Lecture 3: Innovation

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NBER Entrepreneurship Boot Camp (July 2013)
Innovation

• A Huge area

• A lot of measured innovation by incumbents

• But more radical innovation by entrant entrepreneurs?
Lecture 3: Overview

1. Measuring innovation

2. Effects of innovation on productivity: Own & spillovers

3. Some determinants of innovation: Competition.
   - **Not covering:**
     - Market size/demand (Schmookler, Acemoglu)
     - Finance (Lerner, NBER lectures)
     - Human capital (Jones, NBER lectures)
     - Institutions (e.g. Acemoglu-Robinson, 2012)
     - Labor markets (e.g. Machin & Van Reenen, 1998)
Measuring Innovation: Indirect via Total Factor Productivity Growth

• TFP growth - crudely, think of TFP level as efficiency & TFP growth as “innovation”

• Solow approach using factor shares as weights (Haltiwanger lectures)
  – Assumption of constant returns & competitive markets
  – Can be relaxed in various ways (e.g. Hall, 1988)

• TFP can also be obtained from parameters in econometrically estimated production function (e.g. Olley-Pakes, 1996; Blundell-Bond, 2000). Hot topic (e.g. de Loecker, 2011, Econometrica)

• Basic problems
  – TFP residual a “measure of our ignorance”: lots of other things apart from technical change
Measuring Innovation: Direct

• Easier if looking at single industry (e.g. New Chemical Entities in pharma; vintages of semi-conductor chips)

• Research and Development (R&D)
  – input based
  – convert into stock (like other intangible capital stocks)

• Patents
  – Widely available for all firm sizes (unlike R&D)
  – Very heterogeneous in value (weight by e.g. citations)
  – Many innovations not patented
  – Subject to legal vagaries

• Other direct innovation measures (e.g. SPRU; CIS)

• Diffusion Measures (e.g. ICT, Hybrid Corn, Beta Blockers)
Lecture 3: Overview

1. Measuring innovation

2. Effects of innovation on productivity: own & spillover

3. Some determinants of innovation: competition & trade
Contribution of own innovation to productivity

- Production Function approach (Griliches, 1979)
  - \( Q = A(G)F(K,L); \ G=\text{R&D knowledge stock} \)
- **Example:** \( Q = B X^{1-\gamma} G^\gamma \)
- \( X = \text{single factor input (e.g. labor at price } w) \)
  - \( G(t) = \text{knowledge stock; e.g. } G(t) = R(t) - (1-\delta)G(t-1) \)
  - \( R(t) = \text{R&D expenditure at time } t \)
  - \( \delta = \text{depreciation rate of knowledge stock} \)
- \( \ln Q = \ln B + (1-\gamma)\ln X + \gamma\ln G \)
  - \( \Delta\ln Q = \Delta\ln B + (1-\gamma)\Delta\ln X + \gamma\Delta\ln G \)
  - \( \text{TFP} = \Delta\ln Y - (1-\gamma)\Delta\ln X = \gamma\Delta\ln G \)
  - Where \( 1-\gamma \) measured by \( wX/pQ \), factor revenue share
Contribution of innovation to productivity: Spillovers

• Crucial issue in innovation: public good nature of knowledge, externalities

• Types of knowledge spillover
  – Technology space (Jaffe, 1986)
  – Geographical (Cockburn, Henderson, Jaffe, 1993)
  – Input/output linkages (but rent spillover issue)
  – Industry. Prob: Mixes competition effect. Innovations are also “business stealing”: a negative spillover

• Early papers approached by aggregating to ind or country

• Example of paper looking at spillovers in technology & product market rivalry: Bloom, Schankerman & Van Reenen (2013, Econometrica)
Combine Compustat and NBER Patents Data

Combine:

• Compustat data (all listed US firms) to measure R&D, Tobin’s Q, Sales, Capital, Labor etc. 1980-2001

• Compustat line-of business data to define sales by SIC’s
  – Sample covers 623 4-digit SIC classes

• NBER/USPTO data: US patents (form 1963) and citations (from 1975)

Final sample of 715 firms (~80% of US aggregate R&D)
Measuring Technology Spillovers

Define technology closeness by uncentered correlation of firm patent nclass distribution (Jaffe, 1986)

\[ T_i = (T_{i1}, T_{i2}, \ldots, T_{i426}) \]

where \( T_{ik} \) is % of firm i’s patents in technology class k (k = 1,..,426) averaged 1963-1999

\[ \text{TECH}_{i,j} = \frac{(T_i T'_j)}{[(T_i T'_i)^{1/2}(T_j T'_j)^{1/2}]} \] lies in [0,1]

Define technology spillover pool as TECH-weighted R&D:

\[ \text{SPILLTECH}_{it} = \sum_{j,j \neq i} \text{TECH}_{i,j} G_{jt} \]

where \( G_{jt} \) is the R&D stock of firm j at time t

Alternative distance metrics (e.g. Mahalanobis)
Product Market Rivalry

- Analogous construction of product market “closeness”
  - Define $S_i = (S_{i1}, S_{i2}, \ldots, S_{i623})$, where $S_{ik}$ is the % of firm $i$’s total sales in 4 digit industry $k$ ($k = 1, \ldots, 623$)

- $SIC_{i,j} = (S_i \cdot S'_j)/[(S_i \cdot S'_i)^{1/2}(S_j \cdot S'_j)^{1/2}]$

- Product market “spillover” pool defined as SIC weighted R&D:
  - $SPILLSIC_{it} = \sum_{j \neq i} SIC_{i,j} G_{jt}$ where $G_{jt}$ is the R&D stock of firm $j$ at time $t$
Examples of innovative firms

<table>
<thead>
<tr>
<th></th>
<th>Correlation</th>
<th>IBM</th>
<th>Apple</th>
<th>Motorola</th>
<th>Intel</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBM</td>
<td>SIC TECH</td>
<td>0.32</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Apple</td>
<td>SIC TECH</td>
<td></td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Moto</td>
<td>SIC TECH</td>
<td></td>
<td></td>
<td>0.35</td>
<td>0.46</td>
</tr>
<tr>
<td>Intel</td>
<td>SIC TECH</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IBM, Apple, Motorola and Intel all close in TECH

But  
  a) IBM close to Apple in product market (.32, computers)
  b) IBM not close to Motorola or Intel in product market (.01)
Market value equation

Use Griliches (1981) Tobin’s Q parameterisation:

\[
\ln \left( \frac{V}{A} \right)_{it} = \ln \kappa_{it} + \ln \left( 1 + \gamma^v \left( \frac{G}{A} \right)_{it} \right)
\]

Positive: knowledge spillovers

\[
\ln \left( \frac{V}{A} \right)_{it} = \phi \left( \left( \frac{G}{A} \right)_{it-1} \right) + \beta_{v1}^v \ln SPILLTECH_{it-1}
+ \beta_{v2}^v \ln SPILLSIC_{it-1} + Z_{it}^v \beta^v_3 + \eta^v_i + \tau^v_t + \nu^v_{it}
\]

Negative: business stealing
Identification: Reflection Problem (Manski, 1993)

Main concern is correlated shocks, demand or supply (e.g. technological opportunity)

To address this use:

- Instrumental Variables (IV) for spillovers: R&D tax credits. These have a state and federal component

- Use parametric determination of neighbours (measures of distance in technology and product market dimensions)

- Compare across multiple equations, where predictions are different: market value, patents, productivity and R&D
## Tobin’s Q Equation

**Dep. variable:** Ln (V/A)

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Only SPILLTEC</th>
<th>Only SPILLSIC</th>
<th>2nd Stage IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln(SPILLTECH$_{t-1}$)</td>
<td>0.381** (0.113)</td>
<td>0.305** (0.109)</td>
<td></td>
<td>1.079** (0.192)</td>
</tr>
<tr>
<td>Ln(SPILLSIC$_{t-1}$)</td>
<td>-0.083** (0.032)</td>
<td></td>
<td>-0.050 (0.031)</td>
<td>-0.235** (0.109)</td>
</tr>
</tbody>
</table>


**Source:** Bloom, Schankerman & Van Reenenen (2013)
Cite-weighted Patent Count Equation

\[
E(P_{it} \mid Z_{it}, P_{it-1}) = \exp \left\{ \delta_1 D_{it} \ln P_{it-1} + \delta_2 D_{it} + \beta^p_1 \ln SPILLTECH_{it-1} + \beta^p_2 \ln SPILLSIC_{it-1} + Z_{it}^p \beta^p_3 + \eta^{psm}_i + \tau^p_t + v^p_{it} \right\}
\]

- **Count data model**
  - Negative Binominal count model
  - Blundell, Griffith and Van Reenen (1999) control for fixed effects through pre-sample mean patents (1968-1984)
Productivity equation

\[
\ln Y_{it} = \alpha^L \ln L_{it} + \alpha^K \ln K_{it} + \beta^y_1 \ln \text{SPILLTECH}_{it-1} \\
+ \beta^y_2 \ln \text{SPILLSIC}_{it-1} + Z_{it} \beta^y_3 + \eta^y_i + \tau^y_t + \nu^y_{it}
\]

R&D Expenditure Equation

\[
\ln (R / S)_{it} = \alpha^r \ln (R / S)_{it-1} + \beta^r_1 \ln \text{SPILLTECH}_{it-1} \\
+ \beta^r_2 \ln \text{SPILLSIC}_{it-1} + Z_{it} \beta^r_3 + \eta^r_i + \tau^r_t + \nu^r_{it}
\]
## Comparing Empirical Results to Predictions of the Model

<table>
<thead>
<tr>
<th>Partial correlation</th>
<th>Theory</th>
<th>Empirics</th>
<th>Consistency?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\partial V_0 / \partial r_T$</td>
<td>Market value with SPILLTECH</td>
<td>Positive</td>
<td>0.381**</td>
</tr>
<tr>
<td>$\partial V_0 / \partial r_m$</td>
<td>Market value with SPILLSIC</td>
<td>Negative</td>
<td>-0.083**</td>
</tr>
<tr>
<td>$\partial k_0 / \partial r_T$</td>
<td>Patents with SPILLTECH</td>
<td>Positive</td>
<td>0.417**</td>
</tr>
<tr>
<td>$\partial k_0 / \partial r_m$</td>
<td>Patents with SPILLSIC</td>
<td>Zero</td>
<td>0.043</td>
</tr>
<tr>
<td>$\partial y_0 / \partial r_T$</td>
<td>Productivity with SPILLTECH</td>
<td>Positive</td>
<td>0.191**</td>
</tr>
<tr>
<td>$\partial y_0 / \partial r_m$</td>
<td>Productivity with SPILLSIC</td>
<td>Zero</td>
<td>-0.005</td>
</tr>
<tr>
<td>$\partial r_0 / \partial r_T$</td>
<td>R&amp;D with SPILLTECH</td>
<td>Ambiguous</td>
<td>0.100</td>
</tr>
<tr>
<td>$\partial r_0 / \partial r_m$</td>
<td>R&amp;D with SPILLSIC</td>
<td>Positive with strategic complements</td>
<td>0.083**</td>
</tr>
</tbody>
</table>
Conclusions of Bloom, Schankerman & VR (2013)

- Find both technology spillovers and product market rivalry effects of R&D, consistent with predictions of simple analytical framework

- Technology spillovers dominate, social returns over twice as large as private returns so “too little” R&D overall (consistent with most of literature using simpler methods)

- Larger firms generate greater social-private returns gap than small firms. Rethink R&D policies favouring small firms? What about other differences, e.g. Imperfections in the capital markets?
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3. Some determinants of innovation: competition & trade
What is effect of product market competition on innovation? Theory: Competition “bad”

• Schumpeterian paradigm (Endogenous growth theory, e.g. Aghion-Howitt, 1992)
  – Competition good for static efficiency (allocative and productive, e.g. management & TFP)
  – R&D has public good aspect, reduces private incentives (reason for IP & R&D subsidies)
  – Tougher competition reduces the innovator’s profits & therefore R&D incentives. So trade off between static & dynamic efficiency

  – Since joint duopoly profits lower than monopoly profits, monopolist has greater innovation incentive than entrant (entrepreneur)
What is effect of product market competition on innovation? Theory: Competition “good”

- Arrow replacement effect
  - Monopolist earns profit: if he innovates some profits “replaced”
  - Competitive firm earns zero profits so nothing to lose if innovates (& gains market power)
  - Therefore competitive industry will be more innovative than monopolistic industry

- Originally Arrow model was between industry comparison, but this “escape competition” effect also exists within industry between entrant/follower & leader (e.g. Aghion et al, 2005, “Inverted U”)

- **Conclusion**
  - Effects of competition on innovation ambiguous, except in special cases (e.g. drastic innovation)
What is effect of product market competition on innovation? Theory: Additional complexities

- **Many empirical papers** (Syverson, 2011, survey)
  - Nickell (1996, JPE) shows changes in competition lead to faster TFP growth within a panel of firms
  - Blundell, Griffith & VR (1999, Restud) find positive effects of competition on innovation

- **Example paper:**
  - Bloom, Draca & Van Reenen (2013)
  - Using China as a shock
Basic Technology Equation

\[ \ln Y_{ijkt} = \alpha IMP^{CH}_{jkt} + \beta x_{ijkt} + \lambda_i + u_{ijkt} \]

- patents, IT, R&D, TFP, management
- Chinese import share
- Fixed Effects

Example: For IT
- \( i = \text{plants} \) (22,957)
- \( j = \text{industries} \) (366)
- \( k = \text{countries} \) (12)
- \( jk = 2,816 \text{ cells} \)
- \( t = 2000, \ldots, 2007 \)

- \( x \): controls like country*time dummies
- Cluster at industry-by-country (jk)
Tab 1: Within Firm OLS Results

<table>
<thead>
<tr>
<th>Method</th>
<th>(1) Δln(Patents)</th>
<th>(2) Δln(IT/N)</th>
<th>(3) Δln(R&amp;D)</th>
<th>(4) ΔTFP</th>
<th>(5) Δmanagement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Chinese Imports</td>
<td>0.321***</td>
<td>0.361**</td>
<td>1.213**</td>
<td>0.257***</td>
<td>0.814***</td>
</tr>
<tr>
<td></td>
<td>(0.102)</td>
<td>(0.076)</td>
<td>(0.549)</td>
<td>(0.072)</td>
<td>(0.314)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td># units</td>
<td>8,480</td>
<td>22,957</td>
<td>459</td>
<td>89,369</td>
<td>1,576</td>
</tr>
<tr>
<td># industry clusters</td>
<td>1,578</td>
<td>2,816</td>
<td>196</td>
<td>1,210</td>
<td>579</td>
</tr>
<tr>
<td>Obs</td>
<td>30,277</td>
<td>37,500</td>
<td>1,626</td>
<td>292,167</td>
<td>3,607</td>
</tr>
</tbody>
</table>

IV using MFA policy experiment


- The MFA was negotiated into GATT (WTO) as part of the Uruguay Round in 1994, with a 4 phase abolition 1995-2005.

- When China entered the WTO in Dec 2001 it gained access to this phased abolition, occurring between 2001 and 2005.

- When Chinese products came off quota in 2005 there was a huge surge of imports into EU and US.

- Because there was some (endogenous) re-introduction of some quotas in 2006 we use baseline quotas in 2000.
Table 2A- Cont: IV estimates using changes in EU textile & clothing quotas – Patents and TFP

<table>
<thead>
<tr>
<th>Method</th>
<th>OLS</th>
<th>IV</th>
<th>OLS</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔChinese Imports</td>
<td>OLS</td>
<td>1.160***</td>
<td>(0.377)</td>
<td>1.864*</td>
</tr>
<tr>
<td>ΔChinese Imports</td>
<td>IV</td>
<td>0.620***</td>
<td>(0.100)</td>
<td>1.897**</td>
</tr>
</tbody>
</table>

Sample period: 2005-1996

Units: 1,866 1,866 55,791 55,791

Industry clusters: 149 149 187 187

Observations: 3,443 3,443 55,791 55,791

SE clustered by 4 digit industries, Country-year dummies included.
C) Employment Equation

Employment growth

If high TECH plants “protected” from Chinese imports then $\gamma^n > 0$

\[
\Delta \ln N_{ijkt} = \gamma^n [TECH_{ijkt-5} \times \Delta IMP_{jkt}^{CH}] + \\
\alpha^n \Delta IMP_{jkt}^{CH} + \delta^n TECH_{ijkt-5} + \beta^n \Delta x^n_{ijkt} + \nu^n_{ijkt}
\]

expect $\alpha^n < 0$  expect $\delta^n > 0$
FIG 3: EMPLOYMENT GROWTH BY INITIAL IT INTENSITY

Low China Import Growth (Lowest Quintile)

Quintiles of initial IT Intensity
### Table 3A: Innovating firms shed less jobs when faced with rising Chinese imports

<table>
<thead>
<tr>
<th>Dependent Variable:</th>
<th>Δln(N)</th>
<th>Δln(N)</th>
<th>Δln(N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TECH Measure:</td>
<td>Patents</td>
<td>IT</td>
<td>TFP</td>
</tr>
<tr>
<td>Chinese Import Growth</td>
<td>-0.352***</td>
<td>-0.379***</td>
<td>-0.382***</td>
</tr>
<tr>
<td></td>
<td>(0.067)</td>
<td>(0.105)</td>
<td>(0.093)</td>
</tr>
<tr>
<td>Ln(pat stock/worker) at t-5</td>
<td>0.469***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.058)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln(pat stock/worker) at t-5*</td>
<td></td>
<td>1.546**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.757)</td>
<td></td>
</tr>
<tr>
<td>Chinese imports growth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IT intensity (t-5)</td>
<td></td>
<td>0.230***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.010)</td>
<td></td>
</tr>
<tr>
<td>(IT/N) (t-5)*Chinese Imp Growth</td>
<td></td>
<td>0.385**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.157)</td>
<td></td>
</tr>
<tr>
<td>Ln(TFP) at t-5</td>
<td></td>
<td></td>
<td>0.256***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.016)</td>
</tr>
<tr>
<td>Ln(TFP) at t-5*</td>
<td></td>
<td></td>
<td>0.956***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.424)</td>
</tr>
</tbody>
</table>

Clusters | 3,123 | 2,816 | 1,210
Observations | 581,474 | 37,500 | 292,167

SE clustered by country-industry, all standard additional controls included.
C) Survival Equation

If high TECH plants partially “protected” from effect of Chinese imports then $\gamma^s > 0$

$$SURVIVAL_{ijkt} = \gamma^s [TECH_{ijkt-5} \times IMP^C_H_{jkt} ] +$$

$$\alpha^s IMP^C_H_{jkt} + \delta^s TECH_{ijkt-5} + \beta^s \Delta x^s_{ijkt} + \nu^s_{ijkt}$$

expect $\alpha^s < 0$  expect $\delta^s > 0$
## Tab 3B: High tech firms more likely to survive Chinese imports

<table>
<thead>
<tr>
<th>TECH measure:</th>
<th>Survival patents</th>
<th>Survival patents</th>
<th>Survival IT</th>
<th>Survival TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Chinese Imports</td>
<td>-0.122**</td>
<td>-0.122**</td>
<td>-0.182**</td>
<td>-0.189***</td>
</tr>
<tr>
<td>(0.036)</td>
<td>(0.036)</td>
<td>(0.072)</td>
<td>(0.056)</td>
<td></td>
</tr>
<tr>
<td>Ln(patent stock/worker	extsubscript{t-5}) * Change in Chinese Imports</td>
<td>0.391***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(IT/N)	extsubscript{t-5} * Change in Chinese Imports</td>
<td></td>
<td>0.137</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.018)</td>
<td>(0.112)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln(TFP	extsubscript{t-5}) * Change in Chinese Imports</td>
<td></td>
<td></td>
<td>0.097</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.076)</td>
<td></td>
</tr>
<tr>
<td>IT Intensity (IT/N)	extsubscript{t-5}</td>
<td></td>
<td></td>
<td>-0.002</td>
<td></td>
</tr>
<tr>
<td>(0.006)</td>
<td></td>
<td></td>
<td>(0.006)</td>
<td></td>
</tr>
<tr>
<td>Ln(patent stock/worker	extsubscript{t-5})</td>
<td>0.052***</td>
<td>0.040**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.008)</td>
<td>(0.011)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln(TFP	extsubscript{t-5})</td>
<td></td>
<td></td>
<td>-0.003</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.004)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>490,095</td>
<td>490,095</td>
<td>28,624</td>
<td>268,335</td>
</tr>
</tbody>
</table>

SE clustered by up to 3.369 country-industry pairs, all standard additional controls included (and lagged Size)
So how big are these magnitudes?

Aggregate effect of trade on technology, 2000-2007, % of Technology Measure that Chinese trade ‘accounts for’

<table>
<thead>
<tr>
<th>Measure</th>
<th>Within (%)</th>
<th>Between (%)</th>
<th>Exit (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patents</td>
<td>5.8</td>
<td>6.3</td>
<td>2.5</td>
<td>14.7</td>
</tr>
</tbody>
</table>

Notes: calculated for the regression sample using OLS coefficients.
Summary

• Innovation a hot topic because of importance for growth
  – Effects on other firms (“spillovers”) therefore critical for welfare
• Tough measurement issues, but much progress in last 20 years
• Role of product market structure is important
  – Theoretically ambiguous
  – But increasing evidence for positive effects, at least over range, especially after trade shocks
Research Areas

• Role of entrants (entrepreneurs) vs. incumbents

• Combining reallocation perspective (getting to frontier) and innovation perspective (moving frontier)

• Directed technical change (e.g. green innovation)

• Structural approaches. Most empirical IO rather static

• Management Innovations
Back Up
Arrow Model

- Consider competitive industry (price = mc) and monopoly industry
- If competitive firm innovates then will set optimal price (i.e. the limit price). Gives some incentive to invest in R&D (if P=MC no incentive)
- Which has bigger incentive to invest in R&D – e.g. consider scientist selling to both industries: who would bid the most?
- Result: Competitive industry will do more R&D.
- Definitions
  - C = old costs; C’ = new costs; Pm=monopolists old prices; P’m= monopolists new prices; Qm= monopolists old profits; Q’m= monopolists new profits; c=competitive quantity (same pre and post because limit pricing)
Social Returns more than twice as big as private returns

<table>
<thead>
<tr>
<th>Group of firms</th>
<th>Closeness measure</th>
<th>Private returns</th>
<th>Social return</th>
<th>Wedge</th>
<th>Median workers</th>
<th>Ave. SIC</th>
<th>Ave. TECH</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Jaffe</td>
<td>20.7</td>
<td>55.0</td>
<td>34.3</td>
<td>3,000</td>
<td>0.015</td>
<td>0.038</td>
</tr>
</tbody>
</table>

**Size splits**

<table>
<thead>
<tr>
<th></th>
<th>Closeness measure</th>
<th>Private returns</th>
<th>Social return</th>
<th>Wedge</th>
<th>Median workers</th>
<th>Ave. SIC</th>
<th>Ave. TECH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Largest quartile</td>
<td>Jaffe</td>
<td>21.1</td>
<td>67.1</td>
<td>46.0</td>
<td>29,700</td>
<td>0.015</td>
<td>0.054</td>
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<tr>
<td>Second quartile</td>
<td>Jaffe</td>
<td>20.4</td>
<td>55.0</td>
<td>34.6</td>
<td>5,900</td>
<td>0.012</td>
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<tr>
<td>Third quartile</td>
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<td>20.7</td>
<td>50.8</td>
<td>30.1</td>
<td>1,680</td>
<td>0.016</td>
<td>0.033</td>
</tr>
<tr>
<td>Smallest quartile</td>
<td>Jaffe</td>
<td>20.6</td>
<td>47.3</td>
<td>26.7</td>
<td>370</td>
<td>0.018</td>
<td>0.029</td>
</tr>
</tbody>
</table>
‘Trapped-Factor’ Innovation after low wage country trade (Bloom, Romer, Terry & Van Reenen, 2012)

- **Idea**: Chinese imports replace domestic products and therefore reduces opportunity cost of innovating.
- Trapped factors (e.g. firm-specific skilled) can produce or innovate.
  - Innovating loses a period of production but then obtain firm-specific skills from learning by doing.
  - Innovation decision depends on opportunity costs.
- **Pre-China**: skilled earn higher wages producing the old good than innovating (high op. cost of “trapped factor”).
- **Post-China**: old lines unprofitable. Firm could close, but op. cost lower so resources redeployed on innovating.
- **Implications**: (i) low wage country imports (e.g. China) competition increases innovation more than high wage country, (ii) bigger effect when more “trapped factors”