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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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 "epidemic effects") using firm-level data for the Swiss business sector. The explanatory variables include numerous dimensions of (anticipated) benefits from and costs of technology adoption allowing for uncertainty as well as for information and adjustment costs. Moreover, the size-dependence of the adoption decision is studied in detail. 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 workplace organisation plays as a determinant of the adoption of ICT.

Keywords: Technology Adoption, Information and Communication Technology (ICT), Rank Model of Adoption, Size-dependence of Adoption Decisions, 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 securing 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 in 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 slightly 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 (for a similar approach see Baldwin and Rafiquzzaman, 1998). 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, in order to clarify the role of firm size, a variable used in almost every study of technology adoption, we proceed in two ways: on the one hand, we use firm size as an independent explanatory factor (in this case it covers size-specific variables not explicitly modelled such as, for example, economies of scope); on the other hand, we take account of the interaction of firm size with other explanatory variables (size-dependence of the model); the latter is explored by estimating the adoption model separately for small and large firms to see whether the driving forces behind adoption differ between the two size classes. Thirdly, 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. Breshnahan et al, 2002). Finally, we estimate the postulated model with several types of adoption measures as dependent variables (e.g. 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 across firms and industries to a larger extent (see e.g. OECD, 2000).

The broadly defined concept of profitability allows to identify bottlenecks of the diffusion process such as, for example, ICT-related manpower deficiencies, which may be addressed by policy measures. Moreover, information deficiencies or lack of finance may be a problem for small firms but not for large ones; therefore, size-specific model estimates may show whether policy, if necessary at all, needs to be differentiated by firm size.

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 main findings, indicate some directions for future research and draw some policy 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, to some extent, epidemic effects. 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 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 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., in various ways (see e.g. Brynjolfsson and Hitt, 2000; OECD, 2000; Lucking et al., 2001): ICT may reduce capital needs through, for example, lower inventory requirements, or it may save labour in general or substitute for specific labour skills (e.g. sales staff, low-skill workers). 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 (e.g. increased product variety and convenience, supply of complementary services). To mention is also the potential of reducing transaction costs, for example, by improving relationships to suppliers of material, components, capital and labour, as well as the consumer-orientation. 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, multi-skilled workers); 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 and exploit them for its own innovative activities 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 vintage; evidence for the importance of learning effects is presented, for example, by 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 ("external learning") in a more general way; various brands of this approach are discussed, for example, 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 belongs to.

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: positive impact on adoption in case of older firms reflecting specific (technological) experience vs. a

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[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).

negative effect for this category of firms due to lower adjustment costs in younger companies with a more up-to-date capital stock (see Dunne, 1994).[2] As already mentioned, the role of firm size, which is expected to be positively related to adoption, is studied in some detail in this paper. Firm size plays a special role: one the one hand, it may prove to be an independent (additional) determinant of adoption, in which case it stands for firm-specific effects not explicitly modelled (capacity to absorb risks related to future ICT developments, economies of scale in E-commerce, access to capital markets, etc.); on the other hand, it may function as a proxy for variables of the model when it is strongly correlated with them (size-dependence of the model). We shall account for both of these aspects at different stages of the empirical analysis.

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 innovative products; for empirical evidence, see Bertschek (1995) and, specifically for ICT (i.e. E-selling), Bertschek and Fryges (2002).

In large parts of theoretical literature, market concentration is taken to reflect competitive pressure. Game-theoretic models (e.g. Reinganum (1981) 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). In addition, in case of a small open economy the usual measures of concentration referring to the home market are not very helpful. Therefore, rather than explicitly including market structure as a determinant of ICT adoption, we assume that it is captured by industry dummies.

Industry dummies are also used to represent two other factors influencing adoption time and intensity: on the demand side, favourable market prospects may exert a positive impact on the adoption of new technology because it enhances 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 certainly are also some firm-specific differences in this respect). The theoretical arguments put forward so far will serve to specify the basic model of the empirical analysis.

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2 In addition, since firm size and firm age are negatively correlated, it is difficult to get reliable empirical results.

3 In accordance to this line of reasoning, we have proxied in an earlier study on the determinants of innovative activity 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). We applied the same argument in an analysis of the adoption of „Advanced Manufacturing Technologies" (Arvanitis and Hollenstein, 2001).

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, 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 models of workplace organisation and the introduction or a more intensive use of ICT. In this view, investments in ICT are more productive if accompanied by suitable organisational innovations, and the productivity of adjustments of workplace organisation is higher if it is supported by investments in ICT (see e.g. Breshnahan 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 five 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-sales, 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.[5] The second variable represents 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

4 An open question is whether complementarity is contemporaneous, or whether one of the two factors is lagging. Breshnahan et al. (2002), for example, assumes that workplace organisation is fixed in the short run whereas the use of ICT can be adjusted quite quickly.

5 Estimates with an alternative number of response levels, e.g. three or four responses, yielded very similar results.

elements (as listed in Table 1)[6] already in use in the year 2000: intensity level 3 in case of 7 to 9 ICT elements, level 2 for 5-6 technologies, level 1 for 3 to 4 items and level 0 if less technologies (0 included) have been introduced. The second intensity variable refers to the intensity of use of 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

Table 3a,b 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 set 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). Not less than 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 included in the questionnaire (for details on the factor solution see Table A.1 in the Appendix).[7] The first factor (MARKET) is related to anticipated benefits on the revenue side; in addition to higher sales in general, ICT is expected to yield benefits from higher quality, more variety, the supply of complementary services, stronger presence at the market and stronger customer-orientation. The second factor (COST) is related to cost reduction in general and, more specifically, to advantages to be gained from improving internal communication and decisionmaking as well as optimising production processes. This factor is, to some extent, related to workplace organisation, which is treated separately in the extended version of the model. The third 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 expected from the use of ICT as proposed by literature (see Section 3), we expect to find a positive influence on the adoption variables.

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6 We decided to rescale the count data information (0 up to 9 technologies) into ordered categories (ordinal variables) because of the non-equivalence of the elements (not each additional ICT element is of the same importance: e.g. PC vs. Extranet). Although this problem of non-equivalence cannot be definitely solved it is much weakened by reducing the 9 counts to 4 ordinal groups.

7 The main characteristics of the factor solution are quite independent from the procedures used for factor extraction (principal component vs. maximum likelihood) and rotation (varimax vs. equamax). The final factor solution as presented in Table A.1 accounts for 58% of total variance which is quite satisfactory.

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). A first variable (NOUSE) captures the fact that in some instances there is hardly a "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 details of the four-factor solution, which is based on the firm's assessment of the relevance of 12 obstacles to adoption and explains 65% of the variance, see Table A.2 in the Appendix). The four metric variables, with the exception of the factor standing for problems of financing ICT investments (INVCOST), can be interpreted, primarily, as proxies for uncertainties, information problems and adjustment costs related to the introduction of ICT (variables KNOWHOW, TECH, 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 captured by three variables measuring the availability of human and knowledge capital (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 (1998-2000), 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 a reference year (1999), attended ICT-oriented training courses (TRAINING) as a proxy for the firm's specific knowledge in ICT; since knowledge required to mastering ICT is rapidly changing, a variable reflecting investment in ICT-specific training is probably a suitable measure.[8] Since some training is necessary when ICT is introduced, this variable is not strictly exogenous reflecting the already mentioned complementarity hypothesis of Breshnahan et al. (2002).

It is not easy to find suitable proxies for measuring learning from previous vintages of ICT in a cross-section framework. Variables which 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 since 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 in 1997 or in earlier years), 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 ICT diffusion rate at industry

8 We do not dispose of information with respect to the share of high- or medium-skilled workers with a degree or certificate in the field of ICT.

level; the percentage share of firms which are, in the year 1997, more ICT-intensive than the average-firm of the industry the company belongs to (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).

Firm size (S) is measured by dummy variables related 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 stands for positive size effects. An alternative specification of firm size based on the number of employees and its square yielded very similar results.

International competition on the product market as an incentive to engage in ICT is proxied by the firm's export propensity, i.e. the sales share of exported goods and services. We use a specification with a linear as well as a quadratic term (variables X, X^2) assuming that the export share is positively related to the adoption rate up to a certain level beyond which no further impact is to be expected.[9]

As a last element of the basic version of our empirical model, we include 15 industry dummies (see Table 3a) which should capture differences with respect to technological opportunities (more scope for ICT in knowledge-based industries), demand prospects (e.g. high growth rates in some service industries), market structure and other not explicitly specified factors determining a firm's propensity to adopt ICT.

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. teamworking (TEAM), job rotation (ROTATE) and multi-skilling (MSKILL). The first two variables measure the diffusion within the firm of teamworking and job rotation respectively on an 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 decisionmaking is assumed to impact positively on the adoption of ICT. To get a measure of the role of workers in decisionmaking, we conducted a principal component factor analysis of 7 dimensions of work for which the surveyed firms assessed the balance of decisionmaking power between managers and workers (5-point scale ranging from "manager decides alone" up to "decision is the sole responsibility of the worker"). This analysis (for details see Table A.3 in the Appendix) yielded two factors, the first one (variable PRODDEC) pertaining to dimensions of work which are related to the production process (design of work process, distribution of tasks among workers, etc.), the second

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9 In earlier work, we used the number of principal competitors at world scale as a measure of international competition (see e.g. Arvanitis and Hollenstein, 1994, 2001); this information, however, is not available in the dataset used in this study.

one (USERDEC) primarily related to customer-oriented tasks (regular contact with customers, contact with clients in case of complaints). Two additional variables reflect the process of decentralising decisionmaking power within a firm during the second half of the nineties: DELCOMP gives information whether there has been an increase of delegation of decisionmaking power towards the workers (yes/no), FLAT stands for a flattening of the hierarchical structure (yes/no); both variables are expected to favour adoption of ICT. Alternatively, using a procedure proposed by Breshnahan et al. (2002), we constructed a compound measure of new workplace organisation (ORG) by adding-up the standardised values of TEAM, ROTATION, MSKILL, PRODDEC, USERDEC, DELCOMP and FLAT.

5. DATA AND METHOD

The analysis is based on firm data of the Swiss business sector collected in a survey we conducted in autumn 2000. The available information is to a large extent qualitative in nature (nominal or ordinal measures). The questionnaire 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 (teamworking, job rotation, distribution of decisionmaking power at the workplace, 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.[10] has been addressed to a sample of 6717 firms with five or more employees, which covered the business sector of the economy (see Table A.6 in the Appendix). 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 is, with a few exceptions, very similar to that of the underlying sample (see Table A.6).

“Item” non-response is another problem of survey data. The usual procedure of dropping observations with incomplete data may produce biased estimates of means, proportions and regression coefficients. To solve this problem, we used the „multiple imputation“ procedure (see Rubin, 1987); the details of this method as applied in the present case, as well as its robustness are documented and discussed in Donzé (1998). By substituting imputed values for missing ones we could avoid a loss of observations.

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[10] The questionnaire can be downloaded from www.kof.gess.ethz.ch.

Since the dependent variables of the adoption model are measured on an ordinal scale (three to six ordinally scaled response levels), the ordered probit procedure is an appropriate method for estimating the adoption equations.

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. As can be seen from the results for specification 1 (columns 1 and 5 respectively), with one exception (export propensity in case of ESALES), all categories of explanatory variables distinguished in Section 5, though not to the same extent, have a statistically significant impact. 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;[11] 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 the adoption of these two ICT elements, insufficient opportunities to benefit from an application (NOUSE) are an important factor in both cases. With regard to other obstacles, 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 a statistically significant (but unpredicted) positive sign for uncertainties with respect to technology and performance (TECH); this result could reflect the fact that E-selling has been characterised by particularly high uncertainties at an early stage of diffusion (see WITSA, 2000). We find no evidence for compatibility problems which imply high adjustment costs (COMPAT); these are presumably more important if a whole bundle of ICT elements is introduced rather than a single element (see the results for ICT intensity below). We also find, as predicted, 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 which is more directly geared to the market than Internet (overriding the impact of absorptive capacity). 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

[11] 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.

costs a firm incurs when it substitutes Internet-based selling for using EDI are lower than the benefits to be captured from this change. In case of Internet, firm size dummies, with companies employing 500 or more persons as reference group, are negatively related to adoption (higher propensity to adopt in case of large firms); however, beyond a threshold of 200 employees, no size effects can be detected any more.

A closer look at these size effects based on a comparison of the results of specification 4 (no size dummies) with those reported for specification 1 (size variables included) points to a certain interaction between firm size and some variables of the model. For example, when firm size is included in the model, the influence of anticipated benefits decreases; small firms expect thus lower benefits from adoption of Internet and E-selling than large ones what implies later adoption for this size-class. There is also some interaction with variables representing absorptive capacity but it is somewhat ambiguous (see EDUC vs. INNOPD), and for learning from EDI (smaller impact when size is included implying higher experience effects in case of small firms). In spite of these interactions, the basic pattern of the results remains quite the same pointing to the robustness of the rank and epidemic effects explicitly modelled in our approach. Interestingly, there is hardly any loss of explanatory power when firm size dummies are dropped. Hence, at least for these two adoption measures, there is no evidence for independent size effects which would cover effects not explicitly specified in the model; the results rather point to some size-dependence of the model which will be investigated later on (see Section 6.2).

Industry dummies (construction sector as reference group), which in many cases are statistically significant, are strongly correlated with epidemic effects (compare specification 2 and 3). Since they are presumed to capture differences among industries with respect to market conditions and technological opportunities, this result is not surprising. The other explanatory variables as well as the model fit are hardly influenced when industry variables are dropped, independent of the adoption variable used (see specification 1 vs. 2).

Intensity of use of ICT

Table 5 shows the results of estimations for two variables representing the intensity of use of ICT based on an overall measure (ICTINT: number of ICT elements) and another one referring to the Internet (NETUSE: share of employees working with Internet). The structure of the table is the same as that of Table 4 (specification 1 to 4 for both dependent variables). The pattern of explanation is similar for the two intensity variables. More importantly, it is also not much different from that we found for the two variables representing the time period of adoption. However, the explanatory power of the model explaining the intensity of adoption is higher, quite distinctly in case of the overall intensity ICTINT.

There are also some differences of the explanatory pattern between ICT intensity and that capturing the first use of ICT elements; this holds particularly true in case of ICTINT. Firstly, on the benefit side of anticipated profitability, market- and customer-orientation is less important in case of both intensity variables, whereas cost-oriented factors are now more relevant. Secondly, among the obstacles to adoption, investment costs and funding restrictions are 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 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. We respect to knowledge and information problems, the comparison of intensity variables and 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 (again: transition to more complex technologies like Intranet, etc.). A similar argument holds for difficulties of compatibility which are, against our prediction, positively correlated with ICT intensity; if the ICT infrastructure is already highly developed, incompatibilities and high adjustment costs may be a more prominent obstacle than in case of ICT adoption from scratch. Fourthly, in case of the two intensity variables we find again some interaction between firm size and some of the other explanatory variables (compare the results of specification 1 including size dummies vs. 4 where these variables are dropped). However, despite this interaction, and in clear contrast to the estimates explaining the time period of adoption, the model fit in case of the overall measure of ICT intensity (but not regarding NETUSE, an intensity variable referring to a single technology variable) is significantly better when size dummies are included. We find thus partial evidence for an independent impact of firm size (representing not explicitly specified influences).

6.2 Size-dependence of the Adoption Behaviour

As just mentioned, firm size is only partially an independent explanatory factor. However, we have got more evidence of an interaction of firm size with other explanatory variables (size-dependence of the model). In the following, we explore the latter aspect by estimating the adoption model separately for small and large firms. In this way we shall see whether the driving forces behind the adoption of ICT differ between the two size classes We use a threshold of 50 employees to separate small from larger firms. This may appear low; however, one should take into account that the cut-off point of the sample in terms of firm size is very low (5 employees) and that the sample covers the service and the construction sector as well which are characterised by a high number of small firms. In addition, it turned out that dummies referring to size classes beyond 200 employees are insignificant. In view of the low threshold we use size dummies *within* the two size categories of firms with the same reference group as before (500 and more employees).

In Table 6, we present estimates differentiated by small and larger firms for the time period of adoption of two ICT elements (Internet, E-selling) and two intensity variables (overall ICT intensity, intensity of Internet use).[12] For both size classes all categories of variables of the model contribute significantly to explaining adoption behaviour. The explanatory power of the model is higher in case of small firms, particularly when the overall ICT intensity (and the first use of Internet) is used as dependent variable.

Taking a closer look at the results reveals some differences between the two size classes with respect to the role played by individual variables. Firstly, although anticipated benefits have the same pattern of impact on ICT in qualitative terms there are some important differences with respect to the magnitude of the parameters (as already mentioned, these can be directly compared since the variables are standardised). In general, market- and customer-orientation (MARKET) and, even more, input-related benefits (e.g. supplier-relations) are of particular relevance in case of small firms. Considering the obstacles to adoption the differences are larger, in the first instance in case of ICT intensity. Whereas the variable NOUSE (lack of a potential to using ICT) is a bigger problem for small firms, the opposite is true with regard to the costs of the technology as well as human and knowledge capital deficiencies (information and management problems; lack of qualified persons). These size-specific differences with respect to the expected net benefits ("revenues net of "costs", i.e. obstacles) seem to be consistent with the more complex nature of ICT in case of larger firms which more often operate near to the technological frontier and the more urgent need to get a quick return on investments in ICT in small companies (either no adoption at all or adoption directly oriented towards input and output markets). However, we do not get a clear size-specific pattern in case of the ability to absorb external knowledge; the differences are not the same for the three variables representing absorptive capacity, and they vary to some extent across the four dependent variables. In contrast, there are some differences with respect to the relevance of competition as a factor forcing firms to adopt ICT: exposure to foreign competition is a more important driver of adoption for small firms than for larger ones; this seems plausible since the differences with respect to export propensity are much smaller among large firms. Similarly, epidemic effects are stronger in case of small firms for three out of four adoption variables; only in case of Internet-based selling, larger firms seem to feel a stronger pressure to follow suit their competitors (variable EPIDSALE).

In view of these (mostly) plausible results, this type of analysis seems to be an appropriate instrument to uncover systematic differences of adoption behaviour of firms belonging to different size classes. This procedure complements the (more traditional) analysis of size-effects based on parameter estimates for firm size included as a separate variable in an adoption model ("independent size-effects").[13]

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[12] Estimates with three firm size classes (less than 20, 20 to 99, 100 and more employees) yielded similar results.

[13] For an alternative procedure, i.e. estimation of size-specific parameters for each explanatory variables in a single equation framework, see Arvanitis (1997). Experience shows that this method leads to very similar results as separate estimates for size-specific subsamples.

6.3 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 Breshnahan et al., 2002). Therefore, one may expect that the adoption of new work practices contributes to intensify 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 7 shows estimations for this extended model using the intensity of use of ICT as dependent variable (ICTINT). Since our survey yielded information about organisational matters only for firms with at least 20 employees (against a threshold of 5 employees in the rest of the survey) we dispose of a reduced dataset of 1667 firms as against 2641 observations in the original sample.[14] Therefore, to start with, we re-estimated the basic model explaining ICTINT (see column 1). The pattern of explanation is more or less the same as based on the larger sample with some (small) differences easily to be explained: by dropping very small firms variables such as NOUSE (no real potential to use ICT) or X (propensity to export) loose some of their explanatory power. Correspondingly, the model fit is slightly lower reflecting the fact that the model performs particularly well in case of small firms (see Section 6.2).

Next we estimated the model where the basic specification is complemented with organisational variables, either based on various elements of new workplace organisation (column 3: teamworking, job rotation, multi-skilling, degree of decentralised decisionmaking in production and in contact with users, tendency of decentralising decisionmaking and of flattening hierarchical structures during 1995 and 2000), or based on an aggregate measure developed from these organisational elements (column 2: ORG4; for details of the variable specification see Table 3b). As can be seen from the two equations, both types of organisational variables exert a statistically significant influence on ICT adoption. Among the individual organisational elements, teamworking, decentralised decisionmaking at the workplace and lowering hierarchical layers are the relevant dimensions of workplace organisation in explaining the use of ICT.

However, as revealed by comparing equation 2 and 3 respectively with equation 1, adding organisational variables to the basic model does hardly improve explanatory power. A closer look at the pattern of explanation shows that including organisational variables reduces, to some extent, the impact of the proxies for human and knowledge capital (absorptive capacity) as well as of firm size. We find, indeed, highly significant correlation coefficients (between 0.20 and 0.30) between these variables and "organisation". Therefore, we dropped in a first step the three variables representing human and knowledge capital (EDUC, TRAINING, INNOPD) and, in a second step, also the firm size dummies. This exercise, as equations 4 and 5 show, leads to a substantial increase of the parameter measuring the impact of workplace organisation (ORG4) from

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[14] 2% of the firms of the final data set answered the questionnaire although they employed less than 20 persons in 2000; since they had a larger staff according to the census data of 1998 on which the sample was based on, they also participated at this part of the survey. For this reason we inserted a dummy S1 also in the extended version of a model.

0.21 to 0.31 and 0.35 respectively; similarly, the coefficient of the objective variable COSTRED representing also elements of workplace organisation (optimisation of the production process, improving decisionmaking, improving internal communication; see Table A1 in the Appendix) increases from 0.37 to 0.42 in equation 5 (with no change in equation 4). These results indicate that organisation may interact with human capital as well as with ICT as put forward in recent work mentioned above and in Section 3.

We are also confronted with the problem of endogeneity in estimating the equation of ICT adoption. A simple way to correct for endogeneity of ORG4, representing (the change of) workplace organisation is to introduce a lag between ORG4 and ICTINT. This procedure reflects the assumption made in Breshnahan et al. (2002) according to which 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. Column 6 of Table 7 shows the result of an estimate where, as dependent variable, the intensity of use of ICT planned (expected) for the year 2003 replaces ICTINT which refers to 2000; in this way, ORG4 is lagged by three years since it is related to the year 2000 (and to changes in the period 1995-2000). The model fit of this specification is substantially better than that of equation 2 (ICT intensity 2000, no lag of ORG4). However, the organisation variable still does not add much to the explanatory power of the basic model. In the same way as before, inclusion of lagged ORG4 reduces the coefficients of human and knowledge capital as well as the impact of firm size. Organisation my thus interact with ICT (and human capital) even if we take account of lagged effects.

A more fundamental way of taking account of such interactions 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 where ICT is 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 (stemming also from our survey) are again condensed to a few variables using the technique of principal component factor analysis. As a result of this exercise, which is documented in the Appendix (Table A4 and A5), we obtain two variables representing anticipated benefits of new work practices as well as three factors depicting barriers to change of workplace organisation. 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 COSTLEX stands for the 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 others 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, a measure of the absence of any necessity to changing organisational structures.

Table 8 shows the results of estimations of this model explaining the adoption of new workplace organisation with column 1 (equation without an ICT variable) as starting point. Anticipated benefits (but not impediments, with the exception of variable NONEED), human and knowledge capital as well as firm size are the most important determinants of (the change of) workplace organisation. The results for the extended version of the "organisation model" where the basic specification is complemented with a variable reflecting the intensity of use of ICT are presented in column 2. It turns out that ICT exerts a statistically significant influence on the adoption of new work practices; however, as in the case of the ICT model, the extension hardly improves the model fit because other variables of the model loose some of their explanatory power (firm size and, to a lesser extent, human and knowledge capital). We also note that the explanatory power of the "organisation model" is substantially lower than that of the "ICT model". Dropping the human and knowledge capital variables (column 4) and, additionally, firm size (column 5) produces a strong increase of the coefficient of the ICT intensity (from 0.31 to 0.45 and 0.51 respectively), an indication of a significant interaction between ICT intensity, human capital and work organisation. If ICT intensity is specified as a lagged variable (lag of 3 years) the model fit does not improve (column 3); endogeneity can thus not resolved in this way.

The results we gained from estimating the extended "organisation model" and those we found with the extended version of the "ICT model" point in the same direction: ICT intensity and workplace organisation seem to interact; both directions of causality yield statistically significant results. This finding is based on estimates in a single-equation framework and should be checked by a simultaneous estimation; this procedure might also give a hint with respect to the relative magnitude of the effects (in this respect the single-equation framework yields no reliable results). However, we would be quite surprised if simultaneous estimations would substantially the basic conclusion.[15] We conclude that our results are in line with those of some recent studies which found that ICT, new workplace organisation and human capital are complementary factors to increase the efficiency of production and the quality of products (see e.g. Breshnahan 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 earlier vintages of a certain technology and (international) competitive pressure. In addition

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[15] Another extension would be the estimation of a simultaneous model where human and knowledge capital input would also be considered as an endogenous variable.

to these firm-specific effects, there is also strong 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 (first use 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 in more detail than it is the case in most empirical models by taking account of a whole set of cost and revenue components. 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, increasing 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.

The role of firm size, which belongs to the most prominent variables included in models of technology adoption, is analysed in some detail. It turned out that firm size is an independent explanatory variable (covering size-specific variables not explicitly accounted for in the model) only in case of one of the four adoption measures we used (i.e. overall intensity of ICT use). However, the adoption model is shown to be size-dependent, i.e. firm size interacts with other explanatory variables. This specific feature of our approach of analysing size-effects is able to uncover systematic differences of adoption behaviour of firms belonging to different size classes. For example, the analysis of anticipated benefits and costs of adoption shows that small firms choose either to not engage in ICT at all or to strive at a quick return on ICT investments (strong customer- and supplier-orientation); large firms, since they operate nearer to the technological frontier are more often impeded, compared to small ones, by information and knowledge deficiencies, management problems and a lack of specialists. Epidemic effects, i.e. information spillovers between firms, are more important in case of small firms.

The analysis with an extended version of our model yielded strong evidence for the influential role played by workplace organisation for decisions to adopt ICT or to intensify their use. Teamworking, decentralised decisionmaking and flattening hierarchical structures are the most relevant organisational dimensions favouring the adoption of ICT, whereas we did not find an impact of other elements of workplace organisation such as 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 found evidence for this relationship. Moreover, human and knowledge capital turned out to be quite strongly correlated with the adoption of ICT as well as with new workplace organisation. Our findings are in line with those of some recent studies which found that ICT, new workplace organisation and human capital are complementary factors in strategies to increasing efficiency of production and quality of products.

Besides, the paper shows that the proposed model of adoption, which in its core has been developed in an earlier study dealing with “Advanced Manufacturing Technologies” (Arvanitis and Hollenstein, 2001), is useful for other technologies too. Moreover, it has been demonstrated that an analysis of adoption behaviour may profit from the use of qualitative data reflecting firms' assessments; in this way the database for empirical research can be substantially enlarged because this type of information is much easier to collect. Future work should be directed, first, to further testing the usefulness of the proposed model of adoption (other technologies and countries). Secondly, and more important, there is a need for additional in-depth studies of the impact of the adoption of ICT on firm performance; in particular, the hypothesis of complementarity of ICT, workplace organisation and human capital (Breshnahan et al., 2002; Brynjolfsson and Hitt, 2000; Bertschek and Kaiser, 2001) should be investigated more thoroughly, e.g. in a simultaneous equation framework.

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 and intensifying their use that can be reduced by policy measures are deficiencies of ICT-specific knowledge and a lack of specialists as well as corresponding information problems. Therefore, policy should strengthen, in the first place, the human capital infrastructure of the economy by intensifying (vocational) education at the secondary and tertiary level as well as recurrent training. In addition, since ICT marks a fundamental change of the production system of practically all industries and in view of the significant role of learning effects it could be sensible to support (temporarily) ICT-specific training programmes oriented, in the first place, towards smaller companies in the early phase of adoption.

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Table 1: Adoption of Information and Communication Technologies (ICT)
(Percentage of business sector firms having adopted a specific ICT element;
2001-2003: planned adoption

	Time Period of Adoption			
Technology Element	Up to 1994	1995-1997	1998-2000	2001-2003
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, for different 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-sales 1998/2000 (value 3), planned for 2001/2003 (value 2), 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: 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; see Table A1 in the Appendix)		
MARKET	Improving quality/variety, etc. of products, improving customer-relations, increasing market presence and sales	+
COSTRED	Improving internal processes, communication, decisionmaking, 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; see Table A2 in the Appendix)		
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	+
Export		
X, X^2	Sales share of exports (%) and its square	+ / ?
Firm size		
S	5 dummy variables based on the number of employees: S5-19, S20-49, S50-99, S100-199, S200-499 (firms with 500 and more employees as reference group)	-
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)*	+
Experience		
EDI	EDI already in use in 1997	+
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 *(with energy/water/construction as reference group)*		?

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

Variable	Description	Sign
Elements of new work practices		
TEAM	Teamworking (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 decisionmaking power *(Scores of a principal component factor analysis of the distribution of decisionmaking power between manager and workers with respect to 7 dimensions of work as assessed by firms on a 5-point Likert scale; see Table A3 in the Appendix*)		
PRODDEC	Production-oriented dimensions of work	+
USERDEC	Customer-oriented dimensions of work	+
Decentralisation of decisionmaking since 1995		
DELCOMP	Increasing delegation of decisionmaking to workers (yes/no)	+
FLAT	Reduction of the number of hierarchical levels (yes/no)	+
Alternatively, we use an aggregate measure of work organisation		
ORG, ORG4	Sum of standardised values (mean 0, standard deviation 1) of TEAM, ROTATION, MSKILL, PRODDEC, USERDEC, DELCOMP, FLAT; or rescaled into four ordinal categories (ORG4)	+

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

Explanatory Variable	INTERNET				ESALES			
	Specification				Specification			
	1	2	3	4	1	2	3	4
Intercepts								
A1	2.32***	2.16***	3.25***	1.49***	-1.91***	-1.79***	-1.46***	-2.47***
	(.30)	(.18)	(.30)	(.24)	(.30)	(.25)	(.28)	(.24)
A2	1.31***	1.14***	2.24***	.496**	-2.55***	-2.43***	-2.08***	-3.09***
	(.29)	(.18)	(.29)	(.23)	(.29)	(.25)	(.28)	(.24)
A3	-2.57***	-2.72***	-1.61***	-3.27***	///	///	///	///
	(.30)	(.19)	(.30)	(.24)				
A4	-5.21***	-5.31***	-4.24***	-5.86***	///	///	///	///
	(.32)	(.24)	(.32)	(.28)				
Objectives								
MARKET	.334***	.325***	.349***	.328***	.547***	.551***	.569***	.548***
	(.04)	(.04)	(.04)	(.04)	(.05)	(.05)	(.05)	(.05)
COSTRED	.182***	.164***	.190***	.258***	-.048	-.057	-.032	-.003
	(.04)	(.04)	(.04)	(.04)	(.05)	(.05)	(.05)	(.05)
INPUT	.200***	.200***	.200***	.245***	.067	.063	.067	.100**
	(.04)	(.04)	(.04)	(.04)	(.05)	(.05)	(.05)	(.05)
Obstacles								
INVCOST	-.092**	-.098**	-.095**	-.093**	-.052	-.046	-.055	-.042
	(.04)	(.04)	(.04)	(.04)	(.05)	(.05)	(.05)	(.05)
KNOWHOW	-.131***	-.139***	-.126***	-.078*	-.038	-.021	-.034	-.011
	(.04)	(.04)	(.04)	(.04)	(.05)	(.05)	(.05)	(.05)
TECH	.028	.023	.034	.065	.112**	.111**	.111**	.133***
	(.04)	(.04)	(.018	(.04)	(.05)	(.05)	(.05)	(.05)
COMPAT	.026	.016	.029	.032	.044	.048	.037	.027
	(.04)	(.04)	(.04)	(.04)	(.05)	(.05)	(.05)	(.05)
NOUSE	-.069*	-.072*	-.077**	-.092**	-.100**	-.097**	-.099**	-.118***
	(.04)	(.04)	(.04)	(.04)	(.05)	(.05)	(.05)	(.05)
Absorptive Capacity								
EDUC	.319**	.558***	.405**	.220**	.100	.084	.122	.109
	(.10)	(.21)	(.18)	(.10)	(.10)	(.10)	(.11)	(.10)
TRAINING	.008***	.009***	.009***	.008***	.003	.002	.004	.003
	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)
INNOPD	.298***	.288***	.321***	.394***	.274***	.281***	.290***	.339***
	(.09)	(.09)	(.09)	(.09)	(.10)	(.10)	(.10)	(.10)
Exports								
X	.027***	.027***	.028***	.031***	.007	.008	.005	.009
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
X^2	-.000***	-.000***	-.000***	-.000***	-.000	-.000	-.000	-.000
	(.00)	(.00)	(.00)	(.06)	(.00)	(.00)	(.00)	(.00)
Firm Size								
S5-19	-1.47***	-1.40***	-1.48***	///	-.971***	-.984***	-.990***	///
	(.19)	(.19)	(.19)		(.20)	(.20)	(.20)	
S20-49	-.488***	-.458***	-.493***	///	-.328***	-.316***	-.333***	///

	(.10)	(.09)	(.10)		(.10)	(.10)	(.10)	
S50-99	-.731***	-.651***	-.761***	///	-.410**	-.398**	-.407**	///
	(.20)	(.20)	(.20)		(.21)	(.21)	(.21)	
S100-199	-.584***	-.529***	-.629***	///	-.521**	-.510**	-.581***	///
	(.20)	(.20)	(.20)		(.21)	(.21)	(.21)	
S200-499	-.308	-.248	-.344	///	-.244	-.258	-.292	///
	(.22)	(.21)	(.22)		(.22)	(.22)	(.22)	
Epidemic Effects								
EPIDINT	.026***	.030***	///	.025***	///	///	///	///
	(.00)	(.00)		(.00)				
EPIDSALE	///	///	///	///	.071***	.059***	///	.071***
					(.01)	(.01)		(.01)
Experience								
EDI	///	///	///	///	.315***	.295***	.357***	.375***
					(.10)	(.10)	(.10)	(.10)
Industry Dummies								
1 Food		///				///	+ ***	
2 Textiles		///				///		
3 Paper		///	+ **			///	+ ***	
4 Chemicals		///				///	+ ***	
5 Base metals		///				///		
6 Metal prod.		///				///	+ **	
7 Machinery		///	+ ***			///	+ **	
8 Electronics		///	+ ***			///	+ **	
9 Wholesale tr.		///	+ ***			///	+ ***	
10 Retail trade		///				///	+ ***	
11 Hotels/Rest.	+ **	///	+ *	+ **		///	+ ***	
12 Trans./Tele.		///				///	+ ***	
13 Financial S.		///				///	+ ***	
14 IT/R&D-S.	+ ***	///	+ ***	+ ***		///		
15 Business S.	+ *	///	+ ***			///		
N	2641	2641	2641	2641	2641	2641	2641	2641
Slope test	241.8***	171.9***	243.0***	188.0***	124.6***	101.8***	121.8***	98.0***
McFadden R^2	.144	.139	.139	.128	.122	.120	.113	.114
% concordance	74.5	74.0	74.0	72.4	74.9	74.8	74.0	73.9

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. In case of industry dummies we show only the signs and their statistical significance.

Table 5: Intensity of the Adoption of ICT (ordered probit estimates)

Explanatory Variable	ICTINT Specification 1	2	3	4	NETUSE Specification 1	2	3	4
Intercepts								
A1	1.43***	1.51***	2.64***	.364*	-.113	-.331	.874***	.060
	(.28)	(.24)	(.23)	(.21)	(.27)	(.22)	(.22)	(.22)
A2	.532*	.426*	.711	-1.40***	-2.94***	-3.17***	-1.92***	-2.75***
	(.28)	(.24)	(.23)	(.21)	(.28)	(.23)	(.22)	(.22)
A3	-2.69***	-2.56***	-1.41***	-3.32***	-4.24***	-4.39***	-3.20***	-4.05***
	(.28)	(.24)	(.23)	(.22)	(.28)	(.24)	(.23)	(.23)
A4	///	///	///	///	-5.12***	-5.24***	-4.08***	-4.93***
					(.29)	(.25)	(.23)	(.24)
A5	///	///	///	///	-6.07***	-6.15***	-5.04***	-5.89***
					(.30)	(.26)	(.24)	(.35)
Objectives								
MARKET	.158***	.174***	.183***	.154***	.281***	.290***	.299***	.283***
	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)
COSTRED	.375***	.385***	.382***	.503***	.212***	.217***	.219***	.219***
	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)
INPUT	.206***	.201***	.204***	.289***	.194***	.182***	.193***	.206***
	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)
Obstacles								
INVCOST	-.121***	-.129***	-.129***	-.107***	-.100***	-.102***	-.105***	-.100***
	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)
KNOWHOW	-.085**	-.089**	-.082**	.022	-.160**	-.176***	-.156***	-.154***
	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)
TECH	.022	.028	.031	.099***	.006	.009	.011	.004
	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)
COMPAT	.061*	.069*	.067*	.104***	.034	.034	.044*	.037
	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)
NOUSE	-.127***	-.130***	-.133***	-.178***	-.102***	-.104***	-.108***	-.103***
	(.03)	(.03)	(.03)	(.03)	(.03)	(.03)	(.03)	(.03)
Absorptive Capacity								
EDUC	.991***	1.03***	1.10***	.452**	1.68***	2.14***	1.76***	1.62***
	(.22)	(.20)	(.22)	(.21)	(.21)	(.19)	(.21)	(.21)
TRAINING	.014***	.016***	.015***	.012***	.014***	.017***	.014***	.014***
	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)
INNOPD	.438***	.398***	.446***	.556***	.269***	.188**	.284***	.279***
	(.08)	(.08)	(.08)	(.08)	(.09)	(.08)	(.09)	(.08)
Exports								
X	.017***	.012**	.018***	.024***	.018***	.011**	.019***	.019***
	(.00)	(.00)	(.01)	(.01)	(.01)	(.00)	(.01)	(.01)
X^2	-.000***	-.000**	-.000***	-.000***	-.000***	-.000**	-.000***	-.000***
	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)
Firm Size								
S5-19	-2.42***	-2.44***	-2.42***	///	.017	.005	-.007	///

	(.19)	(.19)	(.19)		(.18)	(.17)	(.17)	
S20-49	-.756***	-.777***	-.755***	///	.148*	.122	.138	///
	(.10)	(.09)	(.10)		(.18)	(.18)	(.19)	
S50-99	-1.05***	-1.12***	-1.08***	///	.324*	.293	.287	///
	(.20)	(.19)	(.20)		(.19)	(.18)	(.18)	
S100-199	-.449***	-.516***	-.506***	///	.100	.061	.050	///
	(.20)	(.20)	(.20)		(.19)	(.18)	(.19)	
S200-499	-.037	-.110	-.071	///	.122	.097	.083	///
	(.21)	(.21)	(.21)		(.20)	(.20)	(.20)	
Epidemic Effects								
EPIDINT	.035***	.033***	///	.031***	.027***	.036***	///	.027***
	(.00)	(.00)		(.00)	(.00)	(.00)		(.00)
Industry Dummies								
1 Food		///		- **		///		
2 Textiles		///		- **		///		
3 Paper		///	+ **			///		
4 Chemicals		///		-***		///		
5 Base metals		///				///		
6 Metal prod.		///				///		
7 Machinery		///	+ ***	- **		///	+ **	
8 Electronics		///	...+ *	- **		///	+ ***	
9 Wholesale tr.		///	+ ***		+ ***	///	+ ***	+ ***
10 Retail trade		///				///		
11 Hotels/Rest.	- *	///	- **	- ***		///		
12 Trans./Tele.		///			+ **	///	+ **	+ **
13 Financial S.	+ ***	///	+ ***		+ ***	///	+ ***	+ ***
14 IT/R&D-S.		///	+ ***		+ ***	///	+ ***	+ ***
15 Business S.		///	+ ***	- **	+ ***	///	+ ***	+ ***
N	2641	2641	2641	2641	2641	2641	2641	2641
Slope test	119.3***	60.2**	120.7***	103.7***	466.4***	355.7***	64.3***	293.5***
McFadden R^2	.212	.206	.204	.156	.147	.136	.143	.146
% concordance	80.0	79.7	79.6	75.7	76.2	75.4	75.7	76.0

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. In case of industry dummies we show only the signs and their statistical significance.

Table 6: Size Dependence of the Adoption of ICT (ordered probit estimates)

	INTERNET		ESALES		ICTINT		NETUSE	
Explanatory Variable	Small Firms	Large Firms	Small Firms	Large Firms	Small Firms	Large Firms	Small Firms	Large Firms
Intercepts								
A1	1.10***	3.10***	-2.39***	-1.84***	-.321	1.75***	-.565*	1.10***
	(.31)	(.46)	(.36)	(.37)	(.31)	(.38)	(.29)	(.40)
A2	.054	2.04***	-2.83***	-2.68***	-2.32***	-.300	-2.85***	-2.69***
	(.31)	(.43)	(.36)	(.37)	(.31)	(.37)	(.30)	(.41)
A3	-3.65***	-2.28***	///	///	-4.53***	-2.43***	-4.18***	-3.98***
	(.33)	(.44)			(.33)	(.38)	(.32)	(.42)
A4	-6.03***	-5.13***	///	///	///	///	-4.99***	-4.98***
	(.38)	(.48)					(.32)	(.43)
A5	///	///	///	///	///	///	-5.85***	-6.18***
							(.34)	(.45)
Objectives								
MARKET	.392***	.207***	.596***	.502***	.173***	.143***	.290***	.258***
	(.05)	(.07)	(.07)	(.07)	(.05)	(.06)	(.05)	(.06)
COSTRED	.146***	.124*	-.019	-.095	.371***	.361***	.177***	.243***
	(.05)	(.07)	(.07)	(.08)	(.05)	(.06)	(.05)	(.07)
INPUT	.298***	.003	.045	-.094	.303***	.073***	.234***	.110*
	(.05)	(.07)	(.07)	(.07)	(.05)	(.06)	(.05)	(.06)
Obstacles								
INVCOST	-.080	-.127*	-.062	-.051	-.069	-.212***	-.058	-.193***
	(.05)	(.07)	(.07)	(.07)	(.05)	(.06)	(.05)	(.06)
KNOWHOW	-.108**	-.171**	.075	-.127*	-.056	-.138**	-.175***	-.165***
	(.05)	(.07)	(.07)	(.07)	(.05)	(.06)	(.05)	(.06)
TECH	.046	-.024	.112*	.112	.037	-.001	.036	.040
	(.05)	(.07)	(.07)	(.07)	(.05)	(.06)	(.05)	(.06)
COMPAT	.001	.033	.063	-.014	.069	.051	.062	-.011
	(.05)	(.07)	(.07)	(.07)	(.05)	(.06)	(.05)	(.06)
NOUSE	-.062	-.036	-.116*	-.101*	-.210*	.011	-.106**	-.072
	(.05)	(.06)	(.07)	(.07)	(.05)	(.05)	(.04)	(.06)
Absorptive Capacity								
EDUC	1.00***	.057	.360	.139	.586**	1.67***	1.98***	.974***
	(.29)	(.11)	(.37)	(.12)	(.27)	(.39)	(.26)	(.37)
TRAINING	.007**	.010***	.00***	.002	.015***	.012***	.014***	.015***
	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)
INNOPD	.345***	.210*	.344**	.174	.424***	.463***	.230**	.337**
	(.12)	(.15)	(.15)	(.15)	(.11)	(.13)	(.11)	(.14)
Exports								
X	.034***	.020**	.013	.003***	.020***	.013*	.025***	.007
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
X^2	-.000***	-.000*	-.000	-.000***	-.000**	-.000*	-.000**	-.000
	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)
Firm Size								
S5-19	-.426***	///	-.285*	///	-.902***	///	-.211**	///

	(.12)		(.15)		(.11)		(.11)	
S20-49	///	///	///	///	///	///	///	///
S50-99	///	-1.07*** (.22)	///	-.483** (.21)	///	-1.21*** (.20)	///	.181 (.20)
S100-199	///	-.834*** (.22)	///	-.583*** (.22)	///	-.583*** (.20)	///	-.090 (.21)
S200-499	///	-.527** (.23)	///	-.295 (.22)	///	-.128 (.22)	///	-.011 (.21)
Epidemic Effects								
EPIDINT	.025*** (.00)	.023*** (.01)	///	///	.043*** (.01)	.026*** (.01)	.030*** (.01)	.024*** (.01)
EPIDSALE	///	///	.064*** (.02)	.077*** (.02)	///	///	///	///
Experience								
EDI	///	///	.336*** (.15)	.314** (.14)	///	///	///	///
Industry Dummies								
1 Food								
2 Textiles								
3 Paper		+ **						
4 Chemicals								
5 Base metals								
6 Metal prod.					+ *			
7 Machinery								
8 Electronics					+ *			
9 Wholesale tr.							+ ***	+ *
10 Retail trade							+ **	
11 Hotels/Rest.	+ **	+ *						
12 Trans./Tele.							+ ***	
13 Financial S.					+ ***		+ ***	+ ***
14 IT/R&D-S.	+ ***	+ **			+ **	- **	+ ***	+ ***
15 Business S.							+ ***	+ ***
N	1489	1152	1489	1152	1489	1152	1489	1152
Slope test	177.0***	417.5***	76.4***	61.8***	87.7***	132.5***	259***	354.7
McFadden R^2	.152	.102	.134	.107	.206	.124	.164	.125
% concordance	74.8	70.3	76.4	72.6	79.8	73.0	77.2	74.6

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. In case of industry dummies we show only the signs and their statistical significance. Firms with less than 50 employees are considered as "small", those with more employees as "large".

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

Explanatory Variable	ICTINT 2000 1	2	3	4	5	2003 6
Organisation						
Aggregated						
ORG4	///	.210*** (.05)	///	.309*** (.05)	.353*** (.04)	.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)	.117** (.05)	.127*** (.05)	.134*** (.05)	.131*** (.05)	.230** (.05)
COSTRED	.369*** (.05)	.339*** (.05)	.341*** (.05)	.342*** (.05)	.415*** (.05)	.433*** (.05)
INPUT	.138*** (.05)	.133*** (.05)	.120** (.05)	.184*** (.05)	.188*** (.05)	.236*** (.05)
Obstacles						
INVCOST	-.154*** (.05)	-.160*** (.05)	-.165*** (.05)	-.167*** (.05)	-.161*** (.05)	-.014 (.05)
KNOWHOW	-.086* (.05)	-.078 (.05)	-.091* (.05)	-.078* (.05)	-.035 (.05)	.007 (.05)
TECH	-.028 (.05)	-.043 (.05)	-.042 (.05)	-.021 (.05)	-.033 (.05)	.020 (.05)
COMPAT	.039 (.05)	.042 (.05)	.045 (.05)	.038 (.05)	.067 (.05)	.042 (.05)
NOUSE	-.047 (.04)	-.049 (.04)	-.049 (.04)	-.089** (.04)	-.131*** (.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)	.432*** (.10)	.415*** (.10)	///	///	.426*** (.11)
Exports						
X	.012* (.01)	.013* (.01)	.012** (.01)	.017*** (.01)	.019*** (.01)	.019*** (.01)
X^2	-.000* (.00)	-.000* (.00)	-.000* (.00)	-.000** (.00)	-.000* (.00)	-.000** (.00)
Firm Size						
S5-19	-1.83*** (.36)	-1.74*** (.36)	-1.61*** (.37)	-1.59*** (.36)	///	-1.97*** (.38)
S20-49	-1.59*** (.20)	-1.52*** (.20)	-1.44*** (.20)	-1.61*** (.20)	///	-1.69*** (.23)
S50-99	-1.16*** (.20)	-1.12*** (.20)	-1.06*** (.20)	-1.21*** (.20)	///	-1.10*** (.23)
S100-199	-.530*** (.20)	-.482*** (.20)	-.475** (.21)	-.613*** (.20)	///	-.427 (.24)
S200-499	-.060 (.22)	-.039 (.22)	-.040 (.21)	-.180 (.21)	///	-.015 (.26)
Epidemic Effects						
EPIDINT	.035*** (.00)	.034*** (.00)	.032*** (.00)	.037*** (.00)	.034*** (.00)	.023*** (.00)
N	1667	1667	1667	1667	1667	1667
Slope test	131.9***	127.4***	136.5***	130.1***	106.2***	159.2***
McFadden R^2	.152	.157	.161	.140	.110	.20.0
% concordance	75.4	75.6	76.1	74.1	71.1	78.4

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. In case of industry dummies we show only the signs and their statistical significance. The results for intercepts and industry dummies are not reported in the table.

Table 8: The Impact of the Adoption of ICT on Work Organisation
(ordered probit estimates)

Explanatory Variable	ORG4				
	Specification				
	1	2	3	4	5
ICTINT					
1997	///	///	.176***	///	///
2000	///	.307***	///	.451***	.509***
		(.06)		(.06)	(.06)
Objectives					
PERS	.412***	.392***	.409***	.444***	.438***
	(.05)	(.05)	(.05)	(.05)	(.05)
COSTFLEX	.153***	.140***	.149***	.139***	.153***
	(.05)	(.05)	(.05)	(.05)	(.05)
Obstacles					
HUMAN	.023	.017	.024	.007	.006
	(.05)	(.05)	(.05)	(.05)	(.05)
ADJDIFF	-.003	-.017	-.000	-.043	-.027
	(.05)	(.05)	(.05)	(.05)	(.05)
ADJCOST	-.084*	-.082*	-.082*	-.080*	-.086*
	(.05)	(.05)	(.05)	(.05)	(.05)
NONEED	-.125***	-.125***	-.139***	-.134***	-.142***
	(.04)	(.04)	(.04)	(.04)	(.04)
Absorptive Capacity					
EDUC	1.89***	1.67***	1.76***	///	///
	(.31)	(.31)	(.31)		
TRAINING	.014***	.013***	.014***	///	///
	(.00)	(.00)	(.00)		
INNOPD	.451***	.380***	.398***	///	///
	(.10)	(.10)	(.10)		
Exports					
X	-.001	-.007	-.007	-.003	-.003
	(.01)	(.01)	(.01)	(.01)	(.01)
X^2	.000	.000	.000	.000	.000
	(.00)	(.00)	(.00)	(.00)	(.00)
Firm Size					
S5-19	-1.02***	-.797**	-.902***	-.686***	///
	(.35)	(.35)	(.35)	(.35)	
S20-49	-.830***	-.616***	-.739***	-.684***	///
	(.19)	(.19)	(.19)	(.19)	
S50-99	-.610***	-.457**	-.541***	-.557***	///
	(.19)	(.19)	(.19)	(.19)	(.19)
S100-199	-.441**	-.374*	-.401**	-.546**	///
	(.19)	(.19)	(.19)	(.19)	
S200-499	-.202	-.186	-.192	-.306	///
	(.20)	(.20)	(.20)	(.20)	

N	1667	1667	1667	1667	1667
Slope test	87.6**	85.7**	90.2**	79.1**	69.8**
McFadden R^2	.092	.098	.095	.075	.071
% concordance	70.5	71.1	70.80	68.7	68.2

The variables representing objective of and obstacles to the adoption of new work practices are scores of two principal component factor analyses of the importance of 6 objective and 7 obstacles to organisational adjustments as assessed by firms on a 5-point Likert scale; see Tables A4 and A5 in the Appendix. The variable NONEED represents the firms' assessment on the necessity of changing the existing organisational structure.

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 results for intercepts and industry dummies are not reported in the table.

APPENDIX

Table A1: Factor Analysis of the Objectives of ICT Adoption
(based on assessments of the respondents on a five-point Likert-scale)

Objectives	Rotated Factor Pattern (Varimax) Factor 1	2	3
Improving product quality and variety	.72		
Improving presence on the product market	.72		
Increasing sales	.71		
Improving customer-orientation	.68		
Complementing products by new features (on-line payment, etc.)	.65		
Optimisation of production process		.81	
Improving decisionmaking		.73	
Improving internal communication		.64	
Reducing costs		.63	
Improving attractiveness on the labour market			.74
Monitoring performance of employees			.66
Improving the technological position	.41		.59
Improving supplier-relationships	.41		.49
Number of observations			2641
Kaiser's overall measure of sampling adequacy (MSA)			.890
Variance accounted for by the first three factors			.578
Root mean square off-diagonal residuals (RMSE)			.075
Variance accounted for by each factor	5.13	1.43	0.96
Final communality estimate (total)			7.52

Characterisation of the three factors:
(1) Improving market position (MARKET)
(2) Reducing production costs (COSTRED)
(3) Improving position on the input side: labour, technology, material/components (INPUT)

The table shows only factor loadings of 0.4 and higher.

Table A2: Factor Analysis of the Obstacles to ICT Adoption
(based on assessments of the respondents on a five-point Likert-scale)

Obstacles	Rotated Factor Pattern (Varimax) Factor 1	2	3	4
Investment volume to large	.87			
Technology too expensive	.86			
Current costs too high	.76			
Lack of finance	.71			
Resistance to new technology within the firm	.	.76		
ICT-related information problems		.73		
Lack of qualified personnel		..72		
Insufficient attention of the management		.69		
Technology not yet developed far enough			.86	
Insufficient performance of ICT			.85	
Insufficient compatibility with existing ICT systems				.81
Required adjustments of work organisation too large				.77
Number of observations				2641
Kaiser's overall measure of sampling adequacy (MSA)				.875
Variance accounted for by the first four factors				.723
Root mean square off-diagonal residuals (RMSE)				.061
Variance accounted for by each factor	2.86	2.49	1.81	1.52
Final communality estimate (total)				8.68

Characterisation of the four factors:
(1) High investment costs (INVCOST)
(2) Qualification and know-how problems (KNOWHOW)
(3) Technological problems (TECH)
(4) Compatibility problems (COMPAT)

The table shows only factor loadings of 0.4 and higher.

Table A3: Factor Analysis of the Variables Measuring the Distribution of Decisionmaking Power between Workers and Management
(based on assessments of the respondents on a five-point Likert-scale with value 5 indicating decentralised decisionmaking))

Decisionmaking With respect to	**Rotated Factor Pattern (Varimax)**	
	Factor 1	Factor 2
Way of performing tasks	.76	
Design of the work process	.74	
Pace of work	.71	
Distribution of tasks among the workers	.59	
Contact with customers in case of complaints		.89
Regular contact with customers		.85
Problems arising in the production process		.47
Number of observations		2641
Kaiser's overall measure of sampling adequacy (MSA)		.780
Variance accounted for by the first three factors		.571
Root mean square off-diagonal residuals (RMSE)		.103
Variance accounted for by each factor	2.15	1.85
Final communality estimate (total)		4.00

Characterisation of the two factors:
(1) Production-oriented dimensions of work (PR0DDEC)
(2) Customer-oriented dimensions of work (USERDEC)

The table shows only factor loadings of 0.4 and higher.

Table A4: Factor Analysis of Objectives of the Adoption of New Work Practices
(based on assessments of the respondents on a five-point Likert-scale)

Objectives	**Rotated Factor Pattern (Varimax)** Factor 1	2
Improving motivation of workers	.81	
Making use of the specific knowledge of workers	.86	
Shortening the process of decisionmaking	.51	
Reducing costs		.86
Increasing flexibility of adjusting to the environment		.66
Improving quality		.57
Number of observations		1667
Kaiser's overall measure of sampling adequacy (MSA)		.783
Variance accounted for by the first two factors		.642
Root mean square off-diagonal residuals (RMSE)		.111
Variance accounted for by each factor	2.09	1.76
Final communality estimate (total)		3.85

Characterisation of the two factors:
(1) Using untapped human resources (PERS)
(2) Reducing costs and flexibility (COSTFLEX)

The table shows only factor loadings of 0.4 and higher.

Table A5: Factor Analysis of Obstacles to the Adoption of New Work Practices
(based on assessments of the respondents on a five-point Likert-scale)

Obstacles	Rotated Factor Pattern (Varimax)		
	Factor		
	1	2	3
Insufficient training of workers	.79		
Insufficient attention of the management	.73		
Resistance to new work practices within the firm	.68		
Slow adjustment process		.82	
Insufficient information on new forms of work organisation		.75	
Problems of financing organisational adjustments			.91
High adjustment costs			.65
Number of observations			1667
Kaiser's overall measure of sampling adequacy (MSA)			.809
Variance accounted for by the first two factors			.686
Root mean square off-diagonal residuals (RMSE)			.107
Variance accounted for by each factor	1.78	1.71	1.31
Final communality estimate (total)			4.80

Characterisation of the three factors:
(1) Insufficient preparity of personnel and management (HUMAN)
(2) Difficulties of organisational adjustment (ADJDIFF)
(3) Adjustment costs (ADJCOST)

The table shows only factor loadings of 0.4 and higher.

Table A6: Structure of the Sample and the Final Dataset

Industry	Sample N	Sample %	Respondents N	Respondents %	Response rate (3)/(1)
Food, beverages	263	3.9	99	3.7	37.6
Textiles	83	1.2	35	1.3	42.2
Leather, clothing	50	0.7	21	0.8	42.0
Wood (products)	119	1.8	46	1.7	38.7
Paper (products)	69	1.0	34	1.3	49.3
Printing, publishing	217	3.2	77	2.9	35.5
Pharmaceuticals, chemicals	224	3.3	87	3.3	38.8
Rubber, plastics	137	2.0	46	1.7	33.6
Non-metallic minerals	126	1.9	45	1.7	35.7
Metals	67	1.0	26	1.0	38.8
Metalworking	427	6.4	181	6.9	42.4
Machinery	520	7.7	205	7.8	39.4
Electrical machinery	149	2.2	63	2.4	42.3
Electronics, instruments	301	4.5	128	4.8	42.5
Watchmaking	126	1.9	45	1.7	35.7
Vehicles	64	1.0	25	0.9	39.1
Other manufacturing	119	1.8	49	1.9	41.2
Energy, water	80	1.2	38	1.4	47.5
Construction	630	9.4	268	10.1	42.5
Wholesale trade	628	9.3	246	9.3	39.2
Retail trade (-14%)	519	7.7	176	6.7	33.9
Hotels, restaurants (-27%)	411	6.1	118	4.5	28.7
Transport/communication	415	6.2	164	6.2	39.5
Banking/insurance (11%)	296	4.4	129	4.9	43.6
Real estate	38	0.6	13	0.5	34.2
IT and R&D services	116	1.7	52	2.0	44.8
Business services (11%)	468	7.0	204	7.7	43.6
Personal services	55	0.8	21	0.8	38.2
Total	6717	100.0	2641	100.0	39.3