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

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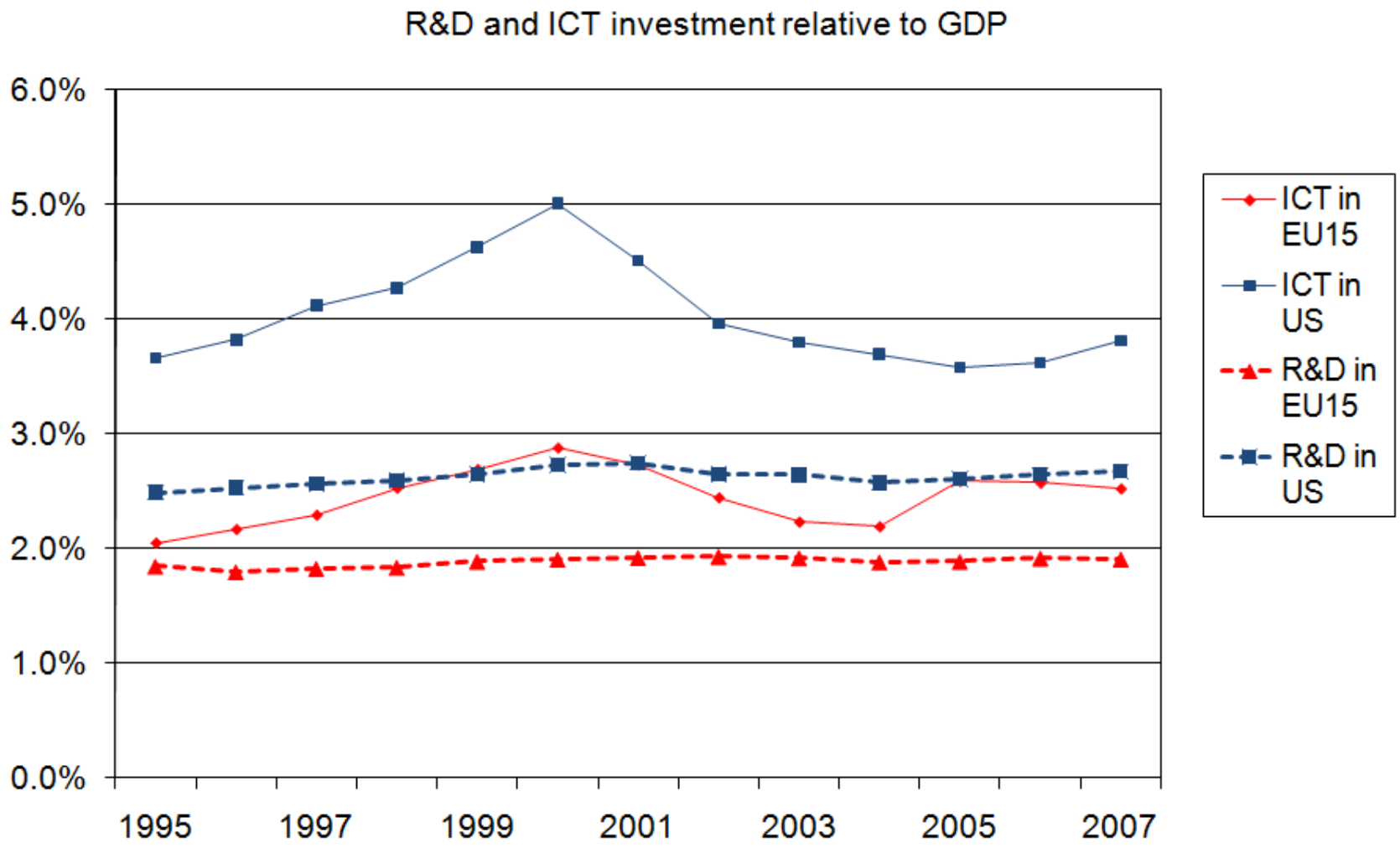
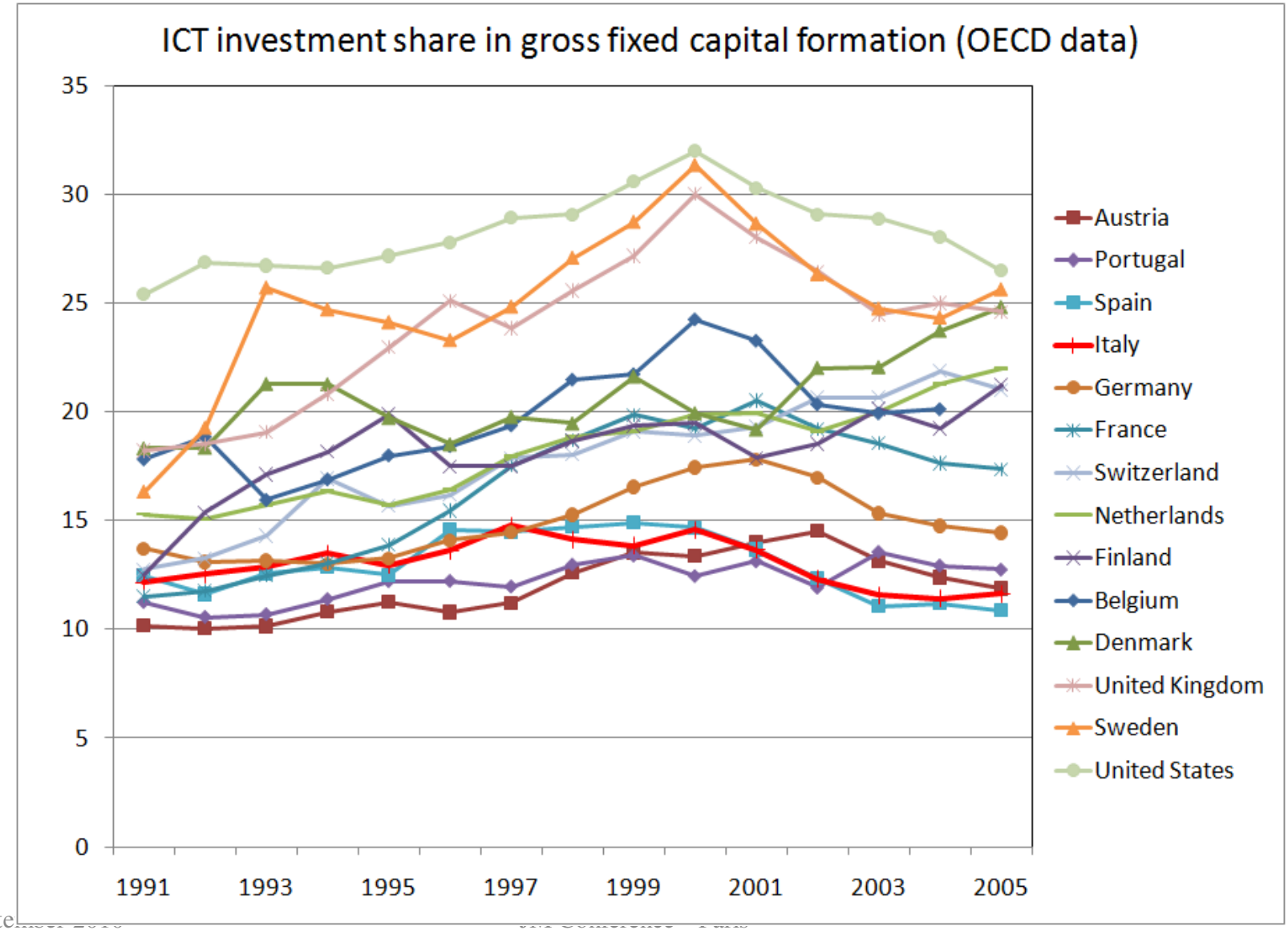
Motivation

- 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
    - Bassanini & Scarpetta (2002) on OECD countries. Entry regulation hampers ICT adoption.

Comparing EU and 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

- Greenan, N., and J. Mairesse (2000). Computers and productivity in France: Some evidence. *Economics of Innovation and New Technology*, 9(3): 275-315.
- Greenan N., A. Topiol-Bensaid and J. Mairesse (2001). Information Technology and Research and Development Impacts on Productivity and Skills: Looking for Correlations on French Firm Level Data, in *Information Technology, Productivity and Economic Growth*, M. Pohjola ed., Oxford University Press, 119-148.
- Crépon B., E. Duguet and J. Mairesse (1998). Research, Innovation and Productivity: An Econometric Analysis at the Firm Level, *Economics of Innovation and New Technology*, 7(2), 115-158.

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 $$RDI_i = \begin{cases} 1 & if \quad RDI_i^* = w_i\alpha + \varepsilon_i > \bar{c} \\ 0 & if \quad RDI_i^* = w_i\alpha + \varepsilon_i \le \bar{c} \end{cases}$$

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

$$RD_i = \begin{cases} RD_i^* = z_i\beta + e_i & if \quad RDI_i = 1 \\ 0 & if \quad RDI_i = 0 \end{cases}$$

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,

$$DI_i = RD_i^* \gamma_1 + X_i \delta_1 + u_{1i}$$

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:

$$y_i = \pi_1 k_i + \pi_2 PROC_i + \pi_3 PROD_i + \pi_4 ICT_i + Z_i \varphi + v_i$$

y = log sales per employee

k = log capital stock per employee

PROD, PROC are predicted probabilities of innovation from second step

ICT = log ICT investment per employee

Z includes size, age, industry, region, year, wave

Estimated by OLS

The Data

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

- Each survey covers previous three years:
  - 1995-1997, 1998-2000, 2001-2003, 2004-2006
- 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

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

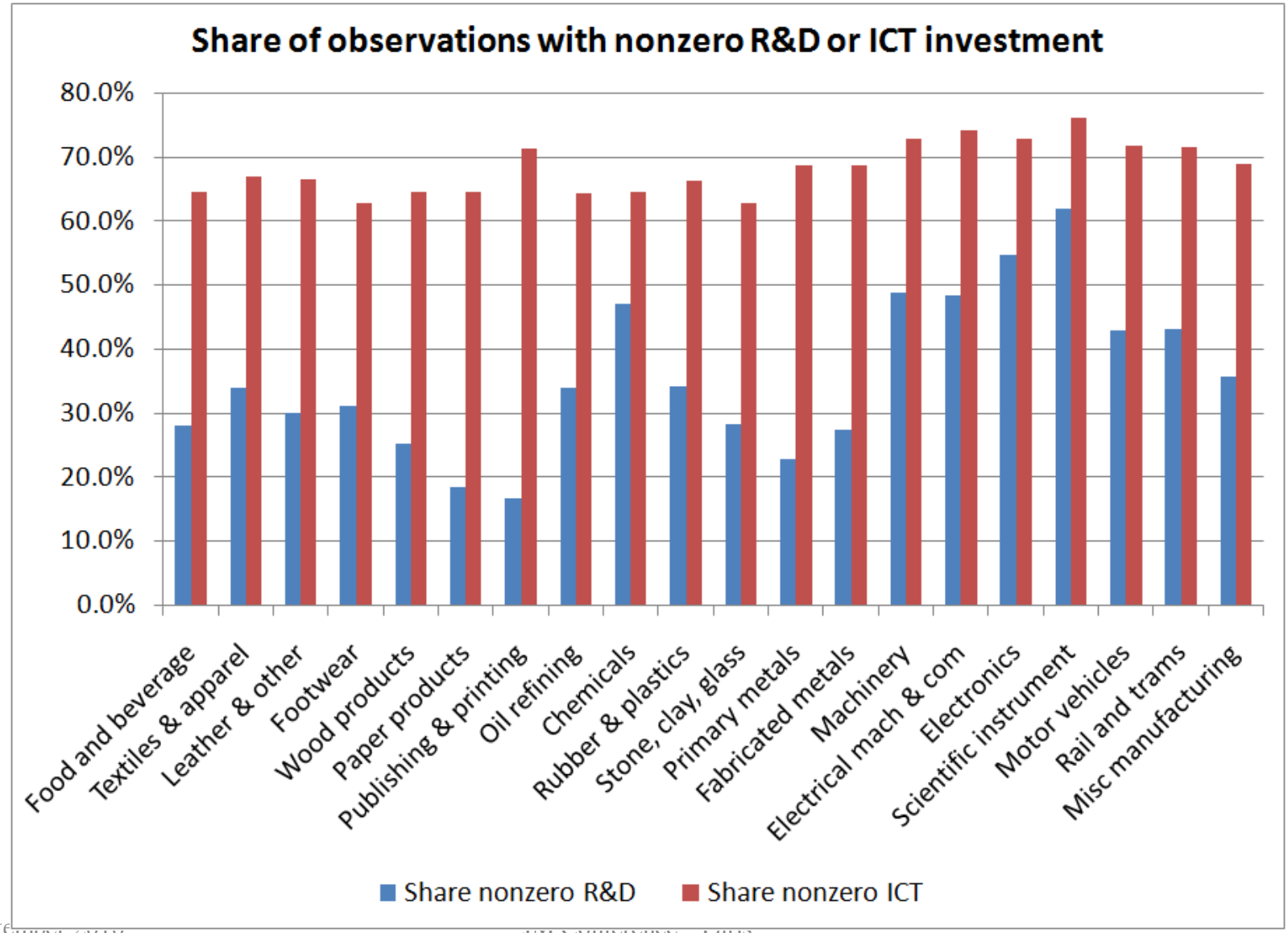
* 1000s euros (base year 2000)

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

Patterns of innovation

Innovation dummy patterns	Obs	Share
None	4,383	32.8%
Process only	2,199	15.4%
Product and process only	2,087	14.6%
All four (proc/prod/org)	1,278	8.9%
Product only	1,212	8.5%
Process and org process only	1,148	8.0%
Remaining 10 categories	1,687	11.8%
Organizational innovation w/o corresponding innovation	734	5.1%

Industrial distribution of R&D and 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

Variable	Process innov.	Product Innov.	Org. change for proc innov	Org. change for prod innov
Predicted R&D intensity	0.434***	0.571***	0.510***	0.496***
ICT per employee	0.018	0.039***	0.024***	0.070***
Investment per employee	0.095***	0.019**	0.039***	0.006
Size at max	1300	700	500	500
Age at max	Insig.	large	Insig.	Insig.

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

Variable	Labor productivity (log sales per employee)			
Prob of any innovation	0.191***	-0.026		
Prob of process & org process together			-0.882***	-0.580***
Prob of product & org product only			1.249***	0.720***
Prob of process & product together			0.460***	0.179***
Log capital per employee	0.153***	0.144***	0.166***	0.151***
Log ICT per employee		0.095***		0.088***
Firm size at minimum	160	140	200	170

Productivity also declines with age (-.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……