</td>
</tr>
</tbody>
</table>

- Especially true in the service sector:
  - Many innovations are not technological, such as new ways of organizing information flow, new designs, etc.
  - Many innovations rely on purchased technology, such as adoption of computer-aided processes, CRM software, etc.
R&D vs innovation spending

- Service sector firms spend more on new equipment, training, and marketing and less on R&D.

The shares shown are for firms that have some form of innovation spending reported.
What do we know?

- A great deal about
  - Contribution of R&D and innovation to firm-level productivity
  - Contribution of R&D and innovation to the productivity of other industries and countries

- Something about
  - Contribution of entry of more efficient and exit of less efficient firms to aggregate productivity growth
  - Contribution of R&D to quality improvement and therefore productivity growth (via lower prices)

- Much less about
  - Contribution of R&D and innovation to welfare and to poorly measured but important outputs (health, environmental quality, etc)
  - Aggregate growth implications in detail
  - Distribution of the benefits from gains in productivity
Interpretive framework

- Innovation-productivity regressions use revenue productivity data
  - Include coarse sectoral dummies
  - Relative within-sector price changes not accounted for
  - Quality change not generally accounted for

- Omitting price change at the firm level can be helpful, as it allows estimation of the contribution of innovation to firm demand as well as efficiency

- Hall (2011) - analysis of the implications of distinguishing productivity from revenue productivity

MEAE/OECD Finland  December 2016
Productivity-innovation model

- Innovation affects
  - price the firm can charge (product)
  - quantity the firm produces from a given set of inputs (process)
- Output measure -- revenue (sales or turnover)
  - joint response of price*quantity to product and process innovation
- Labor demand responds both to increased efficiency (negatively) and to increased output (positively, due to output increases)
- Assume the following:
  - Imperfect competition (positive markup)
  - Downward sloping demand with constant elasticity
Conclusions from analysis

- Product innovation unambiguously increases revenue, productivity and labor demand.
- Process innovation will increase revenue productivity and labor demand only if demand is elastic; even in this case impact is dampened unless there is perfect competition (price taking).
- Empirical results largely confirm these predictions.
  - Product innovation and share of innovative sales strongly positive for both output and labor demand.
  - Process innovation much less so, sometimes negative.
  - R&D (if present) a better predictor, since better measured.
Spillovers

- Principle argument for R&D/innovation policy is the presence of unpriced spillovers to firms that are adjacent in industry, technology, or geographically.
- Lots of evidence that this is true (e.g., Kao et al 1999, Keller 1998, 2001, Coe and Helpman 1995). Some nuances:
  - For foreign R&D, export/import channel is important (Macgarvie 2004)
  - Spillovers from foreign R&D more important for smaller open economies than for countries like US, Japan, and Germany (Park 1995, van Pottelsberghe 1997)
  - Domestic spillovers usually larger than those from other countries (Branstetter 2001, Peri 2004)
  - Absorptive capacity of recipient country is important for making use of R&D spillovers (Guellec and van Pottelsberghe 2001)
  - Typical social rates of return are quite large, but very imprecisely determined
R&D and innovation policy

- Two different emphases
  - Inducing spending on R&D will be successful using fairly direct measures
  - Success in innovation depends to a greater extent on multiple factors in the environment, outside the direct innovation orbit
R&D policy

- Main policies (widely used)
  - Property rights (at the cost of restricted output)
  - Subsidies (often targetted; high administration costs)
  - Tax credits of various kinds

- Brief summary of evidence
  - IP important in some (but definitely not all) sectors
  - Subsidies have a mixed record, but mostly positive in the sense that they increase R&D spending by the firm
  - R&D tax credits unambiguously increase R&D spending, usually with price elasticity around unity

- With the exception of some subsidy programs, these policies target the private rate of return, not the social
R&D and innovation policy

Some governments have turned to IP or patent boxes in order to broaden supported activities.

However, R&D tax credits *strongly preferred* to patent boxes for a number of reasons:

- Directly related to cost of activity (firm decisions)
- Relative size of non-R&E budget does not affect credit (depending on box design)
- No incentive to choose projects with high non-R&E expenses (depending on box design)
- No tax subsidy for patent trolling
- No incentive to use zombie patents to reduce taxes
- Less arbitrage across firms possible – doesn’t matter who does the R&D
- Lower audit cost
Broader policy context

- Innovative activity (including diffusion) affected by many things, not all of which are viewed as susceptible to “innovation policy”
  - Timely bankruptcy procedures and contract enforcement
  - Entry costs and regulation
  - Product market regulation
  - Labor market regulation – startups need flexibility
    - Corollary: lifetime training availability
  - Political resistance from affected firms and workers
- Data on these factors now available, thanks to OECD and IMF

December 2016

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Institutions and innovation

- Barbosa and Faria (2011) – look at product/process innovation 2002-2004 in 10 European countries
  - Product and labor market regulation affects innovation intensity negatively
  - More developed credit markets foster innovation
  - Strengthening of intellectual property rights does not seem to stimulate innovation
- Ciriaci et al. (2016) – Above a threshold of PMR, EPL is negative for R&D location.
Product market regulation in 2013 and threshold value for EPL impact (EU 28)

- PMR measure: 1) state control; 2) barriers to trade and investment; 3) barriers to entrepreneurship
- EPL measure: costs of firing and of hiring on fixed term or temp contracts

![Chart showing countries with PMR above and below the threshold value, with Finland highlighted.](chart.png)
Allocative efficiency & regulation (AE)

- Can resources (capital and workers) move to their most productive use?
- Andrews & Cingano (2014) – controls for endogeneity of policies
  - Higher barriers to entry and creditor-friendly bankruptcy legislation tend to lower AE
  - Tighter employment protection lowers the efficiency of employment allocation
  - Stringent product & labor market regulation, bankruptcy legislation more disruptive to AE in innovative sectors
Cette, Lopez, Mairesse (2016)

- Industry-country study for 14 OECD countries, 18 industries, both mfg and services
  - Impact of non-mfg regulation, harmonized tariffs and EPL on TFP is negative
  - Finland: both non-manufacturing regulation and EPL depress MFP
Institutions and catch-up

- **Andrews, Criscuolo, and Gal (2015)** – study gap between firms on tech frontier and other firms in OECD countries
- **Productivity gaps between national frontier and global frontier firms smaller in countries where**
  - education systems are of higher quality;
  - product market regulations are less cumbersome;
  - businesses and universities collaborate intensively;
  - markets for risk capital are more developed.
- **Mixed results on patent strength: lower gap in R&D intensive sectors, but not in more dynamic sectors**

- **Country-industry results:**
  - Lower PMR associated with higher MFP growth for firms in industries with high firm turnover rates,
  - Lower EPL associated with higher MFP growth for firms in industries with high job turnover rates,
  - Higher R&D collaboration between universities and firms is associated with higher MFP growth for laggard firms in K-intensive industries
Cross-country gains to aggregate labour productivity from reforms to best practice level of four policy variables that partly explain cross-country industry differences in the size of national frontier (NF) firms, relative to global frontier (GF) benchmark. Source: Andrews et al. (2015)

Finland’s position is mixed, relative to global frontier firms (lower is better)
Tentative suggestions for Finland

“Conclusions” would be too strong a word – these are topics for discussion

- Framework conditions fairly favorable for innovation, could be improved - appear to reduce level of TFP by about 5%, after controlling for other inputs
  - PMR (retail, transport, construction, according to OECD 2016 report)
  - EPL (or just labor costs in general?)
- Publicly funded R&D as a share of GDP surprisingly low
  - Why is the takeup of the R&D tax credit so low?
Thank you for listening
(a bit more on aggregate effects and CDM results below)
Aggregation

- How does individual firm relationship aggregate up to macro-economy?
  - productivity gains in existing firms
  - exit and entry

  - Competition and entry encourages innovation unless the sector is very far behind

- Djankov (2010) survey – cross country
  - stronger entry regulation and/or higher entry costs associated with fewer new firms, greater existing firm size and growth, lower TFP, lower investment, and higher profits
Entry and exit

- Olley & Pakes, Haltiwanger & co-authors have developed decompositions that are useful
  - Distinguish between revenue and quantity, and include exit & entry
  - Revenue productivity understates contribution of entrants to real productivity growth because entrants generally have lower prices
  - Demand variation is a more important determinant of firm survival than efficiency in production (consistent with productivity impacts)
Future work?

- Full set of links between innovation, competition, exit/entry, and productivity growth not yet explored
- **Bartelsman et al. (2010):** Size-productivity more highly correlated within industry if regulation is “efficient”
  - Evidence on Eastern European convergence
  - Useful approach to the evaluation of regulatory effects without strong assumptions
- Similar analysis could assess the economy-wide innovation impacts
Innovation surveys contain…..

- **Data on innovation:**
  - Product or process new to firm/market (yes/no)
  - Share of sales during past 3 years from new products
  - More recent surveys have expenditures on various kinds of innovation investments

- **Data on productivity and employment:**
  - Usually sales per worker (labor productivity)
  - Sometimes TFP (adjusted for changes in capital)
  - Issues arising from deflation and level of aggregation
    - of goods, and of enterprises

More information in *Mairesse and Mohnen (2010)*
What do the data say about the relationship?

- Results from a large collection of papers that used the CDM model for estimation (Crepon Duguet Mairesse 1998):
  - Innovation survey data reveals that some non-R&D firms innovate and some R&D firms do not innovate during the relevant period.
  - Data is usually cross-sectional, so possible simultaneity between R&D, innovation, and productivity (productivity sometimes measured a year later).
  - Sequential model: R&D → innovation → productivity.
The CDM model

1. The determinants of R&D choice: whether to do it and how much to do (generalized Tobit)
2. Innovation production function with innovation variables as functions of predicted R&D intensity (regression or probits)
3. Production function including the predicted innovation outcomes to measure their contribution to the firm’s productivity.

Effectively a triangular simultaneous equations model, but nonlinear. (bootstrap s.e.s if sequentially estimated)
CDM model applied to CIS data

- Estimated for 20+ countries
- Confirms high rates of return to R&D found in earlier studies
- Like patents, innovation output statistics are much more variable ("noisier") than R&D,
  - R&D tends to predict productivity better, when available
- Next few slides - results summary
  - regressions of individual firm TFP on innovation
### Productivity-innovation relationship in TFP levels

<table>
<thead>
<tr>
<th>Sample</th>
<th>Time period</th>
<th>Elasticity with respect to innov sales share</th>
<th>Process innovation dummy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chilean mfg sector</td>
<td>1995-1998</td>
<td>0.18 (0.11)*</td>
<td></td>
</tr>
<tr>
<td>Chinese R&amp;D-doing mfg sector</td>
<td>1995-1999</td>
<td>0.035 (0.002)***</td>
<td></td>
</tr>
<tr>
<td>Dutch mfg sector</td>
<td>1994-1996</td>
<td>0.13 (0.03)***</td>
<td>-1.3 (0.5)***</td>
</tr>
<tr>
<td>Finnish mfg sector</td>
<td>1994-1996</td>
<td>0.09 (0.06)</td>
<td>-0.03 (0.06)</td>
</tr>
<tr>
<td>French mfg sector</td>
<td>1986-1990</td>
<td>0.07 (0.02)***</td>
<td></td>
</tr>
<tr>
<td>German K-intensive mfg sector</td>
<td>1998-2000</td>
<td>0.27 (0.10)***</td>
<td>-0.14 (0.07)**</td>
</tr>
<tr>
<td>Norwegian mfg sector</td>
<td>1995-1997</td>
<td>0.26 (0.06)***</td>
<td>0.01 (0.04)</td>
</tr>
<tr>
<td>Swedish K-intensive mfg sector</td>
<td>1998-2000</td>
<td>0.29 (0.08)***</td>
<td>-0.03 (0.12)</td>
</tr>
<tr>
<td>Swedish mfg sector</td>
<td>1994-1996</td>
<td>0.15 (0.04)***</td>
<td>-0.15 (0.04)***</td>
</tr>
<tr>
<td>Swedish mfg sector</td>
<td>1996-1998</td>
<td>0.12 (0.04)***</td>
<td>-0.07 (0.03)***</td>
</tr>
<tr>
<td>Swedish service sector</td>
<td>1996-1998</td>
<td>0.09 (0.05)*</td>
<td>-0.07 (0.05)</td>
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Innovative sales share and process innovation included separately in the production function:

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<tr>
<td>French Hi-tech mfg</td>
<td>1998-2000</td>
<td>0.23 (0.15)*</td>
<td>0.06 (0.02)***</td>
</tr>
<tr>
<td>French Low-tech mfg</td>
<td>1998-2000</td>
<td>0.05 (0.02)***</td>
<td>0.10 (0.04)***</td>
</tr>
<tr>
<td>Irish firms</td>
<td>2004-2008</td>
<td>0.11 (0.02)***</td>
<td>0.33 (0.08)***</td>
</tr>
</tbody>
</table>
TFP levels on innov sales share

- Robustly positive, supports the view that product innovation shifts the firm’s demand curve out and increases revenue
  - Elasticities range from 0.04 to 0.29 with a typical standard error of 0.03
  - R&D-intensive and hi-tech firms have higher elasticities (consistent with equalized rates of return across sectors)
- Coefficient of process innovation dummy usually insignificant or negative, suggesting either inelastic demand and/or substantial measurement error in the innovation variables
## Productivity-innovation using dummies

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<th>Process innovation dummy</th>
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<tr>
<td>Argentinian mfg sector</td>
<td>1998-2000</td>
<td>-0.22 (0.15)</td>
<td></td>
</tr>
<tr>
<td>Brazilian mfg sector</td>
<td>1998-2000</td>
<td>0.22 (0.04)***</td>
<td></td>
</tr>
<tr>
<td>Estonian mfg sector</td>
<td>1998-2000</td>
<td>0.17 (0.08)**</td>
<td>-0.03 (0.09)</td>
</tr>
<tr>
<td>Estonian mfg sector</td>
<td>2002-2004</td>
<td>0.03 (0.04)</td>
<td>0.18 (0.05)***</td>
</tr>
<tr>
<td>French mfg sector</td>
<td>1998-2000</td>
<td>0.08 (0.03)**</td>
<td></td>
</tr>
<tr>
<td>French mfg sector</td>
<td>1998-2000</td>
<td>0.06 (0.02)***</td>
<td>0.07 (0.03)**</td>
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<tr>
<td>French mfg sector</td>
<td>1998-2000</td>
<td>0.05 (0.09)</td>
<td>0.41 (0.12)***</td>
</tr>
<tr>
<td>French mfg sector</td>
<td>2002-2004</td>
<td>-0.08 (0.13)</td>
<td>0.45 (0.16)***</td>
</tr>
<tr>
<td>French service sector</td>
<td>2002-2004</td>
<td>0.27 (0.52)</td>
<td>0.27 (0.45)</td>
</tr>
<tr>
<td>German mfg sector</td>
<td>1998-2000</td>
<td>-0.05 (0.03)</td>
<td>0.02 (0.05)</td>
</tr>
<tr>
<td>Italian mfg sector</td>
<td>1995-2003</td>
<td>0.69 (0.15)***</td>
<td>-0.43 (0.13)***</td>
</tr>
<tr>
<td>Italian mfg sector SMEs</td>
<td>1995-2003</td>
<td>0.60 (0.09)***</td>
<td>0.19 (0.27)</td>
</tr>
<tr>
<td>Mexican mfg sector</td>
<td>1998-2000</td>
<td>0.31 (0.09)**</td>
<td></td>
</tr>
<tr>
<td>Spanish mfg sector</td>
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<td>Swiss mfg sector</td>
<td>1998-2000</td>
<td>0.06 (0.02)***</td>
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<td>UK mfg sector</td>
<td>1998-2000</td>
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<td>0.03 (0.04)</td>
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Innovative sales share and process innovation included separately in the production function:

| Irish firms                  | 2004-2008   | 0.45 (0.08)***           | 0.33 (0.08)***           |
## Productivity-innovation using dummies

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<tr>
<td>German mfg sector</td>
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<td>0.09 (0.05)**</td>
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<tr>
<td>German mfg sector</td>
<td>2006-2008</td>
<td>0.21 (0.07)**</td>
<td></td>
</tr>
<tr>
<td>German service sector</td>
<td>2006-2008</td>
<td>0.18 (0.22)</td>
<td>0.24 (0.24)</td>
</tr>
<tr>
<td>Irish mfg sector</td>
<td>2006-2008</td>
<td>0.51 (0.30)*</td>
<td>0.19 (0.28)</td>
</tr>
<tr>
<td>Irish service sector</td>
<td>2006-2008</td>
<td>0.05 (0.02)**</td>
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<td>UK mfg sector</td>
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<td>UK service sector</td>
<td>2006-2008</td>
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</table>

Source: Peters et al. 2014
TFP level results with dummies

- Product dummy supports innovation sales share result, although much noisier.
- There is substantial correlation between product and process innovation, especially when they are instrumented by R&D and other firm characteristics.
- Without instruments, innovation dummies frequently do not enter productivity equation at all.

NB: Correlated measurement error can lead to bias in both coefficients (upward for the better measured one and downward for the other) – see Hall (2004) [http://bronwynhall.com/papers/BHH04_measerr.pdf](http://bronwynhall.com/papers/BHH04_measerr.pdf)
Employment impacts

- Harrison et al (IJIO 2014) and Hall, Lotti, Mairesse (ICC 2008) - decompose employment change as a function of process and product innovation, using coefficients from a regression of employment growth on innovative sales growth and process innovation:

  \[
  \text{Growth} = \text{industry productivity trend in old products} \\
  + \text{growth due to process innovation in old products} \\
  + \text{growth due to output growth of old products} \\
  + \text{growth due to product innovation (net of substitution away from old products)}
  \]

- A reinterpretation of the labor productivity equation to focus on employment
Summary

- Elasticity wrt innovative sales centers on \((0.09, 0.13)\)
  - Higher for high tech and knowledge-intensive firms
  - Lower on average for low tech and developing countries, but also more variable
- With product innovation included, process innovation often negative or zero
- Without product innovation, process innovation positive for productivity
- When not instrumented, little impact of innovation variables in production function (unlike R&D)
  - See Mairesse & Mohnen (2005), Hall et al. (2012)
- Both process and product innovation are positive on average for firm employment growth in manufacturing,
  - At least during the late 1990s in Europe
- What if we had spending on innovation (rather than just R&D, a component of innovation spending)?
UK evidence

- **Definition of IS:** internal & external R&D; new equip & software; design expense; training; acq of patents & knowhow; marketing – all associated with intro of new products or processes

- **Out of 10,500 firm obs 2001-2006**
  - 6500 have some form of innovation spending (IS)
  - 3400 have internal R&D
  - R&D firms: median IS is 5 times median R&D

- **Compared to R&D:**
  - IS more strongly associated with info from suppliers and innovation to meet environmental or H&S stds; less strongly with exports, collaboration, and info from customers (that is, more process than product)
  - IS is a better predictor of innovation probability
  - Doubling IS has the same impact on TFP as doubling R&D – increase of 0.05
Discussion

- R&D spending remains a better predictor of productivity improvement at the firm level.
- Innovation dummies may be too noisy a measure to be very useful.
  - Share of sales due to new products is more informative.
  - What measure would be useful (and reportable) for process innovation?
- Further exploration with innovation investment (instead of R&D) is warranted.