THE EFFECTS OF SUBSIDIES ON INVESTMENT: AN EMPIRICAL EVALUATION ON ICT IN ITALY*

Gianfranco E. Atzeni and Oliviero A. Carboni

University of Sassari and CRENoS, Italy

Working on a micro based data set this paper attempts to shed light on the effects of public grants on firms' investments, with particular emphasis on ICT adoption. The results show that adoption of ICT is affected by both the industry and firm characteristics. We examine particularly whether subsidies are important in this process and whether there are differences based on firm size. A matching estimator for the average treatment effect is applied to explore the effectiveness of subsidies. Regardless of sector we find evidence that subsidies on average have a significant impact on both overall investment and ICT investment. The impact is more pronounced for small firms and insignificant for the largest firms. Subsidies spill over both to internal and external financial resources. Given the small average size of firms in Italy, we conclude that small firms should receive subsidies to stimulate investment.

JEL Classification: C21, D24, L23, O30.

Keywords: Information and Communication Technologies, Subsidies, Treatment effect, Nearest Neighbour Matching Estimator

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atzeni@uniss.it
ocarboni@uniss.it

1. Introduction

The revolutionary use of ICT in the last decade has produced new opportunities and new challenges in many economic regions of the world. While the benefits of the ICT paradigm may be evident in the US, they are still being quantified in Europe. Available evidence highlights substantial differences in the extent of ICT adoption, not only between the EU and the US, but also within the EU (Bassanini *et al.*, 2000, Schreyer, 2000, Daveri, 2001 among others). The adoption and diffusion of ICT capital goods throughout the productive system are the core of the new economy. New technology and the internet are reducing transport costs, and facilitating the access of marginal regions to more developed markets. It is hoped that this will reduce disparities between regions and thus it is important that any constraints to the rate of ICT adoption be identified.

Information and knowledge are the foundation of the new technological paradigm. The pervasiveness of ICT is affecting traditional production. New products, new processes and new organisational forms are improving the production function and increasing output. New technologies are strengthening the bases of highly innovative firms, widening their set of "eligible choices" and increasing their performance. The traditional labour force is becoming subject to substitution or transformation, not only in traditional input processing but also, and more importantly, in process control. Integration and devolution of tasks is becoming easier for firms. Communication and co-operative working is being made easier and less costly, and is producing several benefits in terms of cost and time saving, routines, information exchange, and increased quality and variety of output (Brynjolfsson and Hitt, 2000).

According to the US Bureau of Economic Analysis estimates between 1970 and 1990, constant dollar investment in office and computer apparatus showed an average growth rate of about 18% compared to the 3.3% for durable equipment in manufacturing. The massive ICT investment in recent decades has been mainly driven by the rapid decline in ICT prices.

It is estimated that quality-adjusted prices of computer hardware fell by around 28% during the period 1995-99. The main reason for this dramatic fall is the progress that has been made in microchips, fibre-optic cables, satellites, memory chips, semiconductors and processors (Jorgenson, 2001, Jorgenson and Stiroh, 2000, Oliner and Sichel, 2000). This progress has continuously ameliorated the price performance ratio of ICT capital goods with a consequent reduction in user cost relative to other forms of capital, and stimulation of a consistent substitution process in labour and traditional production inputs (Tevlin and Whelan, 2000).

The efficiency of ICT capital has improved much faster than more traditional capital over the last two decades. In a period of less than 10 years computing technology improved on the order of 20 times in terms of speed and memory capacities without any increase in costs. This has favoured their spread across the whole economic system and facilitated ICT adoption in most sectors resulting in productivity improvements particularly in *information-intensive* areas.

In Italy there have been several studies conducted based on the new national data that has become available. Employing data from the Survey of Manufacturing Firms by *Mediocredito Centrale*, Becchetti *et al.* (2003) investigated the determinants of ICT investment and the impact of ICT on labour productivity and efficiency. They found that ICT investment is affected by the industry, the geographic location and the characteristics of the firm. Bugamelli and Pagano (2004) used econometric estimates of a short-run conditional demand function for ICT capital. They found a positive correlation between ICT investment, human capital and reorganisation. They argue that the relatively low value of ICT capital among Italian firms is due to certain barriers to investment, such as the low levels of human capital and firms' organisation.

In Atzeni and Carboni (2004) we investigated the impact of ICT on total factor productivity (TFP) and its contribution to output growth, concluding that the impact is positive and relevant. We also concluded that rather than being paradoxically under-productive, ICT has a disproportionately wide impact on output growth compared to its share in total investment. In Atzeni and Carboni (2006) we found that computers have more effect than conventional capital on output growth.

When analysing ICT investment behaviour, we should point to two features of the Italian manufacturing system: sector specialisation and firm size (see also Trento and Warglien, 2001; Fabiani *et al.*, 2005). Firms in the ICT producing sectors in the Italian economy play a minor role when compared to other industrialised economies. Italy is dominated by specialised, traditional sectors (essentially textiles, clothing, leather and shoes), which are not information intensive and generally would not benefit from adoption of ICT.

In addition, there is a high proportion of small firms in Italy which also impacts on the relative incentives to adopt ICT. Although ICT typically reduces co-ordination and communication costs within a firm, to reap their full benefits a minimum operational scale is required. ICT affects optimal firm size and internal organisation and thus it is reasonable to think that the benefits of ICT might be less important for small firms. This is particularly true from the point of view of reorganisation, for example vertical disintegration. Reorganisation affects fixed costs, which may not apply to small firms. Small firms are also more likely to find it difficult to obtain the funding necessary for expansion expand.

This study investigates the effect of state subsidies on investment decisions, based on a large sample of Italian manufacturing firms. Given the characteristics of the Italian productive system we examine whether subsidies are important, and whether their effects differ according to firm size. We check for the potential effects of subsidies on both internal and external financial resources. We question whether specificities in terms of firm size and sector specialisation play a role in decisions about investment in ICT.

The Heckman selection procedure is applied to distinguish between determinants of ICT adoption choice on the one side, and what induces firms to invest in ICT, on the other. Our results highlight the importance of subsidies and other factors. We investigate whether the effect of state subsidies on traditional capital and ICT differs.

The objective of subsidy policy is fairly straightforward. The purpose of a subsidy is to encourage investment that would not otherwise have been made. The private returns on investment play a role in subsidy policy. In general, the lower the private return on investment, the more effective a subsidy will be. The rationale behind subsidisation is that the private return is too low (costs too high) to justify private investment expenditure. This is likely to be particularly true for small firms. Given the few benefits they will receive from ICT, they are less keen to adopt it. In this case a subsidy might overcome some of the disincentives to investment.

We use a matching estimation method for the average treatment effect to measure the impact of subsidies on investment. This allows us to determine whether the subsidised firms would have invested the same amount if they had not received the grant. In line with *a priori* expectations we find that public grants positively affect investment. Total investment increased by almost €15.000 per worker. However, the investigation also shows that the size of the firm is a critical factor. The effect of public grants on small firms is substantial, while for large firms the effects are less clear. Subsidies boost ICT investment by small firms by 32%; for medium-large firms the benefits are insignificant. Subsidies are effective in promoting ICT. On average they improve ICT investment by roughly 21% per worker, with small firms more dependent on public aid for ICT investment.

The paper is structured as follows. The next main Section describes the data and descriptive statistics. In Section 3 we estimate the ICT adoption function. Section 4 provides the methodology used to evaluate the impact of subsidies on total investment and ICT. Section 5 outlines the conclusions.

2. Data and variable description

The data for this study come from the Survey of Manufacturing Firms (SMF) carried out by Capitalia (2002). The SFM considers a stratified sample of Italian firms with 11 to 500 employees. It also includes all manufacturing firms with more than 500 employees. Given the high number of very small firms in Italy (including one person firms) and also bearing in mind that service industries are not included in the survey, generalisations based on this information should be made with caution. The studies of Bugamelli and Pagano (2004), Becchetti *et al*. (2003), Atzeni and Carboni (2004, 2006) and Piga and Vivarelli (2004) all use SMF data.

The data are stratified according to the number of employees, sector and location, using the Census of Italian Firms as a benchmark. The SMF data include information about firm structure and behaviour, and balance sheet data for 12 years (1989-2000). Information about ICT expenditure is available for 1998-2000. For the empirical investigation we drew on information from the 2001 survey, which reports information for 1998 to 2000, while the lagged variables were calculated on 1995-1997. As only a fraction of the observations in these two waves overlapped, the available data cover 2,290 firms.

Table 1 presents descriptive statistics for the whole sample and various sub-groups. SMF data report the sources of investment financing, and gives information about public grants and fiscal incentives. This may be important when describing the processes governing technology adoption, especially as one sixth of investment is financed by various kinds of incentives.

The average firm size is about 80 employees. Firms receiving no investment subsidies are smaller than those that are granted a subsidy (69 vs 107). This fact is also confirmed if we take account of value added. For firms not receiving a grant the value added is 56% of the subsidised group. Subsidised firms are also more capital intensive, with a capital labour ratio value of about €200,000 per worker against €166,330 for non subsidised ones.

Not surprisingly firms receiving grants invest more: total investment as a share of value added is almost twice as high (0.24 vs 0.13). The differences in ICT investment are similar: the absolute value is 71% higher for subsidised firms, while it is 31% per worker for the unsubsidised group. When ICT investment is considered as a share of value added the difference was 1% in both groups.

These data are confirmed when the sample is split by firm size. Medium-large firms (LF) receive more subsidies than small ones (49% vs. 33%).

The last row of table 1 shows the amount of subsidised investment per worker. The sample average is €3,500 per worker, including the zero subsidised firms. On average a subsidised firm receives €9,230 in incentives per worker. No differences were found between small and medium-large firms.

1. Descriptive statistics – thousands euros

variable	Whole sample			Centre-South			North			Small firms			Medium-Large firms			Subsidized firms			Not subsidized firms		
	N	mean	sd	N	mean	sd	N	mean	sd	N	mean	sd	N	mean	sd	N	mean	sd	N	mean	sd
Number of employees (average 1998-2000)	2290	83.54	253.09	803	60.14	175.53	1487	96.18	285.62	1609	24.71	10.09	681	222.54	433.4	868	107.16	345.25	1422	69.12	172.93
Value added (average 1998-2000)	2290	4339.61	19001	803	2856.75	12247	1487	5140.3	21757.2	1609	1006.	649.0	681	12214.5	33555.7	868	5942.6	28202.3	1422	3361.12	9684.6
Value added (average 1995-1997)	2290	3519.95	12116	803	2396.72	9134	1487	4126.5	13418.3	1609	879.1	636.8	681	9759.28	20922.0	868	4677.49	17230.9	1422	2813.38	7349.3
Fixed capital per worker (average 1995-1997)	2261	179.12	230.64	785	190.36	291	1476	173.14	190.75	1581	162.2	233.1	680	218.35	219.97	864	199.8	237.87	1397	166.33	225.19
Fixed capital per worker (average 1998-2000)	2290	195.96	212.41	803	195	220.91	1487	196.47	207.76	1609	182.5	207.8	681	227.71	219.74	868	220.09	212.61	1422	181.22	211.02
Total investment (1998-2000)	2290	2096.46	9813.6	803	1593.33	7548.6	1487	2368.1	10834.4	1609	472.1	789.6	681	5934.21	17370.0	868	3244.23	13964	1422	1395.85	5904.8
Total investment on value added (1998-2000)	2290	0.17	0.41	803	0.19	0.31	1487	0.16	0.45	1609	0.17	0.46	681	0.17	0.23	868	0.24	0.3	1422	0.13	0.46
Total investment per worker (1998-2000)	2290	20.82	30.93	803	21.07	33.45	1487	20.68	29.49	1609	19.07	29.13	681	24.94	34.5	868	30.77	36.9	1422	14.74	24.76
ICT investment (1998-2000)	2290	114.81	408.78	803	76.75	314.38	1487	135.36	450.39	1609	26.48	49.04	681	323.5	703.37	868	154.16	504.24	1422	90.79	335.44
ICT investment on value added (1998-2000)	2290	0.01	0.02	803	0.01	0.02	1487	0.01	0.01	1609	0.01	0.02	681	0.01	0.01	868	0.01	0.02	1422	0.01	0.01
ICT investment per worker (1998-2000)	2290	1.17	1.8	803	1.05	1.74	1487	1.24	1.83	1609	1.05	1.75	681	1.47	1.9	868	1.38	1.9	1422	1.05	1.73
ICT investment on total investment (1998-2000)	2063	0.16	0.27	705	0.16	0.3	1358	0.16	0.26	1405	0.17	0.29	658	0.13	0.22	855	0.1	0.19	1208	0.2	0.31

1. Descriptive statistics – thousands euros (...)

variable	Whole sample			Centre-South			North			Small firms			Medium-Large firms			Subsidized firms			Not subsidized firms		
	N	mean	sd	N	mean	sd	N	mean	sd	N	mean	sd	N	mean	sd	N	mean	sd	N	mean	sd
Average short term regional interest rate (1998-2000)	2290	6.58	0.85	803	7.39	0.82	1487	6.14	0.43	1609	6.61	0.86	681	6.5	0.81	868	6.72	0.93	1422	6.49	0.78
Mark up 1997	2251	0.26	0.87	780	0.25	0.18	1471	0.27	1.07	1571	0.24	1.04	680	0.32	0.15	861	0.29	0.16	1390	0.25	1.1
White collar blue collar ratio (average 1998-2000)	2290	0.72	1.22	803	0.64	0.96	1487	0.77	1.34	1609	0.77	1.28	681	0.62	1.08	868	0.68	1.25	1422	0.75	1.2
Firm Reorganization (dummy=1 if firm has carried out a process of reorganisation)	2290	0.09	0.29	803	0.07	0.26	1487	0.1	0.3	1609	0.06	0.25	681	0.16	0.37	868	0.14	0.34	1422	0.07	0.25
R&D (dummy=1 if firm is engaged in R&D programs)	2290	0.41	0.49	803	0.36	0.48	1487	0.44	0.5	1609	0.32	0.47	681	0.63	0.48	868	0.48	0.5	1422	0.37	0.48
Firm age	2290	25.15	18.24	803	22.07	16.42	1487	26.82	18.94	1609	22.44	15.84	681	31.57	21.62	868	26.19	19.11	1422	24.52	17.66
Credit rationing (dummy =1 if firm is credit rationed)	2290	0.09	0.29	803	0.12	0.33	1487	0.08	0.27	1609	0.09	0.29	681	0.09	0.29	868	0.1	0.3	1422	0.09	0.29
Subsidies (dummy=1 if firm received subsidies to investment)	2290	0.38	0.49	803	0.44	0.5	1487	0.35	0.48	1609	0.33	0.47	681	0.49	0.5	868	1	0	1422	0	0
Subsidised investment per worker	2290	3.50	10.51	803	5.23	14.40	1487	2.57	7.49	1609	3.50	10.80	681	3.50	9.83	868	9.23	15.47	1422	0	0

3. The ICT adoption selection process

In this section we formulate an equation focusing on a range of firm-specific profiles that help to explain the intensity of ICT investment. Several cross-sectional analyses (Lichtenberg, 1995, Brynjolfsson and Hitt, 1995, Lehr and Lichtenberg, 1999, Black and Lynch, 2001, and Bresnahan *et al.*, 2002), find strong relationships between ICT and other factors within firms. We highlight several groups of factors that may influence a firm's decision to adopt new technology at a certain time. The relevance of micro analysis is supported by huge differences in behaviour, productivity, size and performance across firms and industries (e.g. ICT is not normally distributed). Firm level data are better for measuring certain aspects that are difficult to capture at the aggregate level, such as size, industry, age, location, etc.

The decision to adopt ICT may depend on different variables to those that affect the level of ICT investment. We can model this, considering two categories of firms, adopters ($I_{ICT}>0$) and non adopters ($I_{ICT}=0$):

$$I^*_{ICT,i} = \beta_1 + \beta_2 X_i + u_i$$

$$I_{ICT,i} = I^*_{ICT,i} \quad \text{if} \quad I^*_{ICT,i} > 0 \tag{1}$$

$$I_{ICT,i} = 0 \; if \; I^*_{ICT,i} \leqslant 0$$

The adoption decision, which represents the selection process, depends on the net benefit (B^*) the firm obtains from participating. B^* is a latent variable which depends on a set of variables Zj and a random term ε:

$$B^*_i = \delta_1 + \sum_{j=2}^{m} \delta_j Z_{ji} + \varepsilon_i \tag{2}$$

$$I^*_{ICT,i} = \beta_1 + \sum_{j=2}^{k} \beta_j X_{ji} + u_i$$

$$I_{ICT,i} = I^*_{ICT,i} \quad \text{if} \quad B^*_i > 0 \tag{3}$$

$$I_{ICT,i} \quad \text{unobserved if} \quad B^*_i \leqslant 0$$

The X variables may include some of the Z variables giving rise to identification problems. However, a sufficient condition for identification is that at least one of the Z variables is not also a X one.

In this model the expected value of *u* for an observation in the sample is its expected value conditional on $B^{*}>0$:

$$B_i^* > 0 \Leftrightarrow \varepsilon_i > -\delta_1 - \sum_{j=2}^{m} \delta_j Z_{ji} \tag{4}$$

$$E(u_i | B_i^* > 0) = E\left(u_i | \varepsilon_i > -\delta_1 - \sum_{j=2}^{m} \delta_j Z_{ji} > 0\right)$$

The net benefit B^* is greater than zero if ε satisfies the inequality. As in Heckman (1979):

$$E(u_i | B_i^* > 0) = E\left(u_i | \varepsilon_i > -\delta_1 - \sum_{j=2}^{m} \delta_j Z_{ji} > 0\right) = \frac{\sigma_{\varepsilon u}}{\sigma_\varepsilon}\lambda_i \tag{5}$$

where λ_i is the inverse Mill ratio $\lambda_i = \dfrac{f(v_i)}{F(v_i)}$ $\quad v_i = \dfrac{-\delta_1 - \sum \delta_j Z_{ji}}{\sigma_\varepsilon}$.

The f function is the density function of the standardised normal distribution and F is the cumulative standardised normal distribution.

To compute the expected value of I_{ICT} in this model we need to take into account the fact that the observation is in the sample:

$$E\left(I_{ICT,i} | \varepsilon_i > -\delta_1 - \sum_{j=2}^{m} \delta_j Z_{ji} > 0\right) \tag{6}$$

and substituting for I_{ICT} we obtain:

$$\begin{aligned} &E\left(I_{ICT,i} | \varepsilon_i > -\delta_1 - \sum_{j=2}^{m} \delta_j Z_{ji} > 0\right) = \\ &E\left(\beta_1 + \sum_{j=2}^{k} \beta_j X_{ji} + u_i | \varepsilon_i > -\delta_1 - \sum_{j=2}^{m} \delta_j Z_{ji}\right) \end{aligned} \tag{7}$$

Considering that the two first terms of I_{ICT} are not affected by taking expectations, and using (5) we get:

$$
\begin{aligned}
& E\left(I_{ICT,i} \middle| \varepsilon_i > -\delta_i - \sum_{j=2}^{m} \delta_j Z_{ji} > 0\right) \\
&= E\left(\beta_1 + \sum_{j=2}^{k} \beta_j X_{ji} + u_i \middle| \varepsilon_i > -\delta_1 - \sum_{j=2}^{m} \delta_j Z_{ji}\right) \\
&= \beta_1 + \sum_{j=2}^{k} \beta_j X_{ji} + \frac{\sigma_{\varepsilon u}}{\sigma_\varepsilon}\lambda_i
\end{aligned} \tag{8}
$$

If the random components in the selection process are distributed independently of the random component of the function for I_{ICT}, the population covariance of ε and u is zero and the last term in (8) drops out. However, it is possible that the random components are not independently distributed, because some of the unobserved characteristics affecting the decision to adopt ICT also influence the level of ICT investment. In this case, failing to consider the last term in (8) will yield inconsistent estimates caused by the omission of λ.

The model can be estimated under the assumption that ε **and** u are jointly distributed as a normal bivariate, either employing the Heckman two step procedure or maximum likelihood (MLE).

We estimated a two-equation ICT investment model employing MLE. The dependent variable in the selection process is a dummy with the value 1 for firms adopting ICT, 0 otherwise. This allows us to check whether the determinants of adoption are different from the determinants of how much to invest, and also to check for *sample selection* problems, which typically arise when a non-randomly sampled set of observations is used to make inferences about the whole population. In this latter case OLS would yield inconsistent estimates.

The selection equation is:

$$
\begin{aligned}
DUICT_i &= \alpha_1 + \alpha_2 AGE + \alpha_3 RATION \\
&+ \alpha_4 INNORG + \alpha_5 SUBS + \alpha_6 R\,\&\,D + \varepsilon_i
\end{aligned} \tag{9}
$$

The dependent variable is a dummy equal to 1 if firm i invested in ICT in the period. Among the regressors we employed firm age (AGE), a proxy of financial distress ($RATION$), and dummies for reorganisation ($INNORG$), subsidies ($SUBS$) and R&D.

The investment equation is:

$$
\begin{aligned}
\log(I^*_{ICT} | N)_i &= \beta_1 + \beta_2 \log(K|N)_i + \beta_3 INT_j + \beta_4 WCBC_i \\
&+ \beta_5 MKUP_i + u_i
\end{aligned} \tag{10}
$$

The dependent variable is the three-year ICT investment flow (I_{ICT}) over the number of workers (N). Among the regressors we include capital per worker (K/N), the average white collar:blue collar ratio ($WCBC$) and a measure of firm market power (*MKUP*). On a regional basis we also included the short term interest rate (*INT*, $j = 1, 2,\ldots,20$). ICT and divided capital variables by labour units in order to avoid dimension effects and log-transformations (see appendix for variables construction).

The capital intensity (*K/N*) is important since more capital-intensive firms may have a higher demand for ICT investment, assuming complementarity between ICT and non-ICT capital.

The variable *WCBC* is used to capture absorptive capacity linked to ICT. Since the knowledge required to master ICT is rapidly changing, a variable reflecting the level of skills within the firm may be a useful indicator. In order to make use of computers and related technologies, firms need a well-trained labour force. There is plenty of evidence (Autor *et al.*, 1998; Johnson, 1997; Bresnahan *et al.*, 2002, among others) that ICT goes hand-in-hand with a significant and generalised up-skilling of the workforce. This is reflected in the percentage increase in staff with upper-secondary education, which is higher than the change in the total working-age population. Greenan and Mairesse (2000) and Greenan *et al.* (2001) for example, found a positive correlation between the number of computers, and the percentage of administrative managers in France.

We explicitly included a measure of firm mark-up (*MKUP*) to establish the link between ICT adoption and firm market power. The expected sign is not unequivocal. Depending on the industry, firms with a certain degree of competitive advantage may find they do not need to increase their technology level.

AGE is employed as an explanatory variable in most studies of adoption behaviour (see Karshenas and Stoneman, 1995). One reason for including age is that there might be a positive impact on adoption in the case of older firms as specific (technological) experience might be accumulated (learning dynamics).

Some recent studies have revealed a complementarity between the adoption of new models, workplace organisation (*INNORG*) and the introduction of ICT (OECD 2001a, 2001b; Breshnahan *et al.*, 2002; Brynjolfsson and Hitt, 2000; Bertschek and Kaiser, 2004; McKinsey, 2001). Organisational advances directly increase productivity. Thus, it could be expected that the adoption of new work practices will be accompanied by intensification of ICT. A major problem related to investment in ICT capital may be the high degree of uncertainty of the results. Reorganising productive activities (in addition to workforce reskilling) helps to fully exploit the potential offered by the new technologies and to mitigate uncertainty in their use. However, the need for complementary investment might increase the costs of investing in ICT and result in low ICT accumulation. Financial constraints (*RATION*) are generally a reason for under-investment. Here we try to assess if they also constrain adoption of ICT capital. We use this variable to capture financial distress on a regional basis, since it represents a proxy for the firm's capability to access the credit market (see appendix for construction of the variables).

For similar reasons we also include government subsidies (*SUBS*). These are usually very significant in the general investment behaviour of firms and sectors.

The model is estimated as a cross-section. For reasons of endogeneity *K/N* and *MKUP* and *WCBC* are time lagged. The intercept term is replaced by 14 industry dummies using the ISTAT-ATECO classification. Although not completely satisfactory, this allows for some sectoral heterogeneity. The null hypothesis of independence is not accepted, suggesting the presence of a selection process.

Econometric analysis shows that labour composition, age, financial constraints, reorganisation, subsidies and R&D are good predictors of ICT investment decisions.

2. ICT adoption

	Whole sample	SF	MLF
	# obs. 2290 # Cens. Obs. 520 #Unces. Obs. 1770	# obs. 1609 # Cens. Obs. 437 #Unces. Obs. 1172	# obs. 681 # Cens. Obs. 83 #Unces. Obs. 568
Selection equation	Wald Chi ^{2} (18) = 774	Wald Chi ^{2} (18) = 399.2	Wald Chi ^{2} (18) = 346.7
AGE	0.0049	0.001	0.007
	(0.001)	(0.374)	(0.006)
RATION	-0.215	-0.207	-0.186
	(0.012)	(0.038)	(0.260)
INNORG	0.652	0.582	0.815
	(0.000)	(0.001)	(0.001)
SUBS	0.359	0.428	0.076
	(0.000)	(0.000)	(0.468)
R&D	0.491	0.484	0.357
	(0.000)	(0.000)	(0.001)
Depend. Vbl. log INVICT/N			
Log K/N $_{1995\text{-}97}$	0.070	0.055	0.078
	(0.000)	(0.019)	(0.014)
INT $_{1997\text{-}2000}$	-0.060	-0.077	-0.030
	(0.046)	(0.032)	(0.570)

MLE cross-section estimation.
Dependent variable in the selection equation ICT adoption dummy = 1 if firm invested in ICT during the 1998-2000 period. Dependent variable log INVICT/N= log ICT investment per employee. AGE: firm age. RATION: dummy = 1 if firm declared to be credit rationed (see appendix for further details). INNORGA: dummy = 1 if firm carried out a process of reorganisation. SUBS: dummy =1 if firm received investment subsidies. R&D: dummy = 1 if firm is engaged in R&D process. Log K/N: log average capital per employee during 1995-97. INT: short term average regional interest rate during 1998-2000. WC/BC: average white collar blue collar ratio during 1995-97. MKUP: firm mark up in 1997 (see appendix for further details). Intercept terms replaced by industry dummies. P-values in parenthesis.

2. ICT adoption (...)

	Whole sample	SF	MLF
WC/BC $_{1995\text{-}97}$	0.145	0.156	0.135
	(0.000)	(0.000)	(0.001)
MKUP $_{1997}$	-0.407	-0.373	-0.258
	(0.013)	(0.059)	(0.377)
Rho	-1.112	-0.987	-0.919
	(0.000)	(0.000)	(0.030)
L.R. of indep. equat. (Rho=0) Chi ^{2}	82.89	40.51	42.88

MLE cross-section estimation.
Dependent variable in the selection equation ICT adoption dummy = 1 if firm invested in ICT during the 1998-2000 period. Dependent variable log INVICT/N= log ICT investment per employee. AGE: firm age. RATION: dummy = 1 if firm declared to be credit rationed (see appendix for further details). INNORGA: dummy = 1 if firm carried out a process of reorganisation. SUBS: dummy =1 if firm received investment subsidies. R&D: dummy = 1 if firm is engaged in R&D process. Log K/N: log average capital per employee during 1995-97. INT: short term average regional interest rate during 1998-2000. WC/BC: average white collar blue collar ratio during 1995-97. MKUP: firm mark up in 1997 (see appendix for further details). Intercept terms replaced by industry dummies. P-values in parenthesis.

The investment equation results show that the decision about how much to invest in ICT depends on the capital output ratio (+), the regional interest rate (-), the white collar/blue collar ratio as proxy of labour composition (+) and the mark-up (-).

In line with what was expected small firms are more sensitive to regional interest rates. It should be noted that the variables RATION, SUBS and INT, are not significant for large firms. This is likely a sign of less severe financial constraints, and gives an interesting base for analysing the role of subsidies in ICT adoption.

4. The effect of subsidies on ICT adoption

The investment equations show that technology adoption may be strictly dependent on the availability of financial sources. The smaller the firm and the less developed its region's financial system, the more sensitive it is to the cost and the availability of credit. Given the domination of a system small and medium firms, Italy provides a litmus test of the effectiveness of investment subsidy policies on ICT adoption across industries.

In this paper, we address four main issues in evaluating policy efficiency: i) how much does subsidy affect overall investment? ii) do subsidies substitute for some other sources of finance, such as credit or internal funds? iii) how much does the proportion of subsidy to overall investments affect ICT spending? iv) do subsidies induce or replace ICT spending?

There have been several empirical studies attempting to estimate the impact of subsidies on R&D investment at firm level, but not to our knowledge, on ICT. The most common approach to this type of investigation is to employ a simple regression model in which an outcome variable (e.g. R&D or ICT spending) is regressed on the value of the incentive. In the presence of significant and positive elasticity of the outcome variable with respect to the subsidy one can say that such a link exists.

The regression approach, however, has a major drawback. To obtain a subsidy the firm needs to apply for it. The decision to grant the subsidy is made by government which takes into consideration a set of firm and project characteristics. It may be that there are unobservable variables that influence both the outcome and the decision to award a subsidy, giving rise to a non-zero correlation between public funding and the error term.

In order to address this issue we modelled participation of the firm in the incentive programme, based on the fact that the outcome "receiving a subsidy" depends on the decision of the firm to apply for it and on the decision of the government to grant it. In terms of investment, this means that, conditional on obtaining the incentive, the firm then decides the level of investment spending:

$$A = f_A\ (L,u) \tag{11}$$

$$G = f_G\ (Z,v) \tag{12}$$

$$Y_1 = g_1\ (W,\varepsilon_1) \tag{13}$$

$$Y_0 = g_0\ (W_0,\varepsilon_0) \tag{14}$$

where A is the expected probability of applying for an investment subsidy, and G the probability of the incentive being awarded, while Y_1 and Y_0 represent the ICT effort in both cases. The states associated with receiving the incentive and not receiving it are 1 and 0 respectively. L, Z and W are vectors of explanatory variables and u, v and ε the errors terms. A and G are usually unobserved, giving rise to a case of limited observability, where we observe who is granted a subsidy and who is not, regardless of their decision to apply for it. The first two equations become:

$$D = D_A{*}D_G = f_D\ (X,\phi) \quad \text{where} \tag{15}$$

$$D_A = 1 \text{ if } A > 0 \text{ and } D_A = 0 \text{ otherwise} \tag{16}$$

$$D_G = 1 \text{ if } G > 0 \text{ and } D_G = 0 \text{ otherwise}$$

This formulation implies that when $D = 1$ a firm has received the subsidy having applied for it. In equation (15) X is the set of firm characteristics affecting the decision of the firm to join the public funding programme and the decision of government to grant it. ϕ is an error term.

Y_1 and Y_0 are observed respectively for participant and non-participant firms. The evaluation problem is then one of missing data (Heckman *et al.*, 1998). The benefit of receiving the subsidy can be measured as the difference $\Delta = Y_1 - Y_0$ if we observe the two outcomes (investment effort) for the same firm. Observational data do not contain missing counterfactual Y_0 for subsidised firms, which needs to be inferred in some way from the sample.

A frequently used method is *matching* (Heckman *et al.*, 1998; Heckman and Navarro-Lozano, 2004). In the absence of experimental data, matching estimators are convenient in that they approximate a randomised experiment *ex post*. Angrist and Hahn (2004) show that matching is more efficient than the propensity score technique, while Smith and Todd (2005) provide a detailed evaluation of the performance of different matching estimators such as nearest neighbour matching, kernel and local linear matching, and difference-in-differences matching.

Matching estimations are characterised by the algorithm and the distance measure chosen (Augurzky and Kluwe, 2004). Smith and Todd (2005) show that with high quality data, rich in variables related to participation and outcomes, matching is the best choice.

The most common evaluation parameter is the mean effect of treatment on the treated, which gives us information about how much a treated firm (receiving the incentive) benefits compared to how much it would have done if not treated (i.e. not receiving a subsidy). The parameter is given by:

$$E(Y_1 - Y_0 | X, D = 1) = E(\Delta | X, D = 1) \qquad (17)$$

Using non-experimental data the parameter estimation is obtained assuming that conditional on X, (Y_1, Y_0) and D are independent:

$$(Y_1, Y_0) \perp D | X \qquad (18)$$

where $\perp$ denotes independence. This restriction, also known as “selection on observables” or unconfoundness, requires that the choice of participation is “purely random” for similar individuals (Abadie and Imbens, 2002).

In terms of our analysis this means that, given firms’ characteristics, if receiving the subsidies affects only the level of investment (total and ICT), but not the distribution of investment efforts across firms, we may construct the missing counterfactual (i.e. the behaviour of the firms that are in the programme, if they were not in the programme) using the outcomes (investment) of non-subsidised firms.

An identification assumption is also required. If all individuals with given characteristics choose to participate in the programme, there would be no observation for similar individuals that choose not to participate (Abadie and Imbens, 2002). Formally:

$$c < \Pr\,(D = 1 | X = x) < 1 - c \text{ for some } c > 0 \qquad (19)$$

In the terms first used by Rosenbaum and Rubin (1983), when both conditions are satisfied, the treatment is said to be "strongly ignorable", such that the non-randomised experiment can be treated as if it were a randomised one.

As pointed out by Abadie and Imbens (2002), these conditions are in many cases not satisfied, giving rise to some bias in the estimation. However, various studies make extensive use of matching methods (Rosenbaum and Rubin, 1985; Rosenbaum, 1995; Heckman *et al.*, 1998). Imbens (2004) reviewed various methods used to estimate the average treatment effect under the above assumptions, discussing the plausibility of the exogeneity assumption in economic application.

In order to consider the bias arising in the estimation of the average treatment effect we employ the routine provided in Abadie *et al.* (2004), which implements the specific bias-corrected matching estimator developed in Abadie and Imbens (2002). The methodology employs "nearest neighbour matching" for average treatment effect.

As discussed above, only one potential outcome is observed for each firm. Nearest neighbour matching calculates the missing potential outcome by taking average outcomes for firms with similar values for the covariates[1]. We use matching with replacement which allows a given non-subsidised firm to be matched more than once. Allowing replacement improves the quality of matches at the expense of the number of observations used to calculate the counterfactual mean, increasing the variance of the estimator (Smith and Todd, 2005). Although matching on a multidimensional set of firm characteristics (*X*) may give rise to a non-negligible bias, the matching approach combined with the bias adjustment procedure leads to estimators with little distortion.

We estimate the average treatment effect for the treated firms using total investment per worker or ICT investment per worker as the outcome variable. The treatment is a dummy $D_i = 1$ if the firm received a subsidy and $D_i = 0$ otherwise.

Unlike the propensity score approach, in which covariates need to determine the probability of receiving the treatment, the matching estimator considers only those characteristics that affect the outcome variable (the level of total investment per worker).

The choice of the matching variables is based on the following criteria:

1. firm specific variables that at the time of application were observable by the public agency and relevant to the decision to grant a subsidy;

1. Let $\|x\|_v = (x'Vx)^{1/2}$ be the vector norm with positive definite weight matrix V. $\|z - x\|_v$ is defined as the distance between the vectors x and z. Let $d_M(i)$ be the distance from the covariates for unit i, Xi, to the *Mth* nearest match with the opposite treatment. This is the distance that delineates strictly fewer than M units being closer to unit i than $dM(i)$, and at least M units being as close as $dM(i)$ (Abadie *et al.*, 2004).

2. variables that capture financial market disparities (i.e. regional interest rate);

3. variables that are statistically significant in the estimation of ICT adoption determinants.

For the first estimation the outcome variable is the logarithm of total investment per worker. The regressors used for the matching come from the two stage investment equation in section 3. They are: the logarithm of the average capital per worker in the previous period (1995-97), the average white collar:blue collar ratio (1995-97), the level of mark-up in 1997, the average regional short term interest rate during the three year period, a dummy R&D equal to 1 if the firm is engaged in R&D projects, and dummies for the Pavitt industry classification (Pavitt, 1984). Moreover, given Italian regional differences, we impose the dummy North to be constrained as an exact match, so that no firm from the North can be matched with one located in the Centre-South. This procedure gives a more homogeneous distribution of investment efforts among subsidised and non-subsidised firms since firms are matched only with firms that are similar in terms of investment determinants.

We estimate the average effect of treatment (ATT) on the level of total investment per worker (see Tab. 3.a). Given that data are expressed in millions of euros, the coefficient has an immediate interpretation: the overall effect of treatment amounts to €14,890 per employee. This simply means that treated firms would have spent less if they had received a grant.

Interesting differences are found if we consider small (SF) and medium-large firms (MLF) separately. While the treatment significantly affects investment by about € 7,500 per employee for MLF, the effect is much more significant, and more than the double for SF (€18,900). Considering that subsidised MLF receive around €7,000 per employee, one conclusion for this result is that public support may merely be a substitute for other kinds of financing.

In order to investigate this issue more deeply we estimate the treatment effect on the part of total investment financed by credit and by internal sources (Tab. 3.b and 3.c). The availability of low cost or totally free funds may help firms to overcome financial constraints improving their borrowing capacity or inducing entrepreneurs to direct cash flows to new finance capital acquisition.

Receiving a grant increases credit availability by €2,160 per worker, across the whole sample. We find that on average firms with grants invest an additional €2,430 of their own funds. In the case of the difference between SF and MLF, treated SF contributed €3,720 of internal financing, while investments by MLF were not significantly affected.

Firms in the sample receive on average €9,230 of incentive for investment (table 1), but they spend an additional € 4,600 (credit plus self

3. Average treatment effect on total investment*

a. Total investment for subsidised firms

Sample	# obs.	ATT	Std. Error	Z	P >| z |
Whole sample	2251	14.89	1.48	10.03	0.000
MLF	689	7.52	2.57	2.92	0.004
SF	1562	18.92	1.97	9.59	0.000

b. Total investment financed by credit for subsidised firms

Sample	# obs.	ATT	Std. Error	Z	P >| z |
Whole sample	2251	2.16	0.69	3.11	0.002
MLF	689	1.89	1.27	1.49	0.136
SF	1562	2.29	0.72	3.15	0.002

c. Total investment financed by internal sources for subsidised firms

Sample	# obs.	ATT	Std. Error	Z	P >| z |
Whole sample	2251	2.43	0.86	2.83	0.005
MLF	689	0.80	1.28	0.63	0.531
SF	1562	3.72	1.07	3.47	0.001

* ATT obtained with nearest neighbour matching estimator, with bias correction and controlling for heteroskedasticity (Abadie *et al*, 2004). Treatment variable: dummy=1 if firm received a subsidy to total investment and 0 otherwise. Outcome variable: logarithm of total investment per worker [log (I/N)]. Matching variables: logarithm of the average capital per worker in the previous period (1995-1997) [log (K/N) $_{1995\text{-}97}$]; the average white collar blue collar ratio in the previous period [$WC/BC_{\ 1995\text{-}97}$]; the level of mark-up in 1997 [$MKUP_{\ 1997}$]; the regional average short term interest rate during the period 1997-2000 [$INT_{\ 1997\text{-}2000}$]; a dummy R&D = 1 if the firm is involved in R&D projects and 0 otherwise; dummy North= 1 if the firm is located in a northern region. North is constrained to be an exact match.

financing and venture capital) which they would otherwise have not invested. Therefore, more than 90% of the overall effect of subsidies (€14,890) is attributable to the direct effect of the subsidy (61%) and to a spill-over effect (31%) on credit and internal financing.

We now turn to the effect of incentive policy on ICT. Even though we have no information about the level of incentives specifically for ICT investment, it is possible to test whether the availability of costless financial resources increases technology adoption.

The matching estimator is calculated using as the outcome variable the logarithm of ICT investment per worker, and the same set of covariates as before.

4. Average treatment effect on ICT investment for subsidised firms.*

	Sample	# obs.	ATT	Std. Error	z	P >| z |
1	Whole sample	2251	**0.248**	0.087	2.86	0.004
2	Medium and Large firms (MLF)	689	**0.054**	0.161	0.34	0.737
3	Small Firms (SF)	1562	**0.336**	0.099	3.37	0.001

* ATT obtained with nearest neighbour matching estimator, with bias correction and controlling for heteroskedasticity (Abadie *et al*, 2004). Treatment variable: dummy=1 if firm received a subsidy to total investment and 0 otherwise. Outcome variable: logarithm of ICT investment per worker [log (I_{ICT}/N)]. Matching variables: logarithm of the average capital per worker in the previous period (1995-1997) [log (K/N) $_{1995\text{-}97}$]; the average white collar blue collar ratio in the previous period [WC/BC $_{1995\text{-}97}$]; the level of mark-up in 1997[MKUP $_{1997}$]; the regional average short term interest rate during the period 1997-2000 [INT $_{1997\text{-}2000}$]; a dummy R&D=1 if the firm is involved in R&D projects and 0 otherwise; dummy North=1 if the firm is located in a northern region; dummies for Pavitt industry classification. North is constrained to be an exact match.

In Table 4 the average treatment effect for those treated (ATT) is reported in row 1: receiving the subsidy has a positive effect on the receiving firms, increasing ICT investment per employee by €248. The estimation confirms that aids to investment have a positive and significant effect on ICT. Had the subsidy not been granted the treated firms would have invested less in ICT.

Rows 2 and 3 of the table take account of firm dimension. Again we find that SF receive a significant and greater benefit from receiving a subsidy. In the absence of a subsidy SF would have invested less (€336 per worker), while for MLF receipt of the subsidy had no effect. The non-significance of the parameters for these firms may be due to a substitution effect, since it is likely that exploitation of other sources of financing is reduced as a result of receiving the subsidy. This clearly suggests that the incentive policy should be directed to SF since they make much more efficient use of subsidies.

The fourth question relates to how much of the grant to total investment spills over to technology spending. Even if the subsidy is not specifically for ICT, it has a beneficial effect on its adoption as it eases the firm's financial constraints. The impact of subsidies on ICT is only 1.3% of the overall effect, which is quite small considering that expenditure on ICT represents 16% of total investment (see Table 1 for descriptive statistics). Although not specific, grants have a widespread benefit on ICT, supporting the introduction of specifically designed policy promoting technology adoption. This would be particularly effective and desirable for SF.

5. Conclusion

Using a sample of Italian firms this paper has investigated the effect of subsidies on investment. The overall effect of subsidies is found to be positive, implying that firms would have invested less had they not received public support. Grants affect investment by boosting internal and external (credit market) financial sources and increasing firms' financial capacity. Interestingly, these effects are strongly dependent on firm size. Small firms seem to make the best use of grants while for medium and large firms subsidies seem to be merely a substitute for more costly sources of finance.

The study looked at the determinants of and the effects of subsidies on ICT spending. We find that the decision to adopt is positively correlated with age, workplace organisation, R&D and subsidies, while it is negatively affected by credit constraints. The decision about the extent of ICT adoption is positively linked to capital per worker ratio, and worker structure and negatively linked to regional interest rates and mark-up. A dominant position in the market seems to slow down the introduction of new technologies.

In exploring the effect of subsidies on the level of a company's ICT expenditures, we found that the global effect of incentives is positive. Again, differences in ICT adoption are closely related to firm size. For small firms, there is no crowding out of private investment, which is not the case for medium-large firms, since they are likely to adopt ICT regardless of government support. Given the characteristics of the Italian productive system these results appear to be particularly relevant.

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APPENDIX

1. Selection equation

$$DUICT_i = \alpha_1 + \alpha_2 AGE + \alpha_3 RATION + \alpha_4 INNORG + \alpha_5 SUBS + \alpha_6 R\&D + \varepsilon_i$$

AGE: firm age at the end of period (2000)

RATION: in the SMF there are three questions that can be used to directly evaluate the firm's access to the credit market: 1) whether at the current market interest rate the firm wants an additional amount of credit; 2) whether the firm is willing to pay a higher interest rate to obtain that additional credit; 3) whether the firm applied, but the credit was denied. *RATION* is a dummy = 1 if the firm answers yes to the second or third questions. It is a proxy for firm financial distress.

INNORG: dummy = 1 if firm has undertaken a process of reorganisation during the period.

SUBS: dummy = 1 if firm received a subsidy or a tax reduction.

R&D: dummy = 1 if firm has positive R&D outlays.

2. Investment equation

$$\log(I^*_{ICT}|N)_i = \beta_1 + \beta_2 \log(K|N)_i + \beta_3 INT_i + \beta_4 WCBC_i + \beta_5 MKUP_i + u_i$$

I_{ICT}/N: investment per worker. N is the average number of employees during the period.

K/N: gross book value of fixed assests per worker.

INT: average short term interest rate at regional level during 1998-2000.

$WCBC$: white collar:blue collar ratio.

$$MKUP = sales_{i,1997} + (\Delta inventories_{i,1997} - intermediate\ inputs_{i,1997}) / (sales_{i,1997} + \Delta inventories_{i,1997})$$

Firm mark-up in 1997.