CHAPTER 3

THE DECISION TO ADOPT INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT): FIRM-LEVEL EVIDENCE FOR SWITZERLAND

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Abstract

The paper aims, firstly, at explaining the decision of firms to adopt ICT. To this end, we present econometric estimates of a basic and extended version of a model of adoption, where the second approach investigates the role of new workplace organisation in adoption decisions. The second goal of the analysis is to derive from the model estimates a set of policy recommendations. The empirical analysis of the adoption decision yields a quite robust pattern of explanation, which is largely in line with theory. Estimation of the extended model shows that the introduction of new work practices favours the adoption of ICT; however, we also find evidence for the reverse relationship, indicating that ICT adoption and organisational change are, to some extent, complements. Based on the explanatory part of the study, we identified six areas of policies suited to promoting the adoption of ICT: enhancing the human capital base of the economy, enhancing the flexibility of the labour market, securing more intensive competition, fostering innovative activities, increasing macroeconomic stability, and improving the regulatory framework for e-business. The results thus support a framework-oriented policy design rather than a more activist policy orientation.

3.1 Introduction

Recent contributions to the literature have shown that an ICT producing sector is not a precondition to capture the benefits of “information and communication technologies” (ICT). Timely diffusion of new technology or, from a firm’s point of view, its adoption is at least as important to promoting macroeconomic growth (see, for example, Pilat and Lee, 2001; van Ark *et al.*, 2002). From this perspective, understanding the factors determining technology adoption becomes highly relevant also from the policy point of view.

In the present paper, we aim, firstly, at explaining the decision of firms to adopt (elements of) ICT. To this end, we present econometric estimates of a basic as well as an extended version of a model of adoption, where the second approach investigates the role of new workplace organisation in adoption decisions. The second goal of the analysis is to derive from the model estimates a set of policy recommendations and to compare them with those formulated in the OECD growth project (OECD, 2001*a*).

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 account of information spillovers from users to non-users which are the main element of the “epidemic model” of technology diffusion (for a survey of diffusion models, see Karshenas and Stoneman, 1995; Geroski, 2000).

The data used in this analysis stem from a survey on the use of ICT we conducted in the Swiss business sector in autumn 2000. We have at our disposal firm-specific information on, for example, the time period of adoption of nine technology elements, the proportion of employees using specific technologies, the range of application of Internet and Intranet respectively, the objectives of and obstacles to the adoption of ICT, etc. Moreover, we have information referring to various structural characteristics of the firm (size, industry affiliation, etc.) as well as a large number of variables pertaining to workplace organisation which may serve as determinants of the adoption decision.

The set-up of the paper is as follows: in Section 3.2, we provide some information on the data and describe briefly the time profile of the diffusion of various elements of ICT in the Swiss economy. Section 3.3 is devoted to the analysis of the adoption decision of firms. The theoretical background is presented in subsection 3.3.1, followed by the specification and estimation of the basic and the extended version of the model of ICT adoption. In Section 3.4, we turn to the policy analysis, and, finally, we draw some conclusions.

3.2 Database and time profile of the diffusion of ICT

3.2.1 Data

The analysis is based on firm data of the Swiss business sector collected in a survey carried out in autumn 2000. The questionnaire was addressed to a sample of 6 717 firms with five or more employees. The sample is (disproportionally) stratified by 28 industries and three industry-specific firm size classes, with full coverage of large firms. The response rate of about 40% (2 641 firms) is quite satisfactory in view of the very demanding questionnaire. The data are corrected for “unit” as well as for “item” non-response (for the methods used see Donzé, 1998).

The questionnaire[1] 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 received information on the adoption of new work practices (team-work, job rotation, etc.) and training activities, which presumably are relevant when a firm decides on the adoption of ICT. Finally, we dispose of information about structural characteristics of firms such as size, industry affiliation, propensity to export, human capital endowment, etc. which may also serve as determinants of ICT adoption.

3.2.2 Time path of diffusion

Table 3.1 contains some information on the time path of adoption of nine elements of ICT in the Swiss business sector. The degree of diffusion in 2003 (percentage of firms using a certain technology in the year 2000 or planning to use it till 2003) and the velocity of diffusion (increase of the percentage of firms using a certain ICT element in the period 1994-2003) vary quite strongly among these technologies. For example, diffusion of PCs, being already an “old” technology, was quite high in 1994 and increased since then (compared to other ICT elements), by “only” 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 the use of these technologies “exploded” in the second half of the last decade. The growth of the degree of diffusion, as planned by the surveyed firms for the period 2000/2003, has slowed 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.

Table 3.1. **Diffusion of information and communication technologies (ICT)**

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

	Degree of diffusion (%)			
Technology element	1994	1997	2000	2003
Digital assistants	7.2	16.2	32.6	38.4
Laptop	12.0	27.1	46.2	50.2
PCs, 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

Note: Weighted to account for deviations of the sample structure from that of the underlying population, different response rates by “size-industry cells” of the sample and for “unit“ non-response (see Donzé, 1998).

Source: Arvanitis and Hollenstein (2002).

1. The questionnaire can be downloaded from http://www.kof.ethz.ch.

A characterisation of the various technology elements according to the criteria “degree of diffusion” and “velocity of diffusion” leads to the following mapping: technologies with a high degree of diffusion are PCs (with low velocity) as well as e-mail and Internet (very high velocity); ICT elements with a medium degree of diffusion are LAN/WAN, EDI, Laptop and to some extent also Digital Assistants (high velocity, particularly EDI), and, finally, technologies with still low diffusion 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. Compared to other countries, diffusion of ICT in Switzerland (*i.e.* the business sector) is high; Switzerland ranks behind the USA and Scandinavia, but is (perhaps together with the Netherlands) ahead of other European countries (see Arvanitis and Hollenstein, 2002 and Arvantis, *et al.*, 2003, based on various sources such as OECD, 2001*b* or Deiss, 2002 as well as Hollenstein *et al.*, 2003).

3.3 Explaining the adoption of ICT

3.3.1 Theoretical background

3.3.1.2 Approach

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 primarily to the category of “rank models” emphasising the heterogeneity of firms as determinant of inter-firm diffusion patterns. However, we also take into account some elements of the “epidemic model” which stresses information spillovers from adopters to non-adopters. In the rank model, it is assumed that potential users of a new technology differ in important dimensions so that some firms obtain a greater return from new technology than others. The larger the net advantage resulting from adoption, the stronger the tendency to introduce a technology early and intensively.

3.3.1.3 Basic model

We distinguish several groups of factors which potentially influence a firm’s profitability from adopting new technology and therefore the decision to introduce it at a certain point in time. A first one includes a set of anticipated benefits of new technology (for the case of ICT see *e.g.* Brynjolfsson and Hitt, 2000; OECD, 2000) such as savings of capital and labour, general efficiency gains, reduced transaction costs, higher flexibility, improvement of product quality in a broad sense (*e.g.* variety, convenience), etc. For this group of variables we expect a positive influence on the adoption decision, *i.e.* they will favour early and/or intensive use of the new technology.

A second category of variables, which are negatively related to adoption, refers to anticipated barriers to the use of new technology. We identify five main types of such hindrances: unfavourable financial conditions, human capital restrictions, information and knowledge barriers (reflecting, for example, uncertainties with respect to the performance of ICT); organisational and managerial barriers (resistance to new technology; insufficient awareness of managers of the potential gains of ICT), and, finally, sunk cost barriers. This latter factor refers to the substitution costs that 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.[2]

The firm's ability to absorb knowledge from external sources is another major determinant of technology adoption in a similar way as it supports innovation performance. 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 on its endowment of 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 already embodies constituent elements of later applied, more advanced vintages (see *e.g.* Colombo and Mosconi, 1995; McWilliams and Zilberman, 1996). Both elements of absorptive capacity should be positively related to early and intensive use of ICT.

Whereas these aspects of absorptive capacity are specifically related to internal conditions, the standard epidemic model of technology diffusion stresses information spillovers from users to non-users of the technology. This 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 in the industry to which the firm is affiliated to. This proposition captures also network externalities which are important in the case of ICT[3] .

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 markets where competition is stronger, 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).[4] In case of (small) open economies like Switzerland international competition is a particularly effective way of forcing firms to adopt the most efficient way of producing, or to temporarily evade competitive pressure through product innovations (see *e.g.* Bertschek, 1995). We do not include a measure of concentration as a determinant of ICT adoption, since (game-)theoretic models do not come up with unambiguous results (Reinganum, 1989), and because the usual measures of concentration, which refer to the home market only, are not helpful in case of small open economies like Switzerland.

Firm size is an explanatory variable which is used in most studies of adoption.[5] It captures size-specific variables which are not explicitly modelled, such as the capacity to absorb risks related to future developments of ICT, economies of scale in e-commerce, etc. Finally, industry dummies represent demand and supply side factors influencing adoption time and intensity which are, to some extent, common to most firms of an industry (*e.g.* trend growth of demand, (technological) oppor-

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2. 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).

3. For a discussion of the various brands of this approach see *e.g.* Geroski (2000).

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

5. The same holds for firm age. However, we do not include this variable, since the theoretical arguments with respect to the role of firm age are not conclusive (positive experience effects vs. negative adjustment cost effects in case of older firms, see *e.g.* Dunne, 1994).

tunities determining extent and limits of the use of ICT, etc.). Industry dummies are thus used to control for unobserved variable bias.

3.3.1.4 Extended model

The past decade saw an impressive increase of adoption not only of ICT but also of new workplace organisation (see *e.g.* OECD, 1999). 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 (for an overview see, for example, Murphy, 2002). Whereas most studies have tried to establish a direct link between organisational change and the use of ICT on productivity growth,[6] some recent studies have stressed the complementarity of the adoption of new modes of workplace organisation and the introduction or a more intensive use of ICT. In this view, investment in ICT is more productive if accompanied by suitable organisational innovations, and the productivity gains from adjusting workplace organisation are higher if it is supported by investments in ICT (see *e.g.* Bresnahan *et al.*, 2002; Brynjolfsson and Hitt, 2000; Bertschek and Kaiser, 2001; McKinsey, 2001). Against this background, we formulate an extended model of ICT adoption which complements the basic approach by variables representing (the change of) workplace organisation.

3.3.2 Basic model: specification and empirical results

3.3.2.1 Adoption variables

The database allows the construction of 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 (see Table 3.2).

Time period of adoption

We dispose of information on five time periods of adoption for the nine ICT elements listed in Table 3.1. In addition, there is information on the actual and planned use of the Internet for various objectives (e-selling, e-procurement, etc.). We shall present results for two variables. The first one refers to the adoption of Internet (INTERNET) which is specified as a variable with five response levels, ranging from value 4 for the earliest adoption period (up to 1994) to value 0 for firms not even planning adoption up to 2003. The second variable captures 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”.

Intensity of adoption

To construct a variable for adoption intensity, we used information on the within-firm diffusion of certain elements of ICT (PC’s, Internet, Intranet, etc.). We present again results for two variables. Firstly, we calculated a four level ordinal measure of the overall ICT intensity (ICTINT), defined as the number of ICT elements (as listed in Table 3.1) already in use in the year 2000, ranging from an intensity level 3 (seven to nine ICT elements) to level 0 (less than three elements; zero included). The

6. For an empirical analysis of the direct link between organisational change and productivity growth at the micro-level see *e.g.* Ichniovski *et al.* (1997) or Black and Lynch (2000). The (direct) impact of the use of ICT on productivity growth is investigated at the aggregate level (see *e.g.* Jorgenson and Stiroh, 2000; Jorgenson 2001; Colecchia and Schreyer, 2001) as well as at the firm-level (see *e.g.* Lichtenberg, 1995; Brynjolfsson and Hitt, 1995; Greenan and Mairesse, 1996).

second intensity variable refers to the 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; the surveyed firms reported estimates on the share of Internet workers based on five categories (1-20% up to 81-100% of employees). Adding the non-users we get an ordinal variable with six response levels.

These models are estimated in a cross-section framework, since our data, except the time period of adoption, refer to one year only. We used the ordered probit procedure which is an appropriate method when the dependent variables are measured on an ordinal scale.

Table 3.2. **Specification of adoption variables**

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

3.3.2.2 Determinants of adoption

Anticipated net benefits from adoption

Table 3.3 gives an overview on the empirical specification of the variables which reflect the various groups of factors determining technology adoption as set out in Subsection 3.3.1. The first two groups of variables refer to the objectives of and the obstacles to ICT adoption. Whereas the objectives are interpreted as proxies for anticipated revenue increases (benefits),[7] which should have a positive impact on adoption, the obstacles represent (expected) costs of adoption, which are negatively related to early and intensive technology use. From these two groups of variables we thus get an overall measure of anticipated *net* benefits accruing to a firm adopting ICT.

The three metric variables listed in Table 3.3 under the heading “objectives” are factor scores resulting from a principal component factor analysis of 13 objectives of the use of ICT; the factor solution is described in detail in Hollenstein (2002). MARKET is related to anticipated benefits from

7. This interpretation can be justified on ground of evidence on the impact of the use of ICT on the firms’ efficiency. 61% of the surveyed firms report positive effects, whereas only 1% see a negative impact of ICT adoption on overall efficiency.

ICT use on the revenue side capturing, besides increasing sales in general, benefits from higher quality, more variety, providing complementary services, better market presence and stronger customer-orientation. COST stands for expected cost reductions in general, and, more specifically, for advantages to be gained from improving internal communication and decision-making as well as optimising the production process. The factor INPUT covers anticipated advantages from improving external relationships on the input side (labour market, co-operation with suppliers) as well as with respect to technology. These three variables capture to a large extent the benefits accruing from the use of ICT as proposed by the literature.

The model covers all five categories of obstacles to the adoption of ICT we mentioned above. The variable NOUSE captures the fact that in some instances there is only a very limited 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 (see Hollenstein, 2002). These variables, with the exception of INVCOST which stands for problems of financing ICT investments, can be interpreted, primarily, as proxies for uncertainties, knowledge deficiencies and information problems as well as adjustment costs related to the introduction of ICT (TECH, KNOWHOW, COMPAT). They thus capture determinants of adoption which, according to Karshenas and Stoneman (1995), are neglected in most studies examining this topic.

Absorptive capacity and learning

The firm's ability to absorb knowledge from external sources, which we expect to be positively related to early and intensive adoption, is represented by three variables measuring the availability of human and knowledge capital as well as innovative activity (see Table 3.3): EDUC, the share of employees with qualifications at the tertiary level, is a general measure of the firm's ability to assess technological opportunities and to use external knowledge for own innovative activities. INNOPD, a dichotomous measure indicating whether a firm launched product innovations in a three years reference period, is used to take into account the well-known proposition according to which internal innovative activity is a precondition for successfully using external knowledge. The third variable we employ to capture absorptive capacity is more directly linked with ICT; we use the share of employees which in 1999 attended ICT-oriented training courses (TRAINING) as a proxy for the firm's specific knowledge in ICT.[8]

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

8. Since some training is necessary when ICT is introduced, this variable is not strictly exogenous.

Table 3.3. **Basic model of ICT adoption: specification of the explanatory variables**

Variable	Description	Sign
Objectives of ICT adoption		
(Scores of a principal component factor analysis of the importance of 13 objectives of ICT adoption as assessed by firms on a five-point Likert scale)		
MARKET	Improving quality, increasing variety, etc. of products, improving customer-relations, increasing market presence and sales	+
COSTRED	Improving internal processes, communication and/or decision-making, reducing costs	+
INPUT	Improving position with respect to input factors (technology, suppliers of inputs, labour)	+
Obstacles to ICT adoption		
(The first four variables are scores of a principal component factor analysis of the importance of 12 obstacles to ICT adoption as assessed by firms on a five-point Likert scale)		
INVCOST	Technology too expensive, investment volume to large, lack of finance	-
KNOWHOW	Lack of ICT personnel, information and management problems	-
TECH	Technological uncertainties, performance of ICT not sufficient	-
COMPAT	Insufficient compatibility with existing ICT and work organisation	-
NOUSE	Limited potential to use ICT (firms' assessments on a five-point scale)	-
Human capital, absorptive capacity		
EDUC	Share of employees with qualifications at the tertiary level (%)	+
TRAINING	Share of employees having attended ICT-oriented training courses (%)	+
INNOPD	Introduction of new products (yes/no) in the period 1998-2000	+
Experience		
EDI	EDI already in use in 1997	+
Epidemic effects (alternative measures depending on the variable to be explained)		
EPIDINT	Share of firms (%) with above-average use of ICT in 1997 in the industry the company is affiliated to *(used for explaining INTER, ICTINT and NETUSE)*	+
EPIDSALE	Share of firms (%) active in e-selling in the year 2000 in the industry the company is affiliated to *(used for explaining ESALES)*	+
Export		
X, X^2	Sales share of exports (%) and its square	+ and -
Firm size		
S	5 dummy variables based on the number of employees: S5-19, S20-49, S50-99, S100-199, S200-499 (reference group: firms with 500 and more employees)	-
Industry affiliation		
Fifteen dummies: food, textiles/clothing, wood/paper/printing, non-metallic minerals/base metals, metal products, machinery/vehicles/electrical machinery, electronics/instruments/watchmaking, wholesale trade, retail trade/personal services, hotels/restaurants, transport/telecommunication, banking/insurance, IT-/R&D services, business services (reference group: energy/water/construction).		?

Competition

Competitive pressure on the (international) product market is proxied by the firm's export propensity (export-to-sales ratio). We use a specification with a linear and a quadratic term (variables X,

X^2) assuming that beyond a certain export intensity competitive pressure increases less than proportionally, or does not increase any more (positive sign for X, negative sign for X^2).

Firm size and industry affiliation

Firm size (S), which we expect to be positively related to early and intensive adoption, is represented by dummy variables referring to five size classes based on the number of employees, with large firms (500 and more employees) as reference group. In this specification, a negative sign indicates a positive size effect. Finally, we include fourteen industry dummies which should capture differences between industries with respect to technological opportunities and demand prospects, and are used as controls for an unobserved variable bias.

3.3.2.3 Empirical results

Time period of ICT adoption

Estimation results referring to the time period of adoption of Internet and Internet-based selling respectively (variables INTERNET and ESALES) are presented in column 1 and 2 of Table 3.4. All categories of explanatory variables have a statistically significant impact on the timing of adoption decisions, and the overall fit of the model is satisfactory. The core of our adoption model is thus confirmed.

Among the anticipated benefits, those related to market- and customer-orientation (MARKET) are the most important ones in case of both dependent variables;[9] it is not surprising that this is particularly pronounced in case of ESALES. Cost- and input-related benefits (COSTRED, INPUT) are only relevant for explaining the adoption of Internet. Among the obstacles to adoption, insufficient opportunities to benefit from an application (NOUSE) are an important factor in both cases. With regard to other impediments, Internet and Internet-based selling are different: for the former, investment costs and financial restrictions, and, even more, knowledge problems (deficiencies with respect to qualified manpower, management as well as information problems) are important (INVCOST, KNOWHOW). In the latter case, we find, against our prediction, a positive sign for technological uncertainty (TECH), presumably reflecting the particularly high uncertainty of adoption of e-selling at an early stage (see WITSA, 2000). We find no evidence for compatibility problems (COMPAT); high adjustment costs seem to be unimportant when only a single element of ICT is introduced.

We also find that the various dimensions of absorptive capacity as well as the propensity to export strongly stimulate early adoption of the Internet, but only weakly that of e-selling (variable INNOPD only). This difference may be compensated by the strong effect of information spillovers ("epidemic effects") we find in case of ESALES, which reflects a high pressure to keep up with competitors. In addition, learning from the use of a predecessor technology (EDI) also plays an important role in fostering early adoption of e-selling; this result implies that the adjustment costs a firm incurs when it substitutes Internet-based selling for using EDI are lower than the benefits to be captured from this change.

Larger firms have a higher propensity to adopt these two technologies. However, beyond a threshold of 200 employees, we cannot find any significant size-specific differences of adoption.[10] We

9. 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.

10. See Hollenstein (2002) for an in-depth analysis of the role of firm size in adoption decisions.

find a strong correlation between industry effects (which are not reported in Table 3.4) and epidemic effects, which is not surprising since the latter are defined at the industry level. At the empirical level, it is thus difficult to disentangle epidemic effects from unspecified factors we assume to be captured by industry dummies (demand prospects, technological opportunities, etc.).

Table 3.4. **Time period and intensity of the adoption of ICT (ordered probit estimates)**

Explanatory	**Time period of adoption**		**Intensity of adoption**	
Variable	INTERNET	ESALES	ICTINT	NETUSE
Objectives				
MARKET	.334***	.547***	.158***	.281***
	(.04)	(.05)	(.04)	(.04)
COSTRED	.182***	-.048	.375***	.212***
	(.04)	(.05)	(.04)	(.04)
INPUT	.200***	.067	.206***	.194***
	(.04)	(.05)	(.04)	(.04)
Obstacles				
INVCOST	-.092**	-.052	-.121***	-.100***
	(.04)	(.05)	(.04)	(.04)
KNOWHOW	-.131***	-.038	-.085**	-.160**
	(.04)	(.05)	(.04)	(.04)
TECH	.028	.112**	.022	.006
	(.04)	(.05)	(.04)	(.04)
COMPAT	.026	.044	.061*	.034
	(.04)	(.05)	(.04)	(.04)
NOUSE	-.069*	-.100**	-.127***	-.102***
	(.04)	(.05)	(.03)	(.03)
Absorptive capacity				
EDUC	.319**	.100	.991***	1.68***
	(.10)	(.10)	(.22)	(.21)
TRAINING	.008***	.003	.014***	.014***
	(.00)	(.00)	(.00)	(.00)
INNOPD	.298***	.274***	.438***	.269***
	(.09)	(.10)	(.08)	(.09)
Experience				
EDI	///	.315***	///	///
		(.10)		
Epidemic effects				
EPIDINT	.026***	///	.035***	.027***
	(.00)		(.00)	(.00)
EPIDSALE	///	.071***	///	///
		(.01)		
Exports				
X	.027***	.007	.017***	.018***
	(.01)	(.01)	(.00)	(.01)
X^2	-.000***	-.000	-.000***	-.000***
	(.00)	(.00)	(.00)	(.00)

(continued on next page)

Table 3.4. **Time period and intensity of the adoption of ICT (ordered probit estimates)** *(continued)*

Explanatory	**Time period of adoption**		**Intensity of adoption**	
Variable	INTERNET	ESALES	ICTINT	NETUSE
Firm size				
S5-19	-1.47***	-.971***	-2.42***	.017
	(.19)	(.20)	(.19)	(.18)
S20-49	-.488***	-.328***	-.756***	.148*
	(.10)	(.10)	(.10)	(.18)
S50-99	-.731***	-.410**	-1.05***	.324*
	(.20)	(.21)	(.20)	(.19)
S100-199	-.584***	-.521**	-.449***	.100
	(.20)	(.21)	(.20)	(.19)
S200-499	-.308	-.244	-.037	.122
	(.22)	(.22)	(.21)	(.20)
N	2641	2641	2641	2641
Slope test	241.8***	124.6***	119.3***	466.4***
McFadden R^2	.144	.122	.212	.147
% concordance	74.5	74.9	80.0	76.2

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

Intensity of use of ICT

The results of estimations for the intensity of use of ICT, based on an overall measure (ICTINT, *i.e.* the number of ICT elements) as well as on the intensity of Internet use (NETUSE, *i.e.* the proportion of employees working with Internet) are also depicted in Table 3.4 (column 3 and 4). The pattern of explanation for the two intensity variables is similar. More importantly, they do not much differ from that we found for the timing of adoption decisions. However, the explanatory power of the model explaining the intensity of adoption is higher.

Nevertheless, we also find some differences of the explanatory pattern between intensity and timing variables. Firstly, on the benefit side of anticipated profitability, market- and customer-orientation are less important in case of both intensity variables, and cost-oriented factors become more relevant when the intensity of use is to be explained. Secondly, among the obstacles to adoption, investment costs and funding restrictions are now a bigger problem, indicating that in case of an already larger ICT infrastructure investment needs are increasing (transition to more complex, network-oriented technologies). Similarly, limitations of the potential to use ICT are more of a problem in case of intensity variables, again a plausible result. If, for some firms, the introduction of one ICT element is already not very promising, this holds even more when a more intensive application of ICT is considered. With respect to knowledge and information problems, the comparison of intensity variables and those depicting the first use of ICT yields mixed results; the largest negative impact found 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 is already in use. A similar argument holds for compatibility problems which are, against our prediction, positively correlated with ICT intensity. However, this result is not implausible; if the ICT infrastructure is already highly developed, incompatibilities and high adjustment costs may be more prominent obstacles than in case of ICT adoption from scratch. Fourthly, big firms have a much larger advantage in the adoption process in case of ICTINT, the most complex adoption variable. Interestingly, and not implausible, we do not find any size effects (or even some advantages for medium-sized firms) for the within-firm diffusion of the Internet (NETUSE).

3.3.3 Extended model: the role of workplace organisation

3.3.3.1 Model specification

The extended model, which includes measures of new workplace organisation as additional explanatory variables, is used to clarify the role organisation plays in the process of ICT adoption. It should also yield some indications with regard to potential complementarities of ICT adoption and organisational innovations. At this stage of analysis, we no longer consider the time period of adoption as dependent variable; we only present results for the overall ICT intensity (ICTINT).

New workplace organisation is captured by various elements of workplace organisation as well as some measures of organisational change in the period 1995-2000 (see Table 3.5). Firstly, we take into account three types of (new) work practices, *i.e.* team-working (TEAM), job rotation (ROTATE) and multi-skilling (MSKILL). The first two variables measure the diffusion within the firm of team-working and job rotation respectively on a six-point ordinal scale (value 5 representing "very common practice", value zero standing for "does not exist"). MSKILL represents the degree of diversity of tasks an "average worker" performs (five-point scale; "very high" to "very low"). We expect that the existence of these work practices favours intensive adoption. Similarly, a high degree of worker's participation in decision-making is assumed to impact positively on the adoption of ICT. The two variables we use to measure the role of workers in decision-making processes are factor scores resulting from a principal component factor analysis of seven dimensions of work tasks for which the surveyed firms assessed the balance of decision-making power between workers and managers (five-point scale, ranging from "decision is the sole responsibility of workers" to "manager decides alone"); for details, we again refer to Hollenstein (2002). We identified two factors: PRODDEC pertains to dimensions of work which are related to the production process (design of work process, distribution of tasks among workers, work pace, etc.), USERDEC is primarily related to customer-oriented tasks (*e.g.* regular contact with customers, contact with clients in case of complaints). Two other variables reflect the process of decentralising decision-making power within a firm which took place in many companies during the second half of the nineties: DELCOMP measures whether there has been an increase of delegation of decision-making power towards the workers (yes/no), whereas FLAT stands for a flattening of the hierarchical structure (reduction of the number of management layers yes/no). Both variables are expected to favour adoption of ICT.

As an alternative to the use of this set of variables that capture specific dimensions of (a change of) workplace organisation, we constructed a composite measure of new work practices, applying a procedure proposed by Bresnahan *et al.* (2002): The values of TEAM, ROTATION, MSKILL, PRODDEC, USERDEC, DELCOMP and FLAT are standardised and simply added up.

Table 3.5. **Extended model of ICT adoption: specification of explanatory variables related to workplace organisation**

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

3.3.3.2 Empirical results

Table 3.6 shows results for the two specifications of the extended model (several organisational dimensions in column 1, composite measure of organisation in column 2) using ICTINT (number of ICT elements) as the dependent variable.[11] It turned out that "organisation" exerts a statistically significant influence on ICT adoption in both specifications of the model. Among the various organisational dimensions, team-working, decentralised decision-making in the production process and lowering the number of hierarchical layers are the relevant aspects of workplace organisation for explaining the use of ICT. Estimates, not reported here, point to some interaction between workplace organisation, on the one hand, and education, training and innovation on the other.[12]

11. Since our survey yielded information about organisational matters only for firms with at least 20 employees (against a threshold of five employees in the other sections of the survey), the dataset is reduced to 1 667 firms (as against 2 641 observations in the original sample). Estimates of the basic model using the smaller sample yielded a pattern of explanation which is very similar to that from the larger sample.

12. If EDUC, TRAINING and INNOPD are removed from the equation, the coefficient of ORG increases substantially (from 0.21 to 0.31).

These results, however, may be biased because of an endogeneity problem. This would be the case if the adoption of new workplace organisation depends, among other factors, from the introduction of ICT. A straightforward way to handling this problem is to lag the organisation variable in the ICT equation,[13] assuming, as proposed by Bresnahan *et al.* (2002), that organisational adjustments take longer than changes of technology. In this view, organisation is considered as a quasi-fixed factor in the short run, whereas it is held that new work practices and ICT adoption are complements in the longer run; the same holds, according to these authors for human resource development and product innovation. Estimates of an equation where the variable ORG is lagged by three years yield a slightly better model fit than those based on a contemporaneous specification. In addition, the impact of organisational change increases (see Hollenstein, 2002). The pattern of explanation, however, remains the same as before, and we find again some interaction between organisation and the variables reflecting human capital and innovation.

Table 3.6. **Workplace organisation and the adoption of ICT (ordered probit estimates)**

Explanatory variable	**ICT**		**ORG**
Organisation			
Disaggregated			
TEAM	.130*** (.03)	///	///
ROTATION	.022 (.04)	///	///
MSKILL	-.065 (.06)	///	///
PRODDEC	.123** (.05)	///	///
USERDEC	.041 (.05)	///	///
DELCOMP	.044 (.05)	///	///
FLAT	.250** (.11)	///	///
Aggregated			
ORG	///	.210*** (.05)	///
ICT	///		.307*** (.06)
Objectives of ICT adoption			
MARKET	.127*** (.05)	.117** (.05)	///
COSTRED	.341*** (.05)	.339*** (.05)	///
INPUT	.120** (.05)	.133*** (.05)	///
Obstacles to ICT adoption			
INVCOST	-.165*** (.05)	-.160*** (.05)	///
KNOWHOW	-.091* (.05)	-.078 (.05)	///
TECH	-.042 (.05)	-.043 (.05)	///
COMPAT	.045 (.05)	.042 (.05)	///
NOUSE	-.049 (.04)	-.049 (.04)	///

(continued on next page)

13. Since some of the variables representing new workplace organisation (*i.e.* DELCOMP and FLAT) pertain to changes during the five-year period preceding the measurement of the dependent variable ICTINT, the variable "organisation" is already lagged to some extent even in a contemporaneous specification of the extended model.

Table 3.6. **Workplace organisation and the adoption of ICT (ordered probit estimates)** *(continued)*

Explanatory variable	**ICT**		**ORG**
Objectives of new work organisation			
PERS	///	///	.392***
			(.05)
COSTFLEX	///	///	.140***
			(.05)
Obstacles to new work organisation			
HUMAN	///	///	.017
			(.05)
ADJDIFF	///	///	-.017
			(.05)
ADJCOST	///	///	-.082*
			(.05)
NONEED	///	///	-.125***
			(.04)
Absorptive capacity			
EDUC	1.56***	1.56***	1.67***
	(.33)	(.33)	(.31)
TRAINING	.011***	.011***	.013***
	(.00)	(.00)	(.00)
INNOPD	.415***	.432***	.380***
	(.10)	(.10)	(.10)
Epidemic effects			
EPIDINT	.032***	.034***	///
	(.00)	(.00)	
Exports			
X	.012**	.013*	-.007
	(.01)	(.01)	(.01)
X2	-.000*	-.000*	.000
	(.00)	(.00)	(.00)
Firm size			
S5-19	-1.61***	-1.74***	-.797**
	(.37)	(.36)	(.35)
S20-49	-1.44***	-1.52***	-.616***
	(.20)	(.20)	(.19)
S50-99	-1.06***	-1.12***	-.457**
	(.20)	(.20)	(.19)
S100-199	-.475**	-.482***	-.374*
	(.21)	(.20)	(.19)
S200-499	-.040	-.039	-.186
	(.21)	(.22)	(.20)
N	1667	1667	1667
Slope test	136.5***	127.4***	85.7**
McFadden R2	.161	.157	.098
% concordance	76.1	75.6	71.1

See notes of Table 3.4.

3.3.3.3 Reverse causality?

Specification of a model of adoption of new workplace organisation

A more fundamental way of taking account of endogeneity is to look for evidence of the reverse causality, *i.e.* to investigate whether the adoption of ICT exerts an influence on (the change of) workplace organisation. To this end, we specify an equation explaining the adoption of new work practices, where ICT is one of the explanatory variables. The basic 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 representing anticipated benefits and costs of adoption which makes the difference.

Detailed information about a number of dimensions of objectives of and obstacles to organisational change is condensed to a few variables by means of principal component factor analysis. As a result of this exercise, documented in detail in Hollenstein (2002), we obtain two variables representing anticipated benefits of new work practices as well as three factors depicting barriers to change of workplace organisation (Table 3.7). Among the benefits, the variable PERS represents the potential of exploiting previously untapped human resources by reorganising work processes (strengthening motivation, use of specific knowledge of workers, etc.), and COSTFLEX stands for expected gains from reducing costs and enhancing organisational flexibility to adjust to changes of a firm's environment. Insufficient readiness on the workers and management side is one of the potential barriers preventing reorganisation (HUMAN). The other obstacles refer to difficulties encountered in the adjustment process, that is slow speed and high costs of organisational adjustments (variables ADJDIFF and ADJCOST). Another variable to take account of is NONEED which controls for the fact that, in some instances, it may not be necessary at all to change the firm's organisation (this could be the case, for example, in small firms with simple and flexible organisational structures).

Table 3.7. **Anticipated net benefits of new work practices**

Variable	**Description**	**Sign**
Objectives		
(Scores of a principal component factor analysis of the importance of six objectives of the introduction of new work practices as assessed by firms on a five-point Likert scale)		
PERS	Making use of specific knowledge of workers, improving their motivation, shortening decision-making processes	+
COSTFLEX	Reducing costs, enhancing flexibility to adjusting to changes of the environment	+
Obstacles		
(The first three variables are scores of a principal component factor analysis of the importance of seven obstacles to the introduction of new work practices as assessed by firms on a five-point Likert scale)		
HUMAN	Insufficient training of workers, low attention of managers with respect to organisational innovations, resistance to change	-
ADJDIFF	Slow adjustment process, insufficient information on organisational matters	-
ADJCOST	High adjustment costs and problems of financing the organisational change	-
NONEED	Adjustment of organisation not really necessary	-

Empirical results

The results of estimating this model, which explains the adoption of new workplace organisation, are shown in column 3 of Table 3.6. It turns out that anticipated benefits of and (some of the) obstacles to organisational change exert a statistically significant influence on the adoption of new work practices. The same holds for formal qualifications of the personnel, training and innovativeness as well as for firm size. Moreover, a high ICT intensity, specified as a contemporaneous variable, also favours the introduction of new work practices. The "organisation model" is thus confirmed.

However, in the same way as in case of the "ICT model", we are confronted with an endogeneity problem, this time with respect to the ICT variable. Therefore, we estimated an equation where the measure of ICT intensity is lagged by three years. The results, not reported here, show that the model fit is about the same as in case of the contemporaneous specification; however, the impact of the ICT variable decreases substantially. Besides, there are indications of some interaction between ICT intensity (whether lagged or contemporaneous), on the one hand, and education, training and innovation on the other.[14]

The results we obtained by estimating the "organisation model" and those we found with the extended version of the "ICT model" point in the same direction: ICT intensity and workplace organisation are interrelated; we find statistically significant results for both directions of causality. In addition, there is some evidence for interactions between both ICT intensity and (new) workplace organisation, on the one hand, and, on the other, education, training and innovative activity. Another finding is related to the time structure of the relationship between the adoption of ICT and new work practices; the lagged effect of the "organisational variable" on ICT adoption turns out to be stronger than the contemporaneous one, whereas the opposite is true in modelling the adoption of new work practices. This result seems to be in line with the assumption of a more sluggish change of organisations as compared to technology adoption (*i.e.* the organisation as a quasi-fixed factor in the short run).

3.3.4 Summary and assessment of the empirical results

The basic model of ICT adoption is strongly confirmed by the data. Anticipated benefits (in particular, improved customer-orientation and cost-oriented advantages) and high costs of adoption (in the first instance, investment costs, financial restrictions and knowledge deficiencies), absorptive capacity (human capital, innovative activity), information spillovers and learning effects, competition and, finally, firm size are the core determinants of ICT adoption. The extended model shows that the introduction of new workplace organisation (in particular, team-working, decentralised decision-making and flattening the hierarchical structure of the firm) is also an important factor facilitating ICT adoption. Attempts to control for endogeneity problems related to "organisation" by introducing lags or reversing causality (*i.e.* ICT as one of the factors determining organisational innovations) showed that the adoption of ICT and that of new workplace organisation are interrelated. In addition, both variables are correlated, to some extent, with human capital input and innovation performance.

The empirical explanation of the adoption of ICT and new work practices presented in this paper is based on a single-equation framework. In view of the presumed endogeneity problems, it would be sensible to check the results by means of simultaneous estimations. This procedure might also give some indication of the magnitude of the impact of the introduction of ICT on organisational innovations as compared to that of new work practices on ICT adoption. Although this line of research is recommended, we would be quite surprised when it would alter the basic conclusions. As far as the time structure of the adoption of ICT and the introduction of new work practices is concerned, cross-section analyses clearly are of limited value, although our model has some time dimension represented by the lagged explanatory variables. To get more reliable results, a dynamic modelling of the adoption of ICT and new work practices would be required. However, panel estimates are not feasible with the data at hand.

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

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

3.4 Policy

The relevance of the various factors determining the adoption of ICT and the introduction of new workplace organisation, as identified in our empirical analysis, enables us to draw some policy conclusions. In this respect, the variables referring to the role played by different aspects of absorptive capacity and by the obstacles to adoption are particularly informative. We identify the following six policy areas to be important for promoting the diffusion of ICT.

Firstly, strengthening and enhancing the human capital base of the economy is crucial for the adoption of ICT and new work practices. According to the model estimates, formal qualifications as well as training (on- and off-the-job) exert a strongly positive effect on ICT adoption; in addition, skill deficiencies (lack of qualified personnel as well as management problems which, at least to some extent, are also due to know-how problems), significantly impede early and intensive adoption of ICT. Moreover, information spillovers are an important driver of ICT adoption; the spillover potential can be exploited to a particularly large extent if a firm's workforce is highly qualified. In view of these results, education policy and specific measures to foster ICT-training are core policy areas in the present context. This holds true even if, at present, there is no (general) shortage of ICT-skills.

As far as training is concerned, policy is confronted with a well-known externality problem, since ICT skills, to a large extent, are "general skills" which do not lose their value when a worker leaves a firm. In these circumstances, the incentive for firms to invest in ICT-oriented training is negatively affected, and "poaching" could be an alternative firm strategy to secure ICT skills. From the policy point of view, there is a risk of underinvestment in ICT-oriented training, which might be serious since in case of rapidly developing technologies (like ICT) training is particularly important as compared to basic educational qualification. Moreover, underinvestment in ICT-training might be even larger in case of SMEs, since they cannot offer, to the same degree as large companies, career perspectives (and other opportunities) to newly-trained employees which could encourage them to stay with the firm.

Secondly, as shown in the empirical analysis, measures facilitating organisational change at the workplace are beneficial to the diffusion of ICT. The benefits firms expect from such changes are strongly related to making better use of untapped human resources and increasing flexibility. However, we do not find evidence for resistance on the workers' side being an important obstacle to the adoption of new workplace organisation. This result presumably reflects the fact that, in Switzerland, labour markets are only weakly regulated (Nicoletti *et al.*, 2000), unions are weak in most industries, the relations between management and firm-internal labour representatives are ruled by trust, and, finally, the participation of workers in decision-making, although informal, is quite high (Arvanitis *et al.*, 2002). Therefore, in many countries, reforms facilitating the smooth working of the labour market, as well as measures to strengthening trust between employers and employees (and their representatives) within the firm to support organisational change could significantly contribute to the diffusion of ICT.

Thirdly, more intensive competition on the markets for hardware, software and telecommunication services could reduce the investment and current costs of ICT, which, according to our estimations, are significant obstacles to early and intensive adoption. This result is in line with cross-country evidence (see *e.g.* OECD, 2001*b*). Moreover, intensified competition on the product market enforces firms to introduce ICT to realise the significant cost reductions which, according to the model estimates, can be realised through the adoption of these technologies. Policies strengthening competetion in general and, more specifically, on the markets for ICT products and services could thus significantly contribute to the rapid diffusion of ICT.

Fourthly, the econometric work presented here shows that firms which are innovative in general are also early and intensive adopters of ICT. This result implies that policies fostering innovation in general can also be used to promote the diffusion of ICT. In particular, policies supporting innovative activities of SMEs could be helpful. In the Swiss case, correcting for capital market imperfections would be a sensible way to contribute to this objective, as has been shown in empirical work based on innovation survey data (see Arvanitis and Marmet, 2002).

Fifthly, sound macroeconomic policies can substantially contribute to the diffusion of ICT. This proposition is strongly supported by evidence from Switzerland where the economy, to a large extent because of too restrictive fiscal and monetary policy, did hardly grow between 1991 and 1997 (see Arvanitis *et al.*, 2001). Based on an analysis of data stemming from four rounds of the Swiss Innovation Survey covering the period 1988/90 to 1997/99 we could show that innovative activity is strongly influenced by the business cycle (positive correlation). It seems not far-fetched if we conclude that the same holds in case of investments in ICT, and thus the diffusion of these technologies.

Finally, there are some other problems that can be addressed by policy measures, which are not covered by our firm data base. An important one, as shown, for example, by the results of pilot surveys on e-commerce conducted in thirteen EU countries in 2001 as well as those of OECD work on e-commerce (Deiss, 2002; OECD, 2000), are difficulties related to the security of transactions. Preliminary results from a similar survey for Switzerland, based on the same sample we used for the present study, confirm these results (Hollenstein *et al.*, 2003). Policy should thus provide a legal and regulatory framework which helps to build trust in e-transactions (consumer protection, securing privacy, etc.).

The empirical results thus support a framework-oriented policy rather than a more activist policy design: strengthening the human capital base of the economy, securing competition and correcting for some market imperfections, improving the regulatory environment and macroeconomic stabilisation are the core areas of a policy designed to promote the diffusion of ICT.

3.5 Summary and conclusions

Since recent research at macro-level has shown that the productivity effects of the diffusion of ICT are (at least) as important as those of ICT production, it has become highly relevant, also from the policy point of view, to understand why a firm introduces (some of) these technologies. It is against this background, that, firstly, we tried to explain empirically the decision of firms to adopt ICT and explored the role organisational innovations play in the adoption process. In a second step, the empirical results were used to derive some policy recommendations. The analysis is based on survey data stemming from a large sample of Swiss firms.

The adoption behaviour of firms in the field of ICT is characterised by a basic pattern of explanation which is quite robust across various model estimations based on different adoption variables. All categories of explanatory variables postulated by theory seem to be relevant, although not to the same extent. Most important are anticipated benefits (in particular, by improving customer-relations, increasing product quality and variety and optimising production processes) and costs of adoption (in the first place, too large volume and high costs of investment as well as know-how and management problems). Other key factors to explaining the adoption of ICT are the firm’s ability to absorb knowledge from other companies and institutions, information spillovers from early adopters, experience with earlier vintages of a certain technology, and (international) competitive pressure.

Firm size, which is one of the most prominent variables included in models of adoption, is usually positively correlated with early and intensive use of a new technology. In case of ICT, we get a more differentiated picture: in general, we find positive size-effects only up to a threshold of about 200 employees; for some specific ICT elements, for example Internet, we find that medium-sized companies are even more intensive users than large firms.

In addition to these firm-specific determinants, there is also evidence for industry effects. The probability of adoption is clearly above-average in some high-tech industries, in the trading sector as well as in "modern" service industries. This result reflects, among other factors, differences regarding technological opportunities and demand prospects.

Estimates of an extended version of our model yielded strong evidence for the influential role (new) workplace organisation plays in decisions related to the adoption of ICT. Team-working, decentralised decision-making and flattening hierarchical structures are the most relevant organisational dimensions favouring the adoption of ICT, whereas we do not find an impact of, for example, job rotation or multi-skilling. To circumvent the problem of endogeneity of workplace organisation as an explanatory variable, we introduced time lags and investigated the reverse causality running from the adoption of ICT to the introduction of new work practices; we also find evidence for this reverse relationship. Moreover, the use and development of human resources as well as innovative activities turn out to be correlated to some extent with the adoption of ICT as well as with new workplace organisation. These findings are consistent with those of some recent studies which found that ICT, new workplace organisation, human capital investment and innovative activity are complementary elements of a strategy to increase the efficiency of production and to generate product innovations. However, further research is required to investigate in more detail the relationship between these seemingly complementary variables. Particularly, the use of simultaneous estimation techniques (ICT, organisation and human capital as endogenous variables) and panel estimations (to detect the dynamic relationships between these factors) could yield further insights.

Based on the results of the explanatory part of the study, we could identify six areas of policies suited to promoting the adoption of ICT: enhancing the human capital base of the economy in general and, despite the current oversupply of ICT-workers, with regard to ICT competencies; enhancing the flexibility of the labour market to facilitate structural change and organisational innovations; securing more intensive competition on product markets in general and, specifically, on the markets for ICT goods and services; fostering innovative activities, in the first place of SMEs (correcting capital market imperfections, etc.); increasing macroeconomic stability; and, finally, improving the regulatory framework for e-business (security of transactions, guaranteeing privacy, consumer protection, etc.). The empirical results thus support a framework-oriented policy design rather than a more activist policy orientation. These conclusions are more or less in line with the recommendations on policies to seize the benefits of ICT as formulated in the OECD growth project (OECD, 2001*a*).

REFERENCES

van Ark, B., R. Inklaar and R.H. McGuckin (2002), "Changing Gear – Productivity, ICT and Service Industries: Europe and the United States", *Paper presented at the 2nd ZEW Conference on the Economics of Information and Communication Technologies*, Mannheim, June 24-25.

Arvanitis, S., M. Bezzola, L. Donzé, H. Hollenstein and D. Marmet (2001), "Innovationsaktivitäten in der Schweizer Wirtschaft – Eine Analyse der Ergebnisse der Innovationserhebung 1999", *Strukturberichterstattung Nr. 5,* Staatssekretariat für Wirtschaft (seco), Bern.

Arvanitis, S. and H. Hollenstein (1994), "Demand and Supply Factors in Explaining the Innovative Activity of Swiss Manufacturing Firms. An Analysis Based on Input-, Output- and Market-oriented Innovation Indicators", *Economics of Innovation and New Technology*, 3, 15-30.

Arvanitis, S. and H. Hollenstein (2001), "The Determinants of the Adoption of Advanced Manufacturing Technology. An Empirical Analysis Based on Firm-level Data for Swiss Manufacturing", *Economics of Innovation and New Technology*, 10, 377-414.

Arvanitis, S. and H. Hollenstein (2002), "Die Wirtschaft in der Informationsgesellschaft", in: Swiss Federal Office of Statistics (ed.), *Informationsgesellschaft Schweiz: Standortbestimmung und Perspektiven*, Neuchâtel.

Arvanitis, S., Hollenstein, H. and D. Marmet (2003), "Die Schweiz auf dem Weg zu einer wissensbasierten Ökonomie: Eine Bestandesaufnahme", *Strukturberichterstattung Nr. 17,* Staatssekretariat für Wirtschaft (seco), Bern.

Arvanitis, S. and D. Marmet (2002), "Finanzierung von Innovationsaktivitäten – Eine Empirische Analyse anhand von Unternehmensdaten", *Strukturberichterstattung Nr. 9*, Staatssekretariat für Wirtschaft (seco), Bern.

Bertschek, I. (1995), "Product and Process Innovation as a Response to Increasing Imports and Foreign Direct Investment", *Journal of Industrial Economics,* 43(4), 341-357.

Bertschek, I. and U. Kaiser (2001), "Productivity Effects of Organizational Change: Microeconometric Evidence", *Centre for European Economic Research, Discussion Paper No.01-32*, Mannheim.

Black, S. and L. Lynch (2001), "How to Compete: The Impact of Workplace Practices and Information Technology on Productivity", *Review of Economics and Statistics*, 83(3), 434-445.

Bresnahan, T.F., E. Brynjolfsson and L.M. Hitt (2002), "Information Technology, Workplace Organisation, and the Demand for Skilled Labor: Firm-level Evidence", *Quarterly Journal of Economics*, 112(1), 339-376.

Brynjolfsson, E. and L.M. Hitt (1995), "Information Technology as a Factor of Production: The Role of Differences Among Firms", *Economics of Innovation and New Technology,* 3, 183-200.

Brynjolfsson, E. and L.M. Hitt (2000), "Beyond Computation: Information Technology, Organizational Transformation and Business Performance", *Journal of Economic Perspectives,* 14(4), 23-48.

Cainarca G.C., M.G. Colombo and S. Mariotti (1990), "Firm Size and the Adoption of Flexible Automation", *Small Business Economics*, 2(2), 129-140.

Cohen W.M. and D.A. Levinthal (1989), "Innovation and Learning: The two Faces of R&D", *Economic Journal*, 99(4), 569-596.

Colecchia, A. and P. Schreyer (2001), "ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case? A Comparative Study of Nine OECD Countries", *STI Working Papers 2001/7*, OECD: Paris.

Colombo M. and R. Mosconi (1995), "Complementarity and Cumulative Learning Effects in the Early Diffusion of Multiple Technologies", *Journal of Industrial Economics*, 43(1), 13-48.

Deiss, R. (2002), "E-Commerce in Europe", *Statistics in Focus*, Theme 4, 12/2002, Eurostat, Luxembourg.

Donzé, L., (1998), "Développement et entretien du 'Panel d'entreprise' du KOF/ETHZ. Une étude méthodologique", Zurich, septembre (downloadable from http://www.dplanet.ch/users/ldonze).

Dunne T. (1994), "Plant Age and Technology Use in U.S. Manufacturing Industries", *Rand Journal of Economics*, 25(3), 488-499.

Geroski, P. (2000), "Models of Technology Diffusion", *Research Policy*, 29, 603-625.

Greenan, N. and J. Mairesse (1996), "Computers and Productivity in France: Some Evidence", *NBER Working Paper 5836*, Cambridge, MA.

Hollenstein, H. (2002), "Determinants of the Adoption of Information and Communication Technologies (ICT). An Empirical Analysis Based on Firm-level Data for the Swiss Business Sector", *Swiss Institute for Business Cycle Research (KOF), Working Paper No. 60*, Zurich, July (downloadable from http://www.kof.ethz.ch).

Hollenstein, H., N. Sydow and M. Wörter (2003), "Die Verbreitung von Informations- und Kommunikationstechnologien und E-Commerce in der Schweizer Wirtschaft. Ergebnisse der KOF-Panelumfrage vom Herbst 2002", Swiss Federal Office for Statistics (ed.), Neuchatel.

Ichniovski, C., K. Shaw and G. Prennushi (1997), "The Effects of Human Resource Management Practices on Productivity", *American Economic Review*, 87(3), 291-313.

Jorgenson, D.W. (2001), "Information Technology and the U.S. Economy", *American Economic Review*, 91(1), 1-32.

Jorgenson, D.W. and K.J. Stiroh (2000), "Raising the Speed Limit: US Economic Growth in the Information Age", *Economics Department Working Papers No. 261*, OECD: Paris.

Karshenas M. and P. Stoneman (1995), "Technological Diffusion", in: P. Stoneman (ed.), *Handbook of the Economics of Innovation and Technological Change*, Oxford: Blackwell.

Lichtenberg, F.R. (1995), "The Output Contributions of Computer Equipment and Personal: A Firm-level Analysis", *Economics of Innovation and New Technology*, 3, 201-217.

Link A.N. and P. Kapur (1994), "A Note on the Diffusion of Flexible Manufacturing Systems Technology", *Economics Letters*, 46, 357-362.

Majumdar S.K. and S. Venkataraman (1993), "New Technology Adoption in US Telecommunications: The Role of Competitive Pressures and Firm-level Inducements", *Research Policy*, 22, 521-536.

McKinsey (2001), *US Productivity Growth 1995-2000. Understanding the Contribution of Information Technology Relative to Other Factors*, McKinsey Global Institute, Washington, D.C., October.

McWilliams B. and D. Zilberman (1996), “Time of Technology Absorption and Learning by Using”, *Economics of Innovation and New Technology*, 4(2), 139-154.

Murphy, M. (2002), “Industry Issues: Organisational Change and Firm Performance”, *STI Working Papers 2002/14*, OECD, Paris.

Nicoletti, G., S. Scarpetta and O. Boylaud (2000), “Summary Indicators of Product Market Regulation with an Extension to Employment Protection Legislation”, *Economics Department Working Papers No. 226*, OECD.

OECD (1999), “New Enterprises Work Practices and Their Labour Market Implications”, in: *OECD Employment Outlook 1999*, OECD, Paris, S. 179-221

OECD (2000), *The Economic and Social Impacts of Electronic Commerce: Preliminary Findings and Research Agenda*, Paris.

OECD (2001a), *The New Economy: Beyond the Hype*, the OECD Growth Project, Paris.

OECD (2001b), *OECD Science, Technology and Industry Scoreboard 2001 – Towards a Knowledge-based Economy*, Paris.

Pilat, D. and F.C. Lee (2001), “Productivity Growth in ICT-Producing and ICT-Using Industries: A Source of Growth Differentials in the OECD?”, *STI Working Papers 2001/4*, OECD: Paris.

Reinganum J.F. (1989), “The Timing of Innovation: Research, Development and Diffusion”, in: R. Schmalensee and R. Willig (eds.), *Handbook of Industrial Organisation,* Vol. 1, Elsevier Science Publishers, New York.

WITSA (2000), *International Survey of E-Commerce 2000*, The World Information Technology Services Alliance, London.

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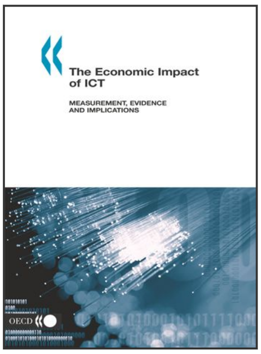

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