Measuring the Returns to R&D

Bronwyn H. Hall
University of Maastricht and UC Berkeley
The problem

- Estimating the returns to R&D (and other intangible investments)
  - Intrinsically of interest
  - May help to choose among R&D strategies
  - Needed for “contributions to growth” analysis based on new systems of national accounts that incorporate intangibles

- Existing methods try to deal with several challenges:
  - Lack of secondary markets for R&D output
  - Smoothness of R&D over time
  - Importance of depreciation measure for estimated net returns
Some illustrative examples

- Internet
  - packet-switching technology funded by the U.S. Department of Defense.
  - protocols of the worldwide web conceptualized and developed by researchers on the payroll at CERN
- Technology underlying biotechnology
  - developed jointly by researchers at the UC San Francisco and Stanford University
  - based on earlier double helix work at Cambridge
- Bell Labs – transistor, radio astronomy

*How do we measure the returns to these R&D efforts?*
Presentation outline

- Basic measurement framework
- Estimating private returns
  - Production functions
  - Market value equations
- Overview of spillover channels
- Estimating social returns
  - Production functions
  - Summary of some results
Starting point for analysis

- Premise: R&D is a kind of investment
- **Definition of returns:** If we spend one $, euro, or krone on R&D today, how much will we receive from increased sales, GDP, etc in the future?
  - Should we compute this by looking backwards at past expenditure or by looking forward to future output?
- As they say in the financial prospectuses: *Past performance is no guarantee of future results*
- In the case of R&D, the uncertainty of returns is magnified
Approaches used

- **Backward looking:** production function of R&D stock
  - Essentially assumes a stationary world
  - Can be used at any level of aggregation
  - Suitable for social as well as private returns

- **Forward looking:** market valuation of R&D-doing firms
  - Assumes market efficiency
  - Can be highly volatile
  - Requires a market that prices firm assets (including R&D)
Measurement Methodologies

- Case study – e.g., the development of the laser
- Trace technology flows from one industry to another using purchased inputs or patent data
- Trace research flows to industry using scientific or patent citations
- Willingness to pay in downstream industry as a measure of benefits received
- Relate productivity growth to R&D at various levels of aggregation
- Attempt to determine the price (valuation) of R&D output
Hall, Mairesse, Mohnen (2009)

- Also available as
  - NBER Working Paper No. w15622 (December 2009)
- Surveys econometric results obtained using production and cost functions on firms, industries, and countries
  - Includes spillover evidence
  - Covers a number of developed economies, mostly US, Canada, and European
Some measurement issues

- Long and variable lags, especially for publicly-funded R&D
- Double counting of R&D inputs (excess return?)
- Rate of return depends crucially on rate of depreciation (obsolescence) of the technology
- How to account for quality change in outputs and inputs?
  - Affects the allocation of returns between producing and using sector
Depreciation of R&D

- Assumption: R&D creates a stock of knowledge ($K$)
- What is its depreciation?
  - At the firm level, the rate at which returns to $K$ decline
  - The result of Schumpeterian competition – endogenous to the behavior of competitors
  - Sometimes called private obsolescence
- Do we need to estimate it?
  - Yes, to estimate net rate of return
  - Yes, to construct knowledge stock
Hall (2005) reference


- Assumes R&D capital receives a normal rate of return (plus a risk premium)
- backs out depreciation from both production function and market value estimates
  - MV approach – qualitative similar results
  - Prod fcn approach – depreciation near zero, but badly identified (with an attempt to correct for double counting of R&D inputs)
Productivity framework

- Cobb–Douglas production (first order log approximation to prod function)
- Line of business, firm, industry, or country level
  - At higher levels of aggregation, includes some spillovers
- Variety of estimating equations:
  - Conventional production function
  - Partial productivity
  - R&D intensity formulation
  - Semi–reduced form (add variable factor demand equations)
Productivity framework (cont.)

\[ Y = AL^\alpha C^\beta K^\gamma e^u \]

where \( L = \) labor
\( C = \) capital
\( K = \) research or knowledge capital
\( u = \) random shock
Productivity framework (cont.)

Take logarithms and model the intercept with year and firm (or industry) effects:

\[ y_{it} = \eta_i + \lambda_t + \alpha l_{it} + \beta c_{it} + \gamma k_{it} + u_{it} \]

\[ i = 1, \ldots, N \quad t = 1, \ldots, T \]

*Simultaneity:* shock \( u \) may possibly be correlated with the current (and future) input levels.

*Correlated firm effects:* \( \eta \) may also be correlated with the input levels.
R&D input measurement

- **Deflation**
  - No good measure of “real” costs of R&D
  - With time dummies, little bias from $R$ deflation
- **Stock computation** ($\delta$ assumed = 15%)
  \[
  K_t = (1 - \delta_K)K_{t-1} + R_t
  \]
  \[
  \Rightarrow K_t \cong \frac{R_t}{\delta_K + g_R}
  \]
- **Externalities**
  - How to measure the external knowledge that is useful to a particular firm or industry?
  - Does leaving this out lead to bias in own R&D coefficient?
Output deflation

Productivity growth regressions at the firm level:

\[
\Delta y_{it} = \Delta \lambda_t + \alpha \Delta l_{it} + \beta \Delta c_{it} + \gamma \Delta k_{it} + \Delta u_{it}
\]

\[
\Delta s_{it} = \Delta y_{it} + \Delta p_{it} = \Delta \lambda_t + \alpha \Delta l_{it} + \beta \Delta c_{it} + \gamma \Delta k_{it} + \Delta u_{it}
\]

where \( s \) is revenue and \( y \) is deflated output

If (2) is estimated instead of (1), we obtain an estimate of

\[\gamma_s = \gamma_y + \gamma_p\]

The revenue productivity of R&D is the sum of

- true productivity
- the effect R&D has on the prices at which goods are sold due to
  - quality improvements (decreases)
  - product differentiation (increases)
Interpretation

- Revenue productivity is a determinant of private returns
- True productivity (more constant quality output for a given set of inputs) is closer to social returns
- The difference represents
  - **Negative** – pecuniary externalities
  - **Positive** – output “stealing” or market power increases due to R&D
Illustration

- Some U.S. deflators at the industry level are hedonic, notably those for the computer industry and now the communications equipment industry (see next slide)
- Deflate firm sales by 2-digit deflators instead of one overall deflator
- Result: true productivity is substantially higher than revenue productivity, because of hedonic price declines in these R&D-intensive industries.
Hedonic Price Deflator for Computers

Shipments Deflators for U.S. Manufacturing
NBER Bartlesman-Gray Productivity Database

Index number vs. Year

- Computers & electronics
- Other manufacturing
Estimated R&D Elasticity – U.S. Manufacturing Firms

<table>
<thead>
<tr>
<th>Period</th>
<th>Dep. Var = Log Sales</th>
<th>Dep. Var = Log Sales, 2-digit deflators</th>
<th>Difference (&quot;price effect&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974-1980</td>
<td>-.003 (.025)</td>
<td>.102 (.035)</td>
<td>0.099</td>
</tr>
<tr>
<td>1983-1989</td>
<td>.035 (.030)</td>
<td>.131 (.049)</td>
<td>0.096</td>
</tr>
<tr>
<td>1992-1998</td>
<td>.118 (.031)</td>
<td>.283 (.041)</td>
<td>0.165</td>
</tr>
</tbody>
</table>

Method of estimation is GMM-system with lag 3 and 4 instruments. Sample sizes for the three subperiods are 7156, 6507, and 6457.
**Private firm level returns to R&D**

<table>
<thead>
<tr>
<th>Authors</th>
<th>Country</th>
<th>Years</th>
<th>Rate of return to R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cuneo-Mairesse (1984)</td>
<td>France</td>
<td>1974-79</td>
<td>~90% *</td>
</tr>
<tr>
<td>Mairesse-Cuneo (1985)</td>
<td>France</td>
<td>1974-79</td>
<td>~128% **</td>
</tr>
<tr>
<td>Griliches (1986)</td>
<td>US</td>
<td>1967, 72, 77</td>
<td>51% to 76% *</td>
</tr>
<tr>
<td>Hall (1993)</td>
<td>US</td>
<td>1964-90</td>
<td>18% to 43% *</td>
</tr>
<tr>
<td>Hall-Mairesse (1995)</td>
<td>France</td>
<td>1980-87</td>
<td>78% *</td>
</tr>
<tr>
<td>Mairesse-Hall (1994)</td>
<td>France</td>
<td>1981-89</td>
<td>75% *, **</td>
</tr>
<tr>
<td>Harhoff (1998)</td>
<td>Germany</td>
<td>1979-89</td>
<td>71% *</td>
</tr>
<tr>
<td>Medda-Piga-Siegel (2003)</td>
<td>Italy</td>
<td>1992-95</td>
<td>29%, 36%</td>
</tr>
<tr>
<td>Bond-Harhoff-van Reenen (2005)</td>
<td>Germany</td>
<td>1988-96</td>
<td>19%</td>
</tr>
<tr>
<td></td>
<td>UK</td>
<td>1988-96</td>
<td>38%</td>
</tr>
<tr>
<td>Mairesse-Mohnen-Kremp (2005)</td>
<td>France</td>
<td>2000</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>France</td>
<td>2000</td>
<td>27%</td>
</tr>
<tr>
<td>Griffith-Harrison-van Reenen (2006)</td>
<td>UK</td>
<td>1990-2000</td>
<td>14% *</td>
</tr>
<tr>
<td>Rogers (2009)</td>
<td>UK</td>
<td>1989-2000</td>
<td>40% to 58% (mfg)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>53% to 108% (non-mfg)**</td>
</tr>
<tr>
<td>Hall-Foray-Mairesse (2009)</td>
<td>US</td>
<td>2004-06</td>
<td>23% *</td>
</tr>
<tr>
<td>Ortega-Argilés et al. (2009)</td>
<td>EU</td>
<td>2000-05</td>
<td>35%</td>
</tr>
</tbody>
</table>

* computed from the elasticities using means or medians of the R&D and output variables

** estimates using capital and labor corrected for double counting.

Unless otherwise noted, estimates use uncorrected data.
Market value model

- Assumes market efficiency
- Two versions
  - Theoretical – value function from firm’s dynamic program as a function of state variables (capital, R&D, etc.)
  - Hedonic – value of a set of goods that have a lower-dimensional vector of characteristics – yields a measure of current shadow value of the assets (not stable over time)
Hedonic regression for market value

\[ V_{it}(A_{it}, K_{it}) = b_t [A_{it} + \gamma K_{it}] \]

Non linear:
\[ \log(V_{it}/A_{it}) = \log Q_{it} = \log b_t + \log(1 + \gamma_t K_{it}/A_{it}) \]

Linear approx.:
\[ \log Q_{it} = \log b_t + \gamma_t K_{it}/A_{it} \]

**Interpretation:**
- \( Q_{it} = V_{it}/A_{it} \) is Tobin’s \( q \) for firm \( i \) in year \( t \)
- \( b_t \) = overall market level (approximately one).
- \( \gamma_t \) = relative shadow value of \( K \) assets
  - \( \gamma = 1 \) if depreciation correct, investment strategy optimal, and no adjustment costs \( \Rightarrow \) no rents).
Summary of past results

- Market value positively related to R&D
- Range of estimates for shadow value
  - R&D expenditure coefficient: ~1.5 to 8 or 9
  - R&D stock coefficient: 0.2 to 2
- Wide variability over time and industry
- Substantial variability in specification, making comparisons difficult
  - Intangibles, patents, trademarks
  - Leverage, sales growth, market share
Extracting depreciation rate

Strong assumptions:
- Equilibrium in R&D
- Market efficiency
- Negligible adjustment costs
- Only mismeasurement in $K$ is using wrong depreciation rate to construct it
### Market value estimates – US manufacturing sector

<table>
<thead>
<tr>
<th>Period</th>
<th>K/A Coefficient</th>
<th>(s.e.)</th>
<th>Median depreciation</th>
<th>(s.e.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974-1978</td>
<td>0.398</td>
<td>0.028</td>
<td>42.8%</td>
<td>9.2%</td>
</tr>
<tr>
<td>1979-1983</td>
<td>0.573</td>
<td>0.028</td>
<td>30.3%</td>
<td>4.9%</td>
</tr>
<tr>
<td>1984-1988</td>
<td>0.362</td>
<td>0.029</td>
<td>54.0%</td>
<td>9.0%</td>
</tr>
<tr>
<td>1989-1993</td>
<td>0.352</td>
<td>0.033</td>
<td>55.3%</td>
<td>7.8%</td>
</tr>
<tr>
<td>1994-1998</td>
<td>0.507</td>
<td>0.040</td>
<td>37.8%</td>
<td>5.5%</td>
</tr>
<tr>
<td>1999-2003</td>
<td>0.745</td>
<td>0.044</td>
<td>21.8%</td>
<td>2.9%</td>
</tr>
</tbody>
</table>
Estimated depreciation of R&D for selected sectors

<table>
<thead>
<tr>
<th>Period</th>
<th>Drugs &amp; medical instruments</th>
<th>Computers &amp; electronics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974-1978</td>
<td>9.9% (4.2%)</td>
<td>31.9% (8.1%)</td>
</tr>
<tr>
<td>1979-1983</td>
<td>19.6% (7.9%)</td>
<td>50.1% (14.5%)</td>
</tr>
<tr>
<td>1984-1988</td>
<td>5.8% (3.1%)</td>
<td>88.1% (27.6%)</td>
</tr>
<tr>
<td>1989-1993</td>
<td>20.6% (6.6%)</td>
<td>51.3% (8.6%)</td>
</tr>
<tr>
<td>1994-1998</td>
<td>18.8% (5.6%)</td>
<td>51.2% (11.6%)</td>
</tr>
</tbody>
</table>

Differences across sectors are plausible, but there is high variability over time.
Returns to R&D

- **Private**
  - firms do R&D and improve their products and processes
  - have higher sales and/or lower costs
  - returns are amount of additional profit achieved per unit of R&D spending

- **Social**
  - firms, universities, PROs in the economy do R&D
  - achieve higher profits and other improvements to health, defense, the environment
  - real output increases more than inputs of capital, labor, materials
  - returns are increase in welfare due to aggregate R&D

Why are these two measures different? **spillovers**
Evidence on social returns

- Early papers show high social returns, using a wide variety of methods
- Most econometric evidence on the direct immediate contribution of public (govt-funded) R&D to private firm returns finds little contribution
  - However, weak identification due to high correlation of company and govt-funded R&D within firms
R&D Spillovers

- From firm to firm in the same or related industries.
  - Reverse engineering
  - Migration of scientists and engineers (e.g., within Silicon Valley)
  - Lower cost imitation of innovative products

- From firms to downstream customers
  - Improved capital equipment (e.g., computers in financial services)
  - Consumer electronics, healthcare (e.g., CT scanner)
  - Much of this welfare increase captured by pricing – flows to consumers
R&D Spillovers (cont.)

- From govt. and university research to firms
  - commercial product improvements from defense R&D (e.g., airframes, satellites)
  - scientific base for innovation (e.g., biotech)
- From govt. and university research to consumers
  - via new industrial products
  - directly (environment, healthcare, etc.)

Conclusion: some of the benefits to R&D go to individuals and firms that do not bear its cost.
R&D spillover schematic

Govt, Univ, PRO research → Firm → Industry 1

Basic science, defense R&D

Firm → User feedback

Related knowhow, scientific personnel

Firm → Consumers

Lower prices, better products

Firm → Industry 2

Firm
Estimating spillover returns

- Usually estimate $\text{social} = \text{private} + \text{spillover}$
- Construct measures of flows from other sectors or countries based on trade, patent citations, inter-industry investments, etc.
- Weight external R&D measure using these flows
- Include in a productivity regression along with own R&D
## Industry estimates of returns

<table>
<thead>
<tr>
<th>Authors</th>
<th>Sample</th>
<th>Years</th>
<th>Private returns</th>
<th>Social returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Griliches-Lichtenberg (1984a)</td>
<td>US industries</td>
<td>1959-78</td>
<td>11% to 31% (8%)</td>
<td>50% to 90% (36%)</td>
</tr>
<tr>
<td>Odagiri (1985)</td>
<td>Japan industries</td>
<td>1960-77</td>
<td>157% to 315%</td>
<td>-606% to 734%</td>
</tr>
<tr>
<td>Sterlacchini (1989)</td>
<td>UK industries</td>
<td>1945-83</td>
<td>12% to 20%</td>
<td>15% to 35%</td>
</tr>
<tr>
<td>Goto-Suzuki (1989)</td>
<td>Japan industries</td>
<td>1978-83</td>
<td>26%</td>
<td>80%</td>
</tr>
<tr>
<td>Bernstein (1989)</td>
<td>Canada industries</td>
<td>1963-83</td>
<td>24% to 47%</td>
<td>29% to 94%</td>
</tr>
<tr>
<td>Bernstein-Nadiri (1989)</td>
<td>US industries</td>
<td>1965-78</td>
<td>7%</td>
<td>9% to 13%</td>
</tr>
<tr>
<td>Mohnen-Lepine (1991)</td>
<td>Canada industries</td>
<td>1975, 77, 79, 81-83</td>
<td>56% (5% to 275%)</td>
<td>30% (2% to 90%)</td>
</tr>
<tr>
<td>Wolff-Nadiri (1993)</td>
<td>US industries</td>
<td>1947, 58, 63, 67, 72,77</td>
<td>11%-19%</td>
<td>0%-14%</td>
</tr>
<tr>
<td>Bernstein-Yan (1997)</td>
<td>Canada industries</td>
<td>1964-82</td>
<td>17.2%</td>
<td>62% to 183%</td>
</tr>
<tr>
<td></td>
<td>Japan industries</td>
<td>1964-82</td>
<td>17.4%</td>
<td>9% to 56%</td>
</tr>
<tr>
<td>Bernstein (1998)</td>
<td>Canada industries</td>
<td>1962-89</td>
<td>12.8%</td>
<td>19% to 145%</td>
</tr>
<tr>
<td></td>
<td>US industries</td>
<td>1962-89</td>
<td>16.4%</td>
<td>28% to 167%</td>
</tr>
<tr>
<td>Bernstein-Mohnen (1998)</td>
<td>Canada industries</td>
<td>1962-86</td>
<td>44.0%</td>
<td>47%</td>
</tr>
<tr>
<td></td>
<td>Japan industries</td>
<td>1962-86</td>
<td>47%</td>
<td>0%</td>
</tr>
</tbody>
</table>
| Griffith-Redding-van Reenen   | 12 OECD countries/11 industries | 1974-90  | 47% to 67%               | 57% to 105%             | (2004)
Conclusions from this literature

- In general, the social returns to most R&D investments are greater than the private returns.
  - Gap varies by industry and type of research
  - some R&D investments have high private returns and do not need to be subsidized.

- Some kinds of public research spending (academic science; advanced training) have very high social returns, some of them geographically concentrated.

- R&D process is highly uncertain; probability of success not sensitive to fine financial tuning; project choice is difficult, for firms or government agencies.
Some remaining questions

- Quality–adjusted price deflators and their effect on measured R&D contribution.
- How do we target the marginal project? If we are going to subsidize some (pre–)commercial projects, how should we choose and evaluate them?
- Conflict between the goals of the firm (product differentiation) and those of society.
- Short run response to R&D subsidies is an increase in the wage of R&D workers (elasticity ~.2). How does the long run play out?
Growth accounting intro

Supplementary slides
Introduction – Growth Accounting

In developed economies, over half of output growth cannot be explained by growth in conventional inputs. Correcting the inputs (labor and capital) for quality improvement leaves about a third unexplained.

Presumption: unexplained growth AND quality improvements are a result of research and technological activity, broadly defined. Thus our interest in the R&D–Growth relationship.
Basic growth accounting (1)

Assume the economy can be described by a “production function” with technical progress $A(t)$ and two inputs, capital $C(t)$ and labor $L(t)$:

$$Q(t) = A(t)F[C(t), L(t)]$$

$Q(t)$ is aggregate output (GDP) in year $t$
Labor $L(t)$ is measured in person–hours or number of workers.
Other inputs such as energy or materials can be included
Productivity level $A(t)$ grows over time
  $\Rightarrow$ more output for a given level of capital and labor
Basic growth accounting (2)

What is the growth of output as a function of the growth of labor and capital?
Differentiate output $Q(t)$ with respect to time $t$, using the chain rule. Express the result in terms of growth rates:

$$G_Q = G_A + \varepsilon_C G_C + \varepsilon_L G_L$$

where elasticity is defined as $\varepsilon_X = \frac{d\log Q}{d\log X}$

in competitive markets, $\varepsilon_X = \text{share of } X \text{ in output};$ competitive assumption can be relaxed somewhat
How do we measure this?

- **output:**
  - sum over sales of all final goods and services in the economy
  - sum value added in each sector

- **capital:**
  - sum over plant and equipment
  - sum over imputed rental cost (depreciation plus interest rate or required net rate of return)

- **labor:**
  - number of workers
  - number of worker hours
Measurement issues

- input utilization
- price deflation
  - Values from National Income Accounts = \( P \times Q \)
  - Choice of deflator \( P \) affects measurement of real output \( Q \)
  - similarly for real capitals \( C,K \)
- quality change
  - Capital, output, labor today not the same quality as that in earlier years
- aggregation
  - Can sum values (in the same units)
  - …..but cannot sum different kinds of output or capital types – must convert to real value
Growth accounting example

Aggregate US Data 1900–1949 (Solow, with elasticities equal to shares):

\[ G_A = G_Q - s_C G_C - s_L G_L \]

\[ = 2.75\% - (.35) 1.75\% - (.65) 1.00\% \]
\[ = 2.75\% - 0.61\% - 0.65\% \]
\[ = 1.49\% \]

Implication: slightly more than half of output growth is not explained by growth in capital and labor inputs. This quantity \( G_A \) is often called the “residual” or “total factor productivity growth.”
## Growth Accounting for the US 1960–2001

<table>
<thead>
<tr>
<th>Period</th>
<th>Growth rate of GDP</th>
<th>Growth due to</th>
<th>Growth rate of GDP/worker</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Capital</td>
<td>Labor</td>
</tr>
<tr>
<td>1960-1970</td>
<td>4.0</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>1970-1980</td>
<td>2.7</td>
<td>0.9</td>
<td>1.5</td>
</tr>
<tr>
<td>1980-1990</td>
<td>3.5</td>
<td>1.5</td>
<td>1.3</td>
</tr>
<tr>
<td>1989-1995</td>
<td>2.5</td>
<td>1.2</td>
<td>1.0</td>
</tr>
<tr>
<td>1995-2001</td>
<td>4.2</td>
<td>2.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>

*Source: Jorgenson (2004)*

These estimates have been corrected for changes in capital and labor quality.
### Contribution of R&D & ICT to growth – France

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth in VA</td>
<td>2.63</td>
<td>0.48</td>
<td>2.55</td>
<td>1.61</td>
</tr>
<tr>
<td>Contribution from:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D</td>
<td>0.08</td>
<td>0.10</td>
<td>0.05</td>
<td>0.06</td>
</tr>
<tr>
<td>ICT</td>
<td>0.08</td>
<td>0.03</td>
<td>0.12</td>
<td>0.25</td>
</tr>
<tr>
<td>Adjusted for quality improvement, using social deprec. rate:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D</td>
<td>0.34</td>
<td>0.42</td>
<td>0.32</td>
<td>0.33</td>
</tr>
<tr>
<td>ICT</td>
<td>0.14</td>
<td>0.11</td>
<td>0.22</td>
<td>0.38</td>
</tr>
</tbody>
</table>

*Scope: Business Sector*

*Source: Kocoglu and Mairesse (2004) – calculations based on National Accounts and OECD (for R&D)*
## Contribution of R&D & ICT to growth – United States

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth in VA</td>
<td>3.09</td>
<td>2.41</td>
<td>4.28</td>
<td>1.13</td>
</tr>
<tr>
<td><strong>Contribution from:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D</td>
<td>0.11</td>
<td>0.07</td>
<td>0.10</td>
<td>0.14</td>
</tr>
<tr>
<td>ICT</td>
<td>0.21</td>
<td>0.14</td>
<td>0.37</td>
<td>0.41</td>
</tr>
<tr>
<td><strong>Adjusted for spillovers, quality improvement:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D</td>
<td>0.47</td>
<td>0.41</td>
<td>0.46</td>
<td>0.57</td>
</tr>
<tr>
<td>ICT</td>
<td>0.33</td>
<td>0.30</td>
<td>0.60</td>
<td>0.67</td>
</tr>
</tbody>
</table>

**Scope:** Business Sector  
**Sources:** Koceglu and Mairesse (2004) – calculations based on National Accounts and OECD (for R&D)
Private returns to public R&D (1)

- Measured returns to govt.-funded R&D performed by private firms (contract R&D for defense, space, etc.):
  - zero at the firm or industry level in the U.S. (Bartelsman, Griliches, Lichtenberg, Nadiri and Mamuneas, etc.)
  - zero using cross-country data (Lichtenberg 1993)
  - zero for Canada (Hanel 1994), Norway (Klette 1991, 1997), Germany (Harhoff 1993), but positive for France (Hall and Mairesse 1995), Israel (Griliches and Regev)
- most studies use TFP methodology with measures of govt. funded R&D together with private R&D
  - Due to high correlation between private & govt R&D across industry, identification often weak
Private returns to public R&D (2)

- Individual case study evidence shows that contribution can be large
  - Mowery (1985) on commercial aircraft spillovers
  - Hertzfeld (1985) on communications satellites
  - Etc……

- Why the difference?
  - long and variable lags
  - diffuse benefits outside the industry of origin
  - measurement difficulties (deflators again)
  - problems defining and measuring the appropriate R&D input cost
  - focus on successes
Social returns to public R&D

- Defense, space, environment, etc. – output not measured.
- Science and basic research – some earlier work
  - Adams (1990) – stocks of scientific articles enter into related industry productivity with long (20 year) lags. Social returns average 70–80%, but very disperse.
  - Mansfield (1995) – direct traceable returns to academic R&D about 20–30 percent, ignoring longer lags, other spillovers, spillovers outside U.S., etc.
  - Griliches (1986); Lichtenberg & Siegel (1991) – basic research has higher returns than ordinary R&D at firm level in US.
  - Hall & Mairese (1995) – French firms with a large share of basic research have lower productivity.