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
Motivation

• Europe underperformance vis-à-vis the US in terms of productivity
  — Labor market rigidities (Dew-Becker & Gordon, 2008, but also Hall, Lotti & Mairesse, 2008, on Italy)
  — R&D investment/Innovation (e.g., Hall, Lotti & Mairesse, 2009, on SMEs)
  — ICT investment/ICT production
    • 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
Comparing EU and US

R&D and ICT investment relative to GDP

- ICT in EU15
- ICT in US
- R&D in EU15
- R&D in US

Italy is one of the laggards
Motivation

• Is the explanation for the gap lower return or underinvestment?

• 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 (Brynjolfsson and Hitt, 1995, 2003)
  — ICT use at the firm level (n of PCs, use of network, n of employees using ICT - Greenan and Mairesse, 1996)

• Our study - ICT investment expenditure - a direct measure of investment easily used in a production function
Building on earlier work by Mairesse and co-authors

Our model

• Treats ICT as an input to knowledge production (and to production)
• Allows for possible complementarities with innovation activity (mainly R&D)
• Explores the complementarities between ICT, organizational innovation and skills
• Uses a variation of the “CDM” framework (Crépon-Duguet-Mairesse, 1998)
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 appears as an explanatory variable

[CDM, extended by Polder et al. 2009]
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:

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

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

\[ DI_i = RD_i^* \gamma_1 + X_i \delta_1 + u_i \]

\( DI \) = 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:

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

\( y \) = log sales per employee
\( k \) = log capital stock per employee
\text{PROD, PROC} are predicted probabilities of innovation from second step
\text{ICT} = log 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>
Industrial distribution of R&D and ICT

Share of observations with nonzero R&D or ICT investment

- Food and beverage
- Textiles & apparel
- Leather & other
- Footwear
- Wood products
- Paper products
- Publishing & printing
- Oil refining
- Chemicals
- Rubber & plastics
- Stone, clay, glass
- Primary metals
- Fabricated metals
- Machinery
- Electrical mach & com
- Scientific instrument
- Electronics
- Motor vehicles
- Rail and trams
- Misc manufacturing

Share nonzero R&D
Share nonzero ICT
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 – financial constraints?
• 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 more (0.25)
### Step 2: Innovation

<table>
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<tr>
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</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, 0.551, 0.295, 0.183, 0.624, 0.639

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*** -0.026</td>
</tr>
<tr>
<td>Prob of process &amp; org process together</td>
<td>-0.882*** -0.580***</td>
</tr>
<tr>
<td>Prob of product &amp; org product only</td>
<td>1.249*** 0.720***</td>
</tr>
<tr>
<td>Prob of process &amp; product together</td>
<td>0.460*** 0.179***</td>
</tr>
<tr>
<td>Log capital per employee</td>
<td>0.153*** 0.144*** 0.166*** 0.151***</td>
</tr>
<tr>
<td>Log ICT per employee</td>
<td>0.095*** 0.088***</td>
</tr>
<tr>
<td>Firm size at minimum</td>
<td>160 140 200 170</td>
</tr>
</tbody>
</table>

Productivity also declines with age (-0.04) throughout. Note that ICT is much more productive than its share in investment (10%).
Conclusions

- Both R&D and ICT are positively correlated to the likelihood of having innovation, much higher for R&D (caution – can be due to sector instruments).
- ICT more important for product and org innovation than process; investment more important for proc.
- 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 appears to be uni-dimensional, not multi-dimensional
• Given its share, ICT investment is far more productive than ordinary capital – suggests underinvestment (not lower returns)
• Medium sized firms invest less per employee in R&D and ICT and are less productive, conditional on the amount invested.
• Work on organizational change and upskill variables in the future......