DISCUSSION PAPER SERIES

IZA DP No. 9239

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July 2015

Forschungsinstitut
zur Zukunft der Arbeit
Institute for the Study
of Labor

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Discussion Paper No. 9239
July 2015

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IZA Discussion Paper No. 9239
July 2015

ABSTRACT

Does ICT Investment Spur or Hamper Offshoring? Empirical Evidence from Microdata*

We provide evidence on the effect of ICT investment on the propensity to offshore for a sample of Italian manufacturing firms. To deal with the endogeneity of ICT investment we adopt an innovative identification strategy based on the availability of local broad band facilities. Contrary to previous literature focusing on services, we find a negative effect of ICT on offshoring. Furthermore, when splitting the sample according to the technological level, the effect is negative and significant only in the sub-sample of low-tech firms. This suggests that ICT capital substitutes for foreign workers in performing routine tasks in low-tech industries.

JEL Classification: C34, C35, F20, L23

Keywords: ICT Investment, offshoring, maximum likelihood system estimation

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* We thank Giuseppe Bertola, Angelo Besana, Giorgio Calzolari, Davide Castellani, Giovanni Ferri, Saul Lach, Laura Magazzini, Chiara Monfardini, Gianmarco Ottaviano, and Fabiano Schivardi for helpful suggestions. We also thanks audiences at the "Innovation, Internationalization and Global Labor Market" conference, Torino, February 2009; at the ITSG meeting, Cagliari, June 2009; at 2009 EARIE conference, Lubliana; at the 2009 European Trade Study Group conference, Rome; and at the 2009 Italian Economic Association meeting, Rome, the for useful comments. The usual disclaimer applies. The authors gratefully acknowledge financial contributions from the FIRB project "International fragmentation of Italian firms. New organizational models and the role of information technologies", a research project funded by the Italian Ministry of Education, University and Research.

1 Introduction

As noted, among others, by Amiti and Wei (2005) and Mankiw and Swagel (2006) the growth in offshoring activities in recent years has raised a lot of public concern in all advanced economies. In particular, a commonly perceived worry is that workers in previously sheltered service sectors of the economy are more likely to suffer from competitive pressure from trade made possible by improved information and communication technologies (ICT thereafter). It is therefore hardly surprising (Grossman and Rossi-Hansberg (2006)) that both the academic and the media attention has progressively shifted towards the offshoring of a variety of services ranging from reading x-rays to developing softwares and from preparing tax forms to answering customer service calls.

Within this general framework a strand of empirical literature has started (Abramovsky and Griffith (2006), Bartel et al. (2005)) to provide econometric estimates of the effect of ICT investment on the outsourcing and offshoring of business services. Broadly speaking—but not without some cautionary remarks—the empirical evidence available so far confirms a positive causal link between ICT and the offshoring of business services. To the extent that the latter negatively affects labour market outcomes in advanced economies, ICT investment itself could be blamed for such "undesirable" results and, therefore, policy makers should take this unintended transmission mechanism into account when designing public policies aimed at the diffusion of ICT technologies.

It must be noted, however, that the scant international descriptive evidence points out that in many industrialized countries most of offshoring activities occurs in manufacturing and not in services and that within manufacturing firms production activities are offshored more often than business services. For instance, according to a survey carried out by Eurostat for 13 EU countries over the 2001-06 period, 21.7% of manufacturing firms are found to offshore part of their production activity, whereas the percentage decreases to 9.9% in service industries. As for Italy, this difference is even more striking, the percentages being, respectively, 15.5 and 3.0%.[1] Furthermore, it has been documented (Amiti and Wei (2005)) that UK manufacturing firms import a much larger proportion of material than of services inputs. In short, the available empirical evidence points out that most offshoring activities refer to the purchase of material inputs by manufacturing firms.

On theoretical ground there is no compelling reason why ICT investment in manufacturing should necessarily increase the propensity to offshore. This will crucially depend on the nature of the ICT investment. On the one hand, the reduction in communication and coordination costs is likely to favor offshoring. On the other hand, the increased complementarity of production stages within the firm or the augmented complexity of tasks induced by ICT investment might reduce the incentive to offshore as opposed to in-house production. Furthermore, ICT is expected to

[1] This survey was carried out in 2007 and it is part of the "development project on international sourcing" launched by Eurostat. This project reflects the growing concern of policy makers at national and EU level on the likely job losses due to offshoring, and the ensuing need for harmonized data on the phenomenon. Note that a more recent survey was conducted in 2012 but this second release does not include Italy. Further details on the surveys can be found at: http://ec.europa.eu/eurostat/web/structural-business-statistics/global-value-chains/international-sourcing

affect the composition of labor demand. Available empirical evidence (see Autor et al. (2003)) indeed suggests that ICT capital complements workers in performing non-routine problem solving and complex communication tasks but substitutes for workers in performing routine cognitive and manual tasks. ICT investment might therefore be associated with a downward shift in the labor demand for workers specialized in performing routine tasks and, ultimately, with a lower propensity to offshore to countries where the supply of such workers is high.

Our paper contributes to shed light on this issue by advancing the existing empirical literature on the effects of ICT on offshoring on several grounds. Firstly, we take a different perspective and look at the offshoring of production activities carried out by manufacturing firms. Secondly, we address the endogeneity problem of the ICT investment decision by specifying and estimating a non-linear equation system where identification of the effects of interest is obtained by relying both on functional form and on exclusion restrictions. This in turn allows us to test the validity of our exclusion restrictions. Thirdly, by estimating our system of equations separately on the sub-samples of high- and low-tech firms we make an attempt to go beyond the pure identification of the effect and to discriminate between the alternative transmission channels suggested by received theory.

What we find in this paper is that, after taking the endogeneity of the offshoring decision into account, the investment in ICT activities has a negative effect on the propensity to offshore in a large sample of Italian small-medium size manufacturing firms. When we split our sample of firms according to their technological level, this negative relationship is found to hold only for the sub-sample of low-tech firms. Furthermore, this main finding is robust to different criteria used for the construction of the relevant sample of firms as well as to alternative specifications of the econometric model and to the inclusion of several firm-level variables as additional regressors. To the extent that routine cognitive and manual tasks play a more relevant role in low- as compared to high-tech firms, our results suggest that the prevailing channel through which ICT affects offshoring activities is the substitution effect between ICT capital and foreign workers specialized in performing routine tasks. Taken at their face value, our overall results imply therefore that—at least in manufacturing—public incentives to ICT investment are unlikely to promote offshoring and therefore this transmission channel should not be a reason of concern for policy makers when designing public policies aimed at the diffusion of ICT technologies.

The remaining of the paper is organized as follows. The next section motivates our paper by reviewing the theoretical literature and the empirical evidence on the relationship between ICT investment and offshoring. In section 3 we introduce our dataset and comment upon some relevant descriptive statistics. Section 4 presents our empirical model and discusses its identification assumptions. In Section 5 our main results are presented whereas section 6 concludes. An appendix reporting the relevant questions included in the Unicredit-Capitalia survey and describing the sample used in this paper is also included.

2 The Link between ICT Investment and Offshoring

ICT investments, as well as the organizational changes they induce, are thought to affect different aspects of firms' decision-making and production activity through several—not mutually exclusive—channels.[2]

According to common wisdom, a higher level of information and telecommunication capital stock is perceived to stimulate offshoring through a direct effect, induced by enhancements in communications abilities, and an indirect effect via increased firms' performances. It is a widely accepted fact that the introduction of new communication technologies amplifies the information flows received and sent by the firm. This phenomenon should lead to higher fragmentation of production processes, irrespectively of whether the transfer of authority occurs within or outside firms' boundaries (i.e. offshoring or outsourcing). On the one hand, a higher efficiency in monitoring information (Colombo and Delmastro (2004)) and controlling choices at all stages of the production process may induce a more frequent delegation of authority and decentralization of decision-making not only within the firm but also among different firms. On the other hand, ICT enhances firm ability to react to external information, to absorb new technologies and to considerably improve the quality of communication with external agents. As Grossman and Helpman (2002) show, the reduction of informational costs may lead to an increase in offshoring/outsourcing by improving the ability and chances of finding new suppliers.

The assumption that ICT facilitates the transfer of information outside firm boundaries, thereby leading to higher fragmentation of production, is however subject to several qualifications. As Leamer and Storper (2001) and Leamer (2007) emphasize, the transfer of competencies critically depends on the *crucial* distinction between routine codifiable tasks and non-routine tasks. The completion of the former relies on a type of information that can be easily conveyed to an external agent, as in the case of standardized services, virtually with zero transportation costs. On the other hand, non-routine tasks are more based on experience or are heavily dependent on creative skills. In this case, tacit—as opposed to codifiable—knowledge plays a predominant role in production decisions, and the experience embodied in these specific tasks can not be easily conveyed within a buyer-seller relationship. As pointed out by Keller and Yeaple (2008), the cost of technological transfer increases with the technological content of the task to be offshored, and the likely impact of ICT is to increase this content, thereby reducing the incentive to offshore.

The decision to offshore (outsource) could not be optimal choice also when, as pointed out by Baccara (2007) and Hempell and Zwick (2008), the externalization of production processes is associated with an unwelcome transfer of internal knowledge outside firm boundaries. This information leakage phenomenon might be especially harmful for highly specialized firms characterized

[2] In the review of the literature we will not make an explicit distinction—unless explicitly stated—between offshoring and outsourcing since most of the transmission channels identified in the literature apply to both phenomena. Note, however, that their policy implications differ substantially, at least from a national perspective.

by complex production processes and a high degree of labor specialization. It might indeed be argued that some of the components of ICT capital (e.g. production and management softwares) are characterized by high degrees of complexity and asset specificity and this in turn might make the offshoring of parts of the production process a less attractive option. Indeed, Hempell and Zwick (2008) provide convincing empirical evidence that whereas ICT capital improves organizational flexibility and employee participation in decision making, its impact on the probability to outsource and on the shares of intermediaries purchased appears to be far less strong. Moreover, according to Transaction Cost Economics (TCE) a high buyer's asset specificity might lead to expropriation by the supplier, in turn leading to an incentive to internalize the production and not to offshore (or outsource). This is exactly the evidence provided by Lileeva and Van Biesebroeck (2008) which use several measures of buyers' investment intensity as proxies for asset specificity.[3]

An additional barrier to offshoring, related but formally distinct from codifiability problems and unwelcome knowledge transfer, is represented by tasks interdependencies. Organizational literature (Thompson (1967) and Van de Ven et al. (1976)) considers a firm as a complex organisation whose design depends on the needs of coordinating interdependent tasks. The breakdown of activities implied by outsourcing entails a larger increase in coordination costs the more complementary are the tasks. These coordination costs are higher in the case of offshoring due to cultural and institutional differences, time-gaps and difficulties in syncronization of activities, thereby leading to difficulties in the design of organizational structures (Kumar et al., 2009; Srikanth and Puranam, 2011). Unlike colocated activities, day-to-day problems cannot be solved by informal face-to-face interactions and a costly system of back-and-forth communications might be necessary to clarify the nature of the problem and to achieve a solution (Srikanth and Puranam, 2011). In this scenario, ICT investments, by increasing the knowledge intensity of the production process exacerbates the interdependencies costs between onshored and offshored activities.

Several studies show that ICT is accompanied by workplace organisational changes and the introduction of new work practices (Black and Lynch, 2004; Brynjolfsson and Hitt, 2000; Bresnahan et al., 1999) leading, for instance, to more team-working. These changes generate gains in productivity that originate more from multitasking rather than specialisation (Bresnahan et al., 1999; Caroli and Van Reenen, 2001). As shown by Dessein and Santos (2006) ICT thus can favour task bundling especially when the workers need flexibility to deal with uncertainty. Firms may adapt their organization to optimize the use of information. When information is local it is optimal to increase the flexibility of workers in order to allow them to deal with uncertainty more efficiently. This implies more autonomy in the choice of assignments and more task bundling. Such higher level of multitasking, however, entails more coordination than the alternative organizational structure where all tasks are predefined, the degree of specialisation is higher and the need of coordination

[3] A related strand of literature (Mol (2005), Magnani (2006)) investigates the effect of technological intensity at the industry level on the propensity to offshore (outsource). The evidence is mixed, but points towards a positive incentive of R&D on offshoring activities.

is smaller. Overall, by improving the level of communication, ICT decreases coordination costs, increases the incentives to use local information and pushes the organizational structure towards more multitasking and less specialisation in tasks. If this effect prevails then the implied task bundling is expected to increase the costs of breakdowns and to reduce the probability of offshoring.

As thoroughly discussed in the literature on skill-biased technological change (Autor et al. (2003)), ICT investment is also expected to reshape the task composition of the workforce and ultimately the structure of labor demand, by fostering automatization and mechanization of production processes. In particular, the complementarity (substitutability) between ICT capital and workers performing non-routine (routine) tasks increases the marginal productivity of non-routine inputs and therefore their relative demand. This in turn might make less attractive the standard offshoring option whenever this choice is driven by the abundance of routine-workers in less developed countries. Therefore, this channel predicts a negative relationship between ICT investment and the propensity to offshore.

The indirect effect of ICT on offshoring can be implicitly derived by jointly considering the two separate strands of existing literature which analyze the relationship between ICT investment and productivity on the one hand (for a review see Draca et al. (2007)), and between productivity and the international fragmentation of production on the other hand (Antràs and Helpman (2004)). Since recent theoretical models on international fragmentation (Antràs and Helpman (2004)) have shown that high productivity firms are more likely to offshore both components and services because they can spread the additional sunk costs from operating abroad on a larger amount of production, ICT investments may also indirectly increase the likelihood of offshoring decisions through productivity enhancement.

Although the role of ICT investments in affecting offshoring decisions has become harshly debated in the last decade, existing econometric evidence is—to the best of our knowledge—confined to a dearth of papers. Both Abramovsky and Griffith (2006) and Bartel et al. (2005) focus on the outsourcing and offshoring of business services put forth by manufacturing firms. In particular, Abramovsky and Griffith build on the idea that ICT investment helps to reduce transaction costs and show that ICT investment makes the acquisition of services from other firms (i.e. outsourcing) or the localization of production stages out of the national boundaries (i.e. offshoring) more convenient than in-house production. The authors implement an IV strategy to account for endogeneity in ICT adoption by future outsourcers and provide cross sectional evidence of the positive effect of ICT investments and internet usage on the probability to outsource and offshore services for a large sample of manufacturing firms. Interestingly for the purpose of this paper, Bartel et al. provide a theoretical model where ICT innovation increases the compatibility between firm own technologies and the technology embedded in the services and products offered by other firms. ICT thus lowers firms adjustment costs and induces a higher level of outsourcing. The authors also analyze US cross sectional data at the industry level and show a positive relationship of ICT with the amount of services outsourced in communication, accounting, advertising, software, and legal assistance. However, a negative effect of ICT on the outsourcing of production related tasks including machine and building repairing is recorded. The authors motivate this negative effect with the low ICT content of these activities and the negligible role of ICT in reducing adjustment costs.

Fort (2014) uses data from the 2007 US Census of Manufacturers to analyze the effect of communication technologies on the decision to purchase "contract manufacturing services", i.e. the processing of materials or components owned by the firm. The author confirms that offshoring is more likely to occur in industries where codifiability of tasks—measured by the use of CAD or CAM—is easier. An important result of the paper is that the use of communication technology at the firm level has a much stronger effect on the probability of relocating production to domestic—rather than to foreign—suppliers. These findings support the idea that ICT reduces coordination costs only when receiving firms possess the necessary skills to deal with such information and to avoid problems induced by an increased organisational complexity. By using import data, the author also shows that high technology firms source more from high human capital countries, thereby confirming their need for high skilled supplier.[4]

To sum up, there is a multiplicity of channels through which ICT capital can affect firms' offshoring decisions. The relative importance of these alternative channels is likely to depend on industry basic characteristics, notably the prevailing technological environment. More specifically, it can be argued that unwelcome information leakages and tasks interdependencies are a more relevant issue in high-tech industries whereas skill-bias technological change should play a more prominent role in low-tech industries. Overall, our summary of existing literature suggests that an unambiguous prediction on the sign and the magnitude of this effect cannot be made. In turn, it becomes ultimately an empirical issue to assess the relevance of alternative transmission channels and indeed this is what we contribute to in the remaining of this paper.

3 Data and Descriptive Statistics

The variables we use are mainly retrieved from the 9^{th} survey "Indagine sulle Imprese Manifatturiere", a survey run by Unicredit-Capitalia (one of the largest Italian banks) covering the 2001-2003 period. This survey contains information on several quantitative and qualitative variables for more than $4,000$ firms as well as their balance sheet and income statement data. The sample contains all Italian manufacturing firms with more than 500 employees whereas firms with less than 500 employees are selected on the basis of a stratified sample, so that small and medium sized firms

[4] Rasel (2012) analyses a cross section of German firms in both the manufacturing and the service sector and finds that ICT increases the probability of offshoring good and service inputs in both sectors. However, she does not control for the likely endogeneity of ICT.

are well represented.[5]

Very importantly for the purposes of the paper, several survey questions refer to firms' ICT investments and offshoring activity. Firms are asked to report the amount they invested in ICT over the three-year period, alongside with the breakdown by type (hardware, software, and telecommunication) and area of application (administration, production, commercial activity, internet, and other applications).[6] Furthermore, firms also report their offshoring activity, i.e. whether they produce abroad part of their production previously performed in-house.

The survey also provides very detailed information on firms' location at the municipal level. Given the likely importance of the local environment in shaping ICT and offshoring decisions, we merged the survey with data on geographic and demographic municipal characteristics, such as population, area, altitude, and geographical coordinates. Given our research strategy, we also collected—at the municipality level—information on the availability of Broad Band (BB, henceforth) infrastructures.[7]

Standard trimming procedures and exclusion of firms without information on the relevant variables reduced the original sample to the set of $3,204$ firms we use in this paper.

— INSERT TABLE 1 ABOUT HERE —

— INSERT TABLE 2 ABOUT HERE —

Tables 1 and 2 report some descriptive statistics for the two crucial variables of our analysis: ICT investments and offshoring activity. Inspection of Table 1, where relevant statistics are presented separately by industry (at 2 digit level), reveals that the bulk of offshoring activities takes place in a limited number of low-tech industries (i.e. Textiles, Clothing, Leather). Offshoring activities are also found to be negligible in the same sub-sample (i.e. Food, beverage and tobacco; Paper products; Printing and publishing; Oil refining; Non-metal minerals; Metals). For this reason we check the robustness of our econometric results to the exclusion of those industries where we observe trivial fragmentability in the data. [8] As to the size of offshoring activities, conditional on offshoring, a sizeable fraction of firms (40%) reports a share of off-shored production below the threshold of 10%

[5]See the Data Appendix for more details on the structure of the survey, sample selection, questions, and variables definition.

[6]Unfortunately, data availability problems prevent us to compute the stock of ICT capital. For a limited number of firms we can however observe ICT investment also in the 1998-2000 period. For those firms, the correlation coefficient between ICT intensities in the two periods is equal to 0.29. This in turn suggests that our three-year ICT investment intensity is a sufficiently persistent variable and therefore can be legitimately used as proxy for ICT capital.

[7]Municipalities are the finest administrative unit in Italy. Our dataset provides information for all 8,106 municipalities.

[8]Operationally we remove those firms operating in industries where the share of offshoring firms is below 4% (see section 5.2)

of total sales. Also, 43% account for a share between 10 and 50%, and 17% for a share larger than 50%. Quite interestingly, the sub-sample of high-tech firms is characterized by a narrow support compared to the sub-sample of low-tech firms. In fact, no high-tech firm is found to offshore more than 50% of total sales.[9] As expected, more ICT investment takes place in high-tech industries. Some of these industries also show moderate offshoring and—overall—high(low) ICT investment industries tend to present also high(low) percentage of offshoring activity.

Additional information on total ICT investment by type and area of application is reported in Table 2. As for the extensive margin, almost 78% of firms has invested in ICT in the three year period and the amount invested represent a fairly sizeable percentage of firm turnover (0.3% for the whole sample, 0.4% for the sample of investing firms). Interesting insights also emerge from the breakdown of ICT investment by type. Most of the investment, in terms of both the number of investing firms and the amount spent, refers to hardware or software, whereas a much less important role is played by the introduction of TLC devices. Note also that a positive and fairly high correlation exists between these types of ICT investments both at the extensive and at the intensive margins. This, in turn, makes it difficult to disentangle the specific contributions of different types of ICT investments to offshoring activities. As for the area of application, production and administration/management are the areas mostly targeted by ICT investments, whereas commercial activities and internet are found to be far less important. Overall, ICT expenditures in our sample seem to be mostly concentrated in administration/management and production and involve the introduction of new hardware or software. Far more limited is instead the role played by those activities (communication, internet, and trade) which are commonly thought as being conducive to offshoring.

The unconditional correlation between offshoring and ICT detected by inspecting Table 1 calls for a deeper analysis. In fact, it might be driven by firm-level observable variables affecting both offshoring and ICT. To this end, Table 3 presents standard descriptive statistics for a number of additional firm-level variables highlighted by previous literature as important drivers of ICT adoption and offshoring activity: age, size (number of employees), and ISO 2002 certification. The vast majority of firms in the sample are relatively "old", as only 25% of them have been established less than 15 years before the first year of the survey. Note also that the median size is 49.50 employees. This provides an additional rationale—on top of the standard EU classification scheme for small firms—to use a size dummy for firms above or below the 50 employees threshold. Finally, 55% of the sampled firms have declared to comply with the ISO 2002 requirements. We interpret this variable as a proxy for observed quality. In fact, a common finding of previous literature

[9] The survey also elicits information on the motivation and the country of destination of international production activities. The most frequently cited motivation for delocalisation is "lower labour cost" (73%), whereas a much less important factor is the reduction in "foreign market penetration costs" (7%). Finally, the offshored production mostly occurs in Romania and China, and virtually all countries mentioned in the survey as offshoring destinations are at much lower levels of economic development than Italy.

is that ICT is mostly effective when it is associated with a high quality workforce and with an appropriate internal organizational structure. Following the existing empirical literature we use the compliance with the ISO 2002 standards as a general proxy for quality.[10] The rationale here is that the ISO 2002 label is given only to those firms which have implemented the required organizational changes in terms of standardization and codification of most of the activities performed within firm boundaries.

A first answer to the crucial question of whether the unconditional positive correlation between ICT investments and offshoring activity we found in our data is robust to the introduction of firm-level variables and dummies capturing local (at regional or provincial level) and industry characteristics is provided in Table 4, where we report the results of several probit estimates of the relationship between ICT and offshoring conditionally on these additional variables.

— INSERT TABLE 3 ABOUT HERE —

— INSERT TABLE 4 ABOUT HERE —

We first control only for industry (2 digit) and regional effects (column (*i*)). Similarly to the scant previous empirical literature on this issue, the relationship between ICT and offshoring is positive and significant at the 1% level. The average partial effect (0.010) implies that increasing the investment intensity from the 25^{th} to the 75^{th} percentile of the distribution (from 0.020 to 0.314%) increases the offshoring probability of approximately 0.3 base points. Although this effect might appear small at first glance, its real magnitude must be assessed by considering the low proportion (7.6%) of offshoring firms in the sample. Notice that industry dummies are very significant whereas regional ones are not. The positive correlation between ICT and offshoring is almost unaffected by the replacement of regional with provincial dummies (column (*ii*)) which are however jointly not significant. In column (*iii*), we include in the specification the additional firm-level variables presented above. As expected, size and observed quality are positively associated to the probability of offshoring, whereas age is negative but not significantly different from zero at conventional statistical levels. More importantly for the purpose of this paper, the average partial effect for ICT—although slightly smaller in size than in columns (*i*) and (*ii*)—is still positive and significant. Finally, in the last two columns we focus separately on the sub-samples of high- and low-tech firms. As probably expected, size and quality turn out to be more relevant for the high-tech sub-sample. On the contrary ICT investments are found to be positive and significant only for the sub-sample of low-tech firm. Also, both the estimated coefficient and the corresponding average partial effect are larger—albeit not substantially so—compared to those reported for the full sample.

[10]See, for instance, Verhoogen (2008).

Obviously, a causal interpretation of this set of results requires that ICT is exogenous in the offshoring equation, i.e. uncorrelated with shocks affecting offshoring. We believe this assumption is very unlikely to hold since one can well think of several unobservable or imperfectly measured firm level variables—including managerial quality and technological/market opportunities—that affect both decisions.

4 Empirical Strategy

The empirical results presented in the last section support the widespread idea that ICT investment is positively associated to offshoring, at least in the low-tech sub-sample. However, as previously noted, we are interested in the causal effect of ICT on offshoring. This in turn implies that the issue of the likely endogeneity of ICT must be tackled in a convincing way. We therefore specify and estimate, as baseline model, a recursive non-linear two-equation system for offshoring and ICT investment. Given the nature of our observables it is convenient to make the joint normal distribution for the two error terms. Within this estimation framework the offshoring and the ICT investment equations can be respectively interpreted as standard probit (equation 1) and Tobit type I (equation 2) models. More specifically, we specify our model as

$$OFF^*_{ijmr} = \mathbf{x}'_i\lambda + \rho ICT_{ijmr} + \mathbf{w}'_m\mu + f_j + g_r + \varepsilon_i \quad (1)$$

$$ICT^*_{ijmr} = \mathbf{x}'_i\beta + \mathbf{z}'_m\gamma + \mathbf{w}'_m\delta + c_j + d_r + \eta_i \quad (2)$$

$$OFF_{ijmr} = \begin{cases} 1 & \text{if } OFF^*_{ijmr} \geq 0 \\ 0 & otherwise \end{cases} \quad (3)$$

$$ICT_{ijmr} = \max(ICT^*_{ijmr}, 0) \quad (4)$$

$$\varepsilon_i, \eta_i \sim iidN\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \sigma_\eta\rho_{\varepsilon,\eta} \\ \sigma_\eta\rho_{\varepsilon,\eta} & \sigma_\eta \end{pmatrix}\right] \quad (5)$$

where subscripts i, j, m, r respectively refer to firm, industry, municipality, and region. Therefore, $\mathbf{x}_i$ and $\mathbf{w}_m$ are vectors of firm- and municipal-level exogenous variables which enter both equations. $c_j(f_j)$ and $d_r(g_r)$ are industry and regional dummies which control for unobservable effects common within a region and an industry respectively. $\mathbf{z}_m$ is a vector of exogenous variables which enter the ICT equation but can be reasonably excluded from the offshoring equation. In this framework, endogeneity of the ICT variable stems from the non-zero correlation coefficient between the errors of the two equations, $\rho_{\varepsilon,\eta}$.

We choose full information maximum likelihood (FIML) as our preferred estimator. As opposed to (two-step) control function methods, joint estimation by ML is more demanding in terms of assumptions (as it requires the full specification of the distributions), but offers the advantage of being more efficient than two-step type estimators if the distributional assumptions are correct.[11]

Irrespective of the estimation method, the issue of identification of the model is crucial. The two equation system above is identified even with $\gamma = 0$ due to the non-linear functional form.[12] However, the availability of legitimate exclusion restrictions is likely to be useful since it increases the precision of the estimates in finite samples (see, for instance, Keane (1992)). Needless to say, however, finding such variables is—as usual in cross-sectional data—a very difficult task.

One potential candidate for this difficult role is the Broad Band provision at the local level. At the time of the survey (still nowadays, actually) the provision of BB connection was very heterogeneous across Italian municipalities as it requires the availability of both optical fiber infrastructures and Digital Subscriber Line Access Multiplexers (DSLAM) network devices.[13]

— INSERT GRAPH 1 ABOUT HERE —

Graph 1 plots the availability of BB across Italian municipalities at the end of our sample period.[14] It also displays regional borders. The heterogeneity between served (dark shaded) and non-served (light shaded) municipalities is striking not only at regional but even at a much finer geographical level. Even within much narrow geographical entities as provinces (whose borders are not shown for clarity sake) municipalities do differ in the availability of BB connections.

The availability of BB is expected to increase the productivity of ICT investments, since it reduces its cost per unit of information flow. Therefore, it enters the ICT equation. At the same time it can be reasonably assumed—and in our framework tested—not to affect offshoring decisions directly. Furthermore, this variable can be safely assumed to be exogenous in the ICT equation, although Graph 1 shows that the BB variable is not randomly distributed across municipalities. What we argue here is that most of the non-random component of this observed heterogeneity can be accounted for by observable socio-geographical characteristics (density, latitude, longitude, altitude, proximity to the sea) which capture the differences in installation cost among municipalities. Indeed, Table 5 shows that BB provision is more likely in areas with a high population density as well as in coastal area but less likely in mountain areas. This in turn can be explained by the fact that most of the optical fibre infrastructures run parallel to main existing railways or electroduct lines.[15] Once we control for these factors we can reasonably defend the assumption that BB provision is

[11] However in the empirical section we also briefly comment upon the results we obtain when estimating our systems of equations with the two-step approach. See footnote 25.

[12] On the general conditions for identification in parametric models see Bekker and Wansbeek (2001). Note also that the argument put forward by Wilde (2000) to verify identification in the context of a bivariate probit model also applies to our case of a Tobit-probit model.

[13] On the diffusion of BB provision in Italy see Ciapanna and Sabbatini (2008).

[14] Information on BB provision at the beginning of our sample period would have obviously been preferable. Unfortunately, the first available data collected with a consistent methodology over the whole country refer to December 2003.

[15] See Ciapanna and Sabbatini (2008).

uncorrelated with common shocks affecting firms' ICT investment decisions within a municipality. As a matter of fact, since not only ICT expenditures but also the offshoring decision might be driven by these geographical factors we include them in both equations.

— INSERT TABLE 5 ABOUT HERE —

5 Econometric Results

5.1 Basic Estimates

In this section we present our econometric results for the full sample of firms (Table 6, Panels A and B). In the first two columns of Panel A we report the results of the unrestricted estimates of the Offshoring (column (*i*)) and the ICT investment (column (*ii*)) equations. Following a sort of general-to-specific approach the equation estimates reported in columns (*iii*) and (*iv*) omit instead those municipal-level variables which have turned out to be insignificant in the equations of the more general systems reported the first two columns. Average partial effects for all probit models for offshoring are summarized in panel B.[16] Since reported results are very similar we focus here mostly on the restricted estimates of Table 6.[17]

In principle we would have liked to estimate additional models with regional dummies being replaced by provincial dummies. Unfortunately convergence was never reached in all our experiments.

— INSERT TABLE 6 ABOUT HERE —

Overall, results for the Tobit model (columns (*ii*) and (*iv*)) are similar to those found by previous literature[18]: age, size, and observed quality (ISO 2002 compliance) positively affect the amount spent in ICT. Among municipal-level variables, the only significant variable is the dummy for firms located in large municipalities (those with a population above 4,000 inhabitants), whose sign is negative.[19] At first sight this result might sound a little bit counter-intuitive. One, admittedly

[16]Estimation of the system has been carried out in Stata with the *cmp* command, version 6.8.5.

[17]In principle we would have liked to estimate additional models with regional dummies being replaced by provincial dummies. Unfortunately convergence was never reached in all our experiments.

[18]The literature on ICT determinants is very large. Evidence on Italy includes Bugamelli and Pagano (2004), Lucchetti and Sterlacchini (2004), Fabiani et al. (2005), and Giunta and Trivieri (2007).

[19]The fact that most municipal-level variables are not significantly different from zero might seem to contradict the empirical evidence reported in Table 5. Note however that in Tables 6 and 7 we also control for regional specific effects which pick up most of the variability in municipal characteristics that we observe in the data.

ad hoc, potential explanation is that firms located in small towns might find it more difficult to externalize ICT intensive activities due to the lack of partners located nearby and therefore are left with the only option to develop them in house. A complementary explanation might also be that these firms have to invest more in ICT to be able to connect to more distant suppliers or customers. Finally, as expected, the BB provision variable turns out to positively affect ICT adoption and to be marginally significant.[20]

As for the offshoring equation, size and observed quality are the most significant variables. Both positively affect the probability of offshoring. Instead, all municipal-level variables turn out to be insignificant. Very interestingly, the coefficient of ICT investment is now negative and very significant. This result must be read jointly with the very high and positive value (0.755) of the correlation coefficient between the two errors. This shows that the positive coefficients we found in Table 4 have to be explained by the positive correlation of the ICT variable with the error term, which biases the estimate upward. To assess the quantitative impact of the ICT variable, we repeated the experiment we performed in Table 4. By increasing the value of ICT from the 25^{th} to the 75^{th} percentile of its distribution the probability of offshoring decreases of approximately 4.3 base points. In order to assess—as before—the magnitude of the impact we have to compare it with the percentage of offshoring firms in the sample (7.6%). This leads to the conclusion that the reduction in probability turns out to be quite large (more than 50%).

Additional insights can be gained by looking at Table 7 where the two equation system is estimated separately for high-tech (columns (*i*) and (*ii*)) and low-tech (columns (*iii*) and (*iv*)) firms. To save on space we report the results only for the restricted estimates.[21] Two additional findings stand out. Firstly, the BB provision variable, which we use as additional exclusion restriction, enters positively and significantly so only in the Tobit equation for the sub-sample of low-tech firms (see columns (*ii*) and (*iv*)). Secondly, and more importantly for our purposes, also the ICT investment variable enters negatively and significantly so only in the probit equation for the sub sample of low-tech firms (see columns (*i*) and (*iii*)). In more detail, it turns out that by increasing the value of ICT investment from the 25^{th} to the 75^{th} percentile of its distribution the probability of offshoring decreases of 6.4 base points which has to be compared and contrasted with the share of off-shoring firms in the sub-sample of low-tech firms (6.7%). Taken at face value, the quantitative effect of investing in ICT on the extensive margin of offshoring is therefore remarkably high.

— INSERT TABLE 7 ABOUT HERE —

[20]Since the exclusion of the BB variable from the primary equation is not necessary for identification we can test the validity of this exclusion restriction by testing the significance of this variable when included in the probit equation. The null hypothesis of no direct impact of BB on offshoring is never rejected at the 5% significance level in all estimated models.

[21]All our findings are unaltered when estimating the unrestricted versions of the system. Results are available upon request.

Finally, by comparing results in Tables 4 and 7, it turns out therefore that the upward bias discussed above refers almost exclusively to the estimated ICT coefficient for low-tech firms. The reason for this result has to be found in the much higher value (0.885 *vs* 0.349) of the correlation coefficient between the two errors in this sub-sample.

5.2 Robustness Checks

In this section we comment upon additional estimation results which provide evidence on the robustness of our main findings with respect to several departures from our baseline specification and sample.[22]

Firstly, we focus on the sub-sample of low-tech firms with no offshoring activities at the beginning of our sample-period. This amounts to remove 100 firms—out of the set of 153 offshorers—with pre-existing offshoring activities from our baseline sample. Intuitively, we are therefore modeling the probability for a given firm to start offshoring. The main reason for doing this empirical exercise is to check whether our results presented so far are contaminated by the previous history of ICT investment—which we do not observe—that might have triggered irreversible offshoring related investment in the past. Results presented in Table 8 confirm our previous findings. The estimated coefficient on Broad Band Provision is still positive and significantly so in the ICT investment equation (Panel A, column (*ii*)). Analogously, the estimated coefficient on ICT investment is negative and significant in the Offshoring equation (Panel A, column (i)). Note however that, when compared to the one computed on the full sample, the average partial effect is almost half in size (-0.119 (Panel B, Table 8) versus -0.212 (Panel B, Table 7)) and is less precisely estimated.

— INSERT TABLE 8 ABOUT HERE —

Secondly, additional insights can be gained by looking at Table 9 where the two equation system for the sub-sample of low-tech firms is estimated by replacing total ICT investment with hardware (columns (*i*) and (*ii*)) and software/TLC (columns (*iii*) and (*iv*)) expenditures, respectively.[23] In the Tobit equation, the dummy for firms located in large municipalities is negative and marginally significant only when software/TLC investment is used as dependent variable (column (*iv*)). This result is consistent with our previous explanation based on the lack of partners located nearby in small municipalities which is far more likely to apply to the software as opposed to the hardware

[22]Results are discussed in detail only for the sub-sample of low tech-firms. We have also replicated the same robustness check strategy for the sub-sample of high-tech firms. Overall, the result of insignificant average partial effects commented upon in the previous sub-section holds in all our additional estimates. They are available upon request.

[23]Given the low number of firms with positive TLC investment in low-tech industries (30.1%) as well as the conditional small TLC investment size (0.06% of total sales), we do not estimate our system separately for software and TLC equipment. See also Table 2 for more details.

component. Secondly, and much more importantly for the purpose of this paper, the BB provision variable also enters positively and significantly only in the Tobit equation for software/TLC investment (column (*iv*)). This finding suggests that TLC infrastructures are complement only to firms' software/TLC investment and the likely candidate to explain this fact is that BB provision has a productivity enhancing effect only for this type of ICT investment. Finally, both types of ICT investment enters with a negative sign (columns (*i*) and (*iii*)), when included separately in the offshoring equation.[24] By increasing the value of the relevant ICT investment from the 25^{th} to the 75^{th} percentile of its distribution the probability of offshoring decreases of 5.7 base points for the hardware and of 3.8 base points for the software/TLC component. Taken at its face value, this finding therefore suggests that the negative effect of ICT investment on offshoring is general and it is not specifically related to a specific investment type, at least as captured by the hardware versus software/TLC dichotomy.

— INSERT TABLES 9 AND 10 ABOUT HERE —

Thirdly, so far we have collapsed the available information on offshoring activities to a binary variable which is equal to zero (one) when no (some) offshoring activities are reported by the firm. However, as it can be seen by looking at Table 1, grouped data are also available at the firm level on the percentage of off-shored turnover. Inspection of the data suggests that this additional breakdown might turn out to be useful especially for the sub-sample of low-tech firms where offshoring firms are found to be more or less evenly distributed in the four classes (see section 3). This in turn suggests for the possibility of estimating a less restrictive ordered probit model for offshoring jointly with our standard tobit model for ICT Investment. Results for low-tech firms are summarized in Table 10. Previous results are all broadly confirmed. By focusing on Panel B, the average partial effect of ICT investment on offshoring is positive only in the first category (as implied by the negative sign of the coefficient) and is negative and significant at conventional significant levels in all other categories. As one might expect, the partial effect reaches its highest value in the $> 50\%$ offshoring category.

Finally, even if we do not report the results in details, we performed two additional robustness checks. By inspecting Table 1 it might be argued that there are some low-tech industries where the fragmentation of production is simply not a feasible option because of technological reasons. Therefore, we would expect a null relationship between offshoring and ICT for these industries so that their inclusion in the estimation sample could bias the results. To address this legitimate concern

[24] A potential criticism to this approach is that the two investment variables should enter the offshoring equation jointly. However, when doing so we should also take into consideration the simultaneity of the two ICT decision variables. This breaks the recursive structure of our system and makes it not identified.

we have rerun all reported equations only on the sub-sample of low-tech firms operating in industries with non-negligible offshoring activities (more than 4% of the firms doing some offshoring). All our previous results are virtually unaltered with respect both to the sign and to the significance level of all estimated parameters. It might be also argued that there are other relevant firm-level determinants of the offshoring decision that we omit from our model. To address this issue we have re-estimated all our equations for low-tech industries by adding a battery of additional firm level variables including R&D intensity, the skill composition of the labor force, business group and district membership, and foreign ownership. Both R&D and skill intensity enter with a positive sign and significantly at conventional statistical levels. Note, however, that these variables—and skill intensity in particular—are likely to be endogenous in the offshoring equation so that a causal interpretation cannot be given to these findings. All other controls turn out not to be significant, with the exception of the business group membership dummy which is positively signed and significant. More importantly for our purposes, however, our crucial result of a negative and significant impact of ICT on offshoring in low-tech industries is virtually unaltered by the inclusion of these additional variables.[25]

6 Conclusions

Available descriptive evidence suggests that the delocalization of productive activities in manufacturing is still quantitatively much more important than the offshoring of business or personal services. This seems to be the case in all advanced countries, but especially so in non-English speaking developed countries where the delocalization of routine services is hampered by language barriers. Furthermore, it seems that the ICT budget of manufacturing firms is mostly allocated to investment in software and hardware and not specifically to investment in TLC. Only around 30% of our sample of Italian manufacturing firms report to have invested in TLC activities over a three-year period and, conditional on a total positive spending in ICT, the average share of TLC investment on total ICT investment is slightly less than one tenth.

Taken together, these two facts point out to the importance of investigating the role played by ICT investment on offshoring in the manufacturing sector. This is exactly what we have done in this paper. Our findings are striking: once we control for the endogeneity of ICT investment we find a negative effect which is both statistically significant and economically sizeable. On the aggregate the estimated average partial effect is equal to -0.148 in our preferred specification. Furthermore,

[25] As mentioned in section 4, we have also re-estimated all our models using linear and non-linear Two-Stage Least Squares (ivprobit Stata command). Note that these alternative estimators are not only less efficient than ML but also not fully appropriate since the former neglects the non-linear nature in both equations and the latter does not take into account the mixed discrete-continuous nature of ICT investment. Still, they are simple to implement and provide intuitive results. Our main result—the negative sign for ICT in the offshoring equation—is confirmed but, as expected, the effect of ICT on offshoring is less precisely estimated, especially in the Two-Stage Least Squares estimation. All these results are available upon request.

this negative relationship is found to be restricted to the sub-sample of firms in low-tech industries. More precisely, in this sub-sample the average partial effect is as high as -0.212. Moving from the first to the third quartile of the ICT distribution our findings imply a reduction of the probability of offshoring of almost 50% for the full sample and of slightly more than 90% for the sub-sample of low-tech firms.

Our preferred explanation for these findings is that ICT capital substitutes for workers performing non-routine tasks in low-tech industries and this makes less attractive the standard offshoring option whenever this choice is driven by the abundance of routine-workers in less developed countries. As for high-tech industries, it might well be the case that the negative impact on offshoring induced by ICT investments, due to increased task interdependency or workplace organisational changes, is not large enough to compensate the positive impact induced by increased communication and monitoring activities. Be that as it may, ICT investments should therefore not be blamed by policy makers and trade unions for spurring offshoring in the manufacturing sector. What emerges quite clearly from this paper is that an exogenous reduction in the cost of ICT investment is unlikely to spur offshoring at all. Indeed, what we find is quite the opposite, at least in low tech industries.

Clearly, more work is needed in this area. In particular, in this paper the identification of the channels at work has been somehow speculative. It would obviously be very interesting and challenging to open the black box more fully and to quantify more precisely the relative importance of alternative transmission channels. Even if at present data requirements prevent us to do so it ranks high in our future research agenda.

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7 Data Appendix

The original dataset is composed of 4,289 firms. We remove firms operating in non-manufacturing industries or with missing industry codes, so that we are left with 4,110 firms. Subsequently we remove firms with missing (596 firms) or non-coherent information (297 firms) on ICT investment or with missing information on offshoring activities (13). This gives us our final sample of 3,204 firms.

The BB provision data have been retrieved from the "Osservatorio banda larga"(*Between*), a private company appointed by the Italian government to monitor the digital divide in Italy.

Municipal-level characteristics are obtained from a database put together by the consulting company Metropolis from Istat sources.

7.1 Survey questions

The 9^{th} wave of the Unicredit-Capitalia survey contains information on ICT expenditures, delocalization of production, and ISO_2002 compliance. The questions we use are listed below.

C1.3.1 In the three-year period 2001-2003 did the firm invest in hardware, software, internet and telecommunications?

1. yes
2. no

C1.3.2 What is the amount of this investment in the three-year period 2001-2003? (Euro)

C1.3.3 Indicate the specific percentage for each type of these investments (Total 100%)

1. Hardware
2. Software
3. Telecommunication

C1.3.4 Indicate the specific percentage for each type of these applications (Total 100%)

1. Administrative/management systems
2. Production systems
3. Commercial systems (included customer databases)
4. Internet (websites, intranet, extranet)
5. Other applications

D3.1 At present does the firm perform abroad part of its production?

D3.2 In which countries does the firm perform its foreign production?

D3.2.2 What is—at present—the overall share of foreign production over total sales?

1 Less than 10%
2 Between 10% and 30%
3 Between 30% and 50%
4 Between 50% and 70%
5 Between 70% and 90%
6 Above 90%

D3.2.2 What was—in the year 2000—the overall share of foreign production over total sales?

1 The firm did not perform any foreign production at that time
2 Less than 10%
3 Between 10% and 30%
4 Between 30% and 50%
5 Between 50% and 70%
6 Between 70% and 90%
7 Above 90%

E.6 Is the firm awarded ISO 9000 certification?

7.2 Variables definition

Size: number of employees averaged over the 2001-03 period.
Size dummy: dummy equal to 1 if **Size**$\geq$ 50, 0 otherwise.
Observed quality: dummy equal to 1 if the firm has been awarded the ISO 9000 quality certificate, 0 otherwise.
Age: measured as 2003 minus the establishment year.
Total ICT: 2001-03 total ICT investment scaled by firm turnover. This definition equally applies to all ICT components (hardware, software/TLC)
Offshoring: dummy equal to 1 if the firm has declared to perform abroad part of his activities, 0 otherwise.
Broad Band provision: dummy equal to 1 if the proportion of broad band coverage in the municipality in December 2003 exceeds 50%, 0 otherwise.
Inhabitants: number of people resident in the municipality in 2003.
Density: number of people resident in the municipality per Kms.

Latitude and Longitude: municipality latitude and longitude converted to the decimal system
Altitude: municipality altitude in meters.
Coastal Area: dummy equal to 1 if the municipality is along the coastline, 0 otherwise.
Industry dummies: Industry dummies have been included in all the equations (15 – food and beverages; 17 – textiles; 18 – clothing; 19 – leather; 20 – wood; 21 – paper products; 22 – printing and publishing; 23 – oil refining; 24 – chemicals; 25 – rubber and plastics; 26 – non-metal minerals; 27 – metals; 28 – metal products; 29 – non-electric machinery; 30 – office equipment and computers; 31 – electric machinery; 32 – electronic material, measuring and communication tools, TV and Radio; 33 – medical apparels and instruments; 34 – vehicles; 35 – other transportation; 36 – furniture). Each dummy equals 1 if firm's main activity is in that industry and 0 otherwise.
Regional dummies: 17 dummies corresponding to Italian administrative regions. Three regions (Molise, Calabria, Valle d'Aosta) have been aggregated with a neighboring region (Abruzzi, Basilicata, Piemonte) due to the low number of firms.
Provincial dummies: 104 dummies corresponding to Italian administrative provinces.

Table 1: Offshoring and ICT Investment

	N. of Firms	*Off.Firms* (%)	*Percentage of turnover offshored* < 10%	10% − 30%	30% − 50%	> 50%	*ICT Inv.* (*mean*)	*ICT Inv.*(%) (*median*)
Full sample	3,204	7.33	2.90	2.28	0.84	1.31	0.308	0.121
Low-tech industries	2,262	6.76	2.21	1.72	0.97	1.86	0.280	0.100
High-tech industries	942	8.70	4.56	3.61	0.53	0.00	0.380	0.170
Food, Bever. and Tobacco	371	0.54	0.00	0.27	0.27	0.00	0.170	0.066
Textiles	240	13.33	4.17	3.75	2.50	2.92	0.255	0.116
Clothing	92	42.39	7.61	8.70	7.61	18.48	0.268	0.156
Leather	117	20.51	3.42	5.98	2.56	8.55	0.197	0.063
Wood	97	9.28	2.06	5.15	0.00	2.06	0.218	0.153
Paper Products	90	1.11	0.00	0.00	0.00	1.11	0.265	0.102
Printing and Publishing	80	3.75	2.50	1.25	0.00	0.00	0.464	0.208
Oil Refining	17	0.00	0.00	0.00	0.00	0.00	0.245	0.032
Chemicals*	177	4.52	3.39	1.13	0.00	0.00	0.244	0.081
Rubber and Plastics	169	5.92	4.14	1.18	0.00	0.59	0.233	0.098
Non-metal Minerals	201	1.00	1.00	0.00	0.00	0.00	0.235	0.076
Metals	121	1.65	1.65	0.00	0.00	0.00	0.306	0.084
Metal Products	462	4.11	1.95	0.87	0.87	0.43	0.382	0.151
Non-electric Machinery*	429	8.16	4.66	3.03	0.47	0.00	0.317	0.182
Office Equip. and Comp.*	12	8.33	0.00	0.00	8.33	0.00	0.413	0.264
Electric Machinery*	130	11.54	6.15	4.62	0.77	0.00	0.364	0.159
Electronic Products.*	64	7.81	3.13	4.69	0.00	0.00	0.855	0.278
Medical App. and Instr.*	58	12.07	5.17	6.90	0.00	0.00	0.608	0.375
Vehicles*	45	11.11	4.44	6.67	0.00	0.00	0.731	0.107
Other Transportation*	27	22.22	7.41	11.11	3.70	0.00	0.227	0.150
Furniture	205	4.88	2.44	0.98	0.49	0.98	0.330	0.122

Note: The first column reports the absolute number of firms whereas the second one the percentage of offshoring firms. Columns 3 to 6 refer to the percentage of offshoring firms whose percentage of offshored turnover falls in the < 10%, 10% − 30%, 30% − 50%, and > 50% category. Columns 7 and 8 report the mean and the median ICT investment measured as the ratio of ICT expenditures over turnover, in %.
* denotes high-tech industries.

Table 2: Descriptive statistics on ICT investments, by type and application

	Firms investing in ICT						ICT investment (%)					
	Number			%			Unconditional			Conditional		
	All	HT	LT	All	HT	LT	All	HT	LT	All	HT	LT
Total ICT	2,490	784	1,706	77.72	83.23	75.42	0.31	0.38	0.28	0.40	0.46	0.37
Hardware	2,310	724	1,586	72.99	78.52	70.71	0.14	0.18	0.13	0.19	0.23	0.18
Software	2,241	714	1,527	70.81	77.44	68.08	0.15	0.18	0.13	0.21	0.23	0.19
Telecommunications	985	310	675	31.12	33.62	30.09	0.02	0.02	0.02	0.06	0.07	0.06
Administrative/Management systems	2,081	652	1,429	64.95	69.21	63.17	0.12	0.15	0.11	0.18	0.21	0.17
Production systems	1,605	539	1,066	50.07	57.22	47.13	0.12	0.15	0.11	0.24	0.25	0.23
Commercial systems	1,034	329	705	32.27	34.93	31.17	0.04	0.04	0.03	0.11	0.11	0.10
Internet	915	301	614	28.56	31.95	27.14	0.02	0.03	0.02	0.07	0.08	0.06
Other applications	319	129	190	9.96	13.69	8.40	0.01	0.02	0.01	0.10	0.13	0.07

Note: Columns 1, 4, 7, and 10 refer to the whole sample of 3,204 firms, Columns 2, 5, 8, and 11 to the sample of 942 firms in High-Tech industries, Columns 3, 6, 9, and 12 to the sample of 2,262 firms in Low-Tech industries. Columns 7-9 report the unconditional mean of ICT investment whereas columns 10-12 report the mean of ICT investment conditional on a positive investment.

Table 3: Additional firm level variables

	Mean	Std. Dev	Median	1st Quart.	3rd Quart.
Age (Years)	27.94	19.44	24	15	36
Size (Employees)	112.19	266.73	49.50	24	101.7
Obs. Quality (ISO 2002)	0.55	..	..	..	..

Table 4: Preliminary Probit Estimates for Offshoring

	(i)	*(ii)*	*(iii)*	*(iv)*	*(v)*
	All	All	All	HT	LT
N. of firms	3, 187	2, 816	2, 816	692	1, 941
Total ICT Inv.	0.085(0.032) [0.010]	0.090(0.033) [0.012]	0.073(0.034) [0.009]	−0.010(0.080) [−0.002]	0.106(0.039) [0.012]
Age	..	..	−0.459(2.079) [−0.056]	−0.275(3.790) [−0.044]	0.006(2.616) [0.000]
Size Dummy	..	..	0.717(0.095) [0.087]	0.996(0.194) [0.162]	0.622(0.116) [0.067]
Obs. Quality	..	..	0.233(0.094) [0.028]	0.436(0.185) [0.071]	0.116(0.117) [0.013]
Industry dummies.	Yes (0.00)	Yes (0.00)	Yes (0.00)	Yes (0.10)	Yes (0.00)
Regional dummies	Yes (0.25)	No	No	No	No
Provincial dummies	No	Yes (0.58)	Yes (0.84)	Yes (0.91)	Yes (0.86)
Log-likelihood	−713.64	−674.40	−632.24	−205.13	−390.31
Pseudo R^2	0.149	0.166	0.218	0.179	0.271

Note: Size dummy takes a value of 1 if the firm has more than 50 employees. Standard errors in round brackets and average partial effects in square brackets. Coefficients, standard errors, and average partial effects for the variables Age have been multiplied by 1, 000. Columns *(i)* to *(iii)* refer to the total sample, column *(iv)* to the sample of high-tech firms, and column *(v)* refers to the sample of low-tech firms. 21 industry dummies are included in all regressions, 17 regional dummies are included in column *(i)* whereas 104 provincial dummies are included in columns *(ii)* to *(v)*.

Table 5: Broad Band Provision (BBP), Geographic and Demographic Characteristics

	BBP Municipalities		Non-BBP Municipalities	
	Mean	Median	Mean	Median
Inhabitants	31, 122	12, 192	4, 142	3, 124
Density (Inhabitants per Kms)	735.49	421.37	306.40	155.79
Latitude (Decimal System)	44.22	45.04	44.43	45.24
Longitude (Decimal System)	11.25	11.02	11.05	10.98
Coastal Area (%)	16.51	..	8.93	..
Altitude (Meters)	164.17	128	257.02	227

Note: Unweighted statistics based on the 1,596 municipalities where firm headquarters are located

Table 6: Non-linear System Estimation, whole sample

Panel A: coefficients and standard errors

	Whole Sample, unrestricted		Whole Sample, restricted	
	(i)	*(ii)*	*(iii)*	*(iv)*
N. of firms	3,187	3,187	3,187	3,187
Dep. Variable	Offshoring	ICT Inv.	Offshoring	ICT Inv.
Total ICT Inv	−0.732(0.129)	..	−0.744(0.124)	..
Age	1.107(1.525)	2.270(0.955)	1.095(1.511)	2.349(0.952)
Size Dummy	0.561(0.098)	0.129(0.038)	0.554(0.098)	0.127(0.038)
Obs. Quality	0.255(0.069)	0.143(0.040)	0.255(0.068)	0.143(0.040)
Broad Band Prov.	..	0.072(0.048)	..	0.075(0.047)
Inhabitants	−0.024(0.088)	−0.113(0.062)	−0.046(0.082)	−0.120(0.061)
Density	0.000(0.022)	0.001(0.013)	..	..
Latitude	0.033(0.117)	0.062(0.068)	..	..
Longitude	0.058(0.063)	−0.022(0.036)	..	..
Altitude	0.164(0.244)	0.095(0.143)	..	..
Coastal Area	−0.046(0.132)	0.035(0.074)	..	..
σ_η	..	0.973(0.014)	..	0.973(0.014)
$\rho_{\varepsilon,\eta}$	0.744(0.114)		0.755(0.110)	
Industry dummies	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes
Log-likelihood	−4,615.83		−4,618.32	

Panel B: Average partial effects for the offshoring equation.

	Whole sample, unrestricted	Whole sample, restricted
	(i)	*(ii)*
Total ICT Inv	−0.142(0.052)	−0.148(0.053)
Size dummy	0.109(0.015)	0.110(0.014)
Inhabitants	−0.005(0.017)	−0.009(0.017)
Obs. Quality	0.050(0.015)	0.051(0.015)
Age	0.215(0.307)	0.217(0.311)
Coastal area	−0.009(0.025)	..
Altitude	0.032(0.047)	..
Density	0.000(0.004)	..
Longitude	0.011(0.012)	..
Latitude	0.007(0.023)	..

Note: standard errors computed with the Delta method in brackets.
Coefficients, average partial effects and standard errors
for the variables Age, Density, and Altitude have been multiplied by 1,000
21 industry dummies and 17 regional dummies are included in all regressions

Table 7: Non-linear System Estimation, high- and low-tech firms

Panel A: coefficients and standard errors

	High-tech, restricted		Low-tech, restricted	
	(i)	*(ii)*	*(iii)*	*(iv)*
N. of firms	942	942	2,245	2,245
Dep. Variable	Offshoring	ICT Inv.	Offshoring	ICT Inv
Total ICT Inv	−0.401(0.355)	..	−0.864(0.091)	..
Age	−1.297(3.314)	2.282(1.660)	1.960(1.550)	2.481(1.154)
Size Dummy	0.929(0.181)	0.115(0.067)	0.402(0.097)	0.140(0.046)
Obs. Quality	0.405(0.157)	0.126(0.071)	0.197(0.068)	0.148(0.048)
Broad Band Prov.	..	0.003(0.102)	..	0.102(0.049)
Inhabitants	0.066(0.223)	−0.236(0.123)	−0.029(0.081)	−0.077(0.068)
σ_η	..	0.926(0.024)	..	0.983(0.017)
$\rho_{\varepsilon,\eta}$	0.349(0.314)		0.885(0.074)	
Industry dummies	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes
Log-likelihood	−1,409.82		−3,169.49	

Panel B: Average partial effects for the offshoring equation.

	High-tech, restricted	Low-tech, restricted
	(i)	*(ii)*
Total ICT Inv	−0.063(0.068)	−0.212(0.065)
Size dummy	0.147(0.031)	0.099(0.016)
Inhabitants	0.010(0.034)	−0.007(0.020)
Obs. Quality	0.064(0.028)	0.048(0.019)
Age	−0.205(0.514)	0.480(0.403)

Note: standard errors computed with the Delta method in brackets. Coefficients, average partial effects and standard errors for the variable Age have been multiplied by 1,000. 8 (13, resp.) industry dummies and 17 regional dummies are included in regressions *(i)* and *(ii)* (*(iii)* and *(iv)*, resp.)

Table 8: Non-linear System Estimation. Low-tech, Starters

Panel A: coefficients and standard errors

	Starters low-tech, restricted	
	(i)	*(ii)*
N. of firms	2,145	2,145
Dep. Variable	Offshoring	ICT Inv.
Total ICT Inv	−0.822(0.181)	..
Age	1.171(2.284)	2.147(1.168)
Size Dummy	0.374(0.132)	0.118(0.047)
Obs. Quality	0.301(0.112)	0.140(0.049)
Broad Band Prov.	..	0.120(0.060)
Inhabitants	0.002(0.123)	−0.091(0.073)
σ_η	..	0.970(0.017)
$\rho_{\varepsilon,\eta}$	0.813(0.163)	
Industry dummies	Yes	Yes
Regional dummies	Yes	Yes
Log-likelihood	−2,793.39	

Panel B: Average partial effects for the offshoring equation.

	Starters low-tech, restricted
	(i)
Total ICT Inv	−0.119(0.084)
Size dummy	0.054(0.020)
Inhabitants	0.000(0.018)
Obs. Quality	0.044(0.021)
Age	0.170(0.358)

Note: standard errors computed with the Delta method in brackets. Coefficients and standard errors for the variable Age has been multiplied by 1,000. 13 industry dummies and 17 regional dummies are included in all regressions.

Table 9: Non-linear System Estimation. Restricted model, low-tech, investment types

Panel A: coefficients and standard errors

	Hardware Inv		Software/TLC Inv	
	(i)	*(ii)*	*(iii)*	*(iv)*
N. of firms	2,227	2,227	2,227	2,227
Dep. Variable	Offshoring	ICT Inv	Offshoring	ICT Inv
Hardware Inv	−1.840(0.188)	..	..	..
Software/TLC Inv	..	..	−1.173(0.127)	..
Age	1.702(1.521)	0.983(0.561)	2.007(1.584)	1.836(0.842)
Size Dummy	0.364(0.107)	0.048(0.022)	0.427(0.099)	0.106(0.034)
Obs. Quality	0.163(0.068)	0.054(0.023)	0.191(0.070)	0.105(0.035)
Broad Band Prov.	..	0.023(0.023)	..	0.086(0.037)
Inhabitants	0.017(0.082)	0.012(0.033)	−0.065(0.083)	−0.087(0.050)
σ_η	..	0.476(0.008)	..	0.714(0.012)
$\rho_{\varepsilon,\eta}$	0.894(0.077)		0.872(0.078)	
Industry dummies	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes
Log-likelihood	−1,926.82		−2,584.47	

Panel B: Average partial effects for the offshoring equation.

	low-tech, restricted, Hardware	low-tech, restricted, Software/TLC
	(i)	*(ii)*
Hardware Inv	−0.465(0.149)	..
Software/TLC Inv	..	−0.273(0.086)
Size dummy	0.092(0.016)	0.100(0.016)
Inhabitants	0.004(0.021)	−0.015(0.019)
Obs. Quality	0.041(0.018)	0.045(0.018)
Age	0.430(0.403)	0.468(0.392)

Note: standard errors computed with the Delta method in brackets. Coefficients and standard errors for the variable Age has been multiplied by 1,000 13 industry dummies and 17 regional dummies are included in all regressions.

Table 10: Non-linear System Estimation (ordered, low-tech sample, restricted model)

Panel A: coefficients and standard errors

	Total ICT Inv	
	(*i*)	(*ii*)
N. of firms	2,245	2,245
Dep. Variable	Offshoring	ICT Inv.
Total ICT Inv	−0.865(0.090)	..
Age	2.260(1.514)	2.480(1.154)
Size Dummy	0.369(0.089)	0.141(0.046)
Obs. Quality	0.196(0.067)	0.148(0.048)
Broad Band Prov.	..	0.102(0.048)
Inhabitants	−0.010(0.079)	−0.078(0.068)
σ_η	..	0.984(0.017)
$\rho_{\varepsilon,\eta}$	0.885(0.074)	
Industry dummies	Yes	Yes
Regional dummies	Yes	Yes
Log-likelihood	−3,331.51	

Panel B: Average partial effects for the offshoring equation.

	Total ICT Inv			
N. of firms	2,262			
Dep. Variable	Offshoring Category			
	0	1	2	3
Total ICT Inv	0.214(0.065)	−0.021(0.005)	−0.041(0.006)	−0.152(0.073)
Age	−0.558(0.397)	0.054(0.039)	0.107(0.075)	0.397(0.313)
Size Dummy	−0.091(0.016)	0.009(0.004)	0.018(0.007)	0.065(0.018)
Obs. Quality	−0.048(0.018)	0.005(0.002)	0.009(0.004)	0.034(0.016)
Inhabitants	0.002(0.020)	−0.000(0.002)	−0.000(0.004)	−0.002(0.014)

Note: standard errors computed with the Delta method in brackets. 13 industry dummies and 17 regional dummies are included in the regression.

Graph 1:Broad Band Provision (BBP) by municipality