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DETERMINANTS OF THE ADOPTION OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT)*

AN EMPIRICAL ANALYSIS BASED ON FIRM-LEVEL DATA FOR THE SWISS BUSINESS SECTOR

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Abstract

The paper investigates empirically the decision of firms to adopt Information and Communication Technologies (ICT) based on a comprehensive specification of a "rank model" of technology adoption (complemented by some elements of the "epidemic model") using firm-level data for the Swiss business sector. The explanatory variables include many dimensions of (anticipated) benefits from and costs of technology adoption allowing for uncertainty as well as for information and adjustment costs. The model yields a quite robust pattern of explanation across estimates with different adoption variables (time period of adoption of specific ICT elements, intensity of use of ICT). Finally, an extended version of the model explores the role of workplace organisation as a determinant of the adoption of ICT, as well as the reverse relationship, that is the impact of ICT on the adoption of new work practices.

Keywords: Technology Adoption, Information and Communication Technology (ICT), Rank Model of Adoption, Workplace Organisation and Adoption of ICT

JEL Codes: L2, O31, O33

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1. INTRODUCTION

It is not only the generation of new technology but also, and perhaps even to a higher extent, its diffusion throughout the economy which affects productivity growth at the macro-level. Pilat and Lee (2001), for example, show that, to capture the benefits of "Information and Communication Technologies" (ICT), it is not necessary to dispose of an ICT producing sector. Timely diffusion of new technology or, from the firm's point of view, its adoption is a key element to fostering economic growth. It is thus not surprising that technology policy stresses the importance of the firms' capacity to absorb and successfully apply technological knowledge. From this perspective, understanding the factors determining technology adoption becomes highly relevant also from the policy point of view.

This paper investigates the adoption of ICT in the Swiss business sector based on data collected by means of a survey we conducted in autumn 2000. We dispose of firm-specific information on ICT use (e.g. time period of adoption of nine technology elements, share of employees using specific technologies, range of application of Internet and Intranet respectively, objectives of and obstacles to the adoption of ICT, etc.). Moreover, we got information referring to various structural characteristics of the firm (size, industry affiliation, human resources, etc.) as well as a large number of variables pertaining to workplace organisation which may (potentially) serve as determinants of the adoption decision.

The aim of the paper is to explain the timing and intensity of the adoption of ICT well as of certain elements of this bundle of technologies such as Internet, E-commerce, etc. The investigation is primarily based on a "rank model" of technology diffusion, which, in explaining inter-firm differences of adoption time and intensity, emphasises differences among firms with respect to the profitability potential of technology adoption arising from the heterogeneity of firms. In addition, we take into account information spillovers from users to non-users which are the main element of the "epidemic model" of technology diffusion; see Karshenas and Stoneman (1995) or Geroski (2000) for a survey of diffusion models.

In this study we apply a modified version of a model of adoption we used in earlier work dealing with the introduction of "Advanced Manufacturing Technologies" (Arvanitis and Hollenstein, 2001). Its main characteristic is a more comprehensive modelling of "rank effects" than it is the case in most other empirical models. In explaining technology adoption we consider a number of factors which gained attention only recently in empirical work. Firstly, (anticipated) profitability, the core factor determining adoption, is specified by taking account of many dimensions of benefits from as well as costs of adoption. To this end, we use information on the relevance of specific objectives of and obstacles to the adoption of ICT as assessed by the firms themselves. In this way, we take account of information and adjustment costs (which, according to the survey of Karshenas and Stoneman (1995), have been neglected in most analyses) as well as of anticipated benefits and related uncertainties as perceived by the firms. Secondly, we explore the role of workplace organisation in determining the adoption of ICT which seems to have a positive impact on productivity, not only directly (see e.g. Ichniovski et al., 1997; Murphy, 2002) but also indirectly through an increase of the propensity to adopt ICT conceptualised as a complementary factor (see e.g. Bresnahan et al, 2002). Thirdly, we estimate the postulated model with several types of adoption measures as dependent variables (time period and intensity of the adoption of specific elements of ICT, intensity of ICT use in general) in order to separate robust from shaky relationships and to identify differences in the pattern of explanation for the various types of adoption variables. We expect, for example, that the first use of Internet (a basic element of ICT with a broad range of application) is driven by somewhat different forces than the introduction of E-commerce whose profitability potential varies substantially across firms and industries (see e.g. OECD, 2000).

The set-up of the paper is as follows: Section 2 gives for the Swiss business sector a brief description of the diffusion profile of the elements of ICT considered in this paper. The theoretical background of the analysis and the specification of the empirical model are presented in Section 3 and 4 respectively, followed by some information on data and method (Section 5). The empirical estimates are found in Section 6. Finally, we summarise and assess the results and draw some conclusions.

2. DIFFUSION OF ICT IN THE SWISS BUSINESS SECTOR

Table 1 contains some information on the time path of adoption of nine elements of ICT in the Swiss business sector. The diffusion rate in 2003 (percentage of firms using a certain technology in the year 2000 or planning to use it till 2003) and diffusion velocity (increase of the percentage of firms using a certain ICT element in the period 1994-2003) varies quite strongly among these technologies.

For example, the degree of diffusion of PC's being already an "old" technology was quite high in 1994 and increased since then (compared to other ICT elements) "only" by 55%. On the other hand, "new" technologies, in particular Internet and related technologies (E-mail, Intranet, Extranet), were used by a very small fraction of firms in the mid-nineties, but this share "exploded" in the second half of the last decade. The growth of the diffusion rate, as planned by the surveyed firms for the period 2000/2003, will slow down for most ICT elements primarily reflecting the high level of diffusion already reached in 2000. In the years to come, diffusion will thus primarily take place within rather than across firms.

A characterisation of the various technology elements according to the criteria "diffusion rate" and "velocity of diffusion" leads to the following mapping: technologies with high diffusion rates are PC's (with low velocity) as well as E-mail and Internet (very high velocity); ICT elements with a medium diffusion rate are LAN/WAN, EDI, Laptop and to some extent also Digital Assistants (high velocity, particularly EDI), and, finally, technologies with a low diffusion rate are Intranet and Extranet (very high velocity).

These tendencies vary by firm size, strongly in case of network technologies (EDI, LAN/WAN, Intranet, Extranet), not very pronounced for other ICT elements. There are also differences among industrial sectors with "modern" service industries (business services, R&D/IT firms, banking/insurance) and high-tech manufacturing taking the lead; low-tech manufacturing and "traditional services" are in a medium position whereas the construction sector is clearly lagging in this respect. Compared to other countries, diffusion of ICT in Switzerland (business sector) is high: It ranks behind the USA and Scandinavia, but (together with the Netherlands) is clearly ahead of other European countries (see Arvanitis and Hollenstein, 2002, based on various sources such as OECD, 2001).

3. THEORETICAL BACKGROUND

The main objective of this section is to formulate an equation explaining the decision to adopt ICT based on a set of mainly firm-specific factors determining the profitability of new technology. Within the general conceptual framework proposed by Karshenas and Stoneman (1995) our approach belongs rather to the category of "rank models" emphasising the heterogeneity of firms as determinant of inter-firm diffusion patterns (although we also take into account some elements of the "epidemic model" which stresses information spillovers from adopters to non-adopters). In the rank model, it is assumed that potential users of a new technology differ from each other in important dimensions so that some firms obtain a greater return from the new technology than others do. The larger the net advantage resulting from the technology adoption, the stronger the tendency to adopt early and intensively.

We distinguish several groups of factors which potentially influence (positively or negatively) a firm's profitability from adopting the new technology and therefore the decision to introduce it at a certain time. A first one includes a set of anticipated benefits of new technology such as savings of inputs, general efficiency gains, higher flexibility, improvement of product quality, etc. (see e.g. Brynjolfsson and Hitt, 2000; OECD, 2000): ICT may reduce capital needs through, for example, lower inventory requirements, it may save labour in general or substitute for specific labour skills (e.g. sales staff), or it may increase the efficient use of inputs in general (making use of the increased scope for flexible and decentralised work organisation). Moreover, it may lead to higher product quality at large in various ways (increased product variety and convenience, provision of complementary services, etc.). To mention is also the potential of reducing transaction costs by improving the relationship to suppliers of materials, capital and labour, as well as to customers. For this group of variables we expect a positive influence on the adoption decision, i.e. early and/or intensive use of the new technology is favoured.

A second category of variables, which are negatively related to adoption, refers to anticipated barriers to the adoption of new technology. We identify five main types of such hindrances: unfavourable financial conditions (e.g. liquidity constraints, large investment requirements, etc.); human capital restrictions (e.g. lack of ICT specialists or highly-skilled workers in general); information and knowledge barriers reflecting, for example, uncertainties with respect to the performance or the future development of ICT; organisational and managerial barriers (e.g. resistance to new technology within the firm; insufficient awareness of managers of the potential gains of ICT), and, finally, sunk cost barriers which refer to the substitution costs firms have to incur, in order to introduce the new technology, for example, in case of insufficient compatibility of ICT with existing equipment or organisation.[1]

The firm's ability to absorb knowledge from external sources is another major determinant of innovation performance in general and of technology adoption in particular. There are mainly two aspects of a firm's absorptive capacity for new technologies: firstly, the firm's overall ability to assess technological opportunities in (or around) its fields of activity in terms of products and production techniques, which depends primarily of the endowment with human and knowledge capital (Cohen and Levinthal, 1989). Secondly, learning effects that may arise from earlier use of ICT or a predecessor of a specific ICT element which embodies constituent elements of later applied, more advanced vintages; for evidence for the importance of learning effects see e.g. Colombo and Mosconi (1995), McWilliams and Zilberman (1996), or Arvanitis and Hollenstein (2001). Both elements of absorptive capacity should be positively related to early and intensive use of ICT.

Whereas these aspects of absorptive capacity are specifically related to internal conditions, the standard epidemic model of technology diffusion stresses information spillovers from users to non-users of the technology at hand ("external learning"); various brands of this approach are discussed e.g. in Geroski (2000). The epidemic model basically states that a firm's propensity to adopt a technology at a certain point in time is positively influenced by the present (or lagged) degree of its diffusion in the economy as a whole or by the proportion of adopters in the industry or sector to which the specific firm is affiliated. The proposition of the stock of past adopters positively influencing adoption later on captures also network externalities which are important in the case of ICT.

Firm size and firm age are two explanatory variables which are used in most studies of adoption behaviour (see Karshenas and Stoneman, 1995). In this investigation, we only include firm size, since the theoretical arguments with respect to the role of firm age are not conclusive.[2] Firm size

[1] See e.g. Cainarca et al. (1990) or Link and Kapur (1994) for a treatment of these aspects based on the case of flexible manufacturing systems, or the results of a survey on obstacles to the adoption of E-commerce (WITSA, 2000).

[2] Positive impact on adoption in case of older firms reflecting specific (technological) experience vs. negative effects for this category of firms due to lower adjustment costs in younger companies with a more up-to-date capital stock (see Dunne, 1994).

captures size-specific variables which are not explicitly modelled, such as, the capacity to absorb risks related to future ICT developments, economies of scale in E-commerce, access to capital markets, etc.

The adoption of ICT may also be affected by (product) market conditions under which firms are operating, particularly the competitive pressure they are exposed to. In those markets where competition is fiercer, demand elasticities can be expected to be higher because of the existence of close substitutes, thus driving firms to innovative activity or rapid technology adoption (see e.g. Majumdar and Venkataraman, 1993).[3] In case of (small) open economies like Switzerland international competition is a particularly effective way of forcing firms to adopt the most efficient way of producing, or to temporarily evade competitive pressure through product innovations; for empirical evidence, see Bertschek (1995) and, specifically for E-commerce, Bertschek and Fryges (2002). In large parts of the theoretical literature, market concentration is taken to reflect competitive pressure. Game-theoretic models show that the impact of market structure upon the schedule of adoption dates depends critically on the difference of profit rates preceding and following adoption; however, this type of models does not come up with unambiguous results (see the review of Reinganum, 1989), and the empirical evidence is very mixed (see Karshenas and Stoneman, 1995). Therefore, and because the usual measures of concentration referring to the home market only are not very helpful in case of small open economies like Switzerland, we do not include a measure of concentration as a determinant of ICT adoption.

Finally, industry dummies are used to represent factors influencing adoption time and intensity which are, to some extent, common to most firms of an industry: on the demand side, favourable market prospects may exert a positive impact on the adoption of new technology, because they enhance the financial room of manoeuvre of the firm; on the supply side, (technological) opportunities determining extent and limits of the use of ICT might vary quite strongly across industries (although there are also some firm-specific differences in this respect). In this way, industry dummies may contribute to controlling for unobserved variable bias. The theoretical arguments put forward so far will serve to specify the basic model of the empirical analysis.

The last decade saw an impressive increase of adoption not only of ICT but also of new work practices. It is thus not surprising that the investigation of the impact of the two factors on variables such as efficiency and productivity, labour and skill demand, etc. has become a prominent field of research. One type of studies tried to establish a direct link between organisational change and productivity growth (see e.g. Ichniovski et al., 1997; Black and Lynch, 2000). Similarly, there has been much research devoted to the analysis of the (direct) relationship of ICT and productivity, particularly at the macro- or meso-level (among many others, see e.g. Jorgenson and Stiroh,

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[3] In accordance with this line of reasoning, we have proxied competitive pressure through the intensity of price and non-price competition on the product market, and postulated a positive relationship to innovative activity (see Arvanitis and Hollenstein, 1994) and technology adoption" (Arvanitis and Hollenstein, 2001).

2000; Jorgenson, 2001; Colecchia and Schreyer, 2001); examples at the micro-level are Lichtenberg (1995), Brynjolfsson and Hitt (1995) or Greenan and Mairesse (1996). Some recent studies stressed the complementarity of the adoption of new modes of workplace organisation and the introduction or the more intensive use of ICT. In this view, investment in ICT is more productive if accompanied by suitable organisational innovations, and the productivity gains from adjusting workplace organisation are higher if it is supported by investments in ICT (see e.g. Bresnahan et al., 2002; Brynjolfsson and Hitt, 2000; Bertschek and Kaiser, 2001; McKinsey, 2001).[4] Against this background, we formulate an extended model of ICT adoption which complements the basic approach by variables representing (the change of) workplace organisation.

4. EMPIRICAL MODEL

4.1 Adoption Variable

The database (see Section 5) allows to construct various adoption variables. A first category of measures refers to the time period of adoption of ICT, a second one to the intensity of use of ICT at a given point in time.

We dispose of information on four time periods of adoption for the nine ICT elements listed in Table 1. In addition, there is information on the actual and planned use of the Internet for various objectives (E-selling, E-procurement, etc.). We shall present results for two variables (see Table 2). The first one refers to the adoption of Internet (INTERNET) which is specified as a variable with five response levels, ranging from value 4 for the earliest adoption period (up to 1994) to value 0 for firms not even planning adoption up to 2003. The second variable refers to the adoption of Internet-based selling (ESALES); it has three response levels with value 2 representing adoption in the time period up to the year 2000, value 1 for 2001-2003 (planned use) and zero for "no use till 2003".

To construct a variable for adoption intensity, we used information on the within-firm diffusion of certain technologies (PC's, Internet, Intranet) as well as on the diffusion rate of the various elements of ICT. We present again results for two variables (see Table 2). Firstly, we calculated a four level ordinal measure of the overall ICT intensity (ICTINT), defined as the number of ICT elements (as listed in Table 1) already in use in the year 2000: intensity level 3 in case of 7 to 9 ICT elements, level 2 for 5 to 6 technologies, level 1 for 3 to 4 items and level 0 if less technologies (zero included) have been introduced.[5] The second intensity variable refers to the intensity of use of

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[4] An open question is whether complementarity is contemporaneous, or whether one of the two factors is lagging.

[5] We decided to rescale the count data information (0 up to 9 technologies) into ordered categories because of the non-equivalence of the elements (not each additional ICT element is of the same importance: e.g. PC vs. Extranet).

Internet measured by the proportion of employees regularly working with this technology in the year 2000; this variable (NETUSE) is also measured on an ordinal scale since the surveyed firms reported estimates on the share of Internet workers based on five categories (up to 20%, 21-40%, 41-60%, 61-80%, 81-100% of employment). Adding the non-users we get an ordinal variable with six response levels.

4.2 Determinants of ICT Adoption

Basic model

Table 3a gives an overview on the empirical specification of the variables which reflect the various groups of factors determining technology adoption as set out in Section 3. The first group of variables refers to the objectives of ICT adoption, which are interpreted as proxies for anticipated revenue increases (benefits) due to the use of new technology. This interpretation can be justified on ground of evidence on the impact of the use of ICT on the firms' efficiency (based on their assessments measured on a five-point Likert scale with a value range of "highly negative contribution to efficiency" (value -2) up to "strong increase of efficiency" (value 2). 61% of the surveyed firms report positive effects, whereas only 1% see a negative impact of ICT adoption on overall efficiency. The three metric variables listed in Table 3a under the heading "objectives" are factor scores resulting from a principal component factor analysis of 13 objectives of the use of ICT; the factor solution is described in detail in Hollenstein (2002, downloadable from http://www.kof.ethz.ch). MARKET is related to anticipated benefits from ICT use on the revenue side capturing, besides increasing sales in general, expected benefits from higher quality, more variety, providing complementary services, better market presence and stronger customer-orientation. COST stands for expected cost reductions in general, and, more specifically, for advantages to be gained from improving internal communication and decision-making as well as optimising the production process. The factor INPUT covers anticipated advantages from improving external relationships on the input side (labour market, co-operation with suppliers) as well as with respect to technology. For these three variables, which cover to a large extent the benefits accruing from the use of ICT as proposed by the literature (see Section 3), we expect to find a positive influence on the adoption variables.

Secondly, the model covers all five categories of obstacles to the adoption of ICT we identified in Section 3 (see Table 3a). They should lead to late and less intensive adoption (negative sign). The variable NOUSE captures the fact that in some instances there is hardly any "real potential" for using ICT. The other four variables reflecting impediments to the use of ICT are again the result of a principal component factor analysis; for a full presentation we refer once more to Hollenstein

Although this problem of non-equivalence cannot be definitely solved, it is much weakened by reducing the 9 counts to 4 ordinal groups. Estimates with alternative numbers of response levels yielded very similar results.

(2002). These variables, with the exception of INVCOST which captures problems of financing ICT investments, can be interpreted, primarily, as proxies for uncertainties, knowledge deficiencies and information problems as well as adjustment costs related to the introduction of ICT (TECH, KNOWHOW, COMPAT). They thus capture determinants of adoption which are neglected in most studies treating this topic (see Karshenas and Stoneman, 1995).

The firm's ability to absorb knowledge from external sources, which we expect to be positively related to early and intensive adoption, is represented by three variables measuring the availability of human and knowledge capital as well as innovative activity (see Table 3a): EDUC, the share of employees with qualifications at the tertiary level, is a general measure of the firm's ability to assess technological opportunities and to use external knowledge for own innovative activities. INNOPD, a dichotomous measure indicating whether a firm launched product innovations in a three years reference period, is used to take into account the finding of Cohen and Levinthal (1979) according to which internal innovative activity is a precondition for successfully using external knowledge. The third variable we employ to capture absorptive capacity is more directly linked with ICT: we use the share of employees which in 1999 attended ICT-oriented training courses (TRAINING) as a proxy for the firm's specific knowledge in ICT. Since some training is necessary when ICT is introduced, this variable is not strictly exogenous.

It is not easy to find suitable proxies for measuring learning from previous vintages of ICT in a cross-section framework. Variables which could be used to measure learning in the field of ICT in general, such as, for example, the intensity of use of PC's at an early stage, are problematic, because they are determined by similar factors as measures reflecting ICT intensity at a later stage. Therefore, we explored the role of learning only in one specific case where an earlier and a later vintage of technology are clearly linked: we hypothesise that experience with electronic data interchange (EDI), measured by the dummy variable EDI97 (adoption of EDI up to 1997), favours adoption of E-selling (although adjustment costs incurred by the substitution of Internet-based selling for the use of EDI work in the opposite direction). "External learning" through information spillovers ("epidemic effects") is represented by the rate of diffusion of ICT at industry level in 1997; the percentage share of firms that are more ICT-intensive than the average-firm of its industry (EPIDINT) is used in explaining the time period of adoption of Internet and the two variables measuring ICT intensity in the year 2000 (lagged epidemic effect). In case of E-selling, where, in our dataset, the first adoption period refers to 1998/2000, "epidemic" effects are proxied by the industry-specific diffusion rate in 2000 (EPIDSALE; contemporaneous effect).

Competitive pressure on the (international) product market is proxied by the firm's export propensity (export-to-sales ratio). We use a specification with a linear and a quadratic term assuming that beyond a certain export intensity competitive pressure increases less than proportionally, or does not increase any more (positive sign for X, negative sign for X^2).

Firm size (S), which we expect to be positively related to early and intensive adoption, is represented by dummy variables referring to five size classes based on the number of employees, with large firms (500 and more employees) as reference group. In this specification, a negative sign indicates a positive size effect. An alternative specification of firm size based on the number of employees and its square yielded similar results. Finally, we include 15 industry dummies which, as set out in Section 3, should capture differences with respect to technological opportunities and demand prospects, and should control for an unobserved variable bias.

Extended model

The extended model includes, as additional variables, various elements of workplace organisation as well as some measures of organisational change related to the period 1995-2000 (see Table 3b). Firstly, we take into account three types of (new) work practices, i.e. team-working (TEAM), job rotation (ROTATE) and multi-skilling (MSKILL). The first two variables measure the diffusion within the firm of team-working and job rotation respectively on a six-point ordinal scale ("very common practice" to "does not exist"). MSKILL represents the degree of diversity of tasks an "average worker" performs (5-point scale; "very high" to "very low"). We expect that the existence of these work practices are a favourable environment for early and intensive adoption of ICT. Similarly, a high degree of worker's participation in decision-making is assumed to impact positively on the adoption of ICT. To get a measure of the role of workers in decision-making, we conducted a principal component factor analysis of 7 dimensions of work for which the surveyed firms assessed the balance of decision-making power between managers and workers (5-point scale ranging from "manager decides alone" up to "decision is the sole responsibility of the worker"); for details, we again refer to Hollenstein (2002). We identified two factors: PRODDEC pertains to dimensions of work which are related to the production process (design of work process, distribution of tasks among workers, work pace, etc.), and USERDEC is primarily related to customer-oriented tasks (regular contact with customers, contact with clients in case of complaints). Another two variables reflect the process of decentralising decision-making power within a firm during the second half of the nineties: DELCOMP measures whether there has been an increase of delegation of decision-making power towards the workers (yes/no). FLAT stands for a flattening of the hierarchical structure (reduction of the number of management layers yes/no). Both variables are expected to favour adoption of ICT.

As an alternative to the use of these variables capturing specific dimensions of (a change of) workplace organisation, we constructed a composite measure of organisation by applying a procedure proposed by Bresnahan et al. (2002): The standardised values of TEAM, ROTATION, MSKILL, PRODDEC, USERDEC, DELCOMP and FLAT are simply added up. We rescaled this sum, for some technical reasons, into four ordinal categories (variable ORG4).

5. DATA AND METHOD

The analysis is based on firm data of the Swiss business sector collected in a survey carried out in autumn 2000. The available information is to a large extent qualitative in nature (nominal or ordinal measures). The questionnaire[6] yielded data on the time profile of the introduction of nine ICT elements, the intensity of use of ICT, the assessment of a number of objectives pursued by introducing ICT and the importance of factors impeding its application, the specific use of ICT elements such as Internet or Intranet and the impact of ICT on efficiency and labour requirements. Besides, we got information on the adoption of new work practices (team-working, job rotation, etc.) and training activities, which presumably are relevant when a firm decides on the adoption of ICT. Finally, we dispose of information about structural characteristics of firms such as size, industry affiliation, propensity to export, human capital endowment, etc., which may also serve as determinants of ICT adoption.

The questionnaire has been addressed to a sample of 6717 firms with five or more employees, which covered the business sector of the economy. The sample has been (disproportionally) stratified by 28 industries and three industry-specific firm size classes, with full coverage of large firms. The response rate of about 40% (2641 firms) is quite satisfactory in view of the very demanding questionnaire. To correct for "unit" non-response, we conducted a non-response analysis with 650 firms (response rate 94%). We found some selectivity bias which has been corrected by a suitable weighting scheme (for the method used, see Donzé, 1998). The structure of the dataset in terms of firm size and industry, with a few exceptions, is similar to that of the underlying sample. "Item" non-response is another problem of survey data. The usual procedure of dropping observations with incomplete data may produce biased estimates. Therefore we substituted imputed for missing values using the "multiple imputation" procedure proposed by Rubin (1987). The details of this method, as applied in the present case, and some tests for robustness are documented and discussed in Donzé (1998).

The model specified in the previous section is estimated in a cross-section framework, since our data, except the adoption variables, refer to one year only. We used the ordered probit procedure, which is an appropriate method when the dependent variables are measured on an ordinal scale (in the present case, three to six response levels).

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[6] The questionnaire can be downloaded from http://www.kof.ethz.ch.

6. EMPIRICAL RESULTS

6.1 Time Period and Intensity of ICT Adoption

Time period of ICT adoption

The estimation results for the time period of adoption of two elements of ICT, i.e. Internet (variable INTERNET) and Internet-based selling (ESALES), using the basic model are presented in Table 4. With one exception (export propensity in case of ESALES), all categories of explanatory variables, though not to the same extent, have a statistically significant impact on the timing of adoption decisions. The overall fit of the model is satisfactory. The core of our adoption model is thus confirmed.

More specifically, we conclude that a multidimensional modelling of anticipated benefits and costs of ICT adoption, a specific feature of our approach, does pay off. Among the anticipated benefits, those related to market- and customer-orientation (MARKET) are the most important ones in case of both dependent variables;[7] it is not surprising that this is particularly pronounced in case of ESALES. Cost- and input-related benefits (COSTRED, INPUT) are only relevant for explaining the adoption of Internet. Among the obstacles to adoption, insufficient opportunities to benefit from an application (NOUSE) are an important factor in both cases. With regard to other impediments, Internet and Internet-based selling are different: for the former, investment costs and financial restrictions, and, even more, knowledge problems (deficiencies with respect to qualified manpower, management as well as information problems) are important (INVCOST, KNOWHOW). In the latter case, we find, against our prediction, a statistically significant positive sign for technological uncertainty (TECH); this result could reflect the fact that E-selling was characterised by particularly high uncertainty at an early stage of its diffusion (see WITSA, 2000). We find no evidence for compatibility problems (COMPAT); high adjustment costs seem to be important only if a whole bundle of ICT elements is introduced (see the results for ICT intensity below). We also find that the various dimensions of absorptive capacity as well as the propensity to export strongly stimulate early adoption of the Internet but not that of E-selling (except variable INNOPD). This difference may be compensated for by the strong effect we find, in case of ESALES, for information spillovers ("epidemic effects") reflecting a particularly strong pressure to keep up to competitors in case of this technology. In addition, "internal" learning" from the use of a predecessor technology (EDI) also plays an important role in fostering early adoption of E-selling; this result implies that the adjustment costs a firm incurs when it substitutes Internet-based selling for using EDI are lower than the benefits to be captured from this change.

[7] The coefficients of the variables measuring the objectives of ICT adoption can be directly compared since their values are standardised; the same holds for the obstacles to adoption.

Larger firms have a higher propensity to adopt these technologies, with somewhat stronger effects in case of INTERNET compared to those found for ESALES. However, beyond a threshold of 200 employees, we cannot find any significant size-specific differences of adoption.[8] With regard to industry effects (which are not reported in Table 4), we find a strong correlation with epidemic effects. Since the latter are defined at the industry level, this result is not very surprising. At the empirical level, it is thus difficult to disentangle epidemic effects from (other) factors we assumed to be captured by industry dummies (demand prospects or technological opportunities).

Intensity of use of ICT

The results of estimations for the intensity of use of ICT, based on an overall measure (ICTINT: number of ICT elements) as well as on the intensity of Internet use (NETUSE: share of employees working with Internet), are also presented in Table 4. The pattern of explanation for the two intensity variables is similar. More importantly, it also does not much differ from that we found for the timing of adoption decisions. However, the explanatory power of the model explaining adoption intensity is higher.

We also find some differences of the explanatory pattern between the two types of adoption variables (intensity vs. timing variables). Firstly, on the benefit side of anticipated profitability, market- and customer-orientation are less important in case of both intensity variables, and cost-oriented factors become more relevant when the intensity of use is to be explained. Secondly, among the obstacles to adoption, investment costs and funding restrictions are now a bigger problem, indicating that in case of an already larger ICT infrastructure investment needs are increasing (transition to more complex, network-oriented technologies). Similarly, the lack of a potential to use these technologies is higher in case of intensity variables, again a plausible result; if, for some firms, the introduction of one ICT element is already not very promising, the more this holds true when a more intensive application of ICT is to be explained. With respect to knowledge and information problems, the comparison of intensity variables and those depicting the first use of ICT yields mixed result; the largest negative impact we find refers to the intensity of use of the Internet, the lowest for the introduction of E-selling. Thirdly, the capacity to absorb external knowledge is distinctly a more important factor determining adoption when intensity measures are used as dependent variable; this result is plausible in view of the more complex problems to be solved when a large set of ICT elements has already been adopted. A similar argument holds true for compatibility problems which are, against our prediction, positively correlated with ICT intensity. However, this result is not implausible: if the ICT infrastructure is already highly developed, incompatibilities and high adjustment costs may be more prominent obstacles than in case of ICT adoption from scratch. Fourthly, big firms have a much larger advantage in the adoption process

[8] An in-depth analysis of the role firm size plays in adoption decisions (in particular, separate model estimates for different firm size classes) is presented in Hollenstein (2002).

in case of ICTINT, the most complex adoption variable. Interestingly, and not implausible, we do not find any size effects (or even some advantages for medium-sized firms) for the within-firm diffusion of the Internet (NETUSE).

6.2 The Role of Workplace Organisation

Organisational change increases productivity directly and, in particular, when it is complemented with the use of ICT and accompanied by training measures (see Bresnahan et al., 2002). Therefore, one may expect that the adoption of new work practices contributes to intensifying the use of ICT (or to adopt it at an early point in time). The extended model of adoption, as specified in Section 3, takes account of this proposition.

Table 5 shows results for this extended model using ICTINT (number of ICT elements) as dependent variable. Since our survey yielded information about organisational matters only for firms with at least 20 employees (against a threshold of 5 employees in the other sections of the survey) we dispose of a reduced dataset of 1667 firms (as against 2641 observations in the original sample). Therefore, we started with re-estimating the basic model. The results (column 1) yielded a pattern of explanation which is very similar to that we got when using the larger sample. Next we estimated the model where the basic specification is complemented with organisational variables, either based on various elements of new workplace organisation (column 2: team-working, job rotation, multi-skilling, degree of decentralised decision-making in production and in contacts with users, tendency of decentralising decision-making and of flattening hierarchical structures), or using an aggregate measure developed from the mentioned organisational elements (column 3). It turns out that both types of organisational variables exert a statistically significant influence on ICT adoption. Among the various organisational dimensions, team-working, decentralised decision-making at the workplace and lowering the number of hierarchical layers are the relevant dimensions of workplace organisation in explaining the use of ICT. Estimates, not reported here, point to some interaction between workplace organisation, on the one hand, and education, training and innovation on the other.[9]

The specification of this extended model of ICT adoption does not take account of the (potential) endogeneity of new workplace organisation. Therefore, the results presented in the columns 2 and 3 of Table 4 may be biased. A straightforward way to handling this problem is to introduce a lag between ORG4 and ICTINT. This procedure assumes, as proposed by Bresnahan et al. (2002), that organisational adjustments take longer than changes of technology or human capital endowment. Organisation is considered as a quasi-fixed factor in the short run, whereas complementarity between the three factors involved is characteristic for the longer run. The last column in Table 4 shows the result of an estimate where, as dependent variable, the intensity of

[9] For example, if EDUC, TRAINING and INNOPD are removed from the equation the coefficient of ORG4 increases substantially, i.e. from 0.21 to 0.31.

use of ICT as planned for the year 2003 replaces ICTINT which refers to 2000; in this way, ORG4 gets a three years lag, since it represents the organisational conditions of the year 2000 (and some changes which took place in the second half of the nineties). The model fit of this specification is better than that of the equation 3 where ORG4 is not lagged. In addition, the impact of lagged organisational change on the adoption of ICT turns out to be somewhat larger than the contemporaneous effect. As shown in additional estimates, workplace organisation and variables capturing human and knowledge capital interact in the same way as before, i.e. in the specification where ORG4 is not lagged.

A more fundamental way of taking account of endogeneity is to look for evidence of the reverse causality, i.e. to investigate whether the adoption of ICT exerts an influence on (the change of) workplace organisation. To this end, we specify an equation explaining the adoption of new work practices, with ICT as one of the explanatory variables. The structure of this "organisation model" is the same as that of the "ICT model"; it is only the content of the two categories of variables "anticipated benefits" (objectives of organisational change) and "adjustment costs" (obstacles to organisational innovations) which makes the difference. Information about a number of dimensions of objectives of and obstacles to organisational change is again condensed to a few variables by means of principal component factor analysis. As a result of this exercise (documented in detail in Hollenstein, 2002), we obtain two variables representing anticipated benefits of new work practices as well as three factors depicting barriers to change of workplace organisation (see Table 6). Among the benefits, the variable PERS represents the potential of exploiting previously untapped human resources by reorganising work (strengthening motivation, use of specific knowledge of workers, etc.), and COSTFLEX stands for expected gains from reducing costs and enhancing organisational flexibility to adjust to exogenous changes. Insufficient readiness on the workers and management side is one of the barriers preventing reorganisation (HUMAN). The other obstacles refer to difficulties encountered in the adjustment process (e.g. slow speed of adjustment; variable ADJDIFF) and the costs of organisational adjustments (ADJCOST). Another variable representing impediments to organisational innovations, which we did not extract by use of factor analysis, is NONEED, which is a measure of the necessity to changing organisational structures (high values stand for a low necessity to adjust).

Table 7 shows the results of estimations of this model explaining the adoption of new workplace organisation. As can be seen from column 1, ICT intensity, specified as a contemporaneous variable (i.e. referring to the year 2000) exerts a statistically significant influence on the adoption of new work practices. The same holds for the anticipated benefits of and (some of the) obstacles to organisational change. Educational attainment, training and innovativeness as well as firm size are also important determinants of (the change of) workplace organisation. We conclude that this model explains the adoption of new work practices quite well. However, in the same way as in case of the "ICT model", we are confronted with an endogeneity problem, this time with respect to the ICT variable. Therefore, we estimated another equation (Table 7, column 2) where the ICT variable is lagged by three years (ICT intensity in 1997). The model fit is about the same as in the case of a contemporaneous specification; however, the impact of the ICT variable decreases substantially. Besides, some estimates, not reported here, indicate quite a strong interaction between ICT intensity, on the one hand, and education, training and innovation on the other; this holds true for both specifications.[10]

The results we obtained by estimating the "organisation model" and those we found with the extended version of the "ICT model" point in the same direction: ICT intensity and workplace organisation are interrelated; we find statistically significant results for both directions of causality. In addition, there is some evidence for interactions between ICT intensity and (new) workplace organisation respectively on the one hand, and, on the other, education, training and innovative activity. These results are based on estimates in a single-equation framework. They should thus be checked by means of a simultaneous estimation of the two equations. This procedure might also give some indication of the relative magnitude of the impact of the adoption of new work practices and ICT. Although this line of research is recommended, we would be quite surprised when simultaneous estimations would substantially alter the basic conclusion.

Another finding is related to the time structure of the relationship between the adoption of ICT and new work practices; it is shown that the lagged effect of the "organisational variable" on ICT adoption is stronger than the contemporaneous one, whereas the opposite is true in modelling the adoption of new work practices. This result seems to be in line with the assumption of a more sluggish change of organisation as compared to technology adoption (organisation as a quasi-fixed factor in the short run). To check this result, we need a dynamic modelling of the adoption of ICT and new work practices; we were not able to undertake such panel estimates, since we only dispose of data for one cross-section.

Taken as a whole, our results are consistent with those of some recent studies which found that ICT, new workplace organisation and human capital are complementary factors to increasing the efficiency of production and the quality of products (see e.g. Bresnahan et al., 2002; Brynjolfsson and Hitt, 2000; Bertschek and Kaiser, 2001).

7. CONCLUSIONS

The adoption behaviour of Swiss firms in the field of ICT is characterised by a basic pattern of explanation which is quite robust across model estimations with different adoption variables. All categories of explanatory variables, though to a different extent, are relevant. Most important are (various dimensions of) anticipated benefits and costs of adoption, the firm's ability to absorb knowledge from other firms and institutions, information spillovers between firms, experience with

[10] If EDUC, TRAINING and INNOPD are removed from the equation the coefficient of ICTINT (contemporaneous specification) increases substantially, i.e. from 0.31 to 0.45.

earlier vintages of a certain technology and (international) competitive pressure and firm size. In addition to these firm-specific effects, there is also evidence for industry effects (with a higher probability of adoption in some high-tech industries, modern services and trade) which, among else, reflect different technological opportunities. Moreover, there are some interesting differences between the results for the various types of adoption variables (timing of the adoption of specific ICT elements vs. measures of the intensity of ICT use), which in most cases seem plausible.

The results strongly confirm the usefulness of modelling anticipated profitability of technology adoption more comprehensively than it is the case in most empirical models; we take account of a whole set of cost and revenue components, also including factors such as uncertainty, information problems and adjustment costs which are often neglected. It turns out that the adoption of ICT is not only a cost-reducing technology but has also a great potential to generating product innovations, improving customer-orientation, etc. In addition, it is shown that financial and know-how problems are more important obstacles to adoption than technological uncertainties and switching costs. This finding is at variance with results we got in earlier work dealing with "Advanced Manufacturing Technologies"; the relative importance of the explanatory variables are thus technology-specific, as also can be seen from the estimates we presented for different ICT elements.

Firm size is one of the most prominent variables included in models of adoption. Usually, it is positively correlated with early and intensive use of a new technology. With respect to ICT, we get a differentiated picture. We find positive size-effects only up to a threshold of about 200 employees. Moreover, in case of the diffusion of Internet within the firm, one of our two measures of ICT intensity, medium-sized firms seem to have the highest propensity to use the new technology.

Estimates with an extended version of our model yield strong evidence for the influential role (new) workplace organisation plays in decisions related to the adoption of ICT. Team-working, decentralised decision-making and flattening hierarchical structures are the most relevant organisational dimensions favouring the adoption of ICT, whereas we do not find an impact of, for example, job rotation or multi-skilling. To circumvent the problem of endogeneity of workplace organisation as an explanatory variable, we introduced time lags and investigated the reverse causality running from the adoption of ICT to the introduction of new work practices; we also find evidence for this reverse relationship. Moreover, human and knowledge capital as well as innovative activities turn out to be correlated quite strongly with the adoption of ICT as well as with new workplace organisation. These findings are consistent with those of some recent studies which found that ICT, new workplace organisation, human capital investment and innovative activity are complementary elements of strategies to increasing efficiency of production and quality of products.

Nevertheless, further research is required to investigate in more detail the relationship between these seemingly complementary variables. Particularly, the use of simultaneous estimation techniques (ICT, organisation and human capital as endogenous variables) and panel estimations (to detect the dynamic relationships between these factors) could yield further insights.

As far as policy is concerned, the empirical results support rather a framework-oriented policy design than a more activist policy orientation. The most important bottlenecks in introducing ICT that can be reduced by policy measures, are deficiencies of ICT-specific knowledge, a lack of specialists and information problems. Therefore, policy should strengthen, in the first place, the human capital infrastructure of the economy (vocational education, recurrent training). In addition, since ICT leads to a fundamental change of the production system in most industries, and in view of the significant role of learning effects, it could be sensible to support (temporarily) ICT-specific training programmes oriented towards smaller companies.

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Table 1: Diffusion of Information and Communication Technologies (ICT)

(Percentage of business sector firms having adopted a specific ICT element; 2003: planned adoption)

	Rate of Diffusion (%)			
Technology Element	1994	1997	2000	2003
Digital assistants	7.2	16.2	32.6	38.4
Laptop	12.0	27.1	46.2	50.2
PC's, Workstations, Terminals	60.4	80.2	93.8	94.6
E-mail	3.0	23.2	86.1	90.2
Internet	1.7	16.1	78.1	88.8
EDI	5.2	15.7	40.1	50.9
LAN/WAN	17.8	34.4	53.4	57.9
Intranet	1.8	8.0	27.0	35.6
Extranet	0.6	3.1	13.3	24.4

Weighted to account for deviations of the sample structure from that of the underlying population, diffe rent response rates by "size-industry cells" of the sample and for "unit" non-response (see Donzé, 1998).

Table 2: Specification of Adoption Variables

Variable	Definition
Time period of ICT adoption (ordered categories)	
INTERNET	Time period of adoption of Internet
	Up to 1994 (value 4), 1995/1997 (value 3), 1998/2000 (value 2), planned for 2001/2003 (value 1), not adopted (value 0)
ESALES	Time period of adoption of E-selling
	1998/2000 (value 2, planned for 2001/2003 (value 1), not adopted (value 0)
Intensity of use of ICT (ordered categories)	
ICTINT	Overall intensity of ICT use in 2000
	Based on the number of ICT elements adopted up to 2000 (see Table 1):
	7-9 (value 3), 5-6 (value 2), 3-4 (value 1), less than 3 (value 0)
NETUSE	Intensity of Internet use in 2000
	Six categories based on the percentage of employees using Internet in 2000:
	81-100% (value 5), 61-80% (value 4), 41-60% (value 3), 21-40% (value2),
	1-20% (value 1), 0% (value 0)

Table 3a:Basic Model of ICT Adoption: Specification of the Explanatory Variables

Variable	Description	Sign
Objectives of ICT adoption		
(Scores of a principal component factor analysis of the importance of 13 objectives of ICT adoption as assessed by firms on a 5-point Likert scale)		
MARKET	Improving quality, increasing variety, etc. of products, improving customer-relations, increasing market presence and sales	+
COSTRED	Improving internal processes, communication and/or decision-making, reducing costs	+
INPUT	Improving position with respect to input factors (technology, suppliers of inputs, labour)	+
Obstacles to ICT adoption		
(The first four variables are scores of a principal component factor analysis of the importance of 12 obstacles to ICT adoption as assessed by firms on a 5-point Likert scale)		
INVCOST	Technology too expensive, investment volume to large, lack of finance	–
KNOWHOW	Lack of ICT personnel, information and management problems	–
TECH	Technological uncertainties, performance of ICT not sufficient	–
COMPAT	Insufficient compatibility with existing ICT and work organisation	–
NOUSE	No potential to use ICT (firms' assessments on a five-point scale)	–
Human capital, absorptive capacity		
EDUC	Share of employees with qualifications at the tertiary level (%)	+
TRAINING	Share of employees having attended ICT-oriented training courses (%)	+
INNOPD	Introduction of new products (yes/no) in the period 1998-2000	+
Experience		
EDI97	EDI already in use in 1997	+
Epidemic effects (alternative measures depending on the variable to be explained)		
EPIDINT	Share of firms (%) with above-average use of ICT in 1997 in the industry the company is affiliated to *(used for explaining INTER, ICTINT and NETUSE)*	+
EPIDSALE	Share of firms (%) active in E-selling in the year 2000 in the industry the company is affiliated to *(used for explaining ESALES)*	+
Export		
X, X2	Sales share of exports (%) and its square	+ and –
Firm size		
S	5 dummy variables based on the number of employees: S5-19, S20-49, S50-99, S100-199, S200-499 (reference group: firms with 500 and more employees)	–
Industry affiliation		
15 dummies: food, textiles/clothing, wood/paper/printing, non-metallic minerals/base metals, metal products, machinery/vehicles/electrical machinery, electronics/instruments/watchmaking, wholesale trade, retail trade/personal services, hotels/restaurants, transport/telecommunication, banking/insurance, IT-/R&D services, business services (reference group: energy/water/construction).		?

Table 3b: Extended Model of ICT Adoption: Specification of Explanatory Variables Related to Workplace Organisation

Variable	Description	Sign
Elements of new work practices		
TEAM	Team-working (6-point-scale: "very common practice", ..., "does not exist")	+
ROTATION	Job rotation (6 point-scale: "very common practice", ..., "does not exist")	+
MSKILL	Diversity of tasks performed by the "average worker" (5-point scale: "very high", ..., "very low")	+
Distribution of decision-making power		
(Scores of a principal component factor analysis of the distribution of decision-making power between workers and managers with respect to 7 dimensions of work as assessed by firms on a 5-point Likert scale)		
High values are associated with high participation of workers in decision-making		
PRODDEC	Production-oriented dimensions of work	+
USERDEC	Customer-oriented dimensions of work	+
Decentralisation of decision-making since 1995		
DELCOMP	Increasing delegation of decision-making to workers (yes/no)	+
FLAT	Reduction of the number of hierarchical layers (yes/no)	+
Alternative specification:		
Aggregate measure of work organisation		
ORG4	Sum of standardised values (mean 0, standard deviation 1) of TEAM, ROTATION, MSKILL, PRODDEC, USERDEC, DELCOMP, FLAT; rescaled into four ordinal categories	+

Table 4: Time Period and Intensity of the Adoption of ICT (ordered probit estimates)

Explanatory Variable	Time Period of Adoption INTERNET	Time Period of Adoption ESALES	Intensity of Adoption ICTINT	Intensity of Adoption NETUSE
Objectives				
MARKET	.334***	.547***	.158***	.281***
	(.04)	(.05)	(.04)	(.04)
COSTRED	.182***	-.048	.375***	.212***
	(.04)	(.05)	(.04)	(.04)
INPUT	.200***	.067	.206***	.194***
	(.04)	(.05)	(.04)	(.04)
Obstacles				
INVCOST	-.092**	-.052	-.121***	-.100***
	(.04)	(.05)	(.04)	(.04)
KNOWHOW	-.131***	-.038	-.085**	-.160**
	(.04)	(.05)	(.04)	(.04)
TECH	.028	.112**	.022	.006
	(.04)	(.05)	(.04)	(.04)
COMPAT	.026	.044	.061*	.034
	(.04)	(.05)	(.04)	(.04)
NOUSE	-.069*	-.100**	-.127***	-.102***
	(.04)	(.05)	(.03)	(.03)
Absorptive Capacity				
EDUC	.319**	.100	.991***	1.68***
	(.10)	(.10)	(.22)	(.21)
TRAINING	.008***	.003	.014***	.014***
	(.00)	(.00)	(.00)	(.00)
INNOPD	.298***	.274***	.438***	.269***
	(.09)	(.10)	(.08)	(.09)
Experience				
EDI97	///	.315***	///	///
		(.10)		
Epidemic Effects				
EPIDINT	.026***	///	.035***	.027***
	(.00)		(.00)	(.00)
EPIDSALE	///	.071***	///	///
		(.01)		
Exports				
X	.027***	.007	.017***	.018***
	(.01)	(.01)	(.00)	(.01)
X2	-.000***	-.000	-.000***	-.000***
	(.00)	(.00)	(.00)	(.00)
Firm Size				
S5-19	-1.47***	-.971***	-2.42***	.017
	(.19)	(.20)	(.19)	(.18)
S20-49	-.488***	-.328***	-.756***	.148*
	(.10)	(.10)	(.10)	(.18)
S50-99	-.731***	-.410**	-1.05***	.324*
	(.20)	(.21)	(.20)	(.19)
S100-199	-.584***	-.521**	-.449***	.100
	(.20)	(.21)	(.20)	(.19)
S200-499	-.308	-.244	-.037	.122
	(.22)	(.22)	(.21)	(.20)
N	2641	2641	2641	2641
Slope test	241.8***	124.6***	119.3***	466.4***
McFadden R2	.144	.122	.212	.147
% concordance	74.5	74.9	80.0	76.2

Each column includes the estimated parameters with standard errors in brackets. The statistical significance of the estimates is indicated with ***, ** and * representing the 1%, 5% and 10%-level respectively. The estimates for the intercepts and the 15 industry dummies are omitted.

Table 5: The Impact of Work Organisation on the Adoption of ICT

(ordered probit estimates)

Explanatory Variable	ICTINT			ICTINT (2003)
Organisation				
Aggregated				
ORG4	///	///	.210*** (.05)	.261*** (.05)
Desegregated				
TEAM	///	.130*** (.03)	///	///
ROTATION	///	.022 (.04)	///	///
MSKILL	///	-.065 (.06)	///	///
PRODEC	///	.123** (.05)	///	///
USERDEC	///	.041 (.05)	///	///
DELCOMP	///	.044 (.05)	///	///
FLAT	///	.250** (.11)	///	///
Objectives				
MARKET	.129*** (.05)	.127*** (.05)	.117** (.05)	.230** (.05)
COSTRED	.369*** (.05)	.341*** (.05)	.339*** (.05)	.433*** (.05)
INPUT	.138*** (.05)	.120** (.05)	.133*** (.05)	.236*** (.05)
Obstacles				
INVCOST	-.154*** (.05)	-.165*** (.05)	-.160*** (.05)	-.014 (.05)
KNOWHOW	-.086* (.05)	-.091* (.05)	-.078 (.05)	.007 (.05)
TECH	-.028 (.05)	-.042 (.05)	-.043 (.05)	.020 (.05)
COMPAT	.039 (.05)	.045 (.05)	.042 (.05)	.042 (.05)
NOUSE	-.047 (.04)	-.049 (.04)	-.049 (.04)	-.124*** (.04)
Absorptive Capacity				
EDUC	1.74*** (.32)	1.56*** (.33)	1.56*** (.33)	1.26*** (.36)
TRAINING	.013*** (.00)	.011*** (.00)	.011*** (.00)	.020*** (.00)
INNOPD	.470*** (.10)	.415*** (.10)	.432*** (.10)	.426*** (.11)
Epidemic Effects				
EPIDINT	.035*** (.00)	.032*** (.00)	.034*** (.00)	.023*** (.00)
Exports				
X	.012* (.01)	.012** (.01)	.013* (.01)	.019*** (.01)
X2	-.000* (.00)	-.000* (.00)	-.000* (.00)	-.000** (.00)

Firm Size				
S5-19	-1.83***	-1.61***	-1.74***	-1.97***
	(.36)	(.37)	(.36)	(.38)
S20-49	-1.59***	-1.44***	-1.52***	-1.69***
	(.20)	(.20)	(.20)	(.23)
S50-99	-1.16***	-1.06***	-1.12***	-1.10***
	(.20)	(.20)	(.20)	(.23)
S100-199	-.530***	-.475**	-.482***	-.427
	(.20)	(.21)	(.20)	(.24)
S200-499	-.060	-.040	-.039	-.015
	(.22)	(.21)	(.22)	(.26)
N	1667	1667	1667	1667
Slope test	131.9***	136.5***	127.4***	159.2***
McFadden R2	.152	.161	.157	.20.0
% concordance	75.4	76.1	75.6	78.4

See notes of Table 4.

Table 6: Anticipated Net Benefits of New Work Practices

Variable	Description	Sign
Objectives		
(Scores of a principal component factor analysis of the importance of 6 objectives of the introduction of new work practices as assessed by firms on a 5-point Likert scale)		
PERS	Making use of specific knowledge of workers, improving their motivation, shortening decision-making processes	+
COSTFLEX	Reducing costs, enhancing flexibility to adjusting to changes of the environment	+
Obstacles		
(The first three variables are scores of a principal component factor analysis of the importance of 7 obstacles to the introduction of new work practices as assessed by firms on a 5-point Likert scale)		
HUMAN	Insufficient training of workers, low attention of managers with respect to organisational innovations, resistance to change	–
ADJDIFF	Slow adjustment process, insufficient information on organisational matters	–
ADJCOST	High adjustment costs and problems of financing organisational change	–
NONEED	Necessity to adopt new work practices (assessments on a five-point scale; *High values stand for a low necessity to adjusting organisation*	–

Table 7: The Impact of the Adoption of ICT on Work Organisation (ordered probit estimates)

Explanatory Variable	ORG4	
ICTINT		
1997	///	.176***
		(.05)
2000	.307***	///
	(.06)	
Objectives		
PERS	.392***	.409***
	(.05)	(.05)
COSTFLEX	.140***	.149***
	(.05)	(.05)
Obstacles		
HUMAN	.017	.024
	(.05)	(.05)
ADJDIFF	-.017	-.000
	(.05)	(.05)
ADJCOST	-.082*	-.082*
	(.05)	(.05)
NONEED	-.125***	-.139***
	(.04)	(.04)
Absorptive Capacity		
EDUC	1.67***	1.76***
	(.31)	(.31)
TRAINING	.013***	.014***
	(.00)	(.00)
INNOPD	.380***	.398***
	(.10)	(.10)
Exports		
X	-.007	-.007
	(.01)	(.01)
X^2	.000	.000
	(.00)	(.00)
Firm Size		
S5-19	-.797**	-.902***
	(.35)	(.35)
S20-49	-.616***	-.739***
	(.19)	(.19)
S50-99	-.457**	-.541***
	(.19)	(.19)
S100-199	-.374*	-.401**
	(.19)	(.19)
S200-499	-.186	-.192
	(.20)	(.20)
N	1667	1667
Slope test	85.7**	90.2**
McFadden R^2	.098	.095
% concordance	71.1	70.8

See notes of Table 4.

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