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ICT Adoption and Diffusion in Italian manufacturing firms

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Abstract. This paper sets out the results of econometric analysis carried out on a closed sample of 519 Italian manufacturing firms in order to determine which variables affected the probability of a firm investing in ICT in the period 2001-03, and which variables have an impact on the level of ICT investment. The estimates bear out a great many of the theoretical predictions and empirical findings, while also casting new light on the role of vertical integration in accounting for higher levels of ICT investment.

Key words: Firm organisation, Information and Communication Technologies, Vertical Integration

Classification Jel L230, O300

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1.Introduction

According to the Istat survey on information and communication technologies in firms with staffs of at least 10 active in the industry and services sector, by January 2007 the diffusion of computers, e-mail and Internet connections had reached practically all the firms, regardless of size and location. Thus, within a span of seven years, the process of basic computerisation of Italian firms seems to have arrived at its conclusion. Nevertheless, on closer examination the same Istat survey shows a rather more limited diffusion and greater differentiation between firms and industries when it comes to the more sophisticated applications such as the software set used to integrate firm process: LAN (*Local Area Networks*); Intranet; EDI (*Electronic Data Interchange*); ERP (*Enterprise Resource Planning*); MRP (*Material Resource Planning*); SCM *(Supply Chain Management)*; and CRM *(Customer Relationship Management)*. The evidence shows Italian firms behind in adjusting to the new technological standards – a lag to be counted among the major causes of the decline in total factor productivity over the five-year period 2001-06 (Rossi, 2007).

It is therefore of primary importance to see which variables determine the diffusion and extent of adoption of the new technologies, and indeed the issue is drawing increasing attention. In the case of the Italian firms, the shortage of empirical evidence denounced in the early years of the new century has since been made up thanks to contributions by Arduini *et al*. 2006; Atzeni and Carboni, 2006a; Bugamelli and Pagano, 2004; Fabiani *et al*., 2005; Giunta and Trivieri, 2007; Giuri *et al*, 2008; Neirotti *et al*., 2008; Rossi, 2003; and Trenti and Chiarvesio, 2006. By far the majority of these contributions assume firm heterogeneity reflecting differences in assessments of the potential profitability of ICT investment, with the consequence that the greater the advantage to be expected with ICT investment, the greater will be the propensity to invest ahead of other firms (diffusion among firms) and make more intensive use of ICT (use within the firm) (Hollenstein, 2004, 317-8). The heterogeneity of the agents implies that the structural and organisational characteristics are significant factors in accounting for ICT adoption and extent of application within the firm.

Our paper is to be understood in terms of this debate, and within the setting of studies so far published on these issues it represents a twofold contribution. In the first place, firm behaviour in the field of ICT investment is assessed in terms of both the probability that the firm will invest in ICT and the propensity to do so (level of ICT investment per employee). This choice led to distinction in the econometric analysis of the variables that influence a firm's decisions (to invest or not) from those that have an impact on the amount of ICT investment. As we will see, this is justified by the fact that the explicative variables are significantly different.

Secondly, with the introduction of a simple model our paper casts light on the relationship between ICT and vertical integration – a relationship that had yet to be adequately examined, above all with reference to Italian firms. Our working hypothesis is that, should there be complementarity between ICT investments, in the upstream and downstream phases, for two firms, then this very complementarity will favour ICT investments. The results of the estimations bear out what the model suggests, i.e. that a reduced degree of firm vertical integration can imply suboptimal ICT investment. This is only a preliminary finding that needs finer definition, but it does imply that the – on average –low vertical integration of Italian firms, which has characterised the model as from the early 1980s, entails a level of ICT investment lower than is to be seen in other countries.

The data used are drawn from the Capitalia triennial survey on Italian manufacturing firms for the periods 1995-97, 1998-2000 and 2001-03; econometric analysis is carried out on a closed sample of 519 firms. Although numerically limited, the closed sample also enables us to make use of the time variable of the phenomenon under analysis, verifying for possible persistence effects in the investment decisions. The paper is structured thus: the following section (§2) provides a concise examination of ICT adoption determinants. With the help of a model, the third explores the relationship between vertical integration and ICT, while the fourth illustrates the econometric technique and the results of the estimations; our conclusions are set out in the last section (§ 5).

2. Adoption and propensity to invest in ICT: a brief overview of the theoretical and empirical literature.

In this section we look into the theoretical predictions and empirical findings regarding certain structural and organisational characteristics that prove – especially in the case of Italian firms – most relevant in accounting for ICT investment decisions and propensity.

Size

As we have seen, ICT diffusion is by now well advanced within the economic system, to the extent that firm size no longer has any influence on basic computerisation, i.e. use of PCs, e-mail and website. However, size still represents a decisive variable when it comes to complex applications. The positive correlation between size and ICT is in the first place fruit of a "Schumpeterian" effect (Schumpeter 1934): the larger firms have greater resources to invest in technological innovations and, thanks to a higher absorption capacity, are better equipped to appropriate the resulting returns. Secondly, favouring size is the fact that use of ICT calls for considerable formalization of procedures and information/communication systems, normally somewhat lacking in small firms (Fabiani *et al*., 2005), where informality tends to characterise exchanges. Moreover, as we will be seeing in greater detail, the presence of complementarity between ICT, level of human capital and reorganizational processes, without which the ICT productivity hikes cannot be concretized marked, does not in practice favour small firms (Giuri *et al*., 2008).

Human capital and reorganisation processes

It is argued in a great many studies that ICT yield gains in efficiency and productivity only when accompanied by organisational changes both within the firm and in exchanges with other firms. What makes internal and external reorganisation necessary is the fact that ICT bring changes in the forms and rates of information transmission. ICT can entail the need for flatter organisational structures with reduction in the hierarchic levels and wider-reaching control over each level (Trento and Warglien, 2003). In addition, ICT entail training and specific skills for the workers – hence the connotation of ICT as skill-biased technological change. It may then be reasonably conjectured that firms with good levels of human capital will be the first to use, and subsequently make more intensive use of, ICT due to the fact that their workers show a greater capacity to absorb the new technological paradigm. In other words, at the theoretical level a close link is hypothesized between ICT adoption, organisational changes, level of human capital, a so called "micro-complementarity", proposed in a great many contributions (to begin with, Bresnahan, 1999 and, subsequently, Bresnahan *et al.*, 2002; Brynjolfsson *et al.*, 2002; Gretton *et al.*, 2004), which constitutes the prerequisite to be able to concretise the productivity gain that ICT could generate.

As for the empirical findings, what emerges unequivocally are: i) the positive link between level of human capital and ICT adoption (for the Italian firms, see Becchetti *et al.*, 2003; Lucchetti and Sterlacchini, 2004; Fabiani *et al.*, 2005);

ii) the inverse correlation between incidence of blue collars in the firm's staff and ICT diffusion (Atzeni and Carboni, 2006b; Bugamelli and Pagano, 2004; Giunta and Trivieri 2007). On the other hand, somewhat contradictory evidence emerges on the impact of organisational change and use of ICT. The problem seems to lie mainly in the poor quality of the data used as proxy for organisational change, suggesting that the lack of real significance may be due to the choice of an inadequate proxy (Bugamelli and Pagano, 2004; Trento and Warglien, 2003; Giurì *et al.*, 2008).

Age

Firm age is frequently used in the theoretical literature on adoption of a new technology (Karshenas and Stoneman, 1995), while relatively few studies take firm age into consideration as explicative variable in the specific case of the new technology being represented by ICT. The theoretical arguments on the impact exerted by age do not lead to univocal evaluations. Positive age impact may reflect technological experience (and is indeed thus used in the empirical analysis by Atzeni and Carboni, 2006b), although it may come up against organisational adjustment costs, higher in the older firms with more consolidated routines (Hollenstein, 2004, 320). In this respect, by virtue of the role played by organisational changes Gambardella and Torrisi (2001) hypothesise that young firms are more inclined to adopt ICT, being less averse to setting about the organisational changes entailed by "micro-complementarity".

Geographical location

The country is divided into geographical macro-areas to detect whatever territorial differences there may be in the diffusion of ICT at the firm level. Here a role is played by the adoption differentials already observed both for the Southern Italian firms, as noted by Atzeni and Carboni (2006b; Giunta and Trivieri, 2007) and for the firms located in the industrial districts, in the regions of the North-East-Centre. In fact, Trento and Warglien (2003) observe that procedures for the exchange of information among the district firms, whether circulating within or outwards, are essentially informal, thus making less use of ICT. However, more recent studies (Trenti *et al.*, 2006, on a sample of 619 firms located in 41 industrial districts) point to a more intensive and sophisticated use of ICT, although this seems to be the prerogative of groups of firms showing high growth dynamics, and more outward looking in terms of both final markets and exchanges with other firms. This is a point we shall be looking into more closely later on. Finally, Fabiani *et al.*, 2005, find no significant difference in adoption between district firms and firms located in other parts of the country.

Subcontracting

The last fifteen years have seen increasing fragmentation of production coming about with the outsourcing of significant segments of the productive process to other firms outside the country[1] – a process that has undoubtedly been catalysed by ICT. In fact, with codified and, consequently, transmittable knowledge, ICT favour operation through a long production network thanks to a series of applications that cut the costs of coordination between units in the network and ease off "space friction", making geographical proximity between firms less of a binding necessity. For at least ten years this phenomenon has also been developing in Italy, where the division of labour between firms has been one of the major features of the organisational pattern. From this point of view, one might expect that the greater the proportion of turnover involving subcontracting activities, the more frequent and intensive should be the exchanges with other firms, and thus the greater the advantage of using coordination technologies such as ICT. This implies a positive correlation between ICT investment and the proportion of turnover accounted for by subcontracting activities. Such, for example, is the finding of Lucchetti and Sterlacchini (2004).

The positive correlation may depend not only on manufacture in subcontracting per se, but also on the type of industry the firm works in and the position it occupies in the value chain. For example, in a considerable number of

[1] The complex of phase sequences and activities necessary for the production of a final good has progressively been falling into the pattern of a value chain with global extension. By value chain we mean the series of activities for the final production and subsequent sale of a good. When the subdivision of activities calls for the contribution of firms located in different parts of the world, the value chain is said to have global extension.

industries, including for example the automobile and aeronautic industries, the division of labour between firms is organised hierarchically, in a pyramid structure with the big firm attending to coordination. The "head" of the value chain plays the role of "standard maker" and decides on the applications to be adopted by the various segments of the chain to reduce costs in the exchange of information. "For the suppliers, the choice of ICT investments thus depends largely on the needs of coordination with the choices of other firms in the chain, and this network externality reduces uncertainties about the standards to adopt, limiting investment risks" (Trento and Warglien, 2003).

Trenti *et al*. (2006) find that the position in the value chain also has a significant impact; firms in contact with the final markets are, in fact, more inclined to make greater investment in ICT. Nevertheless, as is demonstrated by various studies on the relationship between subcontracting and profitability (Kimura, 2002; and, for the Italian case, Giunta, Scalera, 2007), subcontracting activity is often performed by marginal firms, positioned in the lower levels of the value chain, showing relatively simple functional structures and scant technological endowment. In such cases we might even expect a negative relationship between subcontracting activity and ICT adoption.

3. Vertical integration and ICT investment

Over and above the issues discussed in the previous section, another point emerging from the literature as important is the interaction between vertical integration and ICT investment. In fact, some scholars have found an inverse relationship between ICT investment and vertical integration (Brynjolfsson, Malone, Gurbaxany and Kambil, 1994; Hitt, 1999). The theoretical justification for this finding is that ICT reduces the costs of external coordination with the suppliers (Malone, Yates and Benjamin, 1987; Gurbaxani and Whang, 1991; Clemons and Row, 1992), cuts transaction costs and thus favours vertical disintegration of the firm.

ICT certainly reduce the costs of use of suppliers, which account for a significant part of the transaction costs, but this does not seem in itself sufficient to hypothesise that ICT adoption can entail, *tout court*, a reduction in vertical integration. In our opinion, ICT fail to reduce many of the costs involved in drawing up contracts with outside agents (subcontractors and suppliers, in the first place), decisive in transaction cost theory (suffice it to recall the situations that arise from contractual incompleteness). In particular, it is the *ex post* costs, associated with the contemporaneous effects of bounded rationality and opportunism, that do play a highly significant role in Williamson's theory of vertical integration, and which do not appear to be appreciably affected by ICT.

Moreover, according to the transaction theory of Coase (1937) and Williamson (1975), it is the differential between coordination costs and transaction costs that determines, *coeteris paribus*, whether a transaction will be performed within the firm or outside. We may therefore reasonably suppose that ICT contributes to bringing down internal coordination costs just as it does in reducing market use costs. To take just two examples, the possibility of hierarchical organisation in receiving and processing the internal information flow is undoubtedly enhanced by ever growing computer calculation capacity and ever more sophisticated software. Thanks to this capacity, moreover, improved monitoring can be made of the performance of the individual employees and appropriate incentive measures, for example, can be proposed.

Indeed, apart from explaining the effect of ICT on levels of integration, the same arguments can be taken to illustrate why firms invest in ICT. ICT investments can be viewed in terms of any new technology which is adopted if the additional investment is less than the present value of saving determined by the lower operating costs to be borne. In our case such costs obviously comprise both the transaction costs and the costs of internal coordination. In terms of reduced costs, as demonstrated in the literature examined in the previous section, the advantages of ICT will be all the greater in proportion to the organisational changes made in the firm. With this approach we can also appreciate the effects of ICT on vertical integration and the advantage there may be in investing in ICT.

As for the advantageousness of investing in ICT, it cannot be argued *a priori*, using transaction cost theory, turnover being equal, whether it is greater in a vertically integrated firm than in a disintegrated one. ICT reduces both transaction and coordination costs, but we cannot tell *a priori* whether the differential between the two costs narrows or widens. If coordination costs decrease more than transaction costs, it will be the vertically integrated firms that reap the major benefit and vice versa. It may also be that this differential is diversely affected according to the levels from which vertical integration is started.

There are, moreover, various other reasons to argue that vertically integrated firms invest more in ICT than the disintegrated firms. This is an aspect than can be analysed with simple reasoning. Let us take the case of a component necessary for the production of a final good, and let us assume that improvement can be made in the typology of the good thanks to co-design activity between producer (firm or department within a vertically integrated firm) and user for production of the final good. Co-design calls for electronic exchange of data and platforms shared between the two parts. To produce the component, the engineers of the client and supplier firms must get involved in close, intensive communication. Thus the need is for both parties to invest in ICT before the component can be produced. The greater the ICT investments made by the two parties, the higher will be the quality of the component produced. Moreover, the quality of the component produced will only be known after the ICT investments opening up communication between the two parties have been made.

Let us now go on to consider the case of two disintegrated firms, one supplying a certain input and one producing the final good or service. Let us assume that the two parties undertake to trade the good at a certain price, but that, if an improvement in productivity is achieved thanks to the organisational and technological endeavours of the two parties, then the supplier firm is awarded percentage α of the accomplishment, which can translate into an increase in the value of the improvement due to technological progress. Should the case be, as often it is in many sectors, that marked technological complementarity holds between component and final product, for the improvement to be brought about technological progress must be introduced in both the supplier and the client firm. Let us take the value of the improvement in the component to come to V and that it will be all the greater the higher the ICT investments made by both the supplier and the client firm.

Let us compare this situation with the case of a vertically integrated firm. The idea is that the vertically integrated firm will know the effects that can accrue to it in terms of improvement due to investments by both producer and user of the component. Should the firms be producing in the disintegrated mode, they will know only the effects that can accrue from the investments they make in their own activities, for production of both the component and the final good.[2]

These differences influence the incentives to invest in ICT, depending on whether the firms show vertically integrated or disintegrated organisation.

Let $V=f(ICT_x, ICT_y)$ where ICT_x and ICT_y represent the sum of investments made by firm x and firm y, and V the increase in value deriving from these investments.

The profits of the vertically integrated firm, supposing the improvement is achieved will be, in comparison with normal profits,

$$\pi_{x+y} = Vf\left(ICT_x, ICT_y\right) - ICT_X - ICT_y \qquad (1)$$

The vertically integrated firm producing both the component and the final product can decide on the investment to be made in turning out both the final product and the productive component. Let us, then, maximize the profit relatively to investment in ICT in production of the factor and of the final product. The first-order conditions can be written as

$$\frac{\partial \pi_{x+y}}{\partial ICT_x} = \frac{\partial V}{\partial ICT_x} - 1 = 0$$
$$\frac{\partial \pi_{x+y}}{\partial ICT_y} = \frac{\partial V}{\partial ICT_y} - 1 = 0 \qquad (2)$$

Let us now take the case of two vertically disintegrated firms. Neither of the firms will know the effects resulting from investment by the other firm, and each will therefore maximize profits in relation to the only investment variable it controls. We will then have

[2] Our argument begins with the issue of the appropriability of the results of innovations and follows the lines pursued in the contributions by Holmstrom (1982) and Tirole (1998), which show how the distribution of authority affects the division of gains deriving from trade and so on the incentive to invest. V indicates the extra valuation that can be derived in trade when investments are made, as compared with normal gains.

$$\pi_x = \alpha V\left(ICT_x, ICT_y\right) - ICT_x \qquad (3)$$

$$\pi_y = (1-\alpha) - V\left(ICT_x, ICT_y\right) - ICT_y \qquad (4)$$

Maximizing, the first-order conditions are obtained

$$\frac{\partial \pi_x}{\partial ICT_x} = \frac{\alpha \partial V}{\partial ICT_x} - 1 = 0$$

$$\frac{\partial \pi_y}{\partial ICT_y} = \frac{(1-\alpha)\partial V}{\partial ICT_y} - 1 = 0 \qquad (5)$$

respectively for firm x and firm y.
Let us conjecture that the value of V grows with growing investments, $V'_{ICT_x}\, eV'_{ICT_y} > 0$ but shows decreasing returns on the investments $V'_{ICT_x}\, eV'_{ICT_y} < 0$

In this case it is clear that the sum of investments ICT_x+ICT_y made by the disintegrated firms falls below that of the vertically integrated firm.
Let us take an example considering $V = \sqrt{ICT_x} + \sqrt{ICT_y}$.
From the first-order conditions for the vertically integrated firm we will see that the optimal values of ICT_x and ICT_y are

$$ICT_x = \frac{1}{4}$$

$$ICT_y = \frac{1}{4}$$

so that

$$ICT_x + ICT_y = \frac{1}{2}$$

In the case of disintegrated firms, from the first-order condition we have

$$ICT_x \frac{\alpha^2}{4}$$

$ICT_y = \left(1-\alpha^2\right)\frac{1}{4}$ so that

$$ICT_x + ICT_y = \frac{\alpha^2 + 1 + \alpha^2 - 2\alpha}{4} = \frac{2\alpha^2 - 2\alpha + 1}{4}$$

and for $0 < \alpha < 1$

$$\frac{2\alpha^2 - 2\alpha + 1}{4} < \frac{1}{2}$$

This indicates that the sum of two vertically disintegrated firms' ICT investments will come short of that of a vertically integrated firm, and this is all the more so in the case of a vertically disintegrated firm producing for the final market. In this model the vertically integrated firm invests more in ICT and shows a higher value for V than the vertically disintegrated firms[3].

This model does not imply that the vertically integrated firms are more efficient than the non-integrated firms, but simply that the complementarity in ICT investments in the upstream and downstream stages favours ICT investments in the vertically integrated firms. Obviously, if the vertically integrated firm is less efficient than the two disintegrated firms, for example on account of high coordination costs, and the value of the improvement in the integrated firm comes short of the value that could be obtained in two disintegrated firms, then the value of the vertically integrated firm's ICT investment could prove less than that in the two vertically disintegrated firms.

4. Econometric analysis

The data used in the empirical analysis are from the Survey on manufacturing firms carried out by Capitalia; in particular, the sample was drawn from the last three data collections, with a time span thus running from 1995 to 2003. The initial dataset was reduced in order to have as unit for analysis only the firms answering in all three surveys, with the result that the sample upon which econometric analysis was eventually carried out consisted of 519 firms. Although numerically limited, the closed sample offered the possibility to make use also of the temporal variability of the phenomenon under analysis, verifying for the presence of persistence effects in investment decisions. The firms answering the question on the amount of ICT investment made in the three-year period were: 474 in the 1995 – 1997 survey; 476 in the 1998 – 2000 survey; and 420 in the 2001 – 2003 survey. From the original sample we eliminated 4 firms for the first survey, 5 for the second and 3 for the third, as they

[3]It is worth noting the analogies of the results obtained with those obtained by Bresnahan- Trajtenberg (1995) in a model in which there is a sector (semiconductors) which produces "General Purpose technologies"(GPT) and a great many application sectors (AS) that use them. This model shows a divergence between the social optimum, entailing higher levels of investment, and a decentralized Nash equilibrium. The cause for this divergence lies in the complementarity between the levels of innovation pursued in the various sectors and the feedback effects the innovations generate. The firms in each AS application sector and GPT sector innovate only if there is a mechanism allowing for appropriation of the social surplus. The problem is that the incentive for innovation downstream, in a decentralized equilibrium, is too low, and consequently neither of the firms upstream or downstream has sufficient incentive to innovate.

showed ICT investment and total investment values departing wide of the other firms' values.

Table 1 sets out some descriptive statistics calculated for the sample employed and the entire dataset from which the sample was drawn. As far as periods 1995-97 and 1998-2000 are concerned, it emerges that the sample extracted consists of firms showing characteristics very similar to those of the entire set of firms on which the Capitalia survey was conducted. For example, the ratio between turnover per employee in the closed sample and that for all the firms is 0.92 for the three-year period 1995-97 and 1.09 for the following triennium. On the other hand, in the case of the 2001-03 period the ratio comes to 0.75 with corresponding ICT investment per employee value of 0.72. Thus on average, and in particular in the last survey (2001-2003), the firms we analysed invested in ICT less than observed in the Survey. Finally, with regard to the value added, the ratio is greater than 1 for the 1998-2000 survey, and slightly less than unity in the last survey. In general, however, the ratio values differ little from 1.

Table 1 – Sample selection

	ict ratio	**va ratio**	**to ratio**
1995 - 1997	0.88	1.01	0.92
1998 - 2000	0.95	1.19	1.09
2001 - 2003	0.72	0.91	0.75

Legend: **ict ratio** is the ratio between average ICT investment per employee in the closed sample and the average calculated for the entire dataset. Similar definitions apply to the other ratios: **va** is the value added per employee and **to** the turnover per employee.

The explicative variables involved in the analysis are:

- Total value added;
- Total turnover;
- Proportion of turnover accounted for by subcontracting activities;
- Proportion of blue collars workers;
- Average years of education per employee;
- Degree of indebtedness (current and medium-long-term liabilities/ capital invested);
- Age (number of years as from incorporation);
- Dummy R&D;
- Investment in machinery and equipment per employee;
- Dummies for sector (Pavitt Classification), geographical area and legal form.

All the monetary variables are given in millions of Euros. The value added (VA) and total turnover (Tto) find their place in the estimated specifications such as to capture at the same time the twofold dimension-organization effect which we consider relevant in accounting for ICT investment and, moreover, to take into account the non-linear nature of the effect. In particular, the various equation estimated have as dependent variable ICT investment per employee and as determinants VA and VATO where VATO is the product of VA and TtO:

$$ICT = a + bVA + cVATO + Other$$

To appreciate the significance of the preceding relationship note that the marginal effect of the greater total value added, for a given turnover value, is measured with coefficients *b* and *c* and is equal to " b+cTto". Given the total turnover value, the preceding expression can thus be interpreted as the impact that a higher value added/turnover ratio, and so a higher degree of vertical integration, has on ICT investment. As we will see later on, this variable will prove particularly significant in accounting for the level of investment per employee, while it will not prove decisive in accounting for a firm's choice to invest in ICT. Since our specification takes into account the product between value added and turnover, this implies the possibility to capture a non-linear effect of firm size – measured by the level of turnover – on ICT investment, degree of vertical integration being equal.

Let us take the case, for example, of a given value added/turnover ratio by virtue of which the level of vertical integration is constant regardless of the size value. The preceding equation implies a quadratic relationship between investment and turnover, taking a shape like an inverted U if parameter *c* is less than zero. Thus, for each value of the value added percentage with respect to turnover, we have a curve that we may interpret as an "iso-organization" curve. If, then, we interpret the value added-turnover ratio as indicator of vertical integration, we see that, as the ratio grows, so we move up on a higher "iso-organization" curve: thus, the greater the vertical integration, the higher will prove the level of ICT investment per employee.

To verify that a higher value added captures a dimension-organization effect on ICT investment, and not, rather, a greater readiness to make investments in general, we also take account, in the control variables set, of the level of investment in machinery and equipment per employee (Inv_emp). However, the results prove similar with or without this control variable.

Finally, to verify the possibility that investment decisions are characterised by persistence effects we took into account the lag in the dependent variable. As further proxy of the firm's organisational structure we also considered the proportion of turnover deriving from subcontracting (Subto)

The other regressors considered are prompted by the empirical literature mentioned above, and thus have the same justifications. For human capital we used the average years of education per employee (education_emp) and a positive correlation with ICT is to be expected. We also verify for the proportion of blue collar workers in the total of employees (blue-collars_emp), for which the relevant literature finds a negative correlation with ICT investment. With regard to the financial situation of the firm, we included a debt measurement (debt), given by the ratio between current and medium- long-term liabilities and capital invested. It may reasonably be assumed that the firms with greater investments in research and development are also the firms that invest more in ICT, and in this respect we brought in a dummy to detect this possibility. Finally, we also added some other control variables such as the age of the firm, measured in years since the year of incorporation, three sector dummies in accordance with Pavitt classification, and a legal form dummy[4].

[4] Description of the variables are set out below the tables. The estimations presented show the specification with the greater reliability. The authors can supply other model specifications (in particular with inclusion of the geographic area variables) on request.

Table 2 – Descriptive Statistics

	1998-2000							
	ict_emp	inv_emp	va	vato	education_emp	blue-collars_emp	debt	
Average	0.4164	7.22409	2.85598	368.1922	9.84165	6.60362	0.72393	
Standard Deviation	0.5344	8.8529	11.3982	3237.605	1.2999	1.4664	0.1708	
Min	0	0	0	0	8	0	0.1899	
Max	3.7932	65.7747	151.1707	51288.84	17	11.6875	1.0061	
	2001-2003							
	ict_emp	inv_emp	va	vato	education_emp	blue-collars_emp	debt	
Average	0.4117	6.0407	2.1039	112.0699	10.0954	6.9564	0.7051	
Standard Deviation	0.5833	7.0396	4.6990	760.9867	1.2996	1.6476	0.1770	
Min	0	0	0.0119	0.0129	8.1316	0	0.1807	
Max	4.5931	60	46.2523	8193.021	14.2308	13	1.0527	

Note. All the variables are constructed as average over the three years. **ict_emp** is ICT investment per employee; **inv_emp** is investment per employee; **va** is the total value added; **vato** is the product between value added and turnover; **education_emp** is the average of years of education per employee; **blue-collars_emp** is the proportion of total staff accounted for by blue collars; **debt** is an index of indebtedness; **Subto** is the percentage of turnover accounted for by subcontracting.

Table 2 show various descriptive statistics regarding the principal variables used in the empirical analysis. The statistics were calculated separately for the two surveys used in the estimations. In general, the averages in the two periods come very close, apart from: a) the variable of interaction between value added and turnover, which shows a higher average and variance for the 1998-2000 period than for the subsequent three-year period; b) the proportion of turnover accounted for by subcontracting, which shows a higher average in the later survey but similar variance in the two periods.

In the following table (table 3) we see the correlation coefficients calculated for the same variables. In both periods a negative correlation emerges between ICT investment per employee and value added per turnover, as also between ICT and proportion of blue collars (blue-collars_emp), while the correlation with ICT per employee (ict_emp) is consistently positive for level of investment in machinery or equipment per employee and value added; the sign of the other variables is not constant over the two periods. Finally, as expected, high correlation emerges between value added and the term of interaction between value added and turnover (Vato).

Table 3 – Correlation Matrix

	1998-2000							
	ict_emp	inv_emp	va	vato	education_emp	blue-collars_emp	debt	subt
ict_emp	1							
inv_emp	0.2022	1						
va	0.0061	-0.0079	1					
vato	-0.0286	-0.0330	0.9595	1				
education_emp	0.2287	0.0712	0.0409	0.0054	1			
blue-collars_emp	-0.0106	0.0709	0.0572	0.0166	0.1121	1		
debt	0.0086	-0.0360	-0.0643	-0.0597	-0.0440	-0.0786	1	
subto	0.0258	-0.0269	0.0737	0.0720	0.0033	-0.1492	-0.1287	1
	2001-2003							
	ict_emp	inv_emp	va	vato	education_emp	blue-collars_emp	debt	subt
ict_emp	1							
inv_emp	0.2202	1						
va	0.0927	0.0481	1					
vato	-0.0083	0.0101	0.8970	1				
education_emp	0.1499	-0.0111	0.1075	0.0687	1			
blue-collars_emp	-0.2088	0.0258	-0.0411	-0.0888	0.1978	1		
debt	-0.1624	-0.1247	-0.0159	0.0356	-0.0108	-0.0662	1	
subto	-0.0021	-0.0843	-0.0509	-0.0957	-0.0244	0.0757	0.0735	1

Note. All the variables are constructed as average over the three years. **ict_emp** is investment in ICT per employee; **inv_emp** is investment per employee; **va** is the total value added; **vato** is the product between value added and turnover; **education_emp** is the average of years of education per employee; **blue-collars_emp** is the proportion of total staff accounted for by blue collars; **debt** is an index of indebtedness; **subto** is the percentage of turnover accounted for by subcontracting.

We began our econometric analysis using the complete sample, containing both non-investing firms (dependent variable value = 0) and firms that invested (dependent variable value = ICT investment per employee), adopting the OLS method.[5] In this estimation the regressors are lagged to minimise the risk of our estimations being invalidated by endogeneity problems. Table 4 shows that the ICT investment lag per employee does not appear significant, while both the value added and the term of interaction between value added and turnover do in fact prove significant. Note that these conclusions remain valid even should we confine our attention to the later survey alone. In particular, a positive sign is found for the VA coefficient, a negative sign for the VATO coefficient. In the light of our preceding observations this implies that, turnover being equal, ICT investment increases with growing value added, suggesting a positive correlation between investment and a proxy for the degree of vertical integration. At the same time, the VATO coefficient being negative the preceding effect is marginally decreasing with growing firm size. The human capital variable is significant and has the expected positive sign; the same result is observed for the blue-collars variable. As for the other regressors, only debt and total investment in machinery and equipment are significant: the greater the indebtedness of the firm, the less will be its investment in ICT, which however grows with growing total investment. As for the coefficient of the subcontracting activity/total turnover variable, it shows the negative sign as expected in our model, but is not significant. Thus in our estimations, while the type of transactions in which the firm is involved as client (indicated by the degree of vertical integration) affects ICT and vertical integration is seen to have a positive effect on ICT investment (as illustrated above), such is not the case with the transaction typology in which the firm is a subcontracting firm, involved as producer of goods and services for other firms. As pointed out above, this result could derive from the presence of marginal firms performing low-quality work with scant technological content.

[5] It was not possible to carry out in addition panel analysis with fixed effects due to the limited time variability of our sample.

Table 4 – OLS estimation

	OLS – Entire sample		**OLS – Firms that have invested**	
ict_emp$_{(1998-2000)}$	-0.00058 (-1.24)		0.18431** (3.3)	
va$_{(1998-2000)}$	0.02455** (2.66)	0.02761** (2.94)	0.02173* (2.10)	0.02901** (2.97)
vato$_{(1998-2000)}$	-0.00011** (-2.97)	-0.00012** (-3.25)	-0.00010* (-2.54)	-0.00012** (-3.22)
education_emp$_{(1998-2000)}$	0.05645** (3.27)	0.05795** (3.51)	0.02760 (1.52)	0.04729** (2.68)
blue-collars_emp$_{(1998-2000)}$	-0.06990** (-4.75)	-0.06858** (-4.91)	-0.08156** (-5.12)	-0.08641** (-5.80)
debt$_{(1998-2000)}$	-0.26996 (-1.84)	-0.23711 (-1.70)	-0.39016* (-2.44)	-0.31714* (-2.02)
subto$_{(1998-2000)}$	-0.00060 (-1.06)	-0.00055 (-1.00)	-0.00066 (-1.11)	-0.00045 (-0.72)
dR&D$_{(1998-2000)}$	0.06508 (1.38)	0.05345 (1.16)	0.03294 (0.65)	0.03090 (0.61)
age	0.00121 (0.87)	0.00119 (0.90)	0.00130 (0.91)	0.00116 (0.86)
inv_emp$_{(2001-2003)}$	0.01735** (3.97)	0.01480 (3.78)	0.02066** (4.37)	0.02013** (4.30)
d98	0.01593 (0.35)	-0.00305 (-0.07)	0.01995 (0.40)	-0.01605 (-0.32)
Cons	0.34221 (1.51)	0.31348 (1.45)	0.77839** (3.19)	0.65071** (2.75)
Obs	633	674	532	565

Note. All the variables are constructed as average for the three-year period concerned, indicated in brackets. The t–values are in parentheses; significant coefficients are indicated by * (5% level) and ** (1% level). **ict_emp** is investments in ICT per employee, **va** is total value added, **vato** is the product between value added and turnover, **education_emp** is the average of years of education per employee, **blue-collars_emp** is the proportion of total staff accounted for by blue collars, **debt** is the index of indebtedness, **subto** is the percentage of turnover accounted for by subcontracting, **dR&D** is a dummy given value 1 if the firm engages in R&D activities, **age** is the number of years as from incorporation of the firm, **inv_emp** is investment per employee, **d98** is a dummy for 1998.

In the sample considered some firms state that they have not invested in ICT. In particular, in the 1998-2000 survey there are 71 firms declaring zero investment in ICT, while the number rises to 80 in the 2001-2003 survey. The results obtained considering only the firms making positive investment are in line with the findings emerging from estimation on the entire sample except for the years of education, which no longer appear significant (table 4, third column). A possible interpretation of the fact that when firms not investing in ICT are included in the sample a positive correlation with education emerges, while the correlation disappears when the non-investing firms are excluded from the sample, is that education is a significant variable in accounting for the firm's decision as to *whether* to invest, but not for the decision as to *how much* to invest.

Excluding from the sample the firms declaring zero ICT investment the OLS estimator could be distorted. Moreover, any correlation that might appear between the factors influencing the decision to invest and those that determine the level of investment implies a problem of sample selection. In order to take such problems into account we estimated the model with a two-stage estimation procedure (Heckit). The first step consists in a Probit regression on the dichotomic dependent variable which takes on value 1 for all the firms that have invested in ICT, regardless of the level of investment, and value 0 for the firms that have made no ICT investment. Essentially, we study with a probabilistic regression the significance of a set of firm characteristics in the decision to adopt ICT. The second stage is based on a regression including among the regressors a term of correction for the problem of distortion in sample selection; with this equation, where the dependent variable is the level of ICT investment per employee, we can bring out the factors affecting the decision as to how much to invest in ICT. For this type of procedure validity is guaranteed by the *lambda Mills*, which departs significantly from zero in both the equations estimated (with and without ICT lag). This means that the OLS estimations prove distorted due to the omission of a relevant variable. In particular, in order to obtain some indication regarding the variables to use in the Heckman model selection equation, we begin by estimating a Probit model with all the regressors so far considered (table 5).

Table 5 – Heckit estimation

	Probit		Heckman			
			selection	investment	selection	investment
$ict\_occ_{1998-2000}$	-0.0089** (-3.82)		-0.00871 (-1.07)	0.18664** (6.27)		
$va_{1998-2000}$	0.00173 (0.06)	0.005501 (0.18)		0.01989* (2.18)		0.02660** (2.85)
$vato_{1998-2000}$	-3.9E-05 (-0.35)	-5.4E-05 (-0.50)		-0.00009* (-2.53)		-0.00011** (-2.98)
$education\_emp_{1998-2000}$	0.19362** (3.03)	0.17171** (2.93)	0.15785** (3.08)		0.14879** (3.06)	
$blue\text{-}collars\_emp_{1998-2000}$	0.002357 (0.04)	0.00184 (-0.04)		-0.08625** (-5.09)		-0.08947** (-5.20)
$debt_{1998-2000}$	-0.05165 (-0.13)	-0.06264 (-0.17)		-0.41173** (-2.83)		-0.34266* (-2.37)
$subto_{1998-2000}$	-0.00225 (-1.58)	-0.00163 (-1.17)		-0.00073 (-1.31)		-0.00052 (-0.93)
$dR\&D_{1998-2000}$	0.32439* (2.26)	0.26078 (1.87)	0.35864** (2.82)		0.29271* (2.42)	
age	0.00466 (1.15)	0.00439 (1.16)		0.00135 (0.94)		0.00122 (0.85)
group	0.12536 (0.66)	0.17951 (0.96)				
incentives	-0.17669 (-1.35)	-0.23231 (-1.84)				
consortium	0.02500 (0.13)	-0.00899 (-0.05)				
spersona	0.33778 (0.50)	0.28091 (0.41)				
Public limited company	0.69070* (2.23)	0.63092* (2.03)	0.60671* (2.46)		0.60546* 2.46	
Scale	0.37011 (1.94)	0.30231 (1.69)				
Specialized	0.03752 (0.24)	0.01022 (0.07)				
High Tech	-0.26316 (-0.64)	-0.47958 (-1.22)				
$inv\_emp_{2001-2003}$	0.00148 (0.16)	-0.00401 (-0.48)		0.02110** (6.77)		0.02082** (6.77)
D98	0.25122 (1.88)	0.26619* (2.08)	0.02617 (0.22)	0.02643 (0.51)	0.02574 (0.23)	-0.00765 (-0.14)
Cons	-1.63705 (-1.94)	-1.2461 (-1.58)	-1.39086* (-2.55)	1.25721** (6.29)	-1.29539* (-2.48)	1.38622** (6.71)
Mills lambda				-0.43461* (-2.07)		-0.63732* (-2.62)
Obs	609	647		648		688

Note. All the variables are constructed average over the three-year period concerned, indicated in brackets. The t–values are in parentheses; significant coefficients are indicated by * (5% level) and ** (1% level). **ict_emp** is ICT investment per employee, **va** is the total value added, **vato** is the product between value added and turnover, **education_emp** is the average years of education per employee, **blue-collars_emp** is the proportion of staff accounted for by blue collar workers, **debt** is an index of indebtedness, **subto** is the percentage of turnover accounted for by subcontracting, **dR&D** is a dummy taking on value 1 if the firm engages in R&D activities, age is the number of years as from the year of incorporation of the firm. Other dummies included are: **group**, if the firm belongs to a group; **incentives**, if the firm has received financial and/or fiscal incentives; **consortium**, if the firm belong to a consortium; **sperson**, if it is an individual or a public limited company; **Public limited company**; the sector dummies are: **scale, specialized, high technology**. **inv_emp** is investment per employee, **d98** is a dummy for 1998.

According to the results of our estimations, the factors that influence a firm's decision to adopt ICT are: the average level of education – the higher it is, the more likely the firm is to invest in ICT; engagement in R&D activities – firms so doing are, again, more likely to invest in ICT; being a public limited company; persistence, captured by the lag in investment per employee. These variables were introduced into the selection equation estimated with the Heckman model. The first step of the model confirmed that education, R&D and being organised a public limited company are factors influencing decisions to adopt ICT. The results of the second step of the model, regarding the variables influencing the level of ICT investment, are in line with the previous findings and, at least to some extent, with the relevant literature. In particular, the amount of ICT investment increases with the increase in investment in the preceding period, and with growth in the total investment per employee. On the other hand, ICT investment decreases with higher proportions of blue collars and higher indebtedness. Exactly the same considerations made previously also apply to the variables of major interest in that work, namely VA and VATO.

In conclusion, empirical analysis reveals that different factors affect decisions as to "whether to invest" and "how much to invest". The factors that prove decisive in the decision whether to invest are human capital and R&D activity. The elements affecting the amount of investment are size, the incidence of value added in the turnover, and persistence. Investment in ICT increases with increasing vertical integration, with a decreasing marginal effect with regard to the turnover.

5. Conclusions

In this paper we set out to bring further light to bear on the factors accounting for the decision to adopt ICT and the level of such investment among Italian firms over a relatively recent period of time – the period 2001-03 – marked by a decline in total factor productivity due largely to the lag shown by Italian firms in adapting to the technological changes coming in with ICT. Achieved with appropriate modelling and econometric estimation, our findings largely bear out the predictions advanced in the theoretical literature and in empirical observations on the marked heterogeneity of the firms and the explicative relevance of a limited but remarkably robust set of variables.

Our reference here is to an adequate level of human capital employed in the firm and engagement in R&D activities as determinants in the decision whether or not to invest in ICT. In all respects these findings represent further proof of the severe limitations involved in the pattern "small size/specialization in the traditional sectors" – standing in the way of wider ICT diffusion in Italian industry and so obstructing increase in total factor productivity. In fact, the explicative capacity of both variables shows that only firms with adequate functional range, not limited solely and entirely to manufacturing activity, and a high level of human capital take the decision to invest in ICT and, thanks to the employees' capacity to adapt, implement the organisational changes necessary to guarantee future increases in productivity. This firm typology is, on average, more frequent in the sectors with high economies to scale and high technology – industries which are not the core of the Italian specialization. It might be objected that by now ICT can be characterised as general purpose technologies, with a wide range of application, allowing for increases in productivity whatever industry the firm may operate in. Nevertheless, our findings show that this is not altogether the case, seeing that low levels of R&D and dependence on a large proportion of blue collars mean that a firm is less likely to take the decision to invest in ICT. Here we find ourselves echoing the point made by Bresnahan and Trajtenberg (1995): the diffusion of technologies over a wide range and consequent technological advance in the industrial system depend also on the characteristics prevailing among the industries making use of them.

With regard to identification of the variables accounting for ICT investment per employee, our findings show that size, greater vertical integration and persistence of investment in ICT have a positive effect on ICT investment per employee. As far as the positive impact of firm size is concerned, it is hardly surprising and in fact we find it reaffirmed in many other studies on Italian industry. With all due caution given the simple modelling and quality of data used in estimation, we see as particularly interesting the finding on the positive effects of vertical integration on the level of ICT investments per employee. This correlation could well imply that in a country like Italy, with a predominance of firms showing low vertical integration, the level of investments in ICT is actually suboptimal. Moreover, it would appear that the positive pattern, rather than emerging from the simple differential between internal coordination costs and market transaction costs, could derive from the complementarity of investment in ICT made by two firms for the enhancement of the final product and thus of the total pay-off to be shared. This is an aspect that calls for further investigation, but it could well cast fresh light on how, as the new technological paradigm emerges, the organisational patterns change in the firms of a country that has been characterised for at least twenty years by a low level of vertical integration.

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