Evidence on the Impact of R&D and ICT Investment on Innovation and Productivity in Italian Firms

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The views expressed here are those of the authors and do not necessarily reflect those of the Bank of Italy

General motivation

- Europe underperformance vis-à-vis the US in terms of productivity
  - Labor and product market rigidities, e.g., Dew-Becker & Gordon, 2008; Bourles & al., 2010
  - R&D investment/Innovation, e.g., Hall & Mairesse, 2009
  - ICT investment/ICT production, e.g.,
    - Timmer & van Ark, 2005: ICT-capital deepening and TFP growth originating from ICT-goods production almost fully explain the US lead in labor productivity growth
    - Bassanini & Scarpetta 2002: Entry regulation hampers ICT adoption in OECD countries
Comparing EU and US

R&D and ICT investment relative to GDP

Italy is one of the laggards
General motivation

• Is the explanation for the gap lower return or underinvestment in ICT?
• Many studies find an impact of ICT investment on productivity, using data on
  – measures of the volume of firm’s hardware in stocks at the establishment level
  – ICT use at the firm level (n of PCs, use of network, n of employees using ICT)
• Our study - ICT investment expenditure - a direct measure of investment easily used in a production function

Building on earlier work by Hall-Mairesse and co-authors

Our model

- Treats ICT as an input to knowledge production (not only to production)
- Allows for possible complementarities with R&D and innovation activities
- Uses a variation of the “CDM” framework [similar to that by Polder et al. 2009]

A brief overview of the model

- Three blocks of equations
  1. equations explaining the “R&D” decision and the amount of R&D performed
  2. Innovation output equations (KPF) with R&D and ICT investment as inputs
  3. Productivity equation, in which innovation output indicators and ICT investment appear as explanatory variables
Econometrics (1)

Only 35% of firms report R&D; use standard selection model:

Selection eq

\[ RDI_i = \begin{cases} 1 & \text{if } RDI_i^* = w_i \alpha + \varepsilon_i > \bar{c} \\ 0 & \text{if } RDI_i^* = w_i \alpha + \varepsilon_i \leq \bar{c} \end{cases} \]

Conditional on doing R&D, we observe the level:

\[ RD_i = \begin{cases} RDI_i^* = z_i \beta + \delta_i & \text{if } RDI_i = 1 \\ 0 & \text{if } RDI_i = 0 \end{cases} \]

Assume joint normality => generalized tobit or Heckman selection model; Hall et al 2009 found no selection for SMEs, but we find it here using full size range.

Econometrics (2)

Output of the KPF are various binary innovation indicators. For example,

\[ DI_i = RD_i^* \gamma + X_i \delta + u_{ii} \]

\( DI \) = Dummy for innovation

Why do we include the latent R&D variable \( RD^* \)?

1. Account for informal R&D effort that is often not reported
2. Instrument for errors in variables and simultaneity

Estimation is via multivariate probit
Econometrics (3)

Production function:

\[ y_i = \pi_1 k_i + \pi_2 \text{PROC}_i + \pi_3 \text{PROD}_i + \pi_4 \text{ICT}_i + Z_i \varphi + v_i \]

- \( y = \log \text{sales per employee} \)
- \( k = \log \text{capital stock per employee} \)
- \( \text{PROD}, \text{PROC} \) are predicted probabilities of innovation from second step
- \( \text{ICT} = \log \text{ICT investment per employee} \)
- \( Z \) includes size, age, industry, region, year, wave
- Estimated by OLS

The Data

7th-10th waves of the Unicredit (formerly Mediocredito Centrale – Capitalia) survey of more than 4,000 manufacturing firms

- Each survey covers previous three years:
- Merge the 4 waves & clean
  - Some loss due to computation of capital stock, outliers, & missing values
- Result: 14,294 observations on 9,850 firms
Main variables

- **Continuous**
  - R&D, ICT and non-ICT investment - log real expenditure per employee
  - Capital - log real capital per employee
  - Productivity - log deflated sales per employee

- **Binary**
  - Product / process innovation dummies
  - Organizational innovation associated with product / process innovation

Controls in all equations

- Size (log employees) and size squared
- Log age and log age squared
- Competition dummies: large firms, regional, national, European, International
- Whether firm is in a group
- Whether firm received subsidies
- 2-digit industry, region, year and “wave” indicator dummies
- Dummies for missing or zero ICT and non-ICT investment
Some statistics on the data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean/median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employees</td>
<td>114/35</td>
</tr>
<tr>
<td>Age of firm</td>
<td>27/22.5</td>
</tr>
<tr>
<td>Non-ICT investment intensity for firms that invest*</td>
<td>8.64/4.54</td>
</tr>
<tr>
<td>R&amp;D intensity for R&amp;D-doers*</td>
<td>3.79/1.63</td>
</tr>
<tr>
<td>ICT intensity for ICT investors*</td>
<td>0.75/0.34</td>
</tr>
<tr>
<td>Average capital intensity*</td>
<td>52.0/25.8</td>
</tr>
<tr>
<td>Labor productivity*</td>
<td>219.5/157.8</td>
</tr>
</tbody>
</table>

| Firms with nonzero non-ICT investment                      | 84.2%       |
| Firms with nonzero R&D                                      | 34.2%       |
| Firms with nonzero ICT                                      | 68.3%       |

* 1000s euros (base year 2000)

Patterns of innovation

<table>
<thead>
<tr>
<th>Innovation dummy patterns</th>
<th>Obs</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>4,383</td>
<td>32.8%</td>
</tr>
<tr>
<td>Process only</td>
<td>2,199</td>
<td>15.4%</td>
</tr>
<tr>
<td>Product and process only</td>
<td>2,087</td>
<td>14.6%</td>
</tr>
<tr>
<td>All four (proc/prod/org)</td>
<td>1,278</td>
<td>8.9%</td>
</tr>
<tr>
<td>Product only</td>
<td>1,212</td>
<td>8.5%</td>
</tr>
<tr>
<td>Process and org process only</td>
<td>1,148</td>
<td>8.0%</td>
</tr>
<tr>
<td>Remaining 10 categories</td>
<td>1,687</td>
<td>11.8%</td>
</tr>
<tr>
<td>Organizational innovation w/o corresponding innovation</td>
<td>734</td>
<td>5.1%</td>
</tr>
</tbody>
</table>
Step 1 – explaining R&D

- Falls with firm size, minimum at about 400 employees
- Age has no significant impact
- International competition increases R&D slightly
- Having received a subsidy and being part of a group have a strong positive impact
- Compare to ICT:
  - Falls more slowly with firm size, minimum about 200 employees, then increases again
  - Age and competition do not matter
  - Subsidies matter much less and being part of a group matters as much
Step 2: Innovation

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted R&amp;D intensity</td>
<td>0.434***</td>
<td>0.571***</td>
<td>0.510***</td>
<td>0.496***</td>
</tr>
<tr>
<td>ICT per employee</td>
<td>0.018</td>
<td>0.039***</td>
<td>0.024***</td>
<td>0.070***</td>
</tr>
<tr>
<td>Investment per employee</td>
<td>0.095***</td>
<td>0.019**</td>
<td>0.039***</td>
<td>0.006</td>
</tr>
<tr>
<td>Size at max</td>
<td>1300</td>
<td>700</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Age at max</td>
<td>Insig.</td>
<td>large</td>
<td>Insig.</td>
<td>Insig.</td>
</tr>
</tbody>
</table>

Residual correlations: .449, .551, .295, .183, .624, .639 are high (and larger than raw correlations: .292, .346, .163, .128, .412, .433) Results are similar, but non-ICT investment more important for process innovation, and ICT for product and organizational.

Step 3: production function

<table>
<thead>
<tr>
<th>Variable</th>
<th>Labor productivity (log sales per employee)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prob of any innovation</td>
<td>0.191***</td>
</tr>
<tr>
<td>Prob of process &amp; org process together</td>
<td>-0.026</td>
</tr>
<tr>
<td>Prob of product &amp; org product only</td>
<td>-0.882***</td>
</tr>
<tr>
<td>Prob of process &amp; product together</td>
<td>-0.580***</td>
</tr>
<tr>
<td>Log capital per employee</td>
<td>0.153***</td>
</tr>
<tr>
<td>Log ICT per employee</td>
<td>0.095***</td>
</tr>
<tr>
<td>Firm size at minimum</td>
<td>160</td>
</tr>
</tbody>
</table>

Productivity also declines with age (-.04) throughout. Note that ICT is much more productive than its share in investment (10%).
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<tr>
<td>Prob of any innovation</td>
<td>0.191*** 0.015 -0.026 -0.517***</td>
</tr>
<tr>
<td>Log capital per employee</td>
<td>0.153*** 0.154*** 0.144*** 0.140*** 0.150***</td>
</tr>
<tr>
<td>Log R&amp;D per employee</td>
<td>0.114***</td>
</tr>
<tr>
<td>Log ICT per employee</td>
<td>0.095*** 0.093*** 0.101***</td>
</tr>
<tr>
<td>Firm size at minimum</td>
<td>160 140 140 140 70</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.237 0.238 0.255 0.257 0.259</td>
</tr>
</tbody>
</table>

**Conclusions**

- Both R&D and ICT are positively correlated to the likelihood of having innovation, much higher for R&D.
- ICT more important for product and org innovation than process; investment more important for process.
- Firm size increases likelihood of innovation, but flattens at larger firm sizes.
- Age of the firm matters very little
- Industry dummies are much better predictors of R&D and ICT than regional dummies (suggest south-north differences are largely due to industrial structure)
Conclusions

• Innovation as measured appears to be uni-dimensional, not multi-dimensional
• Given its share, ICT investment is far more productive than ordinary capital would suggest underinvestment rather than lower returns
• Medium sized firms invest less per employee in R&D and ICT and are less productive, conditional on the amounts invested.
• More remains to be done but further progress seems largely conditioned on “better data”......