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Working Paper

The decision to adopt internet-based e-commerce: An empirical analysis based on Swiss firm-level data

KOF Working Papers, No. 89

Provided in Cooperation with:
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Suggested Citation: Hollenstein, Heinz; Wörter, Martin (2004) : The decision to adopt internet-based e-commerce: An empirical analysis based on Swiss firm-level data, KOF Working Papers, No. 89, ETH Zurich, KOF Swiss Economic Institute, Zurich

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Business Cycle Research

Arbeitspapiere/ Working Papers

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The Decision to Adopt Internet-based E-Commerce

An Empirical Analysis Based on Swiss Firm-level Data

No. 89, July 2004

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

The Decision to Adopt Internet-based E-Commerce

An Empirical Analysis Based on Swiss Firm-level Data

Heinz Hollenstein and Martin Wörter

July 2004

Abstract

The paper aims at explaining empirically the diffusion of E-commerce based on two large-scale sample surveys conducted in the Swiss economy. The paper adds to previous work in two ways: firstly, we estimate separate models for E-selling and E-purchasing, and, secondly, we distinguish between inter-firm diffusion (i.e. technology adoption) and intra-firm diffusion (i.e. intensity of technology use). It turns out that the pattern of explanation strongly differs between the two types of E-commerce as well as the two types of diffusion. Therefore, further studies dealing with the diffusion of E-commerce should differentiate along these two dimensions. Besides, it is shown that institutional, technological and economic uncertainty as well as adjustment costs, which are neglected in most studies of diffusion, are important explanatory variables. Moreover, it turned out that "rank effects" are clearly more important drivers of adoption and intra-firm diffusion of the two types of E-commerce than "epidemic effects", which are of some importance only in case of adoption.

Keywords: Technology diffusion; Inter- vs. intra-firm diffusion; E-commerce; E-selling vs. E-purchasing; Information and Communication Technologies (ICT); Rank and epidemic effects of diffusion

JEL Codes: L2, O31, O33

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1. Introduction

Rather than the development of new technology it is its diffusion which contributes to economic growth. The economy-wide degree of diffusion can be decomposed into two elements, that is inter-firm diffusion (the firms' first-time use of a new technology, i.e. adoption) and intra-firm diffusion (increasing intensity of technology use).

In this paper, we aim at explaining empirically both elements of diffusion. The analysis refers to E-commerce, thus a specific application of "Information and Communication Technology" (ICT). We separately estimate models for E-selling and E-purchasing. In both cases, we only consider Internet-based E-commerce; electronic transactions realised by use of other types of networks (e.g. EDI) are not taken into account.[1] We present empirical evidence regarding the most important hypotheses put forward in the theoretical literature or investigated in previous empirical work; we also take account of propositions derived from case studies. The paper is empirically-oriented; we do not strive for further developing the theory of technology adoption.

The study, in the first place, is based on a „rank model" of technology diffusion, which, in explaining inter-firm and intra-firm diffusion, emphasises differences among firms with respect to the profitability potential of technology use arising from the heterogeneity of firms. In addition, we take account of learning effects of different kind, such as information spillovers from users to non-users or learning from the use of earlier vintages of a technology which is stressed, for example, by Colombo and Mosconi (1995); learning effects are at the core of the "epidemic model" of technology diffusion. Moreover, we consider network effects, which are relevant in case of the technology analysed in this paper (Economides, 1996). "Rank effects" and "epidemic effects" seem to be the dominant factors explaining the adoption of new technology (Canepa and Stoneman, 2003), whereas there is little empirical evidence for "stock" effects and "order" effects, proposed by game-theoretic models of diffusion (Karshenas and Stoneman, 1995).[2]

The data stem from two large surveys we conducted in the Swiss business sector. The principal source for the present analysis is a survey dealing with the use of ICT and E-commerce carried out in autumn 2002. We have at our disposal firm-specific information on, for example, the time period of adoption of nine elements of ICT, the proportion of employees using specific types of ICT, the range of application of the Internet and websites, the use of E-commerce (purchasing and selling respectively) and the transaction values realised through these electronic trading channels, the objectives of E-selling and E-

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1 Internet-based "Electronic Commerce" (E-commerce) are transactions conducted over Internet Protocol-based networks. The goods and services are ordered over these networks, but payment and ultimate delivery of the good or service may be conducted on-line or off-line. Orders received via telephone, facsimile, or manually typed e-mails are not counted as electronic commerce (Eurostat, 2003).

2 See e.g. Karshenas and Stoneman (1995) or Geroski (2000) for comprehensive surveys of various brands of diffusion models.

purchasing, the obstacles to E-selling, etc.. Moreover, we collected some financial data (sales, intermediate inputs, value added) and information referring to various structural characteristics of the firm (size, industry affiliation, etc.). The second source is an innovation survey also conducted in autumn 2002. It yielded a vast number of variables some of which we used to complement the information stemming from the ICT survey (e.g. variables representing innovative activity, various dimensions of the market environment, firm characteristics such as age, corporate status, etc.). In some model estimates, we only used the ICT sample (2968 firms), other estimations were based one a dataset produced by matching the information of the two surveys ("matched data set": 1655 observations).

The paper adds to previous work in various ways. Firstly, since Internet-based E-commerce is a rather new phenomenon, it is not surprising that empirical work dealing with this matter is dominated by case studies (see the management literature) and the analysis of small samples (usually based on low response rates), mostly remaining at the descriptive level (see e.g. Daniel and Grimshaw, 2002). To mention are two exceptions, firstly Bertschek and Fryges (2002), who investigated the adoption of B2B E-commerce based on firm-level data stemming from a large-scale survey conducted in the German business sector; secondly a study of our own, where we tried to explain Swiss firms' adoption of various elements of ICT, among them the adoption of E-selling (Hollenstein, 2004). The present study, as already mentioned, also is based on large-scale sample surveys, allowing to specify a model which, in terms of explanatory variables, is richer than that underlying our previous work.

Secondly, to our knowledge, the present paper is the first where the diffusion of E-selling and E-purchasing are analysed in parallel, using information from the same set of firms. The distinction of these two types of transactions is important, since the degree of diffusion of E-purchasing is much larger than that of E-selling (see Section 3). In these circumstances, it is likely that the explanation of the diffusion of the two types of electronic transactions is different.[3] Nevertheless, the majority of explanatory variables we used in explaining the diffusion of E-selling and E-purchasing respectively is the same; the common variables, however, are expected to differ with respect to the magnitude of the influence on the diffusion of the two types of E-commerce.

Thirdly, we are able to consider not only inter-firm diffusion of new technology (i.e. adoption) but also intra-firm diffusion. As stressed, for example, by Stoneman (2001) or Battisti and Stoneman (2003a), not much research has been devoted to intra-firm diffusion. This holds true especially as far as empirical studies are concerned, reflecting a lack of intra-firm data. Recent studies dealing with intra-firm diffusion are Battisti and Stoneman (2003b), who analysed the intra-firm diffusion of CNC machine tools using a two-step Heckman

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3 Clayton et al. (2004) also distinguish between E-selling and E-purchasing. However, they did not analyse the diffusion of these practices but their productivity effects. According to their study referring to the British economy, productivity effects differ among the two types of E-commerce (as does the explanation of the adoption of E-selling and E-purchasing in the present paper).

procedure (with inter-firm diffusion as the dependent variable in the selection equation), Fuentelsaz et al. (2003) looking at the intra-firm diffusion of "automated teller machines" (ATM), or Hollenstein (2004) explaining a firm's intensity of use of the Internet (proportion of employees using this technology) and of ICT in general (number of ICT elements in use). In the present paper we investigate systematically, whether inter-firm and intra-firm diffusion are driven by the same factors, as hypothesised by Mansfield (1963), or whether the drivers are different, as claimed, for example, by Battisti and Stoneman (2003a).

Fourthly, the modelling of "anticipated profitability" is more comprehensive than in most previous empirical studies.[4] In profitability-driven (equilibrium) models where technology diffusion depends on the firms' comparing marginal benefits and costs of technology use, profitability usually is conceptualised in a narrow way, reflecting relative prices between old and new technology and their change over time (see Karshenas and Stoneman, 1995). In contrast, we assume that a firm chooses a new technology considering a whole set of (mostly "soft") dimensions of presumed benefits from as well as costs of using the technology. Therefore, we specify anticipated profitability by using detailed survey information referring to the relevance of specific objectives of and obstacles to the adoption and more intensive use of E-commerce, as assessed by the firms themselves. In this way, we try to take into account several cost factors such as market, technological or institutional uncertainty as well as information and adjustment costs which, although highly important, are mostly ignored in the empirical analysis of adoption decisions (see Karshenas and Stoneman, 1995).[5] On the benefit side, anticipations referring to new opportunities with respect to the market position (improving customer-relations, etc.) and the efficiency of the production process (speeding-up business processes, etc.) are included in the model.

The set-up of the paper is as follows: Section 2 is devoted to the conceptual framework and the presentation of the hypotheses underlying the empirical analysis. Section 3 provides information on the database and the current degree of inter-firm and intra-firm diffusion of E-selling and E-purchasing respectively in the Swiss business sector. Model specification and estimation procedure are discussed in Section 4, with the empirical results presented in Section 5. Finally, we summarise, assess the main findings and point to some shortcomings of the analysis.

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4 Exceptions are Baldwin and Rafiquzzaman (1998) and Arvanitis and Hollenstein (2001) dealing with the adoption of "advanced manufacturing technologies" (AMT) as well as Hollenstein (2004) explaining the adoption of ICT.

5 An attempt to take account of uncertainty is made in Battisti and Stoneman (2003b).

2. Conceptual framework

2.1 General characteristics

To analyse empirically the diffusion of E-commerce, we take as starting point the general conceptual framework proposed by Karshenas and Stoneman (1995) to explain inter-firm technology diffusion. These authors distinguish four different sub-models: the (traditional) "epidemic model" (primarily based on information and knowledge spillovers), the "rank model" (where firm heterogeneity is the driver of adoption), and two types of game theoretic approaches giving rise to "stock" effects (with the profitability of adoption at a certain point in time being negatively related to the extent of diffusion reached in the previous period) and "order" effects (reflecting advantages of first moving and early adopting). Whereas the first three elements may be used to explain intra-firm diffusion as well, this is not the case for "order" effects since, in this case, first mover advantages are not relevant (Battisti and Stoneman, 2003b).

Within this general framework, our approach is based on the "rank model" complemented by "epidemic effects". We thus emphasise, one the one hand, the heterogeneity of firms in terms of important dimensions so that some firms obtain a greater return from new technology than others do. The larger the net advantage resulting from adoption (or from an increase of using new technology), the stronger the tendency to introduce a technology early ("inter-firm" diffusion) or to use it intensively ("intra-firm" diffusion). On the other hand, we take account of information spillovers from adopters to non-adopters and of other types of learning effects (e.g. learning by technology use) as determinants of adoption and intra-firm diffusion of technology. Finally, we consider network effects, which are relevant in case of the technology analysed in this paper.

The main objective of the remaining of this section is to identify the factors determining a firm's decision to adopt E-selling and E-purchasing respectively. Since there is quite a large overlap between the variables we propose to explain the uptake of these two types of E-commerce (partly reflecting the current state of the literature which, in many instances, does not distinguish between E-selling and E-purchasing), we discuss them in parallel. The same holds true for the two elements of diffusion, i.e. adoption and intra-firm diffusion, although it might be the case that, depending on the type of diffusion, the impact of some explanatory variables differs in sign or in magnitude.

2.2 Explaining adoption and intensity of use of E-commerce

Anticipated benefits of technology use

The first category of variables refers to anticipated benefits of technology use which, in case of E-commerce, are related to savings of inputs, overall efficiency gains, higher flexibility or keeping-up to "best practice". In addition, there are benefits which are specific to the two

types of E-commerce, some of them related to product markets (E-selling), others to markets for inputs (E-purchasing).

More specifically, E-commerce, firstly, may reduce capital needs through, for example, lowering inventory requirements. Secondly, it may save labour in general (e.g. automation of internal transactions) or substitute for specific labour skills (qualification or functional categories of labour such as low-skilled workers, sales or purchasing staff, servicemen, etc.). Thirdly, it may increase the efficient use of inputs in general (speeding-up internal processes, backward and forward linking of the ICT infrastructure, lowering transaction costs at the interface with users and suppliers). Fourthly, E-selling may increase product quality in various ways (customisation, variety, convenience, etc.) or support the development of new market segments, whereas E-purchasing should improve the knowledge of (alternative) sources of inputs and ease the access to suppliers. Fifthly, E-commerce may be necessary to keep up to market standards and benchmarks (even if it is not more than preserving or improving the firm's image and market appearance). Finally, E-commerce may increase market power by enforcing electronic transactions to upstream and downstream firms.

These categories of benefits are stressed, for example, by Lucking-Reiley and Spulber (2001), Pires and Aisbett (2003) or Garicano and Kaplan (2000), and are reported, in much detail, in OECD (2000). To mention is also a survey conducted in EU countries in 2002, which yielded information on the relevance of various benefits of ICT as perceived by the firms themselves (Eurostat, 2003). As far as labour input is concerned, we refer to the vast literature on skill-biased technical change (specifically for ICT, see e.g. Bresnahan et al., 2002). We expect that this group of variables representing anticipated benefits from E-selling and E-purchasing respectively exerts a positive influence on adoption and intensity of use of E-commerce.

Barriers to technology use

A second category of variables refers to anticipated barriers to the adoption of E-commerce. From the literature, we identify several types of such hindrances. Firstly, high investment costs and unfavourable financial conditions (high price of technology, large investment requirements, liquidity constraints, etc.) are potential barriers to investment and innovation in general; we thus expect the same effect in case of investments to be made in order to use E-commerce.[6] Secondly, adoption of E-commerce may be hampered by human capital restrictions (shortage of highly-skilled workers, lack of ICT specialists, insufficient ICT-oriented training, etc.). The importance of this obstacle is stressed, among many others, by Yap et al. (1992) or Chapman et al. (2000); problems related to ICT-oriented training are analysed, for example, by Lange et al. (2000). Thirdly, adoption often is impeded by

6 For an empirical analysis of the impact of technology prices on adoption and intra-firm diffusion of CNC machine tools respectively see Stoneman and Karshenas (1993) and Battisti and Stoneman (2003b); for the role financial conditions play in decisions on innovation projects in general, see the survey of Goodacre and Tonks (1995).

information barriers, reflecting technological uncertainty (difficulties in assessing the performance of E-commerce-related technologies, unclear technical standards, etc.) as well as economic uncertainty (e.g. difficulty to predict the market potential for E-transactions or the competitors' behaviour in this field). The role played by these two types of uncertainty in case of E-commerce is highlighted in some statistics published by Eurostat (2003); for a theoretical treatment see Battisti and Stoneman (2003b). Fourthly, the adoption of E-commerce may be negatively affected by managerial barriers (e.g. insufficient awareness of managers of the potential gains of this type of transactions, deficient strategic orientation of ICT management, etc.). The importance of management involvement in strategic thinking with regard to the use of E-commerce is emphasised, for example, by Chang et al. (2003). Fifthly, sunk cost barriers may imply high substitution costs firms have to incur in order to increase the firm's use of E-commerce (e.g. insufficient compatibility with existing ICT infrastructure or a firm's organisation). The problem of compatibility between new and existing technology and organisational bottlenecks are stressed with special reference to E-commerce, for example, in OECD (2000) or Kaefer and Bendoly (2004).[7] To overcome restrictions with respect to human capital, information, managerial capabilities as well as sunk cost barriers, a firm has to bear adaptation costs which may be substantial; for the case of ICT, see Brynjolfsson and Hitt (2000), for a theoretical treatment of adjustment costs, see Stoneman (1990). Sixthly, concerns regarding security of electronic transactions (problems of data protection, security of online-payment, etc.) or the legal framework for E-business may be an important obstacle to inter-firm and intra-firm diffusion of E-commerce (see e.g. OECD, 2000)

Barriers to E-commerce, in principle, are expected to exert a negative influence on the use of E-transactions. Whereas in case of the adoption of E-commerce (inter-firm diffusion) there is no doubt in this respect, the matter is more complicated in case of intra-firm diffusion. On the one hand, such obstacles may prevent firms from making intensive use of this technology (negative sign), on the other hand, certain obstacles may become relevant or are perceived by the firms responding to our survey only beyond a certain level of E-transactions; therefore, the intensity of doing E-commerce may be positively correlated with some of the obstacles to intra-firm diffusion of E-commerce.

Application potential

We expect that high potentials of applying E-commerce contribute to early adoption of this type of trading. Application potentials, in the present context, primarily are related to the characteristics of the products/services at hand. For example, products which, in advance to purchase, need to be examined or tried (primarily consumer goods such as shoes, etc.), or which are developed specifically according to the buyers specifications and, in some instances, redesigned after first inspections and tests (investment goods in the first place), are hardly suited for E-commerce; for consumer goods, see Liang and Huang (1998). Similar

7 A more general treatment of this problem is found in Link and Kapur (1994).

arguments may apply for services requiring face-to-face contacts (e.g. concultancy or private banking). In case of multi-product firms, the potential for doing E-business may strongly differ among the various products. Therefore, the application potential is also an important factor determining the volume of E-transactions (intra-firm diffusion). We assume that such opportunities basically are firm-specific, although they are, to some extent, common to many firms of an industry.

Absorptive capacity, learning and experience

The firm's capability to absorb knowledge from external sources is another major determinant of innovation and technology use. There are mainly two aspects of a firm's absorptive capacity for new technologies. A first one is the firm's overall ability to assess technological opportunities that are relevant to its activity (in the present case, the assessment of opportunities to adopt or to intensify the use of E-commerce). This capability, according to (Cohen and Levinthal, 1989), depends primarily on the firm's endowment with human capital and its innovative activity.[8] Secondly, several aspects of learning and experience in the field of ICT are positively related to inter-firm and intra-firm diffusion of E-commerce (Mansfield, 1968). To mention are positive learning effects arising from the availability and use of a well-developed ICT infrastructure which, in addition to be a pre-requisite for E-transactions, mirror capabilities that are, as compared to the overall absorptive capacity, more specifically geared towards technologies relevant to E-commerce. Moreover, if ICT use is widely diffused within a firm, adoption and a high degree of intra-firm diffusion of E-commerce are more likely.

Learning effects may also arise from experience with a predecessor of a specific technology embodying constituent elements of later applied, more advanced vintages, as shown, for example, by Colombo and Mosconi (1995), McWilliams and Zilberman (1996) or Arvanitis and Hollenstein (2001); for E-commerce, see e.g. Windrum and de Berranger (2002). In the present case, experience with E-transactions based on other types of networks, in particular EDI, are expected to foster adoption and intensive use of Internet-based E-commerce. However, we should also consider an effect working in the opposite direction: switching from EDI to Internet-based E-commerce involves learning and sunk costs which may hamper firms to take up the new technology. Therefore, the net effect of learning from a predecessor technology on the adoption of a more up-to-date-technology cannot be determined a priori; the available evidence in case of E-commerce (Bertschek and Fryges, 2002) and E-selling (Hollenstein, 2004) points to a positive net effect.

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8 In accordance with this argument, Battisti and Stoneman (2003b) got a statistical significant positive effect of R&D activity in case of intra-firm diffusion of CNC machine tools. In contrast, Stoneman and Karshenas (1993) as well as Colombo and Mosconi (1995) did not find a positive relationship between (formal) R&D intensity and adoption.

Regarding the volume of E-transactions (intra-firm diffusion), the relationship between EDI-based and Internet-based E-commerce is more complex. The two types of trading may co-exist for quite a long time, with the transaction volume shared among the two technologies. This could be the case if experience with EDI, the older technology, significantly improved the firm's market position, with the effect that there is an incentive to expand E-based trading, this time using (the more up-to-date) Internet technique. On the other hand, it may turn out that a firm can realise scale-economies by concentrating on the old technology. According to Kaefer and Bendoly (2003), the second case is most likely if a "closed" system is used for frequent transactions with the same business partners (e.g. long-term partnerships between suppliers of pharmaceuticals and drugstores). In the first case, intra-firm diffusion of the two technologies are complementary (positive correlation between EDI-based and Internet-based trade); a negative sign has to be expected in the second case. Which effect is dominating, is an empirical question.

Information spillovers and network effects

The standard epidemic model of technology diffusion stresses (risk-reducing) information spillovers from users to non-users and from intensive users to less intensive users (see Geroski (2000) for a discussion of various brands of this approach). The epidemic model basically states that a firm's propensity to adopt a technology at a certain point in time (or to increase the intensity of its use) is positively influenced by the present (or lagged) level of diffusion in the economy as a whole, or by the proportion of adopters in the industry or sector to which the specific firm is affiliated. The size of epidemic effects also is influenced by Bayesian learning (Stoneman, 1981), which may lead to upward- or downward-revisions of profitability expectations in the course of the diffusion process; whereas in the first case, epidemic effects are strengthened, they are weakened in the second one.

The level of diffusion of E-commerce also represents positive network externalities. The larger the number of users of E-commerce, the higher the incentive for a firm to use this trade channel as well (Economides, 1996; specifically for E-commerce see e.g. Easton and Araujo, 2003). At the empirical level, however, it is hardly possible to disentangle the impact of network externalities on adoption from the standard epidemic effects.

The majority of empirical studies show that epidemic effects are powerful drivers of inter-firm diffusion of new technology; see, for example, Colombo and Mosconi (1995) or the synopsis of several studies presented in Canepa and Stoneman (2003); specifically for E-commerce see Bertschek and Fryges (2002) and Hollenstein (2004). The evidence is ambiguous in case of intra-firm diffusion: Battisti and Stoneman (2003b) did not find

evidence for epidemic effects, whereas highly positive effects are reported in Hollenstein (2004).[9]

Competition and market characteristics

The adoption and intra-firm diffusion of E-commerce may also be affected by product market conditions, particularly the competitive pressure firms 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 adoption and intra-firm diffusion of new technology (Majumdar and Venkataraman, 1993). Low entry barriers or other market characteristics implying intensive competition (e.g. rapid change of process technologies) may also drive firms to take up or intensify the use of E-commerce. In case of (small) open economies like Switzerland, international competition may be a particularly effective way of forcing firms to look for the most efficient way of producing, or to temporarily evade competitive pressure through product innovations. In case of E-commerce, Bertschek and Fryges (2002) indeed found positive competition effects due to the international exposure of firms; in contrast, no statistically significant impact was detected for E-selling by Hollenstein (2004).

Another factor to be considered is geographical distance of markets. There is some evidence that E-commerce reduces distance-related trade barriers (Freund and Weinhold, 2004). However, according to several studies, distance seems to remain an important impediment to E-commerce. Rosenbloom and Larsen (2003) and Choi and Geistfeld (2004), for example, stress the importance of cultural (and language) barriers to E-commerce. Moreover, there is some evidence that E-commerce, perhaps with the exception of some niche players, does not really extend geographical markets; it is primarily used to strengthen relations with (existing) customers in geographical markets where a firm already is present (Adelaar et al., 2004; Lewis and Cockrill, 2002). It is also shown (Steinfield et al., 1999), that successful strategies of E-selling to final consumers are mostly accompanied by local physical presence in order to improve trust and reduce consumer risk. E-commerce, in many cases, is part of a strategy to prevent global players from entering local markets. Considering these arguments, we expect that orientation towards local and national markets is positively correlated with the diffusion of E-selling.

Firm size and firm age

Firm size and firm age are two explanatory variables which are used in many studies of adoption behaviour. Firm size basically captures size-specific variables which are not explicitly modelled, such as advantages of larger firms with respect to the capacity to absorb

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9 Whether this difference reflects the fact that the two studies do not consider the same technology (CNC machine tools vs. ICT (and E-selling) is an open question. Besides, Battisti and Stoneman (2003b) point out, that the insignificance of epidemic effects may be due to negative "stock effects" balancing out positive "epidemic effects".

risks related to technology development, economies of scale, preferential access to capital markets, etc.. The positive impact of firm size on inter-firm diffusion is confirmed in many studies (see, for example, Mansfield (1968), Davies (1979); see also Karshenas and Stoneman (1995) for a summary of the evidence). In case of the adoption of E-commerce, positive size effects are reported, for example, by Bertschek and Fryges (2002). The relationship between firm size and technology use is more controversial in case of intra-firm diffusion. Mansfield (1963) finds that small firms, once they adopted a new technology, are at least as quick as their larger rivals to disseminate it inside the firm. Fuentelsaz et al. (2003) got the same result in their empirical analysis of intra-firm diffusion of "automated teller machines" (ATM). Battisti and Stoneman (2003b), however, find a positive size effect in case of intra-firm diffusion of CNC machine tools, whereas, according to Hollenstein (2004), the results differ by technology: no size effect in case of the intensity of Internet use, positive effect as far as the intra-firm diffusion of ICT as a whole (number of technology elements in use) is concerned.

Theoretical arguments with respect to the role of firm age are not conclusive. A positive impact on adoption in case of older firms reflecting specific (technological) experience might be balanced by negative effects for this category of firms due to lower adjustment costs in younger companies with a more up-to-date capital stock (Dunne, 1994). Thus, it is not surprising that the evidence regarding the impact of firm age is mixed. No significant influence is found in case of E-commerce (Bertschek and Fryges, 2002). At the empirical level, however, it is difficult to disentangle the effect of firm size and firm age since the two variables are positively correlated.

Corporate status and foreign ownership

Another variable used in many studies dealing with technology adoption is the corporate status of a firm. Some authors argue that a subsidiary may profit from information and knowledge flows within the group as well as the easier access to financial resources. Others stress the higher flexibility and autonomy in decision-making of independent firms. Which of these effects is stronger is an empirical question. The majority of studies did not find a significant effect of corporate status on the adoption of new technology (see Karshenas and Stoneman, 1995). As far as intra-firm diffusion is concerned, Battisti and Stoneman (2003b) found a positive impact of group membership.

In case of E-commerce, there are some additional considerations (Lucking-Reiley and Spulber, 2001). Since E-commerce might reduce transaction costs within a group, subsidiaries may be more likely to adopt this technology than independent firms. E-commerce also may favour centralisation of some business functions such as purchasing inputs; parent firms may thus be more prone to adopt or intensify the use of E-technology than subsidiaries and independent firms. However, Bertschek and Fryges (2002) did not find a statistically significant impact of group membership on the adoption of E-commerce.

Foreign ownership, to our knowledge, has not been considered as a variable to explain technology diffusion. There is some evidence that technology used by foreign-owned firms often has been sourced from their (foreign) parent firm (Erdilek and Wolf, 1997). With regard to ICT, this aspect may be particularly relevant in the Swiss case, since, compared to other countries, the ICT-producing sector is small (van Ark, 2001). We thus expect that foreign-owned firms are more likely to adopt and use intensively E-commerce.

Industry effects

Similar to firm size, industry dummies are used to capture industry-specific variables which are not explicitly modelled. For example, we expect that favourable market prospects exert a positive influence on investment and innovation as well as on the adoption and intra-firm diffusion of new technology. Stoneman and Karshenas (1993), for example, assuming that market prospects are common to many firms of an industry, used industry-specific indicators to capture the impact of market prospects. Since our database does not contain such information (let alone firm-specific demand variables), industry dummies, in our case, also capture demands effects.

In Section 4, we shall specify empirically the variables discussed so far, in order to estimate equations explaining the adoption and intra-firm diffusion of E-selling and E-purchasing respectively.

3. Database and pattern of diffusion

3.1 Data

The data underlying the econometric analysis was collected by means of two surveys conducted in 2002, the one dealing with innovation activity of Swiss firms, the other with the use of ICT.[10] The two surveys were based on the same sample of firms (with 5 or more employees) covering the manufacturing as well as the service sector. The sample is stratified by 28 industries and 3 industry-specific firm size classes, with full coverage of large firms. We got valid information from 2589 and 2968 firms respectively. A non-response analysis did not indicate any serious selectivity bias in both surveys. “Item” non-response is another problem of survey data. The usual procedure of dropping observations with incomplete data may produce biased estimates. Therefore we substituted imputed for missing values using the “multiple imputation” method proposed by Rubin (1987). Details of this method, as applied in the two surveys, and some tests for robustness are documented and discussed in Donzé (1998). Matching the two data sets yielded a sample containing information from 1655 companies (see Annex, Table A1).

10 The two questionnaires can be downloaded from www.kof.ethz.ch (Section “Industrieökonomik”).

3.2 Diffusion of E-commerce in the Swiss economy

Table 1a and 1b contain some information on the inter- and intra-firm diffusion of E-selling and E-purchasing in the Swiss economy by sector and firm size respectively.

The first two columns of Table 1a show that firms, irrespective of the sector considered, adopted E-purchasing much more often than E-selling. The level of diffusion is highest in high-tech manufacturing and knowledge-intensive services, in particular in case of E-purchasing; the sectorial differences with respect to E-selling are rather small. The columns 3 to 8 show the level of intra-firm diffusion of E-selling and E-purchasing respectively with firms having adopted the corresponding practice as reference group. It turns out that the transaction values are (still) low, that is 6% of purchases of intermediate inputs and 4% of sales in 2002 respectively. Although the transaction value of both types of E-commerce is strongly expanding (in particular E-selling though starting from a very low level), intra-firm diffusion will remain low for many years. Intra-firm diffusion of E-purchasing, in contrast to inter-firm diffusion, is higher in construction and services than in manufacturing. In case of E-selling, construction "falls back" and high-tech manufacturing gains some ground, with knowledge-intensive services ranking first. Combining inter-firm and intra-firm diffusion, we find that only 2.6% of the purchases of intermediate inputs and 0.6% of sales are traded by use of the Internet.

Table 1b shows the same information differentiated by firm size. Adoption of E-commerce is slightly positively related to firm size; however, this relationship almost exclusively shows up at the lower edge of the firm size ranking. Provided that E-purchasing and E-selling respectively have been adopted, a clearly different pattern emerges in case of intra-firm diffusion: very small and very large firms use E-purchasing to a much higher extent than medium-sized firms, whereas this category of firms takes the lead in case of E-selling, with very large companies coming last.

Tables 1a and 1b

4. Specification of the empirical model

4.1 Dependent variables: measures of inter-firm and intra-firm diffusion of E-commerce

The variables representing the adoption of E-selling (ESALE) and E-purchasing (EBUY) are specified as dummy variables. The response level 1 represents adoption up to 2002, zero stands for "no adoption" or "adoption planned for 2003" (see Table 2).

In case of intra-firm diffusion, we constructed two alternative variables based on the transaction values of E-purchasing and E-selling. Firstly, we used the logarithm of E-sales as a percentage of total sales (ESALESPCT) and that of E-purchases as a percentage of total purchases of intermediate inputs (EBUYPCT). We used the logarithmic form, since the

distribution of the percentage shares of both E-sales and E-purchases is very skew (many firms with low values) and characterised by some outliers. Secondly, we calculated a four level ordinal measure of E-sales (ESALESCAT4) and E-purchases (EBUYCAT4) respectively. The boundaries of the two types of E-commerce were set at different levels to account for differences in the distribution of the respective shares. The four classes are defined in a way that each ordinal category contains a similar number of observations (see Table 2 for the definition of the boundaries).

Table 2

4.2 Specification of the determinants of inter-firm and intra-firm diffusion of E-commerce

Anticipated benefits of E-commerce

E-selling: the first group of variables listed in Table 3 refers to the anticipated benefits of E-selling. The four variables DEVELOP, COSTSALE, PROCESS and COMPET are factor scores resulting from a principal component factor analysis of 12 items of benefits potentially accruing from E-selling. The quality of the factor solution, which is described in detail in the annex (see Table A2), is high, with the four extracted factors accounting for 66% of total variance. The variable DEVELOP refers to anticipated benefits from E-selling on the revenue side; it captures benefits resulting from developing new markets and launching new products. COSTSALE stands for expected cost reductions in general as well in marketing. The factor PROCESS depicts advantages to be gained from improving internal processes (speeding-up business processes, linking ICT elements) and optimising the interface to users (e.g. customer orientation). Finally, COMPET stands for anticipated benefits from keeping up to competitors and improving market appearance and image.

E-purchasing: The next two variables depicted in Table 3, represent anticipated benefits of E-purchasing. They also are factor scores resulting from a principal component factor analysis (8 items of potential benefits). The "quality" of the factor solution, which is described in detail in the annex (see Table A3), is quite satisfactory: the (first) two factors account for 53% of total variance. The variable SUPPCOST refers to anticipated benefits accruing from higher transparency of the input market, easier access to suppliers, lower purchasing costs as well as cost-savings resulting from improved internal processes (lower inventory requirements, more rapid processes). The variable SUPPLINK refers to backward and forward linking of ICT elements and a better market presence (image and appearance, keeping up with competitors).

These six variables capture all aspects of anticipated benefits of E-selling and E-buying identified in Section 2, with one exception, that is the potential of E-commerce as a means to increase the firm's market power by enforcing E-transactions to suppliers and/or customers (e.g. enforced participation in a "just-in-time" delivery system). To gain insight into this aspect, would require an analysis of market structure, which is not feasible with the type of

data at hand. All categories of anticipated benefits are expected to be positively related to the use of E-commerce.

Table 3

At this stage of the analysis, we have to point out that the cross-section nature of the investigation involves a problem which is intractable, given the data at hand. Since all dependent and explanatory variables refer to one year (2002 or, in some instances, 2001), the use of E-commerce in 2002 (and thus adoption having occurred in or before that period), in a strict interpretation, is explained by anticipations referring to a later period (2003 onwards). Therefore, we have to assume that anticipated benefits of adoption have been relatively stable over time. Since the diffusion of E-commerce is a very recent phenomenon, in particular in terms of transaction values (see Hollenstein et al., 2003), this assumption may be not as restrictive as it looks at first glance. Moreover, estimates with the dependent variables measured for the year 2003 (adoption and intra-firm diffusion of E-commerce as *planned* for 2003), thus implying some lag of the explanatory variables, yielded very similar results as those reported in this paper. Although this is no substitute for a time-series analysis, it provides some more confidence in the validity of the results.

Obstacles to E-selling

Obstacles to E-selling are captured by seven variables covering all categories of obstacles to the adoption of ICT we identified in Section 2. Using again factor analysis we condensed the information of 18 (potential) barriers to adoption into seven factors. The quality of the factor solution is high, with the seven factors accounting for 76% of total variance (see Table 3; for details see the annex, Table A4). TECHCOST captures high investment and current costs of the technology. Technological and economic uncertainty as well as information problems and knowledge deficiencies are represented by the variables TECH, ECON and KNOWHOW. Problems of compatibility with respect to existing ICT infrastructure, organisation and logistics are contained in ORG, whereas employee resistance and managerial deficiencies (low attention to the opportunities of E-transactions) are captured by RESIST. Finally, SECURITY represents the well-known security problems of E-transactions, uncertainties related to the legal framework as well as problems of data protection (among them also resistance to open up the firm's intranet to trading partners). As this list of variables shows, we capture several factors (uncertainty, information and adjustment costs, institutional factors) which are mostly ignored in empirical analysis of technology diffusion. Our survey yielded information on obstacles to E-commerce only for E-selling. Barriers to E-commerce are expected to exert a negative influence on the adoption and the intra-firm diffusion of E-commerce; in the latter case, however, one would be not surprised to find some positive signs as well (see Section 2).

Application potential

The application potential is captured by a measure of the extent to which the firm's product(s) are suited for E-selling, reflecting firms' assessments on a three-point Likert scale. Application potentials cannot be considered in case of E-purchasing because of missing information.

Absorptive capacity, learning and experience

The capacity to absorb external knowledge is expected to be positively related to early and intensive adoption. It is represented by several variables, with some difference between E-selling and E-purchasing. INNO, a dichotomous variable indicating whether a firm launched product or process innovations in the period 2000-2002, is used as an overall measure of absorptive capacity. Specifically oriented towards learning capacity in the field of ICT, we use the proportion of employees regularly using the Internet at the workplace (DIFFWITHIN). Since a well-developed ICT infrastructure provides a suitable environment for developing ICT skills, the number of ICT elements a firm uses (ICTINFRA; value range 1 to 9; see Table 3) is included as another proxy for absorptive capacity.

ICTINFRA is not only useful to develop the know-how necessary to use E-commerce but also a (technical) prerequisite for its adoption. Another aspect of ICT infrastructure we control for is downstream capacity of data transmission. It is captured by three dummies, representing specific techniques of Internet connection which differ with respect to the speed of data transmission (ISDN, DSL, HSPOTHER) with analogue connection as reference. These variables, for which we expect a positive sign, are only used to explain diffusion of E-purchasing, since it is primarily relevant for this type of E-commerce.

To explore the role of learning from a predecessor technology, we assume that experience with "Electronic Data Interchange" (EDI) is a suitable proxy in case of E-commerce. We note, however, that, in a cross-section framework, it is not easy to capture learning from previous use of technology. Given the data at hand, we could introduce not more than a one-years lag between the use of the "old" and the "new" technology. The proxy representing the predecessor technology (i.e. EDI) measures whether a firm already used this device for E-transactions in 2001 or earlier. We expect a positive sign although high switching (sunk) costs could work in the opposite direction.

The relationship between EDI-based and Internet-based transaction volumes can be complementary (a high volume of EDI-transactions in early years favours high volumes of Internet-based transactions later on without a decrease of the former). However, the use of EDI may be characterised by economies of scale, with the effect that it is more efficient to handle E-transactions with EDI even when the more up-to-date Internet-technology becomes available. We use the percentage share of E-sales (E-purchases) a firm realised in 2001 (one

year lag) as a proxy for this effect, which can be positive or negative (EDISELLPCT, EDIBUYPCT).

Information spillovers and network effects

Information spillovers ("epidemic effects") are represented by the level of diffusion of E-selling (EPIDSELL) and E-purchasing (EPIDBUY) respectively in the industry a firm is affiliated to. These two variables are used to explain inter-firm as well as intra-firm diffusion. They are measured for the year 2001; we thus assume that spillover effects occur with a lag of one year. The two variables also represent network effects.

Competition and market characteristics

The impact of competitive pressure on the adoption and intra-firm diffusion of E-selling is measured by several variables. Firstly, we capture market distance by using information on the firms' principal markets, with the variables NATIONAL and LOCAL, representing two types of "nearby markets", with "international markets" as reference group. We expect that national and local/regional markets are positively related to the diffusion of E-selling.

The intensity of competition is captured alternatively by the sales share of exports X (model A) or, in more detail, by four variables (model B): intensity of price and non-price competition on the product market, as assessed by the firms' themselves (IPC, INPC[11]), as well as two variables capturing more specific market characteristics: High values of CHANGE represent markets characterised by rapidly changing process technologies and short product cycles; high values of ENTRY stand for strongly contestable markets (low entry barriers, behaviour of competitors difficult to predict). These two variables are the outcome of a principal component factor analysis of 5 types of market characteristics; the "quality" of the factor solution, which is described in detail in the annex (Table A6), is satisfactory, with the two factors accounting for 59% of total variance (see Table 3). We expect that all measures of competitive pressure are positively related to adoption and diffusion of both types of E-commerce.

Firm size and firm age

Firm size (L) is represented by five dummy variables referring to 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. We expect positive size effects for adoption decisions, whereas the size dependence of intra-firm diffusion of E-commerce is indeterminate.

Firm age is measured by two dummy variables representing categories of firms that are 1 to 5 and 6 to 10 years old (AGE1-5, AGE6-10), with companies older than 10 years as reference

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11 The variable "intensity of non-price competition" is the outcome of a factor analysis based on 7 non-price market characteristics (see annex, Table A5).

group. Theory and existing evidence do not yield clear expectations with regard to the sign of the age variables.

Corporate status and foreign ownership

Usually, corporate status is captured by one variable, i.e. "group membership". As shown in Section 2, there may be different effects for parents and affiliates as compared to independent firms. Therefore, we specify two dummy variables taking parent companies as reference group, i.e. AFFILIATE and INDEPEND. Once more, the signs are an empirical question. With regard to foreign ownership (dummy variable FOREIGN), we expect, as set out in Section 2, a positive sign.

Industry effects

Finally, we use 15 industry dummies which are included to capture the impact of market prospects as well as other unspecified influences, in order to avoid an "omitted variable bias".

4.3. Estimation procedure

As shown in Table 2, we try to explain both inter-firm diffusion (adoption) of E-selling (E-purchasing) and intra-firm diffusion of these two types of E-commerce.

An appropriate procedure to estimate the *level* of inter-firm diffusion of E-selling (ESALE) and E-purchasing (EBUY) at a given point in time (i.e. the year 2002) is the probit model with the dependent variable taking the value 1 or zero.[12]

The explanation of intra-firm diffusion of E-commerce, that is the *intensity* of E-selling (ESALEPCT) and E-purchasing (EBUYPCT) respectively, is based on the subsample of firms that adopted E-commerce in the years up to 2002. In this case, the sample may not be a random selection. Firms being active in E-commerce may be of a specific size or affiliated to a specific industry, etc.. Therefore, estimation of an equation explaining intra-firm diffusion based on the subsample of adopters may be distorted (selectivity bias). In order to take account of this problem of specification in case of censored data, we applied the Heckman (1976) selection model.[13]. The selection equation contains variables controlling for different firm characteristics, which, if not taken into account, may cause a selection bias (firm size, ICT infrastructure, etc.; see columns 2 and 4 of Table 4 and 5 respectively for the details of the specification of the selection equation).

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12 Duration (hazard) models are the usual procedure to estimate empirical models of adoption. In this case, the time path of adoption is the dependent variable and important elements of the vector of explanatory variables are time-dependent (see, for example, Stoneman and Karshenas, 1993). In the present study, the adoption variable as well as the explanatory variables are time-invariant; therefore, the duration model is not an appropriate procedure.

13 Battisti and Stoneman (2003b) applied a similar approach, i.e. Heckman's two-stage procedure (see Heckman, 1979), to explain intra-firm diffusion of CNC machines.

Based on the Heckman approach, we estimated two alternative intensity equations, which differ in terms of the underlying dataset: model A is based on the respondents of the ICT survey, whereas model B only includes firms which also responded to the innovation survey. Based on the "matched sample" (model B), we could estimate a model, which is richer in terms of the number of explanatory variables than model A, whereas model A is based on a larger number of observations. A comparison of the estimates of the two model alternatives yields some insight into the robustness of the empirical results.

As the results presented in the next section show (Table 4 and 5), we could not find evidence of a selectivity bias neither for model A nor for model B: The likelihood-ratio test[14] for $\rho = 0$ is not significant in the estimates of the intensity of E-sales with prob>chi2 = 0.85 (model A) and prob>chi2 = 0.40 (model B). It also is not significant in case of E-purchases with prob>chi2 = 0.54 (model A) and prob>chi2 = 0.36 (model B).

In the absence of a selectivity bias, estimation of a model of intra-firm diffusion that only is based on the subsample of adopters is appropriate. Therefore, we complemented the Heckman approach by estimates of an ordered probit model based on the subsample of firms having adopted E-commerce in 2002. More specifically, we constructed, as dependent variables, four categories of firms in terms of the share of E-sales as a percentage of total sales (ESALECAT4) and the share of E-purchases as a percentage of total intermediate inputs (EBUYCAT4) respectively (for details see Table 3). Estimates of these ordered probit models may be seen as a kind of sensitivity test for the results we got by using the Heckman specification.

5. Empirical results

General remarks

The empirical results with respect to E-selling and E-purchasing are shown in Table 4 and 5 respectively. In column 1, we present probit estimates of the adoption equation (level of inter-firm diffusion). The columns 2 to 5 show the results of Heckman estimates (probit selection equation and OLS intensity equation for model A and B respectively). For these two model alternatives, the results of ordered probit estimates are shown in the last two columns. Variables missing in the selection equations (columns 2 and 4) which show up in the intensity equations (columns 3 and 5) represent the "exclusion restrictions" necessary to estimate a Heckman model.

The quality of the empirical estimates of the equations explaining the adoption of E-selling and E-purchasing respectively is good in terms of the overall model fit (pseudo R^2) and the influence of the various categories of explanatory variables (although not all of them are statistically significant). The results for the different models explaining intra-firm diffusion of

14 Parameter $\rho = \text{corr}(u_1,u_2)$ with u_1 = residual of the OLS regression (intensity equation) and u_2 = residual of the probit estimate of the selection equation.

the two types of E-commerce are satisfactory as well. There is no selectivity bias in the Heckman procedure both in model A and model B (i.e. the parameter ρ is statistically insignificant). As far as the common variables of model A and B are concerned (remember that the number of explanatory variables is higher in model B than in model A), the results are similar with one important exception, i.e. the impact of firm size; this result holds true both for E-selling and E-purchasing. The different size effect for Model A and B probably reflects some size-dependence of the variables included in model A but not in model B (e.g. INNO). Finally, estimates based on model A and B yield quite the same results irrespective of the estimation procedure used (i.e. Heckman vs. ordered probit); this holds true for both types of E-commerce. To sum up, the results are satisfactory in terms of model fit, significance of the various groups of explanatory variables as well as robustness across various estimation procedures and model alternatives.

In the following we discuss in parallel the results we got for the various groups of variables in the adoption model as well as in the intensity equation based on the Heckman and ordered probit procedure. We concentrate on the general pattern of explanation, i.e. we only discuss results of specific equations (model A vs. B or Heckman vs. ordered probit) in case of important differences.

Table 4 and 5

Anticipated benefits of E-selling

The influence of anticipated benefits only is considered in case of intra-firm diffusion (no data available for non-adopters). Anticipated benefits related to new market opportunities (DEVELOP) and efficiency gains (PROCESS) are the most important ones (see Table 4), whereas the reduction of (marketing) costs (COSTSALE) and the competitive environment (COMPET) seem to be irrelevant. Since the development of E-selling still is in an early stage (see Table 1a), firms do not feel pressed to keep up with their competitors in terms of the intensity of use of E-selling; this result is consistent with the estimates we get for epidemic effects and most variables related to competition on the product market (see below).

Anticipated benefits of E-purchasing

Among the anticipated benefits of E-purchasing, those focussed on higher transparency and lower purchasing cost as well as efficiency gains due to improved internal processes (SUPPCOST) are the most important ones (see Table 5). Besides, in contrast to E-selling, the competitive environment plays a certain role as well (SUPPLINK). This result might be due to the higher level of inter-firm diffusion in case of E-purchasing as compared to E-selling.

Obstacles to E-selling

Some of the obstacles proposed in this paper turn out to be important variables explaining adoption and intra-firm diffusion of E-selling (there is no comparable information for E-

purchasing. However, the relevant obstacles are not the same for inter-firm and intra-firm diffusion (see Table 4). Security concerns (SECURITY) as well as compatibility and organisational problems (ORG) prevent firms from adopting E-selling.[15], whereas intra-firm diffusion is (quite strongly) impeded by economic uncertainties (variable ECON: low propensity of customers to buy via the Internet, difficulties of firms to assess the commercial benefits to be captured by E-selling). In contrast to adoption (negative sign), the variable SECURITY is positively related in case of intra-firm diffusion; it seems that firms become aware of security problems only after E-selling has reached a certain (minimum) level.

Application potential

We find that firms supplying products, which are potentially well-suited to be sold via the Internet, are characterised both by a higher propensity to adopt E-selling and a higher intensity of using this sales channel (see Table 4). The impact of this variable (POTENTIAL), not surprisingly, is quite large. We would expect that this factor also is important in case of E-purchasing; however, since our database does not contain such information, we are not able to test this hypothesis.

Absorptive capacity, learning and experience

As expected, absorptive capacity, measured by innovative activity (INNO) and/or the proportion of a firm's employees using the Internet (DIFFWITHIN), exerts a positive impact on the adoption of both types of E-commerce (see Table 4 and 5). Innovative firms and/or firms where ICT is widely used are early adopters, reflecting an advantage in evaluating potential benefits of E-commerce and particularly high capabilities of implementing this trading channel. Absorptive capacity also favours intra-firm diffusion of E-selling, whereas we do not find such an effect in case of E-purchasing. This difference seems plausible in view of the higher complexity of setting up a platform suited to sell via the Internet as compared to buying electronically.

Besides, in accordance with our expectations, we find that a well-developed ICT infrastructure (ICTINFRA) favours the adoption of both types of E-commerce; but we did not get such an effect in case of intra-firm diffusion. High values of ICTINFRA reflect, to some extent, high absorptive capacities (regular use of a broad set of ICT), but this variable also represents technological prerequisites for adopting E-commerce. Moreover, we hypothesised that the availability of facilities allowing high speed data transmission, another element of a firm's ICT infrastructure, favours adoption and intra-firm diffusion of E-purchasing (but not E-selling); this hypothesis is clearly confirmed, in the first place as far as devices allowing particularly high data transmission are concerned (DLS, HSPOTHER; see Table 5).

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15 There is no sensible interpretation of the significant positive sing of information and skill deficiencies (variable KNOWHOW) on the adoption of E-selling.

The hypothesis stating that experience with EDI, a predecessor technology of Internet-based E-commerce, favours the adoption of the more up-to-date technology is not confirmed; as set out in Section 3, the impact of experience with EDI (positive sign) may be balanced by switching costs (negative sign). We got some evidence of EDI influencing the intra-firm E-selling; but this result is not very robust. The same holds for the findings with respect to the question whether EDI-based and Internet-based transaction values are complementary or substitutive (positive vs. negative sign of EDISELLPCT and EDIBUYPCT); there is some evidence that a complementary relationship prevails in case of E-purchasing.

Information spillovers and network effects

We expect that epidemic effects reflecting information spillovers and, in our specification, network effects drive the adoption of E-commerce. This hypothesis is confirmed in case of E-selling (EPIDSELL), only to a weak extent (see the selection equation of the Heckman approach) with regard to the adoption of E-purchasing (EPIDBUY). In the latter case, network effects may be attenuated, since the level of inter-firm diffusion reached in the year 2002 (i.e. 44%, see Table 1a) may be already higher than some "critical" threshold beyond which the marginal value of network effects is decreasing. There is no evidence for epidemic effects in case of intra-firm diffusion of E-commerce.

Competition and market characteristics

E-selling, as expected, is focussed on national and local rather than on international markets (positive sign of NATIONAL and LOCAL). This is true in case of adoption, whereas the evidence in case of intra-firm diffusion is rather weak.

The hypothesis of competition on the product market being an important driver of the adoption of E-commerce is strongly confirmed in case of E-purchasing (statistical significance of three out of four measures of competition). We do not get similar results in case of E-selling, what is in accordance with the findings with respect to COMPET, an element of anticipated benefits from E-selling (see above). As far as intra-firm diffusion is concerned, we do not find a significant impact of the intensity of price and non-price competition as well as of the degree of export orientation (IPC, INPC, X) on the two types of E-commerce. Intra-firm diffusion of E-selling is higher for firms that are active in markets characterised by rapidly changing process technologies and short product cycles (variable CHANGE); Internet-based selling strategies seem to be profitable rather in markets where heterogeneous products are traded than in those characterised by homogeneous goods/services (as one may suspect).[16] Intra-firm diffusion of E-purchasing is particularly strong, if firms are competing in highly contestable product markets (ENTRY).

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16 EDI and SAP may be more advantageous than the Internet technology in case of standardised transactions between (permanent) contract partners.

Firm size and firm age

We hypothesised that large firms are more likely to adopt E-commerce, whereas, based on previous studies, there is no clear size expectation with respect to intra-firm diffusion. The proposition referring to adoption is confirmed in case of E-purchasing (negative sign implying positive size effects up to a firm size of 200 employees), with only weak evidence for E-selling.[17] In contrast, we find that intra-firm diffusion of E-commerce is higher in small than in large firms (positive sign of the size parameter). This relationship is very robust in case of E-purchasing (up to a firm size of 50 or 100 employees). For E-selling, the same is true in estimations of model A, in case of model B only if the size/age-relationship is taken into account; the size effect is strongest for firms with up to about 100 employees. We conclude that large firms adopt E-commerce more frequently than small ones, but if the technology is adopted, smaller firms (up to a certain size) use E-selling and E-purchasing more intensively than large companies.

As stated in Section 3, there are no clear sign expectations with regard to firm age. We only find significant advantages of specific firm age categories in case of intra-firm diffusion of E-selling (advantages of young firms). Since firm size and firm age are correlated, there is no clear-cut interpretation of this result.

Corporate status and foreign ownership

Corporate status (INDEPEND, AFFILIATE) has no impact on the adoption of the two types of E-commerce. The same holds true for the intra-firm diffusion of E-selling, whereas subsidiaries and other associated firms (AFFILIATE) seem to use E-purchasing less intensively than parent companies. This result may indicate that E-purchasing activities of a group of firms are rather centralised, as hypothesised in Section 3.

The proposition of foreign ownership increasing the probability to adopt E-commerce is not confirmed; we even find a negative sign in case of E-purchasing. Intra-firm diffusion of E-selling, in accordance with our expectations, is higher in foreign-owned than in domestic firms; however, there is no such effect in case of E-purchasing. Taken as a whole, the results with respect to foreign ownership are not very convincing.

6. Summary and conclusions

General remarks

Large-scale econometric investigations of the factors determining the diffusion of E-commerce are still rare. In contrast to previous studies, we estimate separate models for E-selling and E-purchasing. In addition, we go beyond the (usual) analysis of the adoption of E-commerce by also looking for the factors determining the intensity of use of the two types of

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17 Alternative estimates, where some size-dependent explanatory variables (e.g. innovative activity) were dropped, pointed to positive size effects in case of E-selling as well.

E-transactions (intra-firm diffusion). In this way, we fill a serious gap, since not much research has been devoted to this second type of technology diffusion. Besides, we are able to assess the still open question whether inter-firm diffusion and intra-firm diffusion of technology are driven by the same or by different factors. The "wide" understanding of the concept of anticipated profitability as a driver of diffusion is another characteristic of our analysis This approach enables us to take account of several dimensions of net profitability of technology adoption and intra-firm diffusion neglected in most previous studies, such as technological and economic uncertainty, adjustment costs, etc.. The paper is empirically-oriented; we do not strive for further developing the theory of technology adoption. The conceptual framework of the analysis is based on the "rank" and the "epidemic" model of technology diffusion.

The data have been collected by means of two surveys carried out in the Swiss economy in autumn 2002 (ICT survey, innovation survey). In this study, we used two samples, the first one stems from the ICT survey (2968 observations), the second one is the result of matching the two datasets (1655 observations).

We built econometric models explaining adoption (probit estimates) and intra-firm diffusion of the two types of E-commerce (Heckman and ordered probit estimates). The vector of explanatory variables is larger than in previous studies on E-commerce. More specifically, we took into account several factors capturing anticipated benefits of and obstacles to adoption/intra-firm diffusion of E-commerce, the potential for applying these technologies, absorptive capacity, ICT infrastructure, experience and technological complementarities, epidemic effects, competition and a number of other market characteristics as well as firm size and firm characteristics such as age, corporate status and foreign/domestic ownership. Practically all groups of factors determining adoption/intra-firm diffusion of E-selling/E-purchasing, though not every single variable, yielded (statistically significant) results. Moreover, the findings turned out to be quite robust across alternative models and estimation procedures.

The analysis confirms, in the first place, the importance of "rank effects" in explaining inter-firm and intra-firm diffusion of both types of E-commerce. "Epidemic effects" only are relevant in case of inter-firm diffusion (adoption). The dominance of rank effects is in line with previous studies dealing with the adoption of E-commerce and ICT in general (Bertschek and Fryges, 2002; Hollenstein, 2004) as well as the uptake of "advanced manufacturing technologies" (AMT).[18] Moreover, the result of "rank effects" dominating the explanation of intra-firm diffusion confirms the findings of some previous studies dealing with this type of diffusion (see, for example, Battisti and Stoneman, 2003b).[19]

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18 See Canepa and Stoneman (2003) for a synopsis of studies dealing with AMT.

19 A somewhat larger impact of epidemic effects on intra-firm diffusion is found by Fuentelsaz et al. (2003), who investigated the diffusion of "automated teller machines" (ATM).

E-selling vs. E-purchasing

The results strongly recommend to differentiate between E-selling and E-purchasing. An overall analysis of the diffusion of E-commerce yields limited insights, since the determinants of the two types of E-commerce differ quite considerably.

a) Inter-firm diffusion (adoption): The relevant differences between E-selling and E-purchasing are related to epidemic effects, the competitive environment as well as the firms' size, age and foreign/domestic ownership. To mention are, in the first place, the following results: Epidemic effects are stronger in case of E-selling (reflecting higher benefits from information spillovers than in case of E-purchasing, which is much more widely used than E-selling). A highly competitive environment drives the adoption of E-purchasing, but has no impact on the adoption of E-selling: high intensity of price and non-price competition as well as low entry barriers only foster the adoption of E-purchasing. The classical result of a positive relationship between firm size and adoption only is confirmed in case of E-purchasing.

b) Intra-firm diffusion: The most important differences between E-selling and E-purchasing refer to the relevance of specific dimensions of anticipated benefits, absorptive capacity and the competitive environment as well as age, corporate status and foreign/domestic ownership of the firm. The following results might be particularly important: intra firm diffusion of E-selling is driven by anticipated benefits accruing from new market opportunities and efficiency gains, whereas intra-firm diffusion of E-purchasing is positively influenced by cost-related factors and the necessity to keep up with competitors. Absorptive capacity only favours intra-firm diffusion of E-selling (what is plausible in view of the higher complexity of E-selling). A competitive environment also influences quite differently the intra-firm diffusion of the two types of E-commerce: whereas competition characterised by rapid change of process technologies and/or short product cycles fosters a more intensive use of E-selling, it are low entry barriers and difficulties of predicting the behaviour of competitors that favour intra-firm diffusion of E-purchasing. Young firms are more keen to intensify E-selling than older ones, whereas we do not find age effects in case of intra-firm diffusion of E-purchasing.

Inter-firm vs. intra-firm diffusion

Starting with the seminal work of Mansfield (1963) there is an ongoing discussion whether intra-firm diffusion and inter-firm diffusion (adoption) of technologies are driven by the same factors. Whereas Mansfield proposed that the drivers are the same for inter- and intra-firm diffusion, Battisti and Stoneman (2003a) claimed that the opposite is true. Some recent studies show that firm size, a very important driver of diffusion, plays a different role in determining inter- and intra-firm diffusion: positive size effect in case of adoption vs. neutral or negative impact of firm size on intra-firm diffusion (see Fuentelsaz et al., 2003 and

Hollenstein, 2004)[20]. The present analysis strongly contradicts the "Mansfield hypothesis": the differences between the two types of diffusion refer not only to firm size but to quite a large number of other explanatory variables. It is thus strongly recommended to consider adoption and intra-firm diffusion as two different topics of investigation.

a) E-selling: In case of this type of E-commerce, there are quite a few differences between the variables explaining adoption and intra-firm diffusion. These refer to specific obstacles to diffusion, absorptive capacity, epidemic effects, experience, competitive environment as well as size and foreign/domestic ownership of the firm. To mention are, in particular, the following results: inter-firm and intra-firm diffusion are impeded by quite different barriers; security concerns and costs of reorganisation are the factors preventing firms from adopting E-selling, whereas intra-firm diffusion is mainly inhibited by economic uncertainties (insufficient readiness of customers to buy via the Internet). Technological competence is an important precondition of the adoption of E-selling, but it is not a significant driver of intra-firm diffusion; in the latter case, business-related criteria become more important. Epidemic effects only are relevant in case of adoption. Experience with predecessor technologies like EDI only has a (positive) impact on intra-firm diffusion. In accordance with some previous work, small firms use E-selling more intensively than large ones, whereas no size effects are found in case of adoption.

b) E-purchasing: The most important differences between adoption and intra-firm diffusion can be found with respect to a firm's ICT infrastructure, absorptive capacity, epidemic effects, competitive environment as well as size, age, corporate status and foreign/domestic ownership of the firm. To mention are, in particular, the following results: Absorptive capacity and epidemic effects only are relevant in case of adoption. The role of firm size is in line with previous evidence: the level of adoption is higher among large firms than among small ones, but once adopted, large companies are less intensive users than small ones.

Shortcomings of the analysis

Firstly, and most importantly, the cross-section nature of our investigation is not able to uncover the dynamics of the diffusion process; therefore, an extension towards an analysis of longitudinal data (panel estimations), provided suitable data become available, would be highly appreciated in general, and as a means to evaluate the basic results of the present study. Secondly, the paper yields strong evidence for rank effects and, to a lesser extent, also for epidemic effects, with their relative weight depending on the type of diffusion and of E-commerce; however, our approach does not allow a (formal) test of the relative importance of

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20 However, Battisti and Stoneman (2003b) found positive size effects in case of intra-firm diffusion of CNC machine tools.

rank, epidemic, stock and order effects, a procedure highly recommended, for example, by Karshenas and Stoneman (1995). Finally, the evidence presented in this paper refers to the specific circumstances of one country what limits the generalisation of the results.

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Table 1a: Diffusion of (Internet-based) E-commerce in the Swiss economy by sector

	Proportion of firms engaged in E-commerce (%)		E-sales and E-purchases as a proportion of total sales and intermediate inputs respectively (%)					
	Based on all firms		Sector means based on firms with:					
Industry / Sector	E-purchases	E-sales	E-purchases			E-sales		
	2002	2002	2001	2002	2003 (plans)	2001	2002	2003 (plans)
Manufacturing, energy	48	20	3.1	4.4	5.4	2.3	3.5	5.0
- High-tech	52	20	3.1	4.4	5.4	2.7	4.6	6.6
- Low-tech	46	19	3.0	4.3	5.5	2.0	2.6	3.7
Construction	41	14	6.7	9.1	11.7	1.7	2.8	4.6
Services	43	16	5.9	7.3	8.4	2.9	4.9	6.8
- Knowledge-intensive	54	18	6.3	7.7	8.8	2.9	5.9	7.7
- Other	40	15	5.1	6.4	7.4	2.9	4.5	6.4
Total	44	16	4.7	6.0	7.1	2.4	4.0	5.8

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). E-selling is weighted by sales, E-purchasing by intermediate inputs.

High-tech: chemicals/pharmaceuticals, rubber/plastics, electrical and non-electrical machinery, vehicles, electronics/instruments. Low-tech: other manufacturing industries and energy/water. Knowledge-intensive services: banking/insurance, IT-/R&D-services, business services. Other: other than knowledge-intensive service industries.

Source: Hollenstein et al. (2003)

Table 1b: Diffusion of (Internet-based) E-commerce in the Swiss economy by firm size

	Proportion of firms engaged in E-commerce (%)		E-sales and E-purchases as a proportion of total sales and intermediate inputs respectively (%)					
	Based on all firms		Size class means based on firms with:					
Number of Employees	E-Pur-chases	E-Sales	E-Purchases			E-Sales		
	2002	2002	2001	2002	2003 (plans)	2001	2002	2003 (plans)
5-9	27	6	6.9	8.0	9.1	1.3	2.7	4.1
10-49	49	19	4.9	6.3	7.4	2.8	4.5	6.6
50-99	52	23	3.4	4.7	5.5	2.3	3.4	4.8
100-199	56	23	2.5	3.2	3.9	3.2	5.4	7.7
200-499	55	21	2.4	4.0	5.6	2.0	3.4	4.9
500+	56	27	5.1	8.3	10.7	0.9	1.2	1.9
Total	44	16	4.7	6.0	7.1	2.4	4.0	5.8

See the footnotes to Table 1a.

Source: Hollenstein et al. (2003)

Table 2: Specification of variables representing E-commerce

Variable	Definition
E-selling	
Adoption of E-selling	
ESALE	E-selling adopted up to 2002: *yes / no (1, 0)*
If E-selling has been a adopted up to 2002:	
ESALEPCT	Share of E-sales as a *percentage* of total sales (logarithm)
ESALECAT4	*Four* ordinal *categories* based on the percentage share of E-sales: more than 5% (value 4), more than 1% up to 5% (value 3), 0.5% up to 1% (value 2), less than 0.5% but more than 0% (value 1)
E-purchasing	
Adoption of E-purchasing	
EBUY	E-purchasing adopted up to 2002: *yes / no (1, 0)*
If E-purchasing has been adopted up to 2002:	
EBUYPCT	Share of E-purchases as a *percentage* of total intermediate inputs (logarithm)
EBUYCAT4	*Four* ordinal *categories* based on the percentage share of E-purchases: more than 5% (value 4), more than 1% up to 5% (value 3), more than 0.3% up to 1% (value 2), 0.3% or less but more than 0% (value 1)

E-selling and E-purchasing throughout refer to *Internet-based* transactions; electronic commerce realised via EDI or networks other than Internet is not considered.

Table 3: Specification of the explanatory variables
Model A: All variables except those marked by *
Model B: All variables with one exception (variable X)

Variable	Description	Sign Selling	Sign Buying
Anticipated benefits of E-commerce			
E-selling *(Scores of a principal component factor analysis of the importance of 12 types of anticipated benefits from adopting E-selling, as assessed by the firms on a 3-point scale; see Table A2)* Variance accounted for by the first four factors: 65.6%			
DEVELOP	Opportunities of developing new markets/launching new products	+	///
COSTSALE	Cost reduction in general, particularly in selling (marketing, after-sales services)	+	///
PROCESS	Speeding up internal business processes, improving internal ICT networks, improving interfaces with customers	+	///
COMPET	Keeping up to competitors, improving the firm's image and presence on the market	+	///
E-purchasing *(Scores of a principal component factor analysis of the importance of 8 types of anticipated benefits from adopting E-purchasing, as assessed by the firms on a 3-point scale; see Table A3)* Variance accounted for by the first two factors: 52.5%			
SUPPCOST	Better transparency of the input market, easier access to suppliers, lower purchasing costs, lower inventory requirements, improving business processes	///	+
SUPPLINK	Improving internal ICT networks, keeping up to competitors, improving the firm's image and presence on the market	///	+
Obstacles to E-selling *(Scores of a principal component factor analysis of the importance of 19 obstacles to the adoption of E-selling, as assessed by the firms on a 3-point scale; see Table A4)* Variance accounted for by the first seven factors: 75.7%			
TECHCOST	High investment and current costs of technology	- / (+)	///
SECURITY	Problems concerning data protection, security of payment or the legal framework	- / (+)	///
ORG	Insufficient compatibility (ICT infrastructure, organisation), problems/costs of reorganisation, unwanted opening of the firm (i.e. its intranet) to other companies	- / (+)	///
RESIST	Resistance to the new technology within the firm, insufficient attention for E-commerce on the management side	- / (+)	///
TECH	Technological uncertainties, technical standards not clear	- / (+)	///
KNOWHOW	Insufficient information with respect to technology or market opportunities, lack of qualified personnel	- / (+)	///
ECON	Economic uncertainties: customers not ready to use E-commerce, economic benefits too uncertain	- / (+)	///
Application potential			
POTENTIAL	Extent to which the firm's product(s) are suited for *E-selling* (as assessed by the firms on a 3-point scale)	+	///

Absorptive capacity			
INNO *	Introduction of new products and/or processes in the period 2000-2002 (yes/no)	+	+
DIFFWITHIN	Diffusion of the Internet within the firm in 2002: *5 categories* based on the percentage of employees using the Internet: 81-100% (value 5), 61-80% (value 4), 41-60% (value 3), 21-40% (value 2), 1-20% (value 1)	+	+
Technological prerequisites of adoption			
ICTINFRA	*ICT infrastructure in 2001*: Number of ICT elements in use (value range 1 to 9: digital assistant, laptop, PC/workstation, E-mail, Internet, EDI, LAN/WLAN, intranet, extranet)	+	+
	Speed of data transmission via the Internet: 3 dummy variables (*with analogue modem as reference group*):		
ISDN	Use of ISDN	///	+
DSL	Use of xDSL (ADSL, HDSL, SDSL, etc.)	///	+
HSPOTHER	TV cable, satellite, other highspeed fixed or wireless connection (if more than one type of connection is used, that with the highest speed of transmission is assigned)	///	+
Experience, complementarity			
EDI	EDI adopted in the years up to 2001 (yes/no)	(+)	(+)
EDISELLPCT	Share of *sales* realised via EDI (or networks other than Internet) as a percentage of total sales in 2001	?	///
EDIBUYPCT	Share of *purchases* realised via EDI (or networks other than Internet) as a percentage of total intermediate inputs in 2001	///	?
Epidemic effects			
EPIDSELL	Percentage share of firms active in E-selling in the industry the company is affiliated to in the year 2001	+	///
EPIDBUY	Percentage share of firms active in E-purchasing in the industry the company is affiliated to in the year 2001	///	+
Market distance			
	Two dummy variables representing the principal market for the firm's products (reference group: international markets)		
NATIONAL *	National markets beyond a distance of 50 km	+	///
LOCAL *	Regional/local markets (within a distance of 50 km at most)	+	///
Competition, market characteristics			
X	Sales share of exports of at least 3% (dummy variable)	+	+
IPC *	Intensity of price competition on the product market (as assessed by the firms on a 5-point scale)	+	+
INPC *	Intensity of non-price competition on the product market *(Score of a principal component factor analysis of the importance of 7 instruments of non-price competition, as assessed by the firms on a 5-point scale ; see Table A5).* Variance accounted for by the first seven factors: 47.0%	+	+
	Market characteristics *(Scores of a principal component factor analysis of six characteristics of the product market, as assessed by the firms on a 3-point scale; see Table A6)* Variance accounted for by the first six factors: 58.8		
CHANGE *	Rapid change of process technologies, short product cycles	+	+
ENTRY *	Low entry barriers, actions of competitors difficult to predict	+	+

Firm size and firm age			
L	5 dummy variables based on the number of employees: L5-19, L20-49, L50-99, L100-199, L200-499 (reference group: firms with 500 and more employees)	+ / ?	+ / ?
AGE *	2 dummy variables based on the age of the firm: AGE1-5, AGE6-10 (reference group: firms older than 10 years)	?	?
Corporate status			
	Two dummy variables (reference group: parent company)		
INDEPEND *	Independent firm	?	?
AFFILIATE *	Affiliate company (subsidiary, sister and associated firm)	?	?
Foreign owned			
FOREIGN *	Firm owned by foreign company 2002 (yes/no)	+	+
Industry affiliation			
15 dummies: food, textiles/clothing, wood/paper/printing, chemicals/pharmaceuticals/plastics, 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).			

In case of different expectations with respect to the direction of the influence of a specific variable for adoption and intra-firm diffusion respectively, the first-mentioned sign refers to adoption, the second one to intra-firm diffusion. Signs in parenthesis indicate that expectations are not clear-cut (e.g. relevance of countervailing effects).

E-selling and E-purchasing throughout refer to Internet-based transactions, that is, electronic commerce realised via EDI or networks other than Internet is not considered.

Table 4: The adoption of E-selling: cross-section estimates for 2002

Explanatory variable	**ESALE** Probit	**ESALEPCT** OLS with Heckman selection				**ESALECAT4** Ordered probit	
		Model A		Model B		Model A	Model B
		Selection	Intensity	Selection	Intensity	Intensity	Intensity
Benefits							
DEVELOP	///	///	.272* (.15)	///	.326* (.19)	.150 (.10)	.273* (.14)
COSTSALE	///	///	.184 (.16)	///	.197 (.18)	.144 (.11)	.186 (.15)
PROCESS	///	///	.456*** (.15)	///	.504** (.20)	.370*** (.11)	.483*** (.17)
COMPET	///	///	-.075 (.15)	///	-.075 (.18)	-.031 (.11)	-.070 (.15)
Obstacles							
TECHCOST	.016 (.08)	///	-.177 (.14)	///	-.081 (.18)	-.161 (.10)	-.122 (.14)
SECURITY	-.160** (.08)	///	.314** (.16)	///	.278 (.19)	.209** (.10)	.188 (.16)
ORG	-.155* (.08)	///	-.251 (.15)	///	-.254 (.18)	-.135 (.11)	-.219 (.15)
RESIST	.103 (.08)	///	.166 (.15)	///	.195 (.19)	.132 (.10)	.186 (.15)
TECH	.086 (.08)	///	.170 (.14)	///	.137 (.17)	.101 (.10)	.126 (.13)
KNOWHOW	.141* (.08)	///	.034 (.15)	///	.018 (.17)	.039 (.10)	.092 (.14)
ECON	-.062 (.08)	///	-.549*** (.15)	///	-.526*** (.20)	-.443*** (.11)	-.509*** (.16)
Application potential							
POTENTIAL	.363*** (.05)	.360*** (.03)	.313** (.14)	.337*** (.04)	.460*** (.35)	.210*** (.07)	.338*** (.10)
Absorptive Capacity							
INNO	.207** (.09)	///	///	///	.573*** (.20)	///	.454*** (.16)
DIFFWITHIN	.006*** (.00)	///	.006** (.00)	///	.005 (.00)	.002 (.00)	.003 (.00)
Technological Prerequisites							
ICTINFRA	.111*** (.03)	.098*** (.02)	.046 (.06)	.090*** (.02)	-.040 (.07)	.022 (.04)	-.058 (.06)
Experience, Complementarity							
EDI	.121 (.09)	///	.215 (.18)	///	.505** (.22)	.107 (.12)	.407** (.17)
EDISELLPCT	.001 (.00)	///	.004 (.00)	///	-.004 (.00)	.004 (.00)	-.002 (.00)

Epidemic effects							
EPIDSELL	.037*** (.01)	.037*** (.01)	-.004 (.03)	.041*** (.01)	-.010 (.04)	-.003 (.02)	-.025 (.03)
Market distance							
NATIONAL	.220** (.11)	///	///	///	.472* (.27)	///	.267 (.23)
LOCAL	.174* (.10)	///	///	///	.314 (.26)	///	.178 (.23)
Competition							
X	///	///	.219 (.17)	///	///	.157 (.12)	///
IPC	-.021 (.04)	///	///	///	-.073 (.09)	///	-.055 (.08)
INPC	.066 (.04)	///	///	///	-.142 (.10)	///	-.122 (.08)
CHANGE	.025 (.04)	///	///	///	.187** (.09)	///	.150** (.08)
ENTRY	-.019 (.04)	///	///	///	.072 (.09)	///	.042 (.07)
Firm size							
L5-19	-.250 (.19)	-.279*** (.11)	.903*** (.30)	-.125 (.13)	.228 (.39)	.530** (.21)	.128 (.30)
L20-49	-.161 (.18)	-.102 (.10)	.917*** (.27)	.061 (.12)	-.022 (.37)	.605*** (.19)	-.025 (.30)
L50-99	-.205 (.18)	-.192* (.10)	.651** (.28)	-.048 (.13)	-.226 (.38)	.479** (.19)	-.100 (.30)
L100-199	-.257 (.17)	-.182* (.10)	.500 (.31)	-.104 (.13)	-.234 (.41)	.265 (.21)	-.217 (.32)
L200-499	-.126 (.18)	-.228** (.11)	.583* (.31)	-.021 (.14)	-.770** (.37)	.409* (.21)	-.553* (.29)
Firm age							
AGE1-5	-.132 (.23)	///	///	///	.899** (.45)	///	1.25*** (.48)
AGE6-10	-.260 (.20)	///	///	///	.909* (.48)	///	.748** (.36)
Corporate status							
INDEPEND	.155 (.13)	///	///	///	-.020 (.26)	///	.050 (.20)
AFFILIATE	.081 (.13)	///	///	///	-.242 (.34)	///	-.104 (.26)
Foreign-owned							
FOREIGN	-.105 (.12)	///	///	///	.724** (.34)	///	.586** (.26)
Industry dummies	Yes (2)	Yes (3)	Yes (2)	Yes (5)	Yes (4)	Yes (2)	Yes (5)

Statistics							
N	1425	2912	2912	2670	2670	560	318
Censored	///	///	2352	///	2352	///	///
Uncensored	///	///	560	///	318	///	///
Wald χ^2	///	157.6***		267.9***		///	///
ρ	///	.036		.139		///	///
Chi^2	///	.04		.71			
Prob > chi^2	///	.85		.40		///	///
LR test	206.8***	///	///	///	///	132.6***	136.4***
Pseudo R^2	.130	///	///	///	///	.082	.167

Each column includes the estimated parameters with robust 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 for 15 industry dummies are omitted; we only show the number of statistically significant industry dummies.

Parameter $\rho = corr(u_1,u_2)$ with u_1 = residual of the OLS regression (intensity equation) and u_2 = residual of the probit estimate of the selection equation.

Table 5: The adoption of E-purchasing: cross-section estimates for 2002

Explanatory variable	**EBUY** Probit	**EBUYPCT** OLS with Heckman selection				**EBUYCAT4** Ordered probit	
		Model A		Model B		Model A	Model B
		Selection	Intensity	Selection	Intensity	Intensity	Intensity
Benefits							
SUPPCOST	///	///	.513*** (.10)	///	.485*** (.12)	.336*** (.06)	.322*** (.08)
SUPPLINK	///	///	.214** (.10)	///	.146 (.13)	.110* (.06)	.037 (.08)
Technological prerequisites							
ICTINFRA	.087*** (.03)	.147*** (.01)	.062 (.06)	.142*** (.02)	.024 (.05)	.029 (.03)	.010 (.04)
ISDN	.256* (.13)	///	.146 (.19)	///	.247 (.23)	.126 (.11)	.165 (.15)
DSL	.685*** (.13)	///	.362** (.16)	///	.460** (.20)	.251*** (.10)	.280** (.12)
HSPOTHER	.568*** (.14)	///	.268 (.17)	///	.403* (.21)	.160 (.10)	.212 (.14)
Absorptive capacity							
INNO	.289*** (.08)	///	///	///	-.085 (.14)	///	-.030 (.09)
DIFFWITHIN	.003* (.00)	///	.002 (.00)	///	.004 (.00)	.001 (.00)	.003 (.00)
Experience, complementarity							
EDI	.102 (.09)	///	.186 (.12)	///	.086 (.15)	.116 (.08)	.074 (.10)
EDIBUYPCT	.003 (.00)	///	.002 (.00)	///	.007** (.00)	.002 (.00)	.005** (.00)
Epidemic effects							
EPIDBUY	.004 (.01)	.019*** (.01)	-.005 (.02)	.013* (.01)	.005 (.02)	.002 (.01)	.010 (.01)
Competition							
X	///	///	-.013 (.11)	///	///	.013 (.07)	///
IPC	.069* (.04)	///	///	///	-.052 (.06)	///	-.045 (.04)
INPC	.078* (.04)	///	///	///	.039 (.07)	///	.017 (.05)
CHANGE	.008 (.04)	///	///	///	.049 (.07)	///	.034 (.05)
ENTRY	.085** (.04)	///	///	///	.144** (.06)	///	.093** (.04)

Firm size							
L5-19	-.444**	-.065	.643***	-.016	.529*	.444***	.360*
	(.20)	(.09)	(.22)	(.10)	(.29)	(.14)	(.20)
L20-49	-.425**	-.089	.589***	.005	.397	.380***	.221
	(.20)	(.08)	(.21)	(.10)	(.28)	(.13)	(.19)
L50-99	-.560***	-.186**	.359*	-.094	.329	.279**	.223
	(.20)	(.08)	(.21)	(.10)	(.27)	(.13)	(.18)
L100-199	-.408**	-.069	.009	.031	.124	.017	.083
	(.19)	(.08)	(.20)	(.10)	(.25)	(.13)	(.17)
L200-499	-.250	-.014	.299	.066	.199	.217	.138
	(.20)	(.09)	(.21)	(.11)	(.26)	(.13)	(.18)
Firm age							
AGE1-5	.282	///	///	///	-.022	///	-.037
	(.26)				(.38)		(.24)
AGE6-10	.453**	///	///	///	-.124	///	-.044
	(.19)				(.26)		(.19)
Corporate status							
INDEPEND	.132	///	///	///	.051	///	.067
	(12)				(.18)		(.12)
AFFILIATE	-.110	///	///	///	-.443**	///	-.225*
	(13)				(.20)		(.14)
Foreign-owned							
FOREIGN	-.248**	///	///	///	.193	///	.084
	(12)				(.19)		(.13)
Industry Dummies	Yes (1)	Yes (2)	Yes (3)	Yes (2)	Yes (5)	Yes (2)	Yes (3)
Statistics							
N	1410	2810	2810	2264	2264	1343	797
Censored	///	///	1467	///	1467	///	///
Uncensored	///	///	1343	///	797	///	///
Wald χ^2	///	124.5***		109.1***		///	///
ρ	///	.158		.096		///	///
Chi^2	///	.38		.83			
Prob > chi^2	///	.54		.36		///	///
LR test	219.0***	///	///	///	///	112.9***	86.4***
Pseudo R^2	.127	///	///	///	///	.031	.042

Each column includes the estimated parameters with robust 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 for 15 industry dummies are omitted; we only show the number of statistically significant industry dummies.

Parameter $\rho = corr(u_1,u_2)$ with u_1 = residual of the OLS regression (intensity equation) and u_2 = residual of the probit estimate of the selection equation.

Table A1:Structure of the sample and the final data sets

Industry / sector	ICT survey 2002				Matched dataset	
	Sample		Respondents		Respondents	
	N	%	N	%	N	%
Manufacturing/energy	2693	45.0	1468	49.5	879	53.1
Food	221	3.7	123	4.1	68	4.1
Textiles	66	1.1	38	1.3	27	1.6
Clothing	35	0.6	15	0.5	7	0.4
Wood	93	1.6	52	1.8	32	1.9
Paper	59	1.0	45	1.5	28	1.7
Printing	191	3.2	103	3.5	54	3.3
Chemicals/pharmaceuticals	186	3.1	104	3.5	56	3.4
Plastics/Rubber	105	1.8	60	2.0	45	2.7
Non-metallic minerals	96	1.6	48	1.6	30	1.8
Basic metals	57	1.0	35	1.2	18	1.1
Metal products	381	6.4	213	7.2	125	7.6
Machinery	488	8.2	266	9.0	158	9.5
Electrical machinery	126	2.1	73	2.5	44	2.7
Electronic/instruments	266	4.4	138	4.7	82	5.0
Watchmaking	107	1.8	35	1.2	22	1.3
Vehicles	51	0.9	22	0.7	13	0.8
Other industries	99	1.7	50	1.7	35	2.1
Energy/water	66	1.1	48	1.6	35	2.1
Construction	*576*	*9.6*	*279*	*9.4*	*133*	*8.0*
Services	*2710*	*45.3*	*1221*	*41.1*	*643*	*38.9*
Wholesale	592	9.9	272	9.2	140	8.6
Retail sale	476	8.0	179	6.0	108	6.5
Hotels/restaurants	374	6.3	138	4.7	62	3.8
Transport/telecomm.	384	6.4	191	6.4	98	5.9
Banking/insurance	271	4.5	142	4.8	76	4.6
Real estate	30	0.5	14	0.5	9	0.5
IT/R&D services	96	1.6	48	1.6	30	1.8
Business services	434	7.3	219	7.4	108	6.5
Personal services	52	0.9	17	0.6	12	0.7
Total	*5979*	*100.0*	*2968*	*100*	*1655*	*100*

The matched dataset covers the observations common to the ICT survey 2002 and the Innovation Survey conducted in the same year.

Table A2: Factor analysis of *anticipated benefits* from adopting *E-selling*
(based on assessments of the respondents on a 3-point scale)

Type of benefit	Rotated factor pattern (Varimax)			
	Factor loadings			
	1	2	3	4
Developing new market segments	.75			
Developing new regional markets	.74			
Launching new products	.71			
Reducing costs in general		.81		
Reducing costs of after-sales services		.79		
Reducing costs of marketing	.44	.70		
Speeding up business processes			.70	
Linking the elements of the internal ICT infrastructure			.68	
Improving customer orientation			.67	
Improving product quality and variety	.47		.54	
Keeping up to competitors				.86
Improving the firm's image and market presence				.84
Number of observations				824
Kaiser's overall measure of sampling adequacy (MSA)				.810
Variance accounted for by the first four factors				.656
Root mean square off-diagonal residuals (RMSE)				.076
Variance accounted for by each factor	4.05	1.55	1.27	1.01
Final communality estimate (total)				7.88

Characterisation of the four factors:
(1) Developing new markets (DEVELOP)
(2) Reducing (selling) costs (COSTSALE)
(3) Improving business processes and interfaces (PROCESS)
(4) Preserving the market position (COMPET)

The table shows only factor loadings of 0.4 and higher.

Table A3: Factor analysis of anticipated *benefits* from adopting *E-purchasing*
(based on assessments of the respondents on a 3-point scale)

Type of benefit	Factor pattern (Varimax) Factor loadings 1	2
Lower costs of buying transactions	.75	
Lower purchase prices	.75	
Lower inventory requirements	.62	
Speeding up business processes	.60	
Better knowledge of supply, easier access to suppliers	.45	
Keeping up to competitors		.86
Improving the firm's image and market presence		.85
Linking the elements of internal ICT infrastructure		.64
Number of observations		1724
Kaiser's overall measure of sampling adequacy (MSA)		.745
Variance accounted for by the first two factors		.525
Root mean square off-diagonal residuals (RMSE)		.104
Variance accounted for by each factor	2.18	2.02
Final communality estimate (total)		4.20

Characterisation of the two factors:
(1) Lowering purchasing costs, improving business processes/interfaces (SUPPCOST)
(2) Improving presence on the supplier market, linking ICT elements (SUPPLINK)

The table shows only factor loadings of 0.4 and higher.

Table A4: Factor analysis of *obstacles* to the adoption of *E-selling*
(based on assessments of the respondents on a 3-point scale)

Type of obstacle	Rotated factor pattern (Varimax)						
	Factor loadings						
	1	2	3	4	5	6	7
Investment volume to large	.86						
Software too expensive	.84						
Current costs too high	.80						
Problems of data protection		.86					
Security problems concerning payments		.82					
Uncertainty with respect to the legal framework		.70					
Logistical problems			.80				
Insufficient compatibility with ICT infrastructure			.69				
Large organisational adjustment requirements			.60				
Opening up the firm to others is not wanted		.46	.48				
Resistance to new technology within the firm				.85			
Insufficient attention of the management				.83			
Technological uncertainties					.82		
Technical standards not clear enough					.82		
Insufficient information (technology, market)						.78	
Lack of qualified personnel						.73	
Customers not ready to use E-commerce							.87
Uncertainty concerning economic benefits							.70
Number of observations							2968
Kaiser's measure of sampling adequacy (MSA)							.903
Variance accounted for by the first seven factors							.757
Root mean square off-diagonal residuals (RMSE)							.050
Variance accounted for by each factor	2.63	2.48	2.09	1.76	1.75	1.48	1.41
Final communality estimate (total)							13.6

Characterisation of the seven factors:
(1) Investment and current costs (TECHCOST)
(2) Security and secrecy problems (SECURITY)
(3) Organisational and compatibility problems (ORG)
(4) Resistance of workers and management (RESIST)
(5) Technological uncertainty (TECH)
(6) Lack of know-how and information (KNOWHOW)
(7) Economic uncertainty (ECON)

The table shows only factor loadings of 0.4 and higher.

Table A5: Factor analysis of the intensity of use of various instruments of *non-price competition* on the product market
(based on assessments of the respondents on a 5-point scale)

Instrument of non-price competition	**Factor pattern** Factor loadings
Product quality	.725
Product differentiation	.716
Product variety	.702
Frequency of launching new products	.702
Technological advantage	.666
Flexible reaction to customer wishes ("customisation")	.656
After-sales services	.623
Number of observations	1655
Kaiser's overall measure of sampling adequacy (MSA)	.803
Variance accounted for by the first factor	.470
Root mean square off-diagonal residuals (RMSE)	.133
Variance accounted for by the extracted factor	3.29
Final communality estimate (total)	3.29

Characterisation of the factor:
Intensity of non-price competition (INPC)

Table A6: Factor analysis of various *characteristics of the product market*
(based on assessments of the respondents on a 5-point scale)

Characteristics	**Rotated factor pattern** (Varimax) Factor loadings 1	2
Rapid change of process technologies	.866	
Short product cycles	.856	
Actions of competitors difficult to predicts		.779
Low entry barriers		.690
Demand changes difficult to predict		.558
Number of observations		1655
Kaiser's overall measure of sampling adequacy (MSA)		.578
Variance accounted for by the first two factors		.588
Root mean square off-diagonal residuals (RMSE)		.163
Variance accounted for by each factor	1.52	1.41
Final communality estimate (total)		2.94

Characterisation of the two factors:
(1) Rapid change of products and processes (CHANGE)
(2) Strong threat by (new) competitors (ENTRY)

The table shows only factor loadings of 0.4 and higher.