B2B or not to Be: On the Adoption of Business-to-Business E-Commerce in German Companies

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Abstract

The fast technological development of the internet as well as the declining prices for the use of this technology have led to an increased diffusion of the internet during the last few years. One important application of the internet technology for firms is the so-called internet commerce or electronic commerce. E-commerce is supposed to reduce transaction costs, to increase transparency and to make the course of business more efficient. Although broadly discussed in the media and glorified as the most promising medium of ordering, buying and selling products and services, e-commerce is in fact still at the beginning of a diffusion process where e-commerce between companies (business-to-business or B2B) finds up to now a broader application than e-commerce between companies and consumers (B2C). This paper concentrates on B2B e-commerce and addresses the question of what determines the early adoption of B2B e-commerce depending for instance on the firm size, the age of the firm, the industry, and the competitive situation firms are faced with. A data set consisting of about 3,000 enterprises of the German manufacturing industry and the German service sector in the year 2000 is used for the empirical analysis. The firms were asked whether they use B2B e-commerce broadly, sporadically or not at all. Therefore, an ordered probit model takes account of the categorical nature of the dependent variable in order to analyse the intensity of firms' utilisation of B2B.

1 Introduction

The fast technological development of the internet as well as the declining prices for the use of this technology have led to an increased diffusion of the internet during the last few years. As a recent study of the ZEW revealed, in the year 2000 about 85% of all German companies had internet access. One important application of the internet technology for firms is the so-called internet commerce or electronic commerce. E-commerce is expected to reduce transaction costs, to increase market transparency and to make the course of business more efficient. Although broadly discussed in the media and glorified as the most promising medium of ordering, buying and selling products and services, e-commerce is in fact still at the beginning of a diffusion process where e-commerce between companies (business-to-business or B2B) finds up to now a broader application than e-commerce between companies and consumers (B2C). The (OECD, 1999, p.12) for example claims that the B2B segment currently accounts for at least 80% of total e-commerce activity.

Up to now there is not much empirical literature on B2B e-commerce. This study attempts to explain the adoption of B2B e-commerce by several hypotheses proposed mainly in the literature on technology diffusion or adoption. Based on a data set containing about 3,000 firms of the German manufacturing and the service industries in the year 2000 these hypotheses are analysed empirically. Since the dependent variable on the use of B2B takes three categories ("no use", "sporadic use" and broad use"), an ordered probit model is chosen as the analytical framework.

We find that the most important effect on the use of B2B is the bandwagon effect, implying that firms are more likely to use this new internet application if others within the same industry likewise do it. Moreover, the firm size as well as the international competition measured by the firms' export ratio have positive and significant impacts. The general openness towards new ICTs positively affects the adoption of B2B. On the other hand, the age of the firm as well as the affiliation to a group of firms turn out to be insignificant.

The paper is organized as follows: section two contains the main hypotheses on the adoption of a new technology derived from the literature. A description of the data set is given in section three. Section four presents the empirical results and section five concludes.

2 Background Discussion

Models of technology diffusion generally attempt to explain the share of firms adopting a new technology over time (so-called "epidemic models"). In this kind of mod-

els, usually a sigmoid form of the diffusion path is assumed "indicating that a few firms adopt the invention early, that the adoption process accelerates as other firms learn about the invention and that the process decelerates when most firms have already adopted" (Tirole, 1988, p. 402). For recent and comprehensive surveys on models of diffusion see for instance Geroski (2000) and Karshenas and Stoneman (1995). For recent empirical analyses see for instance Baptista (2000) and Gruber and Verboven (2001). Baptista (2000) investigates the diffusion of computer numerically controlled (CNC) machine tools and microprocessors using data of about 1,000 firms covering six three-digit industrial sectors and ten regions of Great Britain for the time period 1968 to 1980. Using a hazard rate model, he finds that especially at the early stage of diffusion regional learning effects play an important role in the sense that they reduce the time of adoption. Gruber and Verboven (2001) analyse the diffusion of mobile telecommunications services in the 15 member states of the European Union for the period 1984 to 1997 using a logistic model of diffusion. They find that the transition from analogue to digital technology as well as the deregulation of the telecommunication market have positive effects on the diffusion of mobile telecommunications. This kind of analysis, however, requires a comprehensive data base with observations starting at the phase of invention of the new technology.

As recent surveys have shown, e-commerce is still at the beginning of a diffusion process, see for example Gault, OECD, mediamit. Therefore, the question arises which firms are the early adopters of B2B e-commerce and which characteristics determine their decision to adopt B2B? Since this question can best be answered by analysing individual adoption decisions, the commonly used approach found in the literature is the probit model. In this case, a firm's individual decision whether to adopt or not B2B e-commerce can be studied in dependence of diverse firm-specific and industry-specific characteristics. David (1969) and Davies (1979) provide early examples (see also Thirtle and Ruttan, 1994, p. 108–113 for an overview). David (1975) investigates the use of mechanical reapers. A farmer will adopt this technology if a farm's saving in wages due to the reduction in labor costs exceeds the costs of the reaper which in turn heavily depends on firm size.

A firm's decision whether to use B2B e-commerce or not depends on the (expected) net return involved with the use of B2B. This return is influenced by several factors. Mazon and Pereira (2000) assume a production cost reducing effect by engaging in e-commerce (B2C or B2B). According to the recent work by Lucking-Reiley and Spulber (2001, p. 56) B2B e-commerce might have positive impacts on the productivity of an enterprise via four channels: by efficiencies from automation of transactions, by economic advantages of new market intermediaries, by the consolidation of demand and supply through organized exchange, and by changes in the extent of vertical integration of companies. The aspect of transaction costs is also studied by Garicano and Kaplan (2000).

On the other hand, the implementation of e-commerce involves several costs. First of all, the technical requirements have to be fulfilled. Moreover, the working process has to be reorganized in order to be able to use the new technology efficiently. Depending on whether or not a company produces and distributes physical products, the logistics information system as well as the inventory system have to be adapted accordingly in order to guarantee a more flexible distribution of products. Since direct cost reducing or return increasing effects of using a new technology cannot be identified in a straightforward way in the data, one might set up different hypotheses concerning the factors that are likely to influence the trade-off between costs and benefits of B2B.

Firm size

First of all, the introduction of B2B is likely to depend on the firm size in the sense that adoption is more probable the larger the firm, since, as stated by Davies (1979, p.20), "... the costs and risks of early adoption are more easily borne by large firms." Interpreting B2B as a process innovation allows to embed the analysis of B2B into the vast literature on innovative activity. In this case one is back to the familiar Schumpeterian link between innovation and firm size, see for example Cohen and Levin (1989) for a not very recent but comprehensive study on the determinants of innovative activity.

Age of the firm

According to Christensen and Rosenbloom (1995) new firms are more flexible and thus more likely to adopt a new technology than old firms. The gametheoretic model by Mazon and Pereira (2000) shows that it may depend on the cost reduction whether a new firm has more incentives to engage in e-commerce than an old firm or vice versa (their study is not restricted to the case of B2B e-commerce). Their model distinguishes between a new and an old firm where the new firm does not have a physical shop but only a virtual shop whereas the old firm has a physical shop and decides whether to set up a virtual shop, too.

Bandwagon hypothesis

An often cited hypothesis in the context of technology adoption is the so-called bandwagon hypothesis saying that "... the probability of adoption by a firm at a given date is positively related to the proportion of firms in the industry who have already adopted" (see for instance Jensen 1982, p.183). As Jensen states this assumption corresponds to Schumpeter's imitation hypothesis implying that firms follow others in adopting a new technology if those make successful experiences with this technology.

Availability of qualified personnel

Wozniak (1987) analyses the impact of human capital, measured by education and experience, and of information on the early adoption of a cattle feed additive monensin sodium and finds positive and significant effects of these components using cross-sectional data of about 300 farmers in Iowa. In his model he assumes that a farmer maximizes his expected utility of income and he or she adopts the new technology if the expected utility arising from the adoption of the new technology is larger or equal than the expected utility in the case of sticking to the old technology. One hypothesis derived from this model is that uncertainty and fixed costs of adoption are hampering factors of the adoption of an innovation. However, education and experience might counteract these factors such that " ... more educated and experienced farmers are more likely to be early adopters than other farmers" (Wozniak, 1982, p.104). The empirical results confirm this hypothesis.

Competitive pressure

Adoption and intensity of using a new technology might depend on the presence of international involvement. On the one hand, it seems plausible that companies being engaged in foreign activities such as exports are more likely to use B2B e-commerce since in this case the reduction of transaction costs is even higher than with respect to transactions within the same country. This argument especially holds in the context of digital products. On the other hand, international competition forces domestic companies to produce as efficiently as possible in order to stay competitive. As Bertschek (1995) shows, international competition in the sense of imports and inward foreign direct investment enhances the firms' probability to engage in product or process innovation. These hypotheses are supported by the empirical results based on a panel data set of roughly 1200 firms observed for five time periods. Since B2B e-commerce can be interpreted as a process innovation, the same arguments may hold in this context.

IT-intensity

The decision to engage in B2B e-commerce might depend on the firms' general openness towards new information and communication technologies. This openness can be reflected by the share of ICT staff as a share of all employees or by the proportion of the firm's workforce predominantly working at a PC or a workstation. Moreover, companies that use Electronic Data Interchange (EDI) as a precursor of B2B e-commerce are possibly more likely to adopt this kind of technology than others.

3 The Data

The data result from a CATI-survey (computer-aided telephone interview) based on a stratified random sample of about 11,000 German firms. The sample was stratified by sector[1], size class and region, i.e. West and East Germany. Only firms with at least five employees were included in the survey, thereof 50% in the manufacturing industry and 50% in the service sector. The source data set originates from Creditreform, the largest German credit rating agency.[2] The survey was conducted in the year 2000. About 4,400 enterprises participated in the survey, which corresponds to a response rate of approximately 43%. After performing consistency checks and due to item non-response concerning the variables that were included in the empirical model (see below), a sample of 3,026 firms forms the basis for the empirical analysis.

To operationalize the firms' involvement in electronic commerce, firms have been asked whether they use the internet for distributing products and/or services to other companies and, in a further question, whether they use the internet for ordering products and/or services from other companies. According to OECD (1999, p. 28) the definitions of e-commerce vary between "including all financial and commercial transactions that take place electronically, including electronic data interchange (EDI), electronic funds transfers (EFT), and all credit/debit card activity", and limiting e-commerce "to retail sales to consumers for which the transaction and payment take place on open networks like the internet". The definition of e-commerce in this study is a rather narrow one, only including the ordering and selling of products and services on the internet. Only those firms selling their products/services via the internet to other firms are considered in the empirical analysis. As already mentioned, B2B e-commerce is still the most widespread application of e-commerce. Moreover, selling products/services reflects an active way of implementing (B2B) e-commerce. Firms have to build up an electronic trade platform on their server, they have to reorganize their logistic and workplaces in order to guarantee a smooth handling of orders they receive via the internet and in order to fully explore probable efficiency gains of their e-commerce activities.[3] In contrast, using the internet only passively in the sense of buying products and/or services does not necessarily require substantial adjustments of business activities although these firms might reduce their search and transaction costs and possibly profit from a larger market transparency.

[1] The sectors that were included in the study are listed in detail in the appendix.

[2] As Germany's largest credit rating agency, Creditreform has the most comprehensive database of German firms at its disposal. Since 1989, Creditreform has provided data on German and Austrian firms to the Centre for European Economic Research (ZEW) for research purposes.

[3] The relation between the introduction of new ICT-technologies and the need of organizational changes in the firm in order to achieve positive productivity effects is examined for instance by Bresnahan, Brynjolfsson and Hitt (2000) and also discussed by Brynjolfsson and Hitt (2000).

Table 1: B2B e-commerce by industry sectors

	B2B e-commerce		
Industry	no use	sporadic	broad
Consumer goods industry	60.17	33.47	6.36
Chemical industry	47.70	44.25	8.05
Other basis goods industry	53.16	35.44	11.39
Mechanical engineering	51.24	36.04	12.72
Electrical engineering	40.00	44.39	15.61
Medical, precision and optical instruments	52.56	37.21	10.23
Motor manufacturing industry	51.11	36.44	12.44
Wholesale trade	52.94	33.99	13.07
Retail trade	64.40	26.18	9.42
Transport and post	53.65	33.85	12.50
Financial intermediation	49.09	40.45	10.45
Computer and telecommunications	32.84	40.67	26.49
Technical services	54.26	32.29	13.45
Other business services	58.33	31.37	10.29

In order to take account of different intensities of using B2B e-commerce, the questionnaire distinguishes three stages of diffusion: no use, sporadic use and broad use of B2B e-commerce.[4] 13% of all firms included in the empirical analysis say that they make broad use of B2B e-commerce, additional 36% of the firms indicate sporadic use. 51% don't use the internet for selling their products/services.[5][6] Table 1 summarizes firms' B2B e-commerce activities in the sectors included in the survey.

As expected, the most intensive use of B2B e-commerce can be observed within the sector of computer and telecommunication services. Second comes electrical engineering. These two sectors also form the major part of the ICT-sector, defined by OECD (2000).[7] Moreover the manufacturing of precision instruments and of industrial process control equipment as well as specialized ICT-traders belong to the ICT-sector. Regarding the ICT-sector, almost 22% of these firms broadly carry out B2B transactions. Only 37% of the firms of the ICT-sector say that they don't

[4]The distinction between these three stages of diffusion is based on the firms' own judgement

[5]5% of the firms even don't have access to the internet.

[6]If the reduced sample used in this paper is compared to the whole sample of all firms that participated in the survey, no systematic difference in the use of B2B e-commerce is found.

[7]A detailed description of the ICT-sector is given in the appendix.

Table 2: B2B e-commerce by size classes

	B2B e-commerce		
Employees	no use	sporadic	broad
5-9	63.41	26.83	9.76
10-19	54.64	31.97	13.39
20-49	56.61	31.84	11.55
50-99	51.79	33.16	15.05
100-199	51.41	35.74	12.85
200-499	45.38	41.51	13.12
≥ 500	43.18	44.55	12.27

use the internet for B2B e-commerce. The diffusion of B2B e-commerce is rather low in the consumer goods industry and in the retail trade sector. In the empirical analysis of section four, the share of firms utilizing the internet for B2B e-commerce, computed for each two digit NACE-code[8], will be used to measure the bandwagon effect described in section two.

Differentiating by size classes, table 2 shows that B2B e-commerce is more common for bigger firms. More than the half of all companies that have at least 200 employees sell their products/services via the internet, either sporadically or broadly. In contrast, only 36% of firms with less than 10 employees indicate a use of the internet for selling their products/services.

4 Econometric implementation and empirical results

Due to the fact that the dependent variable of B2B adoption or the use of B2B is observed in terms of three categories "no use", "sporadic use" and "broad use", an ordered probit is used as an analytical framework (see for instance Davidson and MacKinnon, p. 529–530 for details). The intensity of the use of B2B e-commerce

[8]For the NACE-codes 64 "post and telecommunications" and 74 "other business activities" the bandwagon effect will be calculated separately for each three digit NACE-code group.

y_i^* is assumed to linearly depend on a set of variables X_i:

$$y_i^* = X_i\beta + u_i, \quad u_i \sim N(0,1) \tag{1}$$

with normally and identically distributed errors u_i with mean zero and variance normalized to be one. The latent variable y_i^* might represent for instance the intensity of using B2B e-commerce or the share of sales achieved by using B2B e-commerce. However, only a discrete variable y_i is observed taking on three possible values

$$y_i = \begin{cases} 0 & \text{if } y_i^* < \gamma_1 \\ 1 & \text{if } \gamma_1 \leq y_i^* \leq \gamma_2 \\ 2 & \text{if } \gamma_2 \leq y_i^* \quad , \end{cases} \tag{2}$$

where γ_1 and γ_2 are two threshold parameters that have to be estimated together with the parameter vector β. In the present example, y_i takes the value 0 if no B2B e-commerce is applied, the value 1 if a firm uses B2B sporadically and finally the value 2 if B2B is broadly used. The only restriction that has to be imposed on γ_1, γ_2 is that γ_2 has to be larger than γ_1. The matrix X_i contains the explanatory variables as derived from the theoretical literature in section two: Firm age, firm size measured by the logarithm of the number of employees, firm's export quota, the share of firms involved in B2B e-commerce activities in the related industry sector of a firm. Furthermore, the share of employees having a university degree or a degree from a technical college is considered as a measure of the firms' human capital. Firms' openness towards new ICT applications is represented by the number of ICT specialists as a share of all employees and by the proportion of the firm's workforce predominately working at a PC or a workstation. Finally, industry dummy variables as well as a dummy for a firm being part of a group of companies are included in the estimation. The reasoning behind the latter variable is that firms belonging to a group of companies might be less flexible than others and are thus less likely to engage in B2B.

The estimation results are given in tables 7 and 8. The tables report marginal effects of the exogenous variables in X_i on the probability that a firm i chooses the category "no use of B2B e-commerce" and on the probability that the category "broad use" is chosen by firm i respectively. Note that marginal effects are not equal to the estimated parameter vector $\hat{\beta}$ from equation 1. However, the marginal effects can easily be calculated according to

$$\frac{\partial Prob[y=0]}{\partial x} = -\phi(\gamma_1 - \beta' x)\beta \tag{3}$$

and

$$\frac{\partial Prob[y=2]}{\partial x} = \phi(\gamma_2 - \beta' x)\beta \,, \tag{4}$$

with $\phi(\cdot)$ as the density function of the normal distribution.

As reported in table 7, the most significant effect on the probability of a firm's decision to use B2B is given by the bandwagon effect. Not only that the bandwagon effect is highly significant at the 1%-level, the estimated marginal effects are quite high as well. If in the industry of firm i the share of firms using the internet to sell products/services increases by 1%, this will lower the probability of firm i to opt for the alternative "no use of B2B e-commerce" by 0.8%. On the other hand, the probability that firm i will use B2B e-commerce "broadly" will rise by 0.4%. Obviously, in an industry where B2B e-commerce is already widely used, an individual firm tends to imitate its rivals and is likely to introduce B2B e-commerce as well. If it is true that B2B e-commerce reduces transaction costs as stated for example by Garicano and Kaplan (2000)[9], the individual firm will have a strong incentive to use B2B e-commerce in order not to fall behind its competitors. Observing its rivals, e.g. by carrying out benchmark analysis, a firm might be convinced of engaging in e-business itself if a high number of its rivals has introduced B2B e-commerce in the near past.

However, one restriction of this interpretation has to be made: The data of our survey only tell us, whether firm i makes use of B2B e-commerce or not. We don't have any information about when firm i started its e-commerce activities. Insofar, our sample probably includes firms that began with sales of products/services via the internet just before the day of the interview as well as those firms which belong to the very early adopters of this new technology. For the latter type of firms, the interpretation of the bandwagon effect does not hold. Early adopters are by definition not confronted with a more or less working bandwagon effect because they are first movers. The decision of early adopters could not be explain by a bandwagon effect.[10] Quite the reverse, the early adopters themselves constitute the elements of the bandwagon effect for subsequent users of B2B e-commerce. These two sides of the same coin cannot be distinguished within our data set. However, we can argue that, except for the very first users, a relative high proportion of firms that use the internet for selling products/services is also linked with a relative high proportion in the past. Therefore, our definition of the bandwagon effect can represent, at least approximately, the influence of the proportion of firms in the industry who have already adopted B2B e-commerce in the near past - except, as already mentioned, for the very first user of e-commerce. This argumentation, of

[9]The possible reduction of transaction costs as a consequence of the introduction of B2B e-commerce could, however, not be verified by the data of our survey.

[10]At least not, if we define the bandwagon effect on the level of the firm's own industry. However, it is still possible that the decision of a firm is influenced by technological developments in other sectors. Such a kind of an intersectoral spillover effect may be plausible between the software industry and technical services, but also an influence of the software industry on high technical manufacturing sectors seems possible.

course, would not be true, if all firms in an industry decided on the introduction of B2B at the same time, so ruling out any kind of bandwagon effect. But this idea would contradict all we know about diffusion processes and does not seem very realistic.

The firm size variable has a positive and significant effect on the probability to engage in B2B in the sense that larger firms are more likely to adopt a new technology like e-commerce than small firms. This result is in line with the hypothesis that rather large firms are able to carry the risk of implementing a new technology.

Comparing the size of the marginal effects of the bandwagon effect and the firm size respectively, it is obvious that the influence of the firm size is by far lower than the effect due to the bandwagon hypothesis. The same is true for the other two highly significant variables: the share of the workforce working predominantly at a PC or terminal, and a firm's export quota. Concerning the latter, a firm faced to international competition is more likely to engage in B2B. However although significant, the marginal effect of the export quota is quite low. It should be noted in this context that our sample includes a lot of firms especially from the service sector that do not export anything. While about 75% of all firms of our sample that belong to the manufacturing sector say that they exported in 1999, almost 80% of all service firms report no exports. Only 5% of all financial intermediaries and a bit more than 10% of business service firms exported in the year 1999.[11] Restricting the estimations to the manufacturing sector, does not change the results, however: The export quota is still significant, but the marginal effect on the probabilities stays low.

The share of a firm's workforce working predominantly at a PC, a workstation or a terminal also turns out to have a significant, but at the same time rather small marginal effect on a firm's decision to use B2B e-commerce. As hypothesized, a firm more open to the application of new ICTs decides to use B2B e-commerce more intensively. Another variable included in the estimation to measure firm's openness towards new ICT applications, the number of ICT specialists as a share of all employees, does not show a significant effect. In this case, we are faced with a collinearity problem. As the correlation matrix in the appendix shows, the pairwise correlations between the three variables "share of workforce working predominantly at PC", "share of ICT specialists" and "share of employees having a university degree" vary between 0.4240 and 0.5464, so indicating a quite high positive correlation. Excluding the variable "share of workforce working predominantly at a

[11]These figures are based on the firms' own information. Using the definitions of the System of National Accounts, the reported export quotas of many firms would be different. For example, every sale of a retailer to a foreigner, maybe a tourist, accounts for export of a retail trade service according to the official definitions. Transactions like this are, however, not very likely to be considered by firms when answering to the question whether they export or not.

PC" from the regression leads to a significant influence of the variable "share of ICT specialists". The positive impact of the variable "share of employees having a degree from university or a polytechnical school" can be explained by the fact that a high proportion of all ICT specialists have a university degree. From our survey we know that for almost 80% of their vacancies firms wish to hire graduates from universities. Therefore, additional ICT specialists in a firm at the same time rise the share of employees having a university degree. As before excluding the two variables that represent firm's openness towards new ICT applications, the variable "share of employees having a degree from university or from a polytechnical school" becomes significant. Thus, one may conclude that firms with a knowledge intensive production process are more likely to use B2B e-commerce intensively.

Finally, we find no evidence neither for an effect of the age of the firm nor for the effect that firms belonging to a group of companies behave differently from others. Thus, the hypothesis that younger firms can more easily adopt the new technology B2B due to their higher flexibility, unconventionality and a higher readiness to take risks is not confirmed. Similarly, the data give no hint that firms being member of a larger group have a higher or lower incentive for utilizing the internet for B2B e-commerce. At least, the probabilities of deciding between different intensities of using B2B e-commerce are not significantly different.

Most of included dummies representing sector-specific influences are insignificant. Only the dummy variable representing the manufacturing industry without all those firms belonging to the ICT-sector is significant on the 10%-level. The marginal effects indicate that the "traditional" industrial sector, often called the "old economy", makes use of B2B e-commerce to a lower extent than the service sector and the ICT-sector. However, a Wald-test for joint significance of the four sector dummies cannot reject the Null hypothesis that they are jointly zero.[12]

As mentioned in section two, Electronic Data Interchange (EDI) can be regarded as a precursor of B2B e-commerce. In contrast to B2B, which is only at the early stage of its diffusion process, EDI is probably already at the end of its diffusion process. Firms already using EDI could be expected to introduce a more innovative technology for the electronic transfer of documents and forms with a higher probability than others. To examine this hypothesis, we include a dummy variable in the regression equation that takes the value 1 if firm i uses EDI and the value 0 otherwise. Since EDI is a kind of precursor of B2B, the decision to introduce EDI should have been made before the firm decides about the introduction of B2B such that there does not

[12]The reader may suspect that the measurement of the bandwagon effect is correlated with the sector dummies. However, this is not the case since we defined the bandwagon effect on the level of the two digit NACE-code and on the level of the three digit NACE-code for business services respectively. The variation of the bandwagon effect within a sector is therefore higher than the variation between the sectors.

seem to be a problem of simultaneous decisions here. The results of this enriched regression is documented in table 8. Indeed, our results show that firms which use EDI are less likely to choose the alternative "no use of B2B e-commerce" and, consequently, more likely to decide for a broad use of B2B e-commerce.[13] Moreover, all results discussed above in this chapter, i.e. without the inclusion of a dummy variable for the use of EDI, stay valid. The problem with this approach is that we aimed to find out characteristics of firms that use B2B e-commerce, whether sporadically or broadly, and that distinguish these firms from firms that don't use B2B e-commerce. If we knew that a firm uses EDI, it will contribute to *predict* whether this firm also uses B2B e-commerce or not. However, EDI and B2B can both be interpreted as a process innovation in the ICT context. Identifying characteristics that can explain the adoption of an ICT technology should explain *both* the use of EDI and B2B.

This arises the question, how well our empirical model fits with the data. Using McFadden's R^2 as a simple measurement of the goodness of fit, we see that the explanatory power of our model is rather low. For the estimation without the dummy variable for EDI a value of the R^2 of 0.0356 was calculated. By including the dummy variable for EDI the value of McFadden's R^2 only increases to 0.0464 due to the predictive power of the dummy variable.

5 Concluding Remarks

In this paper, we examined the diffusion of B2B e-commerce within the German manufacturing industry and selected service sectors. Our empirical work is based on a survey conducted in summer 2000. We analysed the adoption decision using an ordered probit model with the extent of the B2B e-commerce activities as the endogenous variable. We could validate several hypotheses that had been derived from the theoretical and empirical literature. The most significant and crucial effect on a firm's decision is given by the so-called bandwagon effect. The more firms in the particular industry of firm i already use B2B, the higher is the probability that an individual firm decides for a broad use of B2B. Moreover, we find significant effects of firm size, export quota and the share of a firm's workforce working predominantly at a PC or terminal. The latter variable serves as a proxy for a knowledge intensive production process of firm i since this variable is positively correlated with other

[13] As in the case of B2B e-commerce, we only have information whether firms make use of EDI at the time of the interview or whether they do not. But firms may have already replaced their EDI applications by e-commerce transactions, no longer utilizing the EDI technology. If additionally it was known which firms used EDI in the past, our reported results should become even more clear-cut.

variables covering the effect of human capital and the openness of the firm towards new (ICT) applications. All variables mentioned so far lead to an increased probability of a broad use of B2B e-commerce. Some other hypotheses had to be rejected. We found no evidence for any significant effects of firm age and of a dummy variable indicating whether a firm belongs to a group of companies. However, all in all, the explanatory power of our model is quite low, even if we take into account the use of EDI which helps to predict the use of B2B.

A severe restriction of our analysis is due to the fact that it is based on a cross sectional data set. Since we don't know anything about the year when a firm started using B2B, we cannot model the diffusion of B2B as time proceeds. Furthermore, some variables are difficult to interpret in a cross sectional framework. The bandwagon effect for example depends on the time period that is regarded. For the very early adopters of a new technology, the bandwagon effect is, by definition, not valid. With more and more firms making use of B2B e-commerce, the bandwagon effect becomes more and more significant. This time dependent development could not be separated on the basis of a cross sectional data set.

Nevertheless, although of cross sectional nature, our data represent one of the most comprehensive information bases on the diffusion of new ICT applications in German industry which is available.

Further research is needed to describe the diffusion of ICT applications as a time dependent process. Moreover, it would be interesting to see whether the use of B2B has positive impacts on the firms' productivity.

6 Appendix

Table 3: Sectors considered in the sample

Industry	*NACE-Code*
Manufacturing industry	15-37
Wholesale trade	51
Retail trade	50, 52
Transport and post	60-63, 64.1
Financial intermediation	65-67
Computer and telecommunications	64.2, 72
Technical services	73, 74.2, 74.3
Other business services	70, 71, 74.1, 74.4-74.8, 90

Table 4: Definition of the ICT-sector according to OECD

Industry	*NACE-Code*
Manuf. of office machinery and computers	30.0
Manuf. of insulated wire and cable	31.3
Manuf. of electronic values and tubes and other electronic components	32.1
Manuf. of telev. and radio transmitters and apparatus for line telephony and line telegraphy	32.2
Manuf. of television and radio receivers, sound or video recording or reproducing apparatus and associated goods	32.3
Manuf. of instruments and appliances for measuring, checking, testing, navigating and other purposes	33.2
Manuf. of industrial process control equipment	33.3
Wholesale of radio and TV goods †	51.43.3
Wholesale of office machinery	51.64.1
Retail sale of radio and TV goods †	52.45.2
Retail sale of optical and photographic goods, computers and software †	52.48.4
Telecommunications	64.2
Renting of office machinery and equipment including computers	71.33
Computer and related activities	72

† Not included in the definition of OECD (2000, p. 249).

Table 5: Descriptive Statistics of Exogenous Variables

	mean	median	minimum	maximum	stand. deviation
firm age	30.67	15	1	315	30.67
bandwagon effect	0.490	0.482	0.200	0.833	0.105
ln(firm size)	4.599	4.437	1.609	12.32	1.823
share of high skilled employees	23.51	13	0	100	25.09
share of ICT specialists	9.331	1.200	0	100	23.37
share of employees, working predominantly at PCs	47.44	40	0	100	32.67
export quota	15.40	0	0	100	23.59

Table 6: Matrix of pairwise correlations

	firm age	bandwagon effect	ln(firm size)	share of high skilled employees	share of ICT specialists	share of workforce at PC	export quota
firm age	1.0000	-0.0984	0.2565	-0.1819	-0.1436	-0.1175	0.1080
bandwagon effect		1.0000	0.0058	0.3011	0.4682	0.3278	0.0486
ln(firm size)			1.0000	-0.0933	-0.1268	-0.1054	0.2681
share of high skilled employees				1.0000	0.4398	0.5464	-0.0300
share of ICT specialists					1.0000	0.4240	-0.0782
share of workforce at PC						1.0000	-0.0741
export quota							1.0000

Table 7: Estimation Results - Marginal Effects, specification 1

		Marginal effects for $y = 0$ *"no use"*		Marginal effects for $y = 2$ *"broad use"*	
		$\partial y/\partial x$	robust stand. error	$\partial y/\partial x$	robust stand. error
dummy manuf. without ICT †‡		0.0485*	0.0259	-0.0235*	0.0125
dummy financial intermediation †		0.0601	0.0386	-0.0272*	0.0162
dummy technical services †		0.0537	0.0438	-0.0245	0.0187
dummy other business services †		0.0238	0.0408	-0.0113	0.0187
dummy ICT-sector †		0.0427	0.0382	-0.0200	0.0172
dummy group of companies †		0.0117	0.0193	-0.0057	0.0093
firm age		-0.0001	0.0002	0.0000	0.0001
bandwagon effect		-0.7763***	0.1050	0.3781***	0.0515
ln(firm size)		-0.0284***	0.0056	0.0138***	0.0027
share of high skilled employees		0.0000	0.0005	-0.0000	0.0002
share of ICT specialists		-0.0006	0.0004	0.0003	0.0002
share of workforce at PC		-0.0014***	0.0003	0.0006***	0.0002
export quota		-0.0013***	0.0004	0.0006***	0.0002
threshold parameters:	$\hat{\gamma}_1$	1.4380	0.1351		
	$\hat{\gamma}_2$	2.6063	0.1405		
Number of observations (N)				3026	
Log-Likelihood				-2835.185	
McFadden's R^2				0.0356	
Wald-Test					
sector dummies $\chi^2(5)$:	4.40				
$Prob > \chi^2$:	0.4928				

† Discrete change of dummy variable from 0 to 1.

‡ The sector of distributive services (trade, transport and postal services) is use as base category.

* significant on the 10%- level

** significant on the 5%- level

*** significant on the 1%- level

Source: ZEW, own estimation.

Table 8: Estimation Results - Marginal Effects, specification 2

		Marginal effects for $y = 0$ *"no use"*		Marginal effects for $y = 2$ *"broad use"*	
		$\partial y/\partial x$	robust stand. error	$\partial y/\partial x$	robust stand. error
dummy manuf. without ICT †‡		0.0471*	0.0275	-0.0225*	0.0131
dummy financial intermediation †		0.0616	0.0418	-0.0274	0.0172
dummy technical services †		0.0418	0.0477	-0.0190	0.0206
dummy other business services †		0.0094	0.0443	-0.0045	0.0208
dummy ICT-sector †		0.0386	0.0404	-0.0179	0.0180
dummy group of companies †		0.0249	0.0207	-0.0119	0.0098
firm age		-0.0001	0.0003	0.0000	0.0001
dummy EDI †		-0.1333***	0.0195	0.0658***	0.0099
bandwagon effect		-0.7505***	0.1135	0.3606***	0.0553
ln(firm size)		-0.0194***	0.0061	0.0093***	0.0029
share of high skilled employees		0.0002	0.0005	-0.0001	0.0002
share of ICT specialists		-0.0006	0.0005	0.0003	0.0002
share of workforce at PC		-0.0013***	0.0004	0.0006***	0.0002
export quota		-0.0009**	0.0004	0.0004**	0.0002
threshold parameters:	$\hat{\gamma_1}$	1.4102	0.1449		
	$\hat{\gamma_2}$	2.5892	0.1504		
Number of observations (N)				2638	
Log-Likelihood				-2446.941	
McFadden's R^2				0.0464	
Wald-Test					
sector dummies $\chi^2(5)$:	3.99				
$Prob > \chi^2$:	0.5501				

† Discrete change of dummy variable from 0 to 1.
‡ The sector of distributive services (trade, transport and postal services) is use as base category.
* significant on the 10%- level
** significant on the 5%- level
*** significant on the 1%- level
Source: ZEW, own estimation.

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