ICT, R&D and Productivity Growth:
Evidence from Italian Manufacturing Firms

Nicola Matteucci and Alessandro Sterlacchini

Università Politecnica delle Marche

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The R&D and ICT contributions to productivity growth

Theoretical framework: ***specification with technological capital***

$$\frac{\dot{TFP}_i}{TFP_i} = \lambda + \alpha \frac{\dot{KRD}_i}{KRD_i}$$

$$\frac{\dot{TFP}_i}{TFP_i} = \lambda + \alpha \frac{\dot{KRD}_i}{KRD_i} + \beta \frac{\dot{KICT}_i}{KICT_i}$$

α and β = excess elasticities

The R&D and ICT contributions to productivity growth

Theoretical framework: ***specification with technological intensity***

$$\alpha\frac{\dot{KRD}}{KRD}=\frac{\partial VA}{\partial KRD}\frac{KRD}{VA}\frac{\dot{KRD}}{KRD};\qquad \beta\frac{\dot{KICT}}{KICT}=\frac{\partial VA}{\partial KICT}\frac{KICT}{VA}\frac{\dot{KICT}}{KICT}$$

$$\alpha\frac{\dot{KRD}}{KRD}=\rho\frac{\dot{KRD}}{VA};\qquad \beta\frac{\dot{KICT}}{KICT}=\sigma\frac{\dot{KICT}}{VA}$$

$$\frac{\dot{TFP}}{TFP}=\lambda+\rho\frac{R\&D}{VA}+\sigma\frac{ICT}{VA}$$

ρ and σ= excess rates of returns

The R&D and ICT contributions to productivity growth
Survey of the evidence

OLD (MATURE) R&D-BASED LITERATURE

- **R&D: positive and significant coefficient**
- **(Gross) rate of return ρ varies between 10% and 80%**
- **Medda, Piga and Siegel 2004 (Capitalia survey): R&D returns = 29% (1992-94); 36% (1995-97)**
- **Aiello and Cardamone 2004 (Capitalia survey) R&D elasticity = 5% (1994-2000)**

The R&D and ICT contributions to productivity growth
Survey of the evidence

RECENT ICT-BASED CONTRIBUTIONS

- **Encouraging micro-level evidence since the late Nineties**
- **Lehr-Lichtenberg (1999): 1490/10700 US firms; excess output elasticity to IT capital found over 1977-93**
- **Brynjolfsson-Hitt (2003): ICT impact on TFP**

The R&D and ICT contributions to productivity growth

Survey of the evidence

- **B-H (2003): 527 US large firms; 1987-1994**
- **Standard Cobb Douglas: traditional inputs and computer capital**
- **Excess elasticity of computer capital: positive and significant; increases with the time-lag**
- **The need of complementary investments in intangible assets and organisational change (not testable)**

ICT and R&D intensities in Italian manufacturing

Table 1 - ICT investment intensity in the US, UE and Italy: 1997-2000 (current prices)

	US	EU-15	Italy
ICT/GDP	**4.43**	**2.54**	**2.39**
Communication Equipment/GDP	**1.17**	**0.68**	**1.13**
ICT /Total Non Residential Invest.	**28.29**	**16.92**	**16.44**
Communication Equip. / Total Non Residential Invest.	**7.46**	**4.53**	**7.66**

Source: Timmer et al. (2003).

Table 2 - ICT investment intensity in Italian manufacturing

	SFA	Capitalia LONG
ICT/Value Added 1995-97 (curr. Prices)	n.a.	0.99
ICT/Value Added 1998-2000 (curr. Prices)	0.66	0.75
ICT/Value Added 1995-97 (1995 Prices)	n.a.	1.28
ICT/Value Added 1998-2000 (1995 Prices)	0.90	1.13
ICT/Tot. Investment 1995-97 (curr. Prices)	n.a.	6.46
ICT/ Tot. Investment 1998-2000 (curr. Prices)	3.33	3.46
ICT/ Tot. Investment 1995-97 (1995 Prices)	n.a.	8.44
ICT/ Tot. Investment 1998-2000 (1995 Prices)	4.62	5.36

Table 3 - R&D and ICT intensity in Italian manufacturing by firm size (LONG sample)

Size class	N. obs	R&D/VA		ICT/VA	
		1995-97	1998-00	1995-97	1998-00
11-20	228	1.39	2.29	1.48	1.20
21-50	486	1.62	1.68	1.10	1.54
51-250	293	1.55	2.15	1.23	1.56
251-500	66	2.96	2.11	1.61	1.45
Over 500	46	2.59	2.27	1.20	0.70
TOTAL	1119	2.29	2.15	1.28	1.13

Table 5 - ICT investment destination in Italian manufacturing: % on total investment (LONG sample)

Hardware/ICT		Software/ICT		Comm. Equip./ICT	
1995-1997	1998-2000	1995-1997	1998-2000	1995-1997	1998-2000
62.6	60.2	32.1	29.6	5.3	10.3

Regression Analysis

$$\Delta \ln TFPt_{98\text{-}00} = \lambda + \rho\,(R\&D/VA)_{98} + \sigma\,(ICT/VA)_{98} + \delta\,\ln EMPL_{98} + \\ + \gamma\,SPINOFFS + \eta\,M\&A + \Sigma_j \lambda_j\,INDUSTRY_j + \varepsilon$$

- **Two samples: LONG (1995-2000): 1119 obs. and ALL (1998-2000): 3918 obs.**
- **Two-years differences forTFP**
- **$\ln TFP = \ln VA - s_L \ln EMPL - (1-s_L) \ln K$**
- **Size and size changes controls: lnEMPL, SPINOFFS and M&A**
- **16 industry dummies**
- **specification with lagged ICT intensity $(ICT/VA)_{97}$**

Table 6 - Determinants of TFP log differences 1998-2000: specification with non lagged ICT intensity

	LONG SAMPLE (1119 obs.)	ALL SAMPLE (3918 obs.)
$(R\&D/VA)_{98}$	0.558**	0.435 **
$(ICT/VA)_{98}$	0.132*	0.748*
R-squared	0.023	0.026

Constant and dummy variables omitted.
Heteroskedasticity-robust standard errors. *=significant at 0.1; **=significant at 0.05

Table 7 - Determinants of TFP log differences 1998-2000: specification with lagged ICT intensity (LONG sample: 1119 observations)

	1	2	3	4
$(R\&D/VA)_{98}$	0.533**	0.550**	0.532**	0.521**
$(ICT/VA)_{97}$	0.790**			
$(HWICT/VA)_{97}$		0.892*		
$(SWICT/VA)_{97}$			1.833	
$(COMMICT/VA)_{97}$				16.346**
R-squared	0.024	0.023	0.023	0.027

Constant and dummy variables omitted.
Heteroskedasticity-robust standard errors. *=significant at 0.1; **=significant at 0.05

Main conclusions

- **Both R&D and ICT intensity exert a positive impact on TFP changes**
- **However, the intensity of ICT is significant only when lagged. Here, the ICT rate of return is greater than that of R&D**
- **The latter result supports the “delay hypothesis”: need for complementary outlays in intangible assets and organisational changes**
- **Moreover, firms that invested earlier and substantially in communication equipment experienced a higher productivity growth**

Policy Implications

- **The current debate on Italian "industrial decline" and the role of new technologies**
- **Public incentives to private R&D**
- **What policy for ICT?**
- **The crucial role of complementary efforts: these are difficult to incentivate because they mainly depend upon the will/capability of entrepreneurs and managers**

A necessary extension

- **Possible endogeneity of R&D and ICT**
- **Simultaneous system of three equations: for TFP, R&D and ICT**
- **R&D and ICT observations are censored: Tobit procedure**
- **Maximum likelihood estimate of the whole model**

Appendix

Table 4 - R&D and ICT intensity in Italian manufacturing by industry (LONG sample)

Industries	n. obs.	R&D/Value Added		ICT/Value Added	
		1995-97	1998-2000	1995-97	1998-2000
Food, drink & tobacco	100	0.72	0.75	1.33	0.98
Textiles	126	1.85	1.45	0.90	0.88
Clothing	26	0.54	1.37	1.17	1.84
Leather & footwear	40	1.12	1.36	0.81	0.44
Wood & products of wood	46	0.43	0.74	1.24	0.87
Pulp, paper & paper products	37	0.23	0.58	0.90	0.64
Printing & publishing	35	0.37	0.05	3.43	2.20
Chemicals & pharmaceuticals	36	5.14	3.39	1.72	1.07
Rubber & plastics	73	0.87	3.24	1.20	1.22
Non-metallic mineral products	63	1.07	0.83	0.96	0.38
Basic metals & alloys	34	1.38	0.18	0.50	0.11
Fabricated metal products	150	0.77	0.88	1.37	0.75
Mechanical engineering (non electrical)	173	4.38	4.64	1.67	1.77
Office machinery, electrical engines, machinery & apparatus	42	1.29	4.93	0.81	1.52
Electronic apparatus, Radio-TV & Communic. Equipment, medical & precision instruments	37	4.98	3.37	1.65	2.04
All transport vehicles and equipment	37	3.12	1.63	1.10	0.88
Furniture, miscell. manufacturing, recycling	64	1.34	2.30	1.28	2.76
TOTAL	1119	2.29	2.15	1.28	1.13

Appendix

Table 5 - ICT investment destination in Italian manufacturing by industry: percentages on total investment (LONG sample)

	Hardware/ICT		Software/ICT		Comm. Equip./ICT	
Industries	**1995-97**	**1998-2000**	**1995-97**	**1998-2000**	**1995-97**	**1998-2000**
Food, drink & tobacco	**68.5**	**58.2**	**28.6**	**32.8**	**2.9**	**9.0**
Textiles	**64.8**	**54.8**	**29.8**	**33.0**	**5.3**	**12.2**
Clothing	**52.6**	**60.2**	**45.0**	**29.8**	**2.4**	**9.9**
Leather & footwear	**62.5**	**58.9**	**30.0**	**32.1**	**7.5**	**9.0**
Wood & products of wood	**58.6**	**57.5**	**36.3**	**35.2**	**5.1**	**7.3**
Pulp, paper & paper products	**67.1**	**56.3**	**32.0**	**33.2**	**1.0**	**10.4**
Printing & publishing	**73.1**	**62.4**	**19.2**	**22.4**	**7.7**	**15.2**
Chemicals & pharmaceuticals	**48.4**	**51.1**	**38.7**	**29.9**	**12.9**	**19.0**
Rubber & plastics	**58.9**	**58.5**	**34.2**	**31.5**	**6.8**	**10.0**
Non-metallic mineral products	**33.5**	**46.4**	**65.7**	**44.6**	**0.7**	**9.0**
Basic metals & alloys	**62.8**	**59.5**	**29.1**	**31.0**	**8.1**	**9.5**
Fabricated metal products	**62.8**	**59.4**	**32.8**	**32.5**	**4.5**	**8.1**
Mechanical engineering (non electrical)	**69.2**	**66.8**	**27.5**	**24.8**	**3.3**	**8.4**
Office machinery, electrical engines, machinery & apparatus	**76.3**	**62.9**	**20.3**	**29.6**	**3.4**	**7.5**
Electronic apparatus, Radio-TV & Commun. Equipment, Medical & precision instruments	**66.8**	**60.6**	**23.7**	**27.6**	**9.6**	**11.8**
All transport vehicles and equipment	**69.1**	**57.2**	**25.4**	**33.0**	**5.5**	**9.8**
Furniture, miscell. Manufacturing; recycling	**56.0**	**54.8**	**41.9**	**36.6**	**2.0**	**8.7**
TOTAL	**62.6**	**60.2**	**32.1**	**29.6**	**5.3**	**10.3**