Productivity, management & public policy III: Innovation Policy & taxation

John Van Reenen (LSE, Centre for Economic Performance & LEAP Visitor)

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Introduction

• TFP main factor in growth over time & technological innovation critical factor for TFP growth, especially frontier countries like US (cf. developing countries)

• Endogenous growth theory gives room for policy makers to act in a number of ways to affect innovation
  – Lack of econometric evidence on innovation policy despite importance (cf. theory; labor)

• Policies
  – R&D policies: Indirect (Tax system) vs. Direct (grants)
  – More general (IP system, skills supply, competition, etc.)

• Subsidize inputs (R&D) or outputs (prizes)?
Total R&D (GERD) to GDP ratio, 2010

Source: OECD (2013)
Business Conducted R&D (BERD) to GDP ratio, 1981-2001, selected countries

Source: OECD (2013)
Lecture 3: Overview

1. Why should we subsidize innovation?
2. Tax incentives for R&D
3. R&D spillovers
4. Other Innovation Policies
Why subsidize innovation?

• **Too little R&D.** Social under-provision?
  – **Knowledge externalities**
    • Innovation harder than diffusion
    • Patent system highly imperfect (over)

  – **Financial market failures**

• **Too much R&D?**
  – Business stealing effects in IO models
The problems with patents - "Bread Refreshing Method"

United States Patent [19]

Lenahan

[54] BREAD REFRESHING METHOD

[76] Inventor: Terrance F. Lenahan, 246 Unity Dr., Marietta, Ga. 30064-5446

[21] Appl. No.: 09/332,385

[22] Filed: Jun. 14, 1999

[51] Int. Cl. 7 ................................. A21D 6/00

[52] U.S. Cl. .................................. 426/242; 426/496; 99/451; 219/725

[58] Field of Search ............................. 426/241, 242, 426/496; 99/451; 219/725

[56] References Cited

U.S. PATENT DOCUMENTS


[45] Date of Patent: Jun. 27, 2000

5,382,441 1/1995 Lentz et al. ......................... 426/241

5,472,721 12/1995 Eisenberg et al. .................. 426/243

6,013,500 1/2000 Westerberg et al. .................. 219/405

Primary Examiner—Nina Bhat

Attorney, Agent, or Firm—Peter Vrahotos

[57] ABSTRACT

A method of refreshing a bread product by heating the bread product to a temperature between 2500°F and 4500°F. The bread products are maintained at this temperature range for a period of 3 to 90 seconds.

3 Claims, 5 Drawing Sheets
Why subsidize innovation?

• Social under-provision?

  – Financial market failures (Hall & Lerner, 2009, survey)
    • Arrow (1962) information asymmetry generally a problem for investment, but particularly so for R&D
      – E.g. financier takes idea
    • R&D risky & uncertain
    • No collateral

• Too much R&D?
  – Business stealing effect
Policies to incentivize innovation

- General policies – Anti-trust; Human capital, FDI
- IP system
- Research Joint Ventures (e.g. Japan-MITI; US Sematech)
- Subsidise basic science in universities, government labs
- Direct subsidies to firms (grants)
  - e.g. SBIR (Innovation Research program) studied by Wallsten (2000) & Lerner (1999)
- Procurement (e.g. defence)
- Deal with market failures in financial system (VC, Angel, gov pump-priming)
- Indirect subsidies like R&D tax credits
Policies towards diffusion

1. Adoption of specific technologies (e.g. Broadband)
2. Information provision (e.g. Small Business services)
3. Technology transfer (e.g. FDI support or export credits)
4. University-business linkages (TLOs, 1980 Bayh-Dole Act)
Evidence on R&D spillovers

• Big literature suggests positive spillovers

• Patent citations
  – Henderson, Jaffe, Trajtenberg (1993) focus on geography (agglomeration literature)
  – But many citations don’t indicate true knowledge transfer
  – Many knowledge transfers do not need a patent citation

• Does your neighbors’ R&D increase your productivity?
  – Griliches (1979, 1992) introduced general methods using firm productivity, value or patents as a function of industry, economy wide or others in technology class
  – E.g. of Bloom, Schankerman & Van Reenen (2013, BSVR later). Manski reflection problem
Lecture 3: Overview

1. Why should we subsidize innovation?

2. Tax incentives for R&D

3. R&D spillovers

4. Other Innovation Policies
R&D Tax credits

• A way of supporting R&D through the tax code

• Increasingly popular all over the world: a shift from direct support via industrial policies to indirect support via tax

• **Advantages** of fiscal incentives for R&D
  – Performed by private sector: probably more efficient than government labs
  – No need for government to explicitly *choose* projects so economizes on bureaucracy and information
  – Mitigates risk of political capture by single firm/industry
Disadvantages of fiscal incentives for R&D

- Very blunt tool: not well targeted at high externality ideas
  - “near market” doesn’t need incentivizing: basic R&D (e.g. universities) much more important
- Re-labelling Problem
  - Activities get re-classified to be qualified for tax break
- R&D is narrowly defined: many firms do spillover-generating innovation that will not be classified as R&D for tax purposes (e.g. service firms)
- Not good for new/small firms because may have no tax liabilities
- Costly – not targeting marginal investments
- Perverse incentives due to design features (usually designed to limit costs)
  - See below
Simplified tax-adjusted user cost of R&D capital

Discounted value of tax credits and depreciation allowances

\[ \rho_{it} = \left( \frac{1 - D_{it}}{1 - \tau_{it}} \right) \left( i_t + \delta - \frac{\Delta p_t}{p_{t-1}} \right) \]

- R&D is a form of intangible capital
- If R&D treated like other capital \( D = 0 \)
- If R&D just treated as an expense \( D = \tau \) & tax system neutral (so favoured relative to other forms of capital)
Simplified tax-adjusted user cost of R&D capital

\[
\rho_{it}^E = Tax\_Price = \left( \frac{1 - D_{it}}{1 - \tau_{it}} \right)
\]

- \(D = \tau^* (\text{NPV of allowance claims})^* (\%\text{deductables}) + \text{credit}\)
R&D Tax credits design issues

- Whole of tax system interacts
- “Qualified R&D” (scientific vs. marketing)
- Usually territorial – only if R&D performed in geographical area (e.g. within US)
- Sometimes restricted to certain classes of firms (e.g. SMEs, industries) or activities (labor, collaborative)
- Often capped at a maximum (e.g. France)
- Often targeted incremental R&D dollar
  - Seeks to reduce cost & give political cover
  - But creates many perverse incentives
What is the “base” of R&D Tax credits?

- **Volume** – simplest, but expensive for any given credit because of deadweight
- **Incremental** over a “base”
  - Previous year’s R&D spend (e.g. France)
  - “Rolling base” (US 1981, average of last 3 years R&D)
  - Builds in “ratchet”. Firms discouraged from increasing R&D this year as base will be higher next year
    - Reduces the headline generosity of the credit
    - Firms planning rapid growth deterred in order to take advantage of credit (Eisner et al, 1982, 1984)
What are the effects of R&D tax credits?

- Estimate the user cost over time and how it varies across firms (Eisner et al, 1982)
- Case studies and “industrial surveys” (e.g. Mansfield and Switzer, 1985. on Canada) An IQ test for firms?
- Estimate from R&D user cost without R&D tax credit data – variation from asset prices and depreciation (Bernstein and Nadiri, 1989)
  - Unclear where exogenous variation comes from to separate from general user cost of capital
  - And in absence of tax design unclear how to separate from time dummies
- Simple before/after DiD designs
  - Bailey & Lawrence (1992) cross industry analysis
- All these methods up to mid 1990s suggested little effect of R&D tax incentives
What are the effects of R&D tax credits?

• Federal tax credit generates substantial heterogeneity in firm level R&D user cost
• State-specific tax credits generate additional variation
• Cross country variation in R&D tax credits
  – Bloom, Griffith & Van Reenen (BGVR, 2002); OECD
• These “second wave” studies suggest much high tax-price elasticities (e.g. Hall & Van Reenen, 2000; OECD, 2012 surveys)
  – Long-run elasticity of greater than unity
  – Much smaller short-run elasticity (e.g. BGVR find 0.1 in short-run and 1 in long-run & suggest adjustment costs very important)
<table>
<thead>
<tr>
<th>Period</th>
<th>Credit Rate*</th>
<th>Corporate Tax Rate</th>
<th>Definition of Base</th>
<th>Qualified Research Expenditures</th>
<th>Sec. 174 deduction**</th>
<th>Foreign Allocation Rule</th>
<th>Carryback/Carryforward</th>
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<tbody>
<tr>
<td>July 1981 to Dec 1981</td>
<td>25%</td>
<td>40%</td>
<td>Maximum of previous 3 year average or 50% or current year</td>
<td>Excluded: research performed outside US; humanities and social sciences research; research funded by others</td>
<td>None</td>
<td>100% deduction against domestic income</td>
<td>3 years/15 years</td>
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<tr>
<td>Jan 1982 to Dec 1982</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Jan 1983 to Dec 1983</td>
<td>20%</td>
<td>Same</td>
<td>Same</td>
<td>Definition narrowed to technological research. Excluded sharing leasing</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td>Jan 1984 to Dec 1984</td>
<td>Same</td>
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<td>Jan 1985 to Dec 1985</td>
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<td>Jan 1986 to Dec 1986</td>
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<td>Jan 1987 to Dec 1987</td>
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<td>Jan 1989 to Dec 1989</td>
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<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>-50% credit</td>
<td>64% deduction against domestic income; 36% allocation</td>
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<td>Jan 1991 to Dec 1991</td>
<td>Same</td>
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<td>Same</td>
<td>Startup rules modified</td>
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<td>-100% credit</td>
<td>Same</td>
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<td>Jan 1992 to Dec 1992</td>
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<td>Same</td>
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<td>Jan 1993 to June 1993</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td>Jul 1993 to June 1993</td>
<td>0%</td>
<td>Same</td>
<td>None</td>
<td>-</td>
<td>-</td>
<td>Same</td>
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<tr>
<td>Jul 1994 to June 1994</td>
<td>0%</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>-50% credit</td>
<td>64% deduction against domestic income; 36% allocation</td>
<td>Same</td>
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<tr>
<td>Jul 1995 to June 1995</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>None</td>
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<tr>
<td>Jul 1996 to June 1999</td>
<td>20%</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Same as before lapse</td>
<td>-100% credit</td>
<td>Same</td>
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<tr>
<td>Jul 1999 to June 2000</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Also includes research undertaken in Puerto Rico and U.S. possessions.</td>
<td>Same</td>
<td>Same</td>
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<td>Jul 2000 to Dec 2000</td>
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<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
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<td>Jul 2001 to Dec 2001</td>
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<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td>Jul 2002 to Dec 2002</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
<td>Transition rules altered slightly and alternative credits modified as outlined on next sheet</td>
<td>Same</td>
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<tr>
<td>Jul 2003 to Dec 2003</td>
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<td>Same</td>
<td>Same</td>
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<td>Jul 2004 to Dec 2004</td>
<td>Same</td>
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<td>Same</td>
<td>Same</td>
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<td>Same</td>
<td>Same</td>
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</tbody>
</table>

* In all years the firm can apply the credit rate to 50% of current QREs if the base amount is less than 50% of current QREs.

** Section 174 of the IRC provides an immediate deduction for most research and experimentation expenditures. Taxpayers can also elect to amortize these expenditures over 60 months, but in practice most firms immediately expense R&D. However, the IRC does not define what qualifies as R&D expenditures. Treasury regulations have generally interpreted them to mean “R&D costs in the experimental or laboratory sense.”

Note: Based on Hall (2004), the Senate Committee’s 2006 Tax Expenditures composition and Thomas legislative summaries.
Cross firm Heterogeneity of the effective R&D tax credit rate

Effective R&D Credit Rate
U.S. Manufacturing Firms 1981-1991

Source: Hall (1993)
Empirical Models of R&D

First order conditions CES Production function $Y = F(L,K,G)$

$G = \text{R&D capital stock}$

$$\ln G = \sigma \ln \rho + \mu \ln Y$$

$$G_t = R_t + (1 - \delta)G_{t-1}$$

In steady state:

$$R = \delta G$$

$$\ln R = \ln G + \ln \delta$$

$$\ln R_{it} = \beta \ln \rho_{it} + \alpha' x_{it} + u_{it}$$
Empirical Models of R&D, R

Typical firm $i$-level empirical model

$$\ln R_{it} = \beta \ln \rho_{it} + \alpha' \ x_{it} + u_{it}$$

- Add fixed effects and time dummies
- $x$ should control for demand, but sales endogenous (use $\ln(R&D/sales)$ as dependent variable
- Static: adjustment costs mean that investment model is more complex. Path of R depends on expectations of fundamentals & shocks.
- Dynamics of adjustment: add lagged dependent variable & distributed lag of R&D user cost
  - Standard issues of dynamic panel data models
Some issues with simple empirical model

\[ \ln R_{it} = \alpha \ln R_{it-1} + \beta_1 \ln \rho_{it} + \gamma' x_{it} + \eta_i + \tau_t + e_{it} \]

- User cost will in general be correlated with error term.
  - E.g. a positive shock raising incentive to R&D will affect the base, incremental credit & incentives
  - Many elements that are plausibly exogenous (like interest rates, tax rate) do not usually vary across firms and so are collinear with time dummies

- **Solutions?**
  - Exploit just cross country or cross state variation
  - Synthetic instruments
  - Exploit lag structure
  - More “structural models”
Further issues

• General equilibrium effects. If demand curve inelastic then price effects rather than quantity effects
  – But “full crowd out” hard to identify (Goolsbee just in aggregate time series)
  – In long-run more people switch into R&D; international mobility of R&D workers in short-run

• International issues
  – Free ride off R&D of other countries
    • Counter: “2 faces of R&D?” (Griffith et al, 2004)
  – International tax competition (e.g. patent box)

• Policy uncertainty: e.g. US credit always “temporary”
International variation (BGVR)

• Many different R&D tax regimes generates much variation in use cost over countries & over time
• UK introduces tax credit in 2001, Australia 1985 150% super deduction, France changes every year
• BGVR look at 9 OECD countries 1979-1997 & use tax rules in all nations to construct user cost (See over)
• Focus on tax price & use this to IV total R&D user cost
• Find long-run elasticity of ~1 & short-run ~0.15. Interpret this as indicating substantial adjustment costs for R&D
<table>
<thead>
<tr>
<th>Design of the R&amp;D tax incentive scheme</th>
<th>Australia, Canada, France, Norway, Brazil, China, India</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volume base R&amp;D tax credit</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Incremental R&amp;D tax credit</strong></td>
<td>United States</td>
</tr>
<tr>
<td><strong>Hybrid system of a volume and an incremental credit</strong></td>
<td>Japan, Korea, Portugal, Spain</td>
</tr>
<tr>
<td><strong>R&amp;D tax allowance</strong></td>
<td>Denmark, Czech Republic, Austria, Hungary, UK</td>
</tr>
</tbody>
</table>

| Payroll withholding tax credit for R&D wages | Belgium, Hungary, Netherlands, Spain |

| More generous R&D tax incentives for SMEs | Canada, Australia, Japan, United Kingdom, Hungary, Korea, Norway |

<table>
<thead>
<tr>
<th>Targeting</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Special for energy</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Special for collaboration</strong></td>
<td>Italy, Hungary, Japan, Norway</td>
</tr>
<tr>
<td><strong>Special for new claimants</strong></td>
<td>France</td>
</tr>
<tr>
<td><strong>Special for young firms and start-ups</strong></td>
<td>France, Netherlands, Korea</td>
</tr>
</tbody>
</table>

| Ceilings on amounts that can be claimed | Italy, Japan, United States, Austria, Netherlands |

| Income based R&D tax incentives | Belgium, Netherlands, Spain |

| No R&D tax incentives | Estonia, Finland, Germany, Luxembourg, Mexico, New Zealand, Sweden, Switzerland |

Note: R&D tax allowances are tax concessions up to a certain percentage of the R&D expenditure and can be used to offset taxable income; R&D tax credits reduce the actual amount of tax that must be paid.

Source: OECD (2010a).
Figure 2. Tax treatment of R&D: Tax subsidy rate for USD 1 of R&D, large firms and SMEs, 2008

Note: The tax subsidy rate is calculated as 1 minus the B-index. The B-index measures the before-tax income needed to break even on one dollar of R&D outlays and is calculated for representative small and large corporations in a country. The tax subsidy rate is reported for a profitable firm able to claim tax credits/allowances. The subsidy rate calculations only include expenditure-based tax incentives and does not account for income-based tax incentives.


Source: OECD (2011)
Cross country Heterogeneity of the effective R&D tax credit rate

Source: Bloom, Griffith & Van Reenen, 2002
Main BGVR Specification

\[
\ln R_{it} = \alpha \ln R_{it-1} + \beta_1 \ln \rho_{it} + \gamma \ln GDP_{it} + \eta_i + \tau_t + e_{it}
\]

\[
\rho_{it} = \left(\frac{1 - D_{it}}{1 - \tau_{it}}\right) \left( i_{it} + \delta - \frac{\Delta p_{it}}{p_{it-1}} \right)
\]

\[i = \text{country, } t= \text{year}\]
## Effects of tax price on R&D: cross country panel

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>(1) $r_t$ OLS</th>
<th>(2) $r_t$ IV</th>
<th>(3) $r_t$ IV</th>
<th>(4) $r_t - y_t$ IV</th>
<th>(5) $r_t - y_t$ IV</th>
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<td>Lagged ln (R&amp;D)</td>
<td>$r_{t-1}$</td>
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<td>0.868</td>
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<td>–</td>
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<td>0.043</td>
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<tr>
<td>Lagged ln (R&amp;D/Y_t)</td>
<td>$r_{t-1} - y_{t-1}$</td>
<td>–</td>
<td>–</td>
<td>0.859</td>
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<td>0.047</td>
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<td>ln (user cost)</td>
<td>$\rho_t$</td>
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<tr>
<td>ln (output)</td>
<td>$y_t$</td>
<td>1.184</td>
<td>1.364</td>
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<td>0.224</td>
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<td>Long run elasticity — user cost</td>
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<td>(P-value)</td>
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<td>Durbin–Watson statistic</td>
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<td>Year dums</td>
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<td>155</td>
<td>164</td>
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</table>

Source: Bloom, Griffith & Van Reenen (2002)
Problems with Cross country approach

- Many other factors varying in a year that are country-specific and could be correlated with use cost
  - Many states have a more generous R&D tax credit that Federal government (like Minimum Wage)
  - Use this to construct state-specific user cost and estimate using a state-level panel
Cross State Heterogeneity of the R&D tax credit

Source: Chang, 2013
Wilson (2009) findings

- Wilson finds similar long-run elasticity to BGVR
  - Argues that this is mainly due to cross-state competition, i.e. aggregate US R&D stays the same, but “tax competition” effects the location of activity
  - Important policy implications (e.g. EU)
  - Uses geographical proximity to say who the competitors are. But may not be appropriate (e.g. California vs. Massachusetts rather than California vs. Nevada)
Problem of R&D policy endogeneity

- All papers using policy experiments face issue that policy introduction may be in response to shocks affecting R&D
- Similar issue to assessing impact of fiscal policy as stimulus programmes are introduced when government expects a downturn (Romer & Romer; Barro, Ramey, etc.)
- Little work on this
  - BGVR/BSVR: tax credits can’t be Granger predicted by shocks
  - Chang (2013) uses “exogenous” element of state tax credit caused by Federal changes to R&D code.
    - E.g. 1989 change to fixed base was followed (with lag) by other states & this was heterogeneous across states
    - Finds larger effects of R&D tax credits because states cut in “bad times”
Endogeneity of firms R&D user cost

• In panel, lagged values of dependent or independent variable may be “weakly exogenous”, i.e. do not immediately respond to shocks
  – Hence can be used to construct instruments

• Synthetic instruments idea (e.g. Gruber & Saez, 2002)
  – Use changes of tax rules interacted with lagged values
    • Elasticity between -1 and -2
Panel Data & GMM estimators

• Arellano & Bond (1992) use Anderson-Hsiao (1982) moments to construct optimal GMM estimators
  – Problem of weak instruments as $x(t-2)$ usually only weakly correlated with $\Delta x(t)$.

• Blundell & Bond (1998) use additional Arellano & Bover moments (1995). $\Delta x(t-1)$ as IV for $x(t)$. Stronger conditions (stationarity is sufficient) than A-B, but typically large increases in precision
  – Hall (1993), Bond, Harhoff & Van Reenen (2005) apply these to R&D and investment models.
More Structural models of R&D?

• If R&D is an investment, then standard approaches can all be applied

• Bond & Van Reenen (2007) have survey of structural approaches to investment. Easy to apply to multiple investment goods (e.g. R&D and fixed capital)
  – But none have performed well empirically. The simpler “reduced form” models described above much better fit in data

• Some approaches (analytical solutions)
  – Q-Theory (Hall et al, 1999)
  – Euler Equations (Bond & Meghir, 1994)
  – Abel & Blanchard (1986)

• More recently, numerical simulation approaches have become more popular (e.g. Bloom, 2009)
Summary on R&D tax credits

• Extensively studied investment subsidy
• Variety of methods & identification strategies suggest that:
  – R&D does respond to changes in its user costs so policy can be effective
  – Short-run effects much smaller than long-run effects
• More needed to be done to bring into standard models
  – Using as a potential IV for R&D to look at classic questions like effect on output, complementarity/substitutability with other inputs, SBTC, etc.
Lecture 3: Overview

1. Why should we subsidize innovation?

2. Tax incentives for R&D

3. R&D spillovers

4. Other Innovation Policies
Application to an R&D model: BSVR

- Bloom, Schankerman & Van Reenen (BSVR, 2013, Econometrica)

- Focus on R&D spillovers. Firm’s neighbors R&D matters for its performance as well as its own. Two types:
  - Knowledge spillover (Growth literature)
  - Product market rivalry (IO literature)

- Methodology for identifying the distinct effects by using two “distance metrics”
  - In technology space for knowledge spillovers (Jaffe, 1986) using patent classes
  - In product market space using SIC-4 codes (firms operate in multiple industries)
    - Examples: plasma vs. LED TV screens; IBM & Motorola

- Needs IVs for R&D spillovers: use R&D tax credits
Combine Compustat and NBER Patents Data

Combine:

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

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

• NBER patent data with US patents and citations from 1978

Final sample of 795 firms 1980-2001
Measuring Technology Spillovers

- Define **technology closeness** by uncentred 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 1968–1999.
  - $TECH_{i,j} = (T_i' T_j')/[(T_i' T_i')^{1/2}(T_j' T_j')^{1/2}]$; ranges between 0 and 1 for any firm pair $i$ and $j$.

- Define **Technology spillover** pool as TECH weighted R&D:
  - $SPILLTECH_{it} = \sum_{j, j \neq i} TECH_{i,j} G_{jt}$ where $G_{jt}$ is the R&D stock of firm $j$ at time $t$. 

Product Market Spillovers

• 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 $k$ ($k = 1, \ldots, 623$)
  – $SIC_{i,j} = (S_i S'_j)/[(S_i S'_i)^{1/2}(S_j S'_j)^{1/2}]$

• Product market “spillover” pool defined as SIC weighted R&D:
  – $SPILLSIC_{it} = \sum_{j,j\neq i} SIC_{i,j} G_{jt}$ where $G_{jt}$ is the R&D stock of firm $j$ at time $t$
Figure 1: Correlation between Technology and Product Market closeness

correlation 0.46
Table 3: Tobin’s Q

<table>
<thead>
<tr>
<th>Dependent variable: Ln (V/A)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All SPILLTEC Only</td>
<td>Only SPILLSIC only</td>
<td></td>
</tr>
<tr>
<td>Ln(SOILTEC_{t-1}) knowledge</td>
<td>0.381** (0.113)</td>
<td>0.305** (0.109)</td>
<td></td>
</tr>
<tr>
<td>Ln(SOILSIC_{t-1}) Business stealing</td>
<td>-0.083** (0.032)</td>
<td></td>
<td>-0.050 (0.031)</td>
</tr>
</tbody>
</table>

## 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>$\partial V_0 / \partial r_\tau$</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>$\partial k_0 / \partial r_\tau$</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>$\partial y_0 / \partial r_\tau$</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>$\partial r_0 / \partial r_\tau$</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>
Results using R&D tax credits as an instrument

- Wilson (2009) provides data on state level R&D tax credits
- Interact this with firms location of R&D by states to get a firm-level R&D tax credit rate, and use this as the instrument

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tobin’s Q</td>
<td>1.079***</td>
<td>0.407***</td>
<td>0.206**</td>
<td>0.138</td>
</tr>
<tr>
<td></td>
<td>(0.192)</td>
<td>(0.059)</td>
<td>(0.081)</td>
<td>(0.122)</td>
</tr>
<tr>
<td>Ln(SPILLTECH) _t-1</td>
<td>0.235*</td>
<td>0.037</td>
<td>0.030</td>
<td>-0.022</td>
</tr>
<tr>
<td></td>
<td>(0.109)</td>
<td>(0.028)</td>
<td>(0.054)</td>
<td>(0.071)</td>
</tr>
<tr>
<td>Patents</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TFP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Marginal Private Return \[= \frac{Y}{G}(\phi + \lambda)\]
\[= 20.1\%\]

Marginal Social Return \[= \frac{Y}{G}(\phi + \sigma)\]
\[= 38.7\%\]

\(\frac{Y}{G}\) = ratio output to R&D stock
\(\phi\) = prod. function coefficient of own R&D stock
\(\sigma\) = prod. function coefficient of SPILLTECH
\(\lambda\) = market value coefficient of SPILLSIC (divided by 2)

Note that MPR can be either smaller or larger than MSR.
Conclusions from BSVR (2013)

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

• Technology effects dominate, so “too little” R&D overall

• Using both technology and product market closeness measures AND multiple outcome indicators, plus R&D tax credit IV, can help to identify these different effects
Lecture 3: Overview

1. Why should we subsidize innovation?
2. Tax incentives for R&D
3. R&D spillovers

4. Other Innovation Policies
Direct R&D subsidies

- Grant giving agencies (like NSF, NIH, etc.)
  - Target high spillover activities
  - Can be a positive signal & crowds in private R&D
  - But equally could “crowd out” private R&D

- Many papers regressing R&D (or other outcomes) on receipt of subsidies
  - Mixed results (surveys by David et al, 2000; Bronzini & Iachini, 2013). Of ~30 studies half find no effect in 1/2
  - Problem is that if gov “pick winners” there is upwards bias but if they “reward losers” then downward bias (cf. industrial policy in general)

- Some mild evidence of a positive effect of subsidies, especially for small firms (financial constraints? Less able to game?)
Direct R&D subsidies – more causal evidence

- Regression discontinuity designs. Get application data and consider the score of application as the running variable
- Bronzini & Iachini (2013) Northern Italian R&D subsidies
  - Sharp RD design: 1246 applicants
  - No overall effect, but positive & significant for small firms
- Jacob & Lefgren (2011) NIH Grants
  - No effect on future academic publications
- General issue with RD
  - Those who just lost out may have been able to obtain funds from other sources. A “local non-effect”
Empirical Evidence on other policies

- Finance (Gompers & Lerner on VC)
- IP – huge literature
- Competition (Aghion et al, 2005)
- Universities (Jaffe, 1989)
- Joint Ventures (Branstetter; )
Conclusions on economics

• Important issue in economics is how nations grow. Modern growth theory suggests innovation at the heart of this & there are multiple market failures

• But what policies could generate more R&D?

• Incentives through tax system
  – Multiple problems as we have discussed (perverse incentives)
  – But be aware of sins of omission as well as commission
  – Evidence suggests R&D does respond & elastic in long-run. Need to balance this against benefits

• Much less empirical work on other R&D/innovation policies
  – Need more R&D on R&D policy!
The Commissioner of Patents and Trademarks

Has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.

Therefore, this 5,860,492

United States Patent

Grants to the person(s) having title to this patent the right to exclude others from making, using, offering for sale, or selling the invention throughout the United States of America or importing the invention into the United States of America for the term set forth below, subject to the payment of maintenance fees as provided by law.

If this application was filed prior to June 8, 1995, the term of this patent is the longer of seventeen years from the date of grant of this patent or twenty years from the earliest effective U.S. filing date of the application, subject to any statutory extension.

If this application was filed on or after June 8, 1995, the term of this patent is twenty years from the U.S. filing date, subject to any statutory extension. If the application contains a specific reference to an earlier filed application or applications under 35 U.S.C. 120, 121 or 365(c), the term of the patent is twenty years from the date on which the earliest application was filed, subject to any statutory extension.

Acting Commissioner of Patents and Trademarks

Margarita V. Nunez

Acting
Figure 1. Direct government funding of business R&D (BERD) and tax incentives for R&D, 2009
As a percentage of GDP

Source: OECD (2012)
### Papers on R&D Incentives Published in the Last Decade (1)

<table>
<thead>
<tr>
<th>Articles</th>
<th>Country</th>
<th>Outcome variable</th>
<th>Methodology</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wallsten (2000)</td>
<td>United States</td>
<td>Employment, investment</td>
<td>Instrumental variables</td>
<td>No effect</td>
</tr>
<tr>
<td>Busom (2000)</td>
<td>Spain</td>
<td>Employment, investment</td>
<td>Structural model</td>
<td>Positive effect</td>
</tr>
<tr>
<td>Lach (2002)</td>
<td>Israel</td>
<td>Investment</td>
<td>Diff-in-diff with controls</td>
<td>No effect</td>
</tr>
<tr>
<td>Hujer and Radic (2005)</td>
<td>Germany</td>
<td>Innovation activity</td>
<td>Matching</td>
<td>No effect</td>
</tr>
<tr>
<td>Gonzalez et al. (2005)</td>
<td>Spain</td>
<td>Investment</td>
<td>Instrumental variables</td>
<td>Positive effect</td>
</tr>
<tr>
<td>Gorg and Strobl (2007)</td>
<td>Ireland</td>
<td>Investment</td>
<td>Matching</td>
<td>Positive effect for smaller grants only</td>
</tr>
<tr>
<td>Merito et al. (2007)</td>
<td>Italy</td>
<td>Employment, sales, productivity</td>
<td>Matching</td>
<td>No effect</td>
</tr>
<tr>
<td>Takalo et al. (2013)</td>
<td>Finland</td>
<td>Welfare</td>
<td>Structural model</td>
<td>Positive effect</td>
</tr>
</tbody>
</table>

(1) The table reports the reviewed studies that examined the effect of firms' subsidies for R&D; those evaluating the impact of tax incentives are not included.
**Examples: Computer and chip makers**

<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><strong>IBM</strong></td>
<td>SIC TECH</td>
<td>0.32</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td><strong>IBM</strong></td>
<td></td>
<td>0.64</td>
<td>0.47</td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td><strong>Apple</strong></td>
<td>SIC TECH</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td><strong>Motorola</strong></td>
<td>SIC TECH</td>
<td>0.35</td>
<td>0.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intel</strong></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)
Empirical Models of R&D

Alternative in differences ("accelerator" model of investment)

\[ \Delta \ln G = \sigma \Delta \ln \rho + \mu \Delta \ln Y \]

\[ \Delta \ln G_t \approx \frac{G_t - G_{t-1}}{G_{t-1}} = \frac{R_t - \delta G_{t-1}}{G_{t-1}} = \frac{R_t}{G_{t-1}} - \delta \]

\[ \frac{R_t}{G_{t-1}} = \delta + \sigma \Delta \ln \rho + \mu \Delta \ln Y \]

Source: Hall, 1993
Figure 3. Tax treatment of R&D: Change in the tax subsidy rate for USD 1 of R&D between 1999 and 2008

Large firms and SMEs

Source: OECD (2011)
Table 4. Direct versus indirect financing of business R&D in select OECD countries

(millions of 1995 PPP dollars)

<table>
<thead>
<tr>
<th>Country</th>
<th>Cost to government of tax credits</th>
<th>Direct government funding of business R&amp;D</th>
<th>Industry R&amp;D expenditures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia (1997)</td>
<td>138</td>
<td>84</td>
<td>3 233</td>
</tr>
<tr>
<td>Canada (1995)</td>
<td>685</td>
<td>441</td>
<td>5 143</td>
</tr>
<tr>
<td>France (1997)</td>
<td>376</td>
<td>1 778</td>
<td>14 159</td>
</tr>
<tr>
<td>Japan (1997)</td>
<td>202</td>
<td>828</td>
<td>65 173</td>
</tr>
<tr>
<td>Netherlands (1997)</td>
<td>207</td>
<td>210</td>
<td>3 269</td>
</tr>
<tr>
<td>United States (1999)</td>
<td>2 393</td>
<td>23 595</td>
<td>152 617</td>
</tr>
</tbody>
</table>


Percentage of BERD financed by government, 2000 or latest year

Notes: B-Index = before-tax income needed to break even on one dollar of R&D outlay; BERD = business expenditures on research and development; DPI = business value-added. Source: OECD.
Alternative Spillover Measures

• Mahalanobis – using co-location among patent classes to characterize distance between classes and use it in measuring distance between firms. Jaffe measure treats all classes as orthogonal to each other.

• Economic Geography – does physical closeness of R&D labs matter for either type of spillovers

• Thompson and Fox-Kean: uses our baseline measure applied to more detailed disaggregation of patents

• Plus range of other variations using different closeness metrics (e.g. Ellison-Glaser) and datasets (e.g. Amadeus)
### Table 4: Patent Model

<table>
<thead>
<tr>
<th>Dependent var: Patent Count</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial conditions, static</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ln(SPILLTECH)(_{t-1})</strong></td>
<td>0.468***</td>
<td>0.417***</td>
</tr>
<tr>
<td><em>knowledge</em></td>
<td>(0.080)</td>
<td>(0.056)</td>
</tr>
<tr>
<td><strong>Ln(SPILLSIC)(_{t-1})</strong></td>
<td>0.056</td>
<td>0.043</td>
</tr>
<tr>
<td><em>Business stealing</em></td>
<td>(0.037)</td>
<td>(0.026)</td>
</tr>
<tr>
<td><strong>Ln(R&amp;D Stock)(_{t-1})</strong></td>
<td>0.222***</td>
<td>0.104***</td>
</tr>
<tr>
<td></td>
<td>(0.053)</td>
<td>(0.039)</td>
</tr>
<tr>
<td><strong>Ln(Patents)(_{t-1})</strong></td>
<td></td>
<td>0.420***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.020)</td>
</tr>
</tbody>
</table>

Note: Time dummies and 4 digit industry dummies included. Estimation period is 1985-1998. Negative binomial model; Obs=9,023. Standard errors clustered by firm.
Table 5: Total Factor Productivity Equation

<table>
<thead>
<tr>
<th>Dep Var: Ln(Sales)</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fixed effects</td>
<td>Fixed effects</td>
</tr>
<tr>
<td><strong>Ln(SPILLTECH)_t-1</strong></td>
<td>0.191*** (0.046)</td>
<td>0.186*** (0.045)</td>
</tr>
<tr>
<td>knowledge</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ln(SPILLSIC)_t-1</strong></td>
<td>-0.005 (0.011)</td>
<td></td>
</tr>
<tr>
<td>Business stealing</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ln(Capital)_t-1</strong></td>
<td>0.154*** (0.012)</td>
<td>0.153*** (0.012)</td>
</tr>
<tr>
<td><strong>Ln(Labour)_t-1</strong></td>
<td>0.636*** (0.015)</td>
<td>0.636*** (0.015)</td>
</tr>
<tr>
<td><strong>Ln(R&amp;D Stock)_t-1</strong></td>
<td>0.043*** (0.007)</td>
<td>0.042*** (0.007)</td>
</tr>
</tbody>
</table>

Note: Includes controls for industry sales, time dummies and industry deflators included. Estimation period is 1981-2001; Obs=9,935. Newey-West first order serial correlation and heteroskedasticity robust SEs.
Simulation of model to quantify returns to R&D

• Calculate long-run response of productivity to an exogenous increase in R&D – e.g. from a tax credit

• Private returns to R&D include own productivity impact plus the business stealing effects

• Social returns include own productivity impact plus technology spillover effects

• Complex because of depends on firm-level distribution of R&D and linkages in TECH and SIC space
Table 6: R&D Equations

<table>
<thead>
<tr>
<th>Dep Var: ln(R&amp;D)</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fixed Effects, static</td>
<td>Fixed Effects, Dynamic</td>
</tr>
<tr>
<td>ln(SPILLTECH)_{t-1}</td>
<td>0.100</td>
<td>-0.049</td>
</tr>
<tr>
<td></td>
<td>(0.076)</td>
<td>(0.042)</td>
</tr>
<tr>
<td>ln(SPILLSIC)_{t-1}</td>
<td>0.083**</td>
<td>0.034*</td>
</tr>
<tr>
<td></td>
<td>(0.034)</td>
<td>(0.019)</td>
</tr>
</tbody>
</table>