Software, Firm Performance and Work Organisation: An Empirical Analysis

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Zusammenfassung

Diese Arbeit untersucht die Nutzung und die Auswirkungen von Informations- und Kommunikationstechnologien (IKT) auf Unternehmen und deren Mitarbeiter. Die Arten von IKT, die in dieser Studie verwendet werden, sind Unternehmenssoftware, die entweder für eine bestimmte Branche in standardisierter Form oder individuell für ein einzelnes Unternehmen entwickelt wird, sowie soziale Software wie Wikis, Blogs und soziale Netzwerke. Die Verbindung zwischen Unternehmenssoftware und sozialer Software bildet eine weitere Softwareart, die in dieser Studie verwendet wird und den Namen Social Enterprise Software (SES) trägt. Im zweiten Kapitel dieser Arbeit untersuche ich den Zusammenhang zwischen der Nutzung von Unternehmenssoftware und der Innovationstätigkeit im Dienstleistungssektor. Das dritte Kapitel gibt Aufschluss über den Einsatz und die Nutzungspotenziale von Social Enterprise Software als eine Art IKT-Innovation. Die Arbeit beschäftigt sich zudem im vierten Kapitel mit der Frage ob die Nutzung sozialer Software in Unternehmen einen Einfluss auf die Arbeitsproduktivität hat. Das fünfte Kapitel dieser Arbeit bewegt sich weg von der Unternehmensebene hin zur Individualebene und fokussiert sich auf das Thema Arbeitsplatzorganisation. Ich untersuche die Determinanten für das Arbeiten von zu Hause aus, das eine flexible Form der Arbeitsorganisation darstellt und in der heutigen Zeit maßgeblich durch den Einsatz von IKT ermöglicht wird.

Die Arbeit beruht auf drei verschiedenen Datensätzen. Zwei dieser Datensätze stammen aus Umfragen unter deutschen Unternehmen, die das Zentrum für Europäische Wirtschaftsforschung (ZEW) durchgeführt hat. Sie werden in den Kapiteln 2 bis 4 verwendet. Der erste Datensatz stammt aus einer schriftlichen Umfrage unter den "Dienstleistern der Informationsgesellschaft" während der zweite Datensatz von einer Telefonumfrage stammt und als "IKT-Umfrage" bezeichnet wird. Der dritte Datensatz ist die auf Individualdaten basierende BIBB/BAuA Erwerbstätigenbefragung, die per Telefon durchgeführt wurde.

Die Doktorarbeit bietet verschiedene analytische Rahmenbedingungen: die Produktions- und Wissensproduktionsfunktion sowie die Einführung neuer Technologien und die Persistenz von Innovationen auf Unternehmensebene. Das Discrete Choice-Modell wird für die Analyse der flexiblen Formen der Arbeitsorganisation auf Individualebene verwendet.

Die Ergebnisse der Analyse auf Unternehmensebene in Kapitel 2 zeigen, dass Individualsoftware die Wahrscheinlichkeit für Unternehmen erhöht, Dienstleistungsinnovationen zu realisieren. Dagegen hat standardisierte Branchensoftware keinen Einfluss auf die Innovationstätigkeit im Dienstleistungssektor. Die Ergebnisse aus Kapitel 3 zeigen, dass Unternehmen, die B2B E-Commerce nutzen, eine höhere Wahrscheinlichkeit haben Social Enterprise Software einzuführen. Die Korrelationen liefern auch schwache Hinweise für eine Komplementarität zwischen B2B E-Commerce und Social Enterprise Software. Darüberhinaus sind Umsatz und Arbeitsproduktivität für Unternehmen, die B2B E-Commerce und Social Enterprise Software gemeinsam nutzen, am höchsten. Die Ergebnisse aus Kapitel 4 deuten darauf hin, dass die Auswirkungen von sozialen Netzwerken auf die Arbeitsproduktivität negativ sind. Bezüglich der flexiblen Formen der Arbeitsorganisation liefern die Ergebnisse aus Kapitel 5 Hinweise dafür, dass Männer eine höhere Wahrscheinlichkeit haben, von zu Hause aus zu arbeiten. Frauen haben hingehen eine höhere Wahrscheinlichkeit intensiv von zu Hause aus zu arbeiten. Bildung, Beschäftigungsdauer und Computernutzung erhöhen die Wahrscheinlichkeit von zu Hause aus zu arbeiten während die Unternehmensgröße und ein junges Alter der Mitarbeiter unter 30 Jahren diese Wahrscheinlichkeit senken. Die Präsenz von Kindern unter sechs Jahren, Überstunden und die Arbeitszeit haben positive Auswirkungen sowohl auf die Arbeit von zu Hause aus als auch auf deren Häufigkeit.

Résumé

Cette recherche se propose d'analyser l'utilisation et l'impact des technologies de l'information et de la communication (TIC) dans les compagnies et leurs employés. Pour ce faire, des systèmes de logiciels d'entreprise sont utilisé, comme par exemple du logiciel d'entreprise standardisé, conçu pour satisfaire les besoins d'un certain secteur business ou bien des logiciels d'entreprise personnalisés à une seule compagnie, aussi bien que des applications du type logiciels sociaux comme wikis, blogs et les réseaux sociaux. Le lien entre les applications des logiciels d'entreprise et les logiciels sociaux nous a conduits à un autre type de logiciel qui est nommé dans la thèse "social enterprise software" (SES).

Dans le deuxième chapitre de ce travail, j'ai analysé la relation entre les systèmes logiciels d'entreprise et les innovation de service. Le troisième chapitre met en évidence les impacts sur la performance et les bénéfices apportés par l'adoption de SES en tant qu'innovation TIC. Cette thèse se pose aussi la question si l'utilisation d'un logiciel de type social dans une compagnie peut influencer la productivité, et ceci dans le quatrième chapitre. Le cinquième chapitre quitte le niveau de la compagnie au profit de celui de l'individu et se concentre sur l'organisation du travail. J'ai fait une analyse des déterminants du travail au domicile en tant que forme de travail flexible, devenue possible de nos jours grâce au grand nombre de moyens TIC.

La thèse est basée sur trois ensembles de données differents. Deux d'entre eux ont été fournis par des sondages éfectués dans des compagnies allemandes par le Centre de Recherches Economiques Européennes (ZEW). Je les ai utilisés dans les analyses au niveau de la compagnie, dans le deuxième jusqu'au quatrième chapitre. Le premier ensemble de données provient d'un sondage fait à travers des lettres, qu'on a réalisé parmi les "prestateurs de service dans la société informatique", tandis que le deuxième, qu'on a nommé "sondage TIC", est basé sur des interviews téléphoniques. Le troisième ensemble de données est basé sur un sondage parmi les employés (BIBB/BAuA employee survey) et il contient des données de type individuel qu'on a obtenues par des interviews téléphoniques. La thèse fournit deux cadres analytiques différents: la production et la production cadre des connaissances aussi bien que l'adoption des nouvelles technologies et la persistance des innovations au niveau de la compagnie. Au niveau de l'analyse individuelle d'un programme de travail flexible on a utilisé le modèle du choix discret.

Les résultats de l'analyse au niveau de la compagnie, dans le deuxième chapitre, mettent en évidence le fait que l'utilisation d'un logiciel d'entreprise personnalisé accroît la probabilité que les compagnies dans le domaine du service accomplissent des innovations du service, tandis que le logiciel d'entreprise spécifique au secteur n'a pas d'influence sur l'innovation du service. En ce qui concerne le logiciel SES, les résultats du Chapitre 3 montrent que les compagnies qui utilisent "business-to-business (B2B) e-commerce" sont plus susceptibles d'adopter le SES. Les correlations révèlent aussi une évidence faible de complémentarité entre B2B e-commerce et SES. En outre, les ventes et la productivité du travail sont les plus hautes dans les compagnies qui utilisent en conjonction le SES et les applications B2B e-commerce. Les résultats dans le Chapitre 4 suggèrent que l'impact du logiciel social sur la productivité du travail est négatif. Dans le cas du programme de travail flexible, dans le Chapitre 5, les résultats indiquent une probabilité plus grande que les hommes travaillent au domicile, mais les femmes sont plutôt susceptibles de travailler plus intensément au domicile. L'éducation, l'occupation et l'utilisation des ordinateurs accroîent la probabilité de travailler au domicile, tandis que les dimensions de la compagnie et l'âge jeune des employés (moins de 30 ans) la réduisent. Avoir des enfants de moins de six ans, les heures supplémentaires et le temps du travail ont un impact positif aussi bien sur le travail au domicile que sur le travail intense au domicile.

Summary

This thesis analyses the use and impact of information and communication technologies (ICT) on firms and employees. The types of ICT which are used for the analyses in this thesis are enterprise software systems such as standardised enterprise software designed to fit one certain business sector and enterprise software customised for a single firm as well as social software applications like wikis, blogs and social networks. The link between enterprise software and social software applications forms a further software type used in the thesis called social enterprise software (SES). In the second chapter of this thesis, I analyse the relationship between enterprise software systems and service innovations. The third chapter sheds light on the performance impacts and benefits of the adoption of SES as an ICT innovation. The thesis also deals with the question of whether the use of social software in a firm has an impact on labour productivity in Chapter 4. The fifth chapter of this thesis moves away from the firm level to the individual level and focuses on work organisation. I investigate the determinants of working at home as a form of flexible work arrangements which is nowadays enabled to a large amount by ICT.

The thesis relies on three different data sets. Two of the data sets used in this thesis are surveys among German firms collected by the Centre for European Economic Research (ZEW). They are used in the firm-level analysis in Chapters 2 to 4. The first data set stems from a letter based survey among the "service providers of the information society" while the second data set is called the "ICT survey" and is based on telephone interviews. The third data set is the BIBB/BAuA employee survey that contains individual-level data collected by telephone interviews.

The thesis provides different analytical frameworks: the production and knowledge production function framework as well as the adoption of new technologies and persistence in innovations on the firm level. The discrete choice model is used for the individual-level analysis of flexible work arrangements.

The results of the firm-level analysis in Chapter 2 reveal that using customised enterprise software increases the probability of firms in the service sector to realise service innovations while sector-specific enterprise software has no influence on service innovation. Concerning social enterprise software, the results in Chapter 3 show that firms which use

business-to-business (B2B) e-commerce applications are more likely to adopt SES. The correlations also reveal weak evidence for complementarity between B2B e-commerce and SES. In addition, sales and labour productivity are highest for firms using SES and B2B e-commerce applications in conjunction. The results in Chapter 4 suggest that the impact of social software on labour productivity is negative. In the case of flexible work arrangements in Chapter 5, the results indicate that men have a higher probability to work at home but women are more likely to work at home intensively. Education, tenure and the use of computers increase the probability of working at home while firm size and a young age of employees under 30 years reduce it. Having children less than six years old, overtime and work time have positive impacts on both working at home and on working at home intensively.

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1 Introduction

1.1 Motivation

Many firms nowadays use enterprise software systems in order to support their day-to-day business operations. These software applications help in decision-making by providing crucial information such as sales or cost structures in real-time. The common enterprise software systems are Enterprise Resource Planning (ERP), Supply Chain Management (SCM) and Customer Relationship Management (CRM). Each of these software applications help the firms to automate operations reaching from supply management, inventory control or sales force automation to other data-oriented management processes. According to SAP (2010), who is the largest global enterprise software vendor, the global market for all enterprise software applications amounts to \$ 110 billion in 2010. Enterprise software can be categorised into three types, as users distinguish between generic applications purchased in standardised form from the vendor, software systems or special modules specifically designed to fit one business sector or completely customised enterprise software packages developed for a single firm in particular and adapted to its specific needs.

A further range of web-based applications are a rather new phenomenon and are often referred to as Web 2.0 applications. They are not only extremely prevalent in private internet use, but are furthermore increasingly applied in firms. Social software is a particular category of Web 2.0 applications that serves to facilitate communication, cooperation and information sharing between individuals. Examples for social software applications include wikis, blogs or social networks. Social software can be used for different purposes. It can be applied to strengthen external communication with other firms or enhance customer relationship management, marketing and market research (Döbler 2007; Raabe 2007). Firms can access external knowledge by using social software (Döbler 2008). A further application form of social software is the internal use as a knowledge management tool to facilitate internal communication, including knowledge and project management or product development. Information sharing and communication between employees, customers and business partners can be made faster and more efficient by using social software.

A completely new type of enterprise software emerged in the year 2008 (Chess Media Group 2010), linking firms' social software applications with their enterprise software systems. This ICT innovation called social enterprise software (SES) represents an upgrade for already implemented enterprise software. It offers a new and fast real-time information transfer through combining business collaboration, content sharing and instant messaging into a single interface that is easy to use by employees.

ICT or software in general has a positive effect on firm performance. Enterprise software enables enhanced information handling and processing thereby facilitating communication, knowledge transfer and contact maintenance between employees or consumers and partners. The firms' business units reach a more centralised network position due to the fact that all necessary information reaches them faster which may result in the business becoming more innovative (Tsai 2001). Delivering information in an adequate manner and providing frequently updated real-time databases, enterprise software might be a "softer" source of innovation according to Tether (2005) and can be expected to improve innovative performance in service firms. In line with that, SES applications enhance the management of relations with customers even further by tracking data from customer surveys, feedback, reviews or user profiles on social networks or blogs. Based on this data firms might be able to identify new customers, new market segments and observe recent trends. SES also offers new ways of communication and interaction between companies and their customers and business partners. Furthermore, social software applications might have a positive impact on firm performance. Koch and Richter (2009) claim that firms have a greater flexibility and can operate faster by using social software which makes firms even more productive as it results in better time management. Firms using social software applications also face lower costs as their adoption and use in firms is usually cheaper compared to content management systems (Döbler 2008). According to Döbler (2008), social software can be utilised as a tool supporting e-commerce in a firm. It opens up new communication channels with customers, leading faster and more efficiently to business deals. Moreover, e-commerce can be integrated into social software applications allowing customers to directly purchase firms' products via social software, thus making firms more productive.

The empirical analyses done so far on the topic of software and firm performance confirm that enterprise software positively impacts firm performance (Aral et al. 2006; Hendricks et al. 2007; Hitt et al. 2002). However, there is no distinction in sector-specific or customised enterprise software and the potential impact of these software types on innovation performance in the service sector is still not investigated. In addition, there is nearly no data available for SES as this technology is still rather new. However, it is possible to analyse performance impacts and benefits of the adoption of SES as information about its adoption is available. Although research on the impact of social software on innovation in the service sector has been done by Meyer (2010), empirical studies on the impact of this kind of software on firm-level productivity are still missing.

Overall, software applications are important for firms nowadays as they offer new forms of work organisation and work arrangement. Flexible work arrangements such as the opportunity to work at home are increasingly widespread among firms and employees. Since ICT or software applications in particular have been applied in nearly every firm, it is now easier than ever for firms to offer these arrangements to their employees or for employees to make use of them. Taking regular work home from time to time is the most common way of working flexibly. The work output is delivered to the firm by software applications which emphasises the importance of software for firms to provide flexible work arrangements. Flexible work arrangements enable women to work and provide child care at the same time as well as reducing commute time and commute stress for employees. The reduction of commuting is associated with a reduction in road congestion and pollution (Mokhtarian 1991). In line with that, these work arrangements may reduce firm expenses and enhance work-life balance leading to higher employee productivity (Hill et al. 1998). Furthermore, firms can organise teamwork across different locations more efficiently by online collaboration (TNS Infratest and ZEW 2013). A central research question of this topic might ask which firms and employees will offer or make use of these flexible work arrangements. A large number of studies have been conducted with U.S. data sets but no econometric studies with German data sets have been done so far, except a descriptive study by Brenke (2014).

1.2 Contribution

Analysing the impacts of various software applications on firms and employees, the thesis contributes to different fields of research and literature. These fields are the impact of ICT on productivity and innovation, the adoption of new technologies and the determinants of flexible work organisation and arrangement.

Chapter 2 contributes to the literature on impacts of ICT on innovation where ICT is proxied by enterprise software and innovation is measured explicitly by service innovation. Based on firm-level data collected by the ZEW, the chapter confirms that customised enterprise software has a positive impact on innovation in the service sector while sector-specific enterprise software has no influence on service innovation.

Contributing to the literature on the adoption of new technologies, Chapter 3 of the thesis explores the performance impacts and benefits of the adoption of SES. Relying on a survey among German firms conducted by the ZEW, the results show that firms which use B2B e-commerce are more likely to adopt SES. The correlations also reveal weak evidence for complementarity between B2B e-commerce and SES. In addition, sales and labour productivity, are highest for firms using SES and B2B e-commerce applications in conjunction.

Chapter 4 is related with the literature on the productivity impact of ICT. This chapter of the thesis fits into this literature by focusing specifically on social software as an ICT application and its influence on labour productivity. Using firm-level data collected in a survey by the ZEW, the results indicate that social software might reduce labour productivity.

The next chapter of the thesis can be classified in the literature on labour markets and work organisation. Using the BIBB/BAuA employee survey, Chapter 5 analyses the determinants of flexible work arrangements as forms of work organisation which are measured by working at home. The results indicate that men have a higher probability to work at home but women are more likely to work at home intensively. Other determinants that have a positive impact on working at home are education, tenure and the use of computers. In contrast, firm size and a young age of employees under 30 years have negative impacts on working at home. Having children less than six years old, overtime and work time have positive impacts on both working at home and on working at home intensively.

1.3 Thesis Outline

This thesis contains six chapters. Chapters 2 to 5 contain empirical analyses divided into the subchapters introduction, literature review, description of data, analytical framework, results and conclusion. Chapters 2 to 4 present the firm-level analyses described above. These analyses are based on two different surveys among German companies conducted by the ZEW between 2007 and 2010. The surveys are the ICT survey based on telephone interviews and the letter based survey among the "service providers of the information society" each with about 4000 firms. Chapter 5 uses individual-level data that stems form the BIBB/BAuA employee survey conducted in the year 2006.[1]

The results of the firm-level analyses show that the use of customised enterprise software positively impacts the innovative performance of firms in the service sector while sector-specific enterprise software has no significant impact on service innovation. Concerning the adoption of SES, the results show that firms which use B2B e-commerce are more likely to adopt SES. There is also weak evidence for complementarity between B2B e-commerce and SES. In addition, sales and labour productivity are highest for firms using SES and B2B e-commerce applications in conjunction. Regarding the impact of social software on labour productivity, the analysis shows that the use of social software applications might reduce labour productivity. The results of the analysis on the individual level sheds light on the determinants of working at home. As already mentioned above, the positive determinants are being male, qualification level, tenure and computer use. In addition, the presence of small children, overtime and work time are determinants for both working at home and working at home intensively while women have a higher probability of working at home intensively once they decide to work at home. In contrast, firm size is a negative determinant for working at home and its frequency. A young age of employees under 30 years reduces the probability of working at home and its frequency.

Chapter 6 concludes and provides a summary of all results as well as pointing to limitations. This chapter also gives opportunities and outlooks for further research.

[1] Detailed descriptions of all data sets used in this thesis are included in each corresponding chapter.

2 Does Enterprise Software Matter for Service Innovation? Standardisation versus Customisation*

Abstract

This paper analyses the relationship between service innovation and different types of enterprise software systems, i.e. standardised enterprise software designed to fit one certain business sector and enterprise software specifically customised for a single firm. Using recent firm-level data of a survey among information and communication technology service providers as well as knowledge-intensive service providers in Germany, this is the first paper which empirically analyses whether the use of sector-specific or customised enterprise software triggers innovation. The results based on a knowledge production function suggest that customised enterprise software is related to the occurrence of service innovation. However, there is no relationship between sector-specific enterprise software and innovation activity. The results stay robust to several different specifications and suggest that the causality runs from customised software usage to service innovation.

Keywords: enterprise systems, service innovation, customised enterprise software, sector-specific enterprise software, service sector

JEL-Classification: L10, M20, O31

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2.1 Introduction

A large range of enterprise software products nowadays supports day-to-day business operations, controls manufacturing plants, schedules services or facilitates decision-making. The purpose of these software applications is, in general, to automate operations reaching from supply management, inventory control or sales force automation to almost any other data-oriented management process. Especially in many fields like semiconductors, biotechnology, information and telecommunication or other knowledge-intensive industry branches, employees might be able to observe, measure or even envision certain phenomena only by using specific enterprise software applications. SAP, the largest global enterprise software vendor, estimates the adressable market for enterprise software applications to be roughly $ 110 billion in 2010.[2]

Overall, enterprise software can be categorised into three types, as users distinguish between generic applications such as an enterprise resource planning system purchased in standardised form from the vendor,[3] software systems or special modules specifically designed to fit one business sector[4] or completely customised enterprise software packages developed for a single firm in particular and adopted to its specific needs.[5] Thus, customised enterprise software systems are usually unique.

Although the usage of information and communication technology (ICT) applications in general is suspected to enhance firms' innovative activity (Hempell and Zwick 2008; Engelstätter 2012; Brynjolfsson and Saunders 2010), the potential impact of sector-specific or completely customised enterprise software on innovation performance in particular is still not investigated. The literature in this field is scarce, offering only a few studies which examine the benefits of enterprise software for innovation activity, see e.g. Shang and Seddon (2002). Empirical evidence is even scarcer, provided only by Engelstätter (2012) who outlines the impact of three common generic enterprise systems on firms' ability to realise process and product innovations. However, being more general based on the available sample, Engelstätter (2012) does not picture the impacts of enterprise

[2]See SAP presentation, available at: `http://www.sap.com/about/investor/presentations/pdf/WB_DB_London_8Sep2010.pdf`, last visited June 29th 2012.

[3]E. g. SAP Business One or Oracle E-Business Suite.

[4]Examples for sector-specific enterprise software contain computer aided design or manufacturing programmes, e. g., solutions offered from Sage.

[5]Examples here are completely designed software solutions like applications from firms as, for instance, Supremistic or Jay Technologies Inc. In addition, firms could also augment generic solutions like SAP packages with custom-made modules.

software on specific service innovations. Those service innovations might be driven by other characteristics such as enhanced knowledge handling or contact to customers compared to mainly research driven innovations in manufacturing. However, to succeed in realising innovations in dynamic, information-rich environments like the service sector a firm should engage in a combination of different practices like promoting information absorption and diffusion, knowledge handling or development of an extended intra- and inter-organisational network (Mendelson and Pillai 1999). Engaging in these practices, however, is expected to be facilitated with advanced knowledge handling and storing capabilities of utilised enterprise software. In light of this research gap, the current study provides the first empirical evidence of the impact of business sector-specific or customised enterprise software on firms' innovation performance. We focus on the specific case of service firms in our analysis as business sector-specific software packages are incomparable between manufacturing and service firms.

Our study relies on a unique database consisting of 336 German firms from ICT and knowledge-intensive service sectors. As an analytical framework we employ a knowledge production function for our empirical analysis. Based on a probit approach, the results indicate that service firms relying on customised enterprise software have a higher probability of realising service innovations compared to firms not using customised software packages. Concerning sector-specific enterprise software we find no evidence of a positive impact on service firms' innovative activity. These results stay robust to many specifications controlling for different sample sizes and several sources of firm heterogeneity like size, age, workforce structure, competitive situation or former innovative experience.

The paper proceeds as follows: Section 2.2 presents the economic framework of ICT, innovation and service innovation our study is based upon. Section 2.3 explains in detail the relationship of enterprise software and service innovation and its potential drawbacks. Section 2.4 introduces the dataset. The estimation procedure is derived in Section 2.5 and Section 2.6 presents the estimation results. Section 2.7 concludes.

2.2 ICT, Innovation and Service Innovation

This study relates to the literature exploring the impacts on innovation activity of ICT in general and of enterprise software on service innovation in particular. ICT is expected to enable productivity and performance gains by supporting the optimization of firms' business processes, see, e.g., Brynjolfsson and Hitt (2000). A crucial prerequisite for these productivity gains, however, is the firms' innovation activity (Crépon et al. 1998; Hall et al. 2009). Nevertheless, the link between ICT and innovation is not as extensively studied in the empirical literature as the relationship between ICT and productivity. Studies investigating the effects of ICT investments on innovative performance at the firm level usually report a positive and significant impact which may emerge directly, see, e.g., Gera and Gu (2004), or indirectly via complementary assets as shown in Bresnahan et al. (2002) or Hempell and Zwick (2008).

The literature on enterprise software applications follows a similar pattern to the literature on ICT. There are many studies extensively examining the performance impacts of enterprise software[6] and nearly no analyses examining potential impacts on innovation activity. Only Engelstätter (2012) empirically shows that different types of generic enterprise software systems enhance the innovation activity of using firms which results in more realised process as well as product innovations. In light of this research gap our study explicitly contributes to the literature on enterprise software as we offer evidence that not only generic but also very specific enterprise software can be associated with increased innovative performance.

For a particular type of innovation, i.e. the innovation in services, however, the impacts of most recent ICT like enterprise software might be even more important. In general, service innovations are argued to be either driven by the adoption of ICT or by the exchange of information which in particular is facilitated using enterprise software. Nevertheless, empirical studies exploring the impact of ICT on service innovation are even scarcer. The reason for this lack of empirical evidence may be due to the fact that the nature of services complicates the use of traditional economic measurements for innovations as this field is very heterogeneous due to features like intangibility, interactivity and coterminality (Gallouj and Weinstein 1997). In detail, services turn out to be intangible, because they are hard to store or transport and can sometimes not even be displayed to a customer in advance (Hipp and Grupp 2005). Interactivity is constituted in high communication and coordination needs between client and supplier as in most cases both have to be present for the transaction. Coterminality captures the

[6]See, e.g., among others, Hunton, Lippincott and Reck (2003), Wier, Hunton and HassabElnaby (2007) or Hendricks, Singhal and Stratman (2007) for analysing the impacts of enterprise software on several return measures. Hitt, Wou and Zhou (2002), Shin (2006), Engelstätter (2013) or Wieder et al. (2006) are some examples for studies exploring the impacts of enterprise software on labour productivity, net profit margin and value added.

fact that services are often produced and consumed at the same place and time. Due to this heterogeneity several streams[7] of literature emerged, each one proclaiming different reasons for innovative activity in services.

Several studies, e.g., Pilat (2001) and Agrawal and Berg (2008), adopt the so called technologist approach for explaining service innovation in their analysis. This most prominent approach argues that service innovations might be driven by the external adoption of ICT. However, services are often co-produced and co-made by the provider and the user working together (Howells 2010), exchanging information or knowledge, emotions, verbal or gestural civilities or the performance of repair or rectification tasks (Gallouj 2002). Expecting these exchanges as a driver for the service innovation the service-oriented approach emerged which is also frequently adopted in the literature (see, e.g., Djellal and Gallouj 2001; Sundbo and Gallouj 2000 or den Hertog 2000).

In line with this approach, key elements for service innovation are, in particular, internal knowledge within the firm and its employees and the external network of the firm including customers and other businesses (Sundbo 1997). Human capital, especially personal skills like experience or extensive consumer contact, and knowledge about markets, consumer habits and tastes are also important for realising innovations in a service company (Meyer 2010). In addition, sources of information like consumers and suppliers of equipment can provide essential clues for service enhancement and advancement. However, assuming recent ICT as a driver for service innovation is grounded in both approaches as modern ICT like, e.g., enterprise software not only enhances business process management and shortens response times but also facilitates knowledge handling and management. We provide empirical evidence for this claim as our study empirically tests for the impact of most recent enterprise software applications on service innovation. In the next section, we explain in depth how enterprise software is related to both approaches.

2.3 Enterprise Software and Service Innovation

Enterprise software may impact the firms' innovation activity through different channels: either directly through the particular benefits provided by a specific kind of enterprise software or indirectly as most software packages share common features facilitating

[7] See Howells (2010) for a comprehensive overview of all streams.

knowledge handling which might improve the innovation process. In line with the technologist approach the benefits of enterprise software which directly impact innovation performance are the result of technical features varying between the types of software used. The features facilitating knowledge management most enterprise software applications share support the service-oriented approach claiming that information and knowledge results in service innovation. We will explain both channels of benefits in detail in the following. However, scholars only explore innovation in general in the context of enterprise software and do not investigate service innovation in particular. Our study fills this research gap by analysing the relationship between specific enterprise software applications and service innovations.

The common features of most enterprise software packages enable enhanced information handling and processing thereby facilitating communication, knowledge transfer and contact maintenance between employees or consumers and partners. Thereby its business units reach a more centralised network position as all necessary information reaches them faster which may result in the business becoming more innovative (Tsai 2001). Offering and presenting information in an adequate manner and providing frequently updated real-time databases where they are needed, enterprise software might function as a "softer" source of innovation according to Tether (2005) and can be expected to improve innovative performance in service firms. Following the argument that acquired information drives service innovations, Criscuolo et al. (2005) argue that firms generate more innovations with established upstream/downstream contacts to suppliers and customers. This relation especially holds for service innovations as customers and suppliers are often providers of essential guidelines and ideas for enhancement and advancement of provided services as proclaimed in the service-oriented approach. Roper et al. (2006) even support this argument as they stress the high value of backwards and horizontal knowledge linkages for innovations.

Exploring the benefits of enterprise software it stands out that some industry branches like, e.g., biotechnology, semiconductors or architects need particular sector-specific software like computer aided architecture or simulation software to complete their business tasks. For these industries so called sector-specific enterprise software represents merely a technical working tool which could improve process handling and management but is not necessarily related to improvements in innovation performance. But Thomke (1998) shows for the automotive industry that the use of this working tool in the form of a specific computer simulation software is associated with overall better R&D output. However, if a firm employs enterprise software, which is specifically designed for the company, it can incorporate long-term experience and knowledge into the software. Thereby, a firm is able to create software which perfectly fulfills all requirements for its specific business. Such a software enables shortened response times and fast information delivery resulting in an increased external focus for the utilising firm which is hypothesized to increase the returns on information technology (Tambe et al. 2012). Tambe et al. (2012) also show that this external focus leads to overall improved innovation performance in combination with decentralisation and the use of sophisticated information technology like, e.g. enterprise software solutions. The necessary decentralisation, however, is associated with customised enterprise software usage (Gronau 2010). Malhorta et al. (2001) offer first evidence of these positive impacts of customised enterprise software on firms' innovative performance as they show that externally developed customised virtual teaming software yields crucial innovations at Boeing-Rocketdyne.

Besides all the benefits, firms' relying on enterprise software may also face some serious drawbacks. However, as there are no procedures similar to clinical trials to assess these drawbacks as well as the benefits of enterprise software objectively beforehand (Ghosh 2006) firms can only identify potential drawbacks from experience with using the software. We expect some drawbacks of enterprise software to occur in the long-run. Independent of the type of enterprise software used the increased automation and streamlining of processes might bind the workers to certain limits, restricting the workers' freedom and creativity. Also, enterprise software only tends to store and transfer information crucial for the specific process at hand and may miss vague or tacit knowledge necessary for further innovations in the long-run. Thus, heavily relying on software may result in very homogenous processes, practices and solutions hampering a firms' future innovative potential.

2.4 Description of Data

The data we use in this study are taken from the quarterly business survey among the "service providers of the information society" conducted by the Centre for European Economic Research (ZEW) in cooperation with the credit rating agency Creditreform. The sector "service providers of the information society" comprises nine industry sectors, three of information and communication services sectors and six knowledge-intensive services sectors.[8] Every quarter, a one-page questionnaire is sent to about 4.000 mostly small and medium-sized companies. The sample is stratified with respect to firm size, region (East/West Germany) and sector affiliation. The survey achieves a response rate of about 25% each wave and builds a representative sample of the German service sector. The interviewed candidates may choose between responding via pen and paper, fax or online. The questionnaire consists of two parts. In the first part of the questionnaire, companies complete questions on their current business situation with respect to the previous quarter as well as their expectations for the next quarter. The second part is dedicated to questions concerning diffusion and use of ICT and further firm characteristics like innovative activities or training behavior. The questions in the second part change every quarter but might be repeated annually or biyearly. Details on the survey design are presented in Vanberg (2003). Overall, the survey is constructed as a panel with different waves being employed in several different empirical setting as, e.g., in Bertschek and Kaiser (2004) or Meyer (2010).

In the survey, the questions covering enterprise software usage were only included in the second quarter of 2007. The questions about innovative activities were asked in the second quarter of 2009. Thus, a panel data analysis cannot be provided in this paper. Accordingly, we focus on a cross-section analysis by merging the second wave of the year 2007 to cover enterprise software usage and the second wave of the year 2009 to cover firms' innovative activity thereby forming a well-defined temporal sequence. Considering item non-response for enterprise software and innovation, a sample consisting of 336 firms remains.

According to the OECD (2005) we define service innovations in our analysis as a completely new service or an essential improvement[9] to an existing service that has been introduced between June 2008 and June 2009. Service innovation performance representing the dependent variable in our empirical analysis is accordingly measured as a dummy variable that takes the value one for firms realising a service innovation and zero otherwise.

[8]The industry sectors are listed in Table 3 in the Appendix of Chapter 2.

[9]Based on such improvements firms might also realise productivity gains placing this study also in the literature of IT and productivity. However, as these improvements are determined as service innovations (OECD 2005) we refrain from the IT and productivity literature branch and focus only on the innovative impacts of IT.

In the survey, the firms were asked about using two types of enterprise software, i.e. sector-specific software and customised software. The variables capturing the use of enterprise software are dummy variables which take the value one if a firm uses the respective type of enterprise software in June 2007 and zero otherwise. Figure 1 shows that more than three quarters of the service firms use sector-specific software and 38 percent of the firms use customised software. However, both software types are non-exclusive. Hence, some firms also have customised as well as sector-specific software systems running (27 percent, not reported).

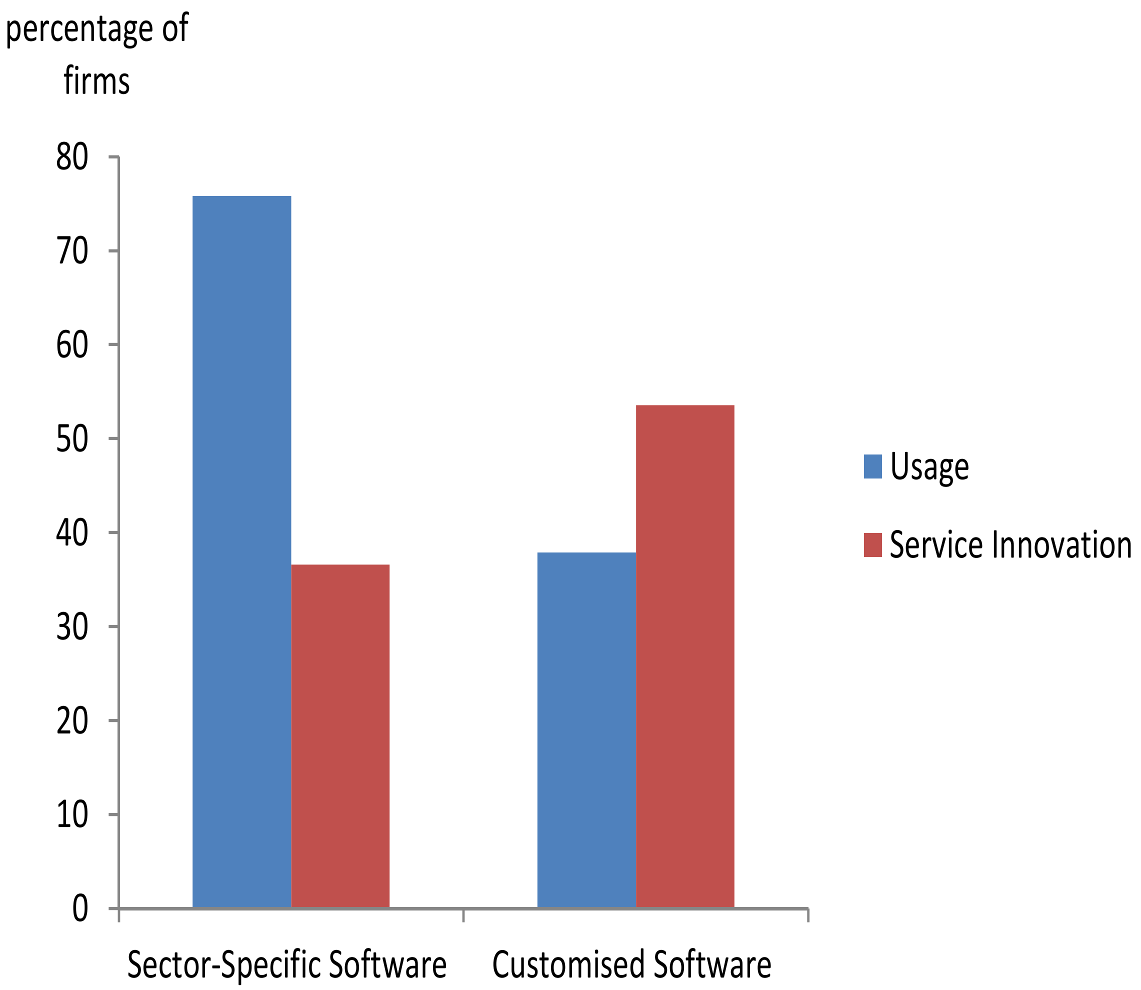

Figure 1: Use of Enterprise Software and Service Innovation

Note: Usage refers to the share of firms using the indicated software. Service Innovation refers to the share of firms which use the indicated software and reported having realised a service innovation.

Overall, 39 percent of the firms in our sample reported realising a service innovation between June 2008 and June 2009.[10] For a first illustration Figure 1 also pictures the share of firms which realised a service innovation and also use enterprise software. Concerning sector-specific enterprise software the according share amounts to 37 percent. In contrast, more than half of the firms using customised enterprise software realised service innovations in the covered time period. This relatively high share yields first descriptive evidence for our hypothesis that the use of customised enterprise software seems to foster the innovative activity in service firms. However, for sector-specific enterprise software there is no descriptive evidence for a positive innovative impact.

For a further overview, Table 1 provides summary statistics for our employed sample. We describe the construction of each variable and its relationship to service innovations in the next section in detail. However, it stands out that our representative sample of the German information service sector contains mostly small and medium sized enterprises with 38 employees at mean. Nevertheless, it seems like bigger firms are more eager to employ customised enterprise software solutions as the mean size amounts to 52 employees for firms using customised software (not reported). The appropriate mean in size for firms relying on sector-specific software systems, in contrast, turns out to be smaller (36, not reported). Two different reasons might explain this issue. First, large firms generally tend to have the financial infrastructure to implement big and complicated customised software solutions. Secondly, the firm structure and business processes in large service firms might, in comparison to the situation in small firms, reach such a high level of complication and integration a simple generic enterprise software solution might be unable to handle. Accordingly, large firms may rely on customised software systems suited for their specific needs more frequently. As one might argue that those large firms could possibly drive the results of our empirical analysis we conduct appropriate robustness checks in Section 2.6.

[10] See the summary statistics pictured in Table 1.

Table 1: Summary Statistics

Variable	Mean	Min.	Max.	N
service innovation	0.386	0	1	336
sector-specific software	0.758	0	1	336
customised software	0.380	0	1	336
number of employees	38	1	449	334
log (number of employees)	2.718	0	6.107	334
firm age	20	2	108	310
log (firm age)	2.851	0.693	4.682	310
0-5 competitors	0.243	0	1	312
6-20 competitors	0.304	0	1	312
more than 20 competitors	0.451	0	1	312
share of employees working with PC	0.786	0.01	1	324
share of highly qualified employees	0.435	0	1	316
share of medium qualified employees	0.159	0	1	303
share of low qualified employees	0.383	0	1	311
share of employees younger than 30 years	0.194	0	1	308
share of employees between 30 and 55 years	0.656	0	1	318
share of employees older than 55 years	0.160	0	1	307
prior service innovation	0.414	0	1	258
prior process innovation	0.437	0	1	265
East Germany	0.405	0	1	335

Source: ZEW Quarterly Business Survey among service providers of the information society, own calculations.

2.5 Analytical Framework and Estimation Procedure

Introduced by Griliches (1979), this study will be based on a knowledge production function, following the basic assumption that the output of the innovation process represents a result of several inputs linked to research and ongoing knowledge accumulation, such as, e.g., former innovative experience or human capital (Vinding 2006). Following Engelstätter (2012), we include enterprise software in the knowledge production function, providing first insights into the relationship between business sector-specific or completely customised enterprise software usage and the firm's innovation activity. This yields the following innovation relation:

$$SI_i = f(ES_i, L_i, C_i, FA_i, FS_{i,-1}, FP_{i,-1}, controls) \quad (1)$$

with SI_i covering service innovation for firm i, ES_i enterprise software used by firm i, L_i the labour input, C_i the competitive environment and FA_i the age of the firm. Former service and process innovations ($FS_{i,-1}$ and $FP_{i,-1}$) as well as controls like industry sector classifications and region dummy are also included. The employed explanatory variables and their temporal sequence are explained in detail below. The endogenous variable we use as measure for innovation contains the information whether the firms are service innovators or not. As this dependent variable is a dummy and we assume a normally distributed error term, the widely established probit model as, e.g., introduced in Greene (2003) is used for inference.

The labour input L_i consists of firm size, qualification structure of employees, age structure of employees and IT intensity. We control for firm size by the logarithm of the number of employees. Larger firms tend to have more lines of activity and therefore more areas in which they can innovate. This is valid for both the manufacturing and the service sector, see, e.g., Meyer (2010) or Leiponen (2005) for further information. Firm size is reported for the year 2008.

We also consider the qualification structure of the workforce by creating three control variables: the share of highly qualified (university or university of applied science degree), medium qualified (degree in technical college or vocational qualification) and low qualified (other) employees. All shares are measured in June 2009. The share of low qualified employees is taken as the reference category. In general, qualification pictures the suitable know-how and human capital which is essential for starting and enhancing innovations. Without suitable know-how, neither will be successful (Meyer 2010). Therefore, we assume that the higher the qualification of employees, the higher the innovative activity.

We control for the age structure of the employees with three variables. The first one represents the share of employees younger than 30 years and builds our reference category. The second variable captures the share of employees between 30 and 55 years whereas the third variable encompasses the share of employees over 55 years. Overall, the age structure of the employees is expected to drive the firms' innovative behavior. Börsch-Supan, Düzgün and Weiss (2006) point out that the process of aging leads to a cutback of fluid intelligence which is needed for new solutions and fast processing of information. Based on this cutback older workers might be less innovative. In addition, older workers may resist innovations as their "human capital" depreciates. However, older workers grew in crystalline intelligence (experience and general knowledge) which in turn could lead to more innovations. Thus, the effect of the age structure of employees on innovative activity is an ambiguous issue. The age structure was measured in June 2009 in our survey.

Following, e.g. Engelstätter (2012), we proxy the IT intensity of firms by the share of employees working with a computer in June 2007. Licht and Moch (1999) mention that IT can improve the quality of existing services, in particular customer service, timeliness and convenience. Moreover the productive use of IT is closely linked to complementary innovations (Hempell 2005).

The effect of firm age on innovation activity is still an ambiguous topic subjected to discussion. Koch and Strotmann (2006) mention that innovative output is higher in younger firms than in older ones. However, it is lowest in the middle-aged (18-20 years) firms and rises again with an age of over 25 years. On the one hand, firms could lose their adaptability to the environment with an increasing age or, on the other hand, organisational aging increases innovativeness due to learning processes. Firm age is also measured in the year 2008 in our sample.

The competitive situation is another relevant driver of innovative activity. We created three dummy variables representing the number of main competitors in June 2009 according to the firms' self assessment. The first one includes zero to five competitors, the second one six to twenty competitors which is our reference category and the last one more than twenty competitors. The relationship between innovation and competition is supposed to look like an inverted U curve (Aghion et al. 2005). A monopolist has less incentives to innovate as he already enjoys a high flow of profit. In a competitive situation, there are less incentives to innovate if there is no possibility to fully reap the returns of the innovation (Gilbert 2006).

There are several reasons for taking prior innovation into account in our analysis. One of them is that innovative experience plays an important role in explaining innovations as successful innovations in the past lead to a higher probability for innovative success in the future (Flaig and Stadler 1994; Peters 2009). Another reason is a potential endogeneity bias our result might face, as it is not clear whether enterprise software leads to innovations or if innovative firms apply enterprise software merely as a diffusion channel for innovations. Both enterprise software variables were collected in June 2007 whereas the innovation variable was measured between June 2008 and June 2009. Accordingly, there is actually a time shift between the dependent and independent variable already forming a well-defined temporal sequence. Nevertheless, it is still possible that firms strategically purchased their enterprise systems in June 2007 or earlier simply for the diffusion of new innovated services starting out in June 2008. This may result in an upward bias of our estimated enterprise software coefficients.

However, by controlling for prior innovative activity we capture the overall innovativeness of a firm to some extent. If enterprise software shows no significant impact on today's innovation any more when controlling for prior innovation, we can expect that the software was employed only because the firm is already innovative. A significant impact of the enterprise software in this case, however, would point towards a causality running from the adoption of the software to the realisation of new service innovations as the employed software still has an impact on recent innovations with firms' overall innovativeness controlled for.[11] We use two dummy variables to control for prior innovations. The first one is prior service innovation that takes the value one if the firm realised at least one new or essentially improved service between March 2006 and March 2007. The second dummy variable is prior process innovation that takes the value one if the firm implemented new or essentially improved technologies during the same time period. We control for both types of prior innovations as service and process innovations are dynamically interrelated. In addition, we use nine industry sector dummies to control for industry-specific fixed effects.[12] A dummy variable for East Germany accounts for potential regional differences.

[11] The endogeneity bias due to commonly unobserved shocks affecting our sample as well as unobserved heterogeneity should also be reduced due to the large set of control variables we employ. However, without an available instrument we cannot exclude a potential bias completely.

[12] We picture the share of the industry classifications represented in our sample in detail in Table 3 in the Appendix. The most prominent industry branches in our sample are tax consultancies (17 percent) and architecture (16 percent).

2.6 Results

2.6.1 Main Results

Table 2 shows the average marginal effects of the probit estimation of equation (1).[13] In the first model specification we estimate the raw effect of both enterprise software types on service innovation. The results indicate that sector-specific software has no impact on service innovation. Firms using customised enterprise software instead seem more likely to innovate than firms which do not use this type of enterprise software. Based on a high significance level the probability to innovate is about 24.2 percentage points higher for firms using customised enterprise software.

In the second specification we include firm size, firm age and IT intensity. The impact of sector-specific and customised software on service innovation remains qualitatively unchanged in this specification suggesting that firms using customised software still face a probability of innovating that is 22.8 percentage points higher compared to firms not using this type of enterprise software. Furthermore, we observe that larger firms seem to have a higher probability of innovating as the marginal effect is significant at the five percent level. Firm age and IT intensity appear to have no effect on service innovation. The insignificant impact of IT intensity suggests that the significantly positive impact of customised enterprise software pictures not only an overall positive IT effect but the real effect of this type of enterprise software.

In the third specification further variables capturing competitive situation, qualification structure and age structure of employees are added. The impacts of both enterprise software systems do again not change compared to former specifications indicating that the probability of realising service innovations is higher for firms utilising customised software. Older firms seem less likely to innovate, based on an estimated marginal effect significant at the five percent level. The age structure of the workforce reveals some interesting results. Firms with a higher share of employees between 30 and 55 years as well as employees over 55 years are less likely to innovate compared to firms with a higher share of younger employees. The impact of employees between 30 and 55 years is significant at one percent while the impact of employees over 55 years is only significant at ten percent.

[13] Sample averages of the changes in the quantities of interest evaluated for each observation. Table 4 in the Appendix of Chapter 2 contains the coefficient estimates.

In the fourth specification, we include dummy variables measuring prior service and process innovations in our analysis. Based on a high significance level the average marginal effect suggests that the probability to innovate is larger for firms which have already realised service innovations in the past. The average marginal effect of customised software remains positive and significant proposing that customised software could indeed lead to service innovation instead of being employed simply because utilising firms are already innovative as argued in Section 2.5. However, the incorporation of former service innovation weakens the impact of customised software by reducing its significance level from one to five percent. In contrast to prior service innovations, prior process innovations seem to have no impact on current service innovations. The impact of firm age and employees between 30 and 55 years and employees over 55 years turns insignificant once we include former innovations into the estimation specification.

In summary, our results suggest that firms using customised enterprise software experience a higher probability of innovating compared to firms without this type of enterprise software or sector-specific enterprise software. This result stays robust across all specifications and supports our hypothesis that customised enterprise software applications tailored to specific firms' needs helps to enhance service innovation activity. Additionally, our results also indicate that sector-specific enterprise software solutions seem to have no impact on service firms' innovative performance.

2.6.2 Robustness Checks

To ensure the validity of our results obtained we also conduct several robustness checks.[14] First, as firms could adopt sector-specific in conjunction with customised enterprise software, we also estimate the model with an interaction term of the two enterprise software systems added. However, the interaction effect is not significant in all specifications and does not change the other results qualitatively.

The consideration of prior innovations reduces our sample to the very low size of 179 observations. Due to the insufficient panel structure, we decide to estimate all specifications with this reduced sample size as another robustness check to ensure that our results are not driven by observation loss.[15] As a further robustness check, we also esti-

[14] All tables of the regressions performed as robustness checks are available from the authors upon request.

[15] Table 5 in the Appendix of Chapter 2 pictures the results of this robustness check.

Table 2: Probit Estimation Results: Average Marginal Effects

	dependent variable: dummy for service innovation			
	(1)	(2)	(3)	(4)
sector-specific software	−0.055	0.026	−0.011	−0.003
	(0.060)	(0.064)	(0.073)	(0.081)
customised software	0.242***	0.228***	0.264***	0.182**
	(0.054)	(0.060)	(0.065)	(0.075)
log. firm size		0.047**	0.026	0.020
		(0.020)	(0.023)	(0.025)
log. firm age		−0.065	−0.150**	−0.098
		(0.055)	(0.063)	(0.072)
IT intensity		0.056	−0.065	0.063
		(0.110)	(0.131)	(0.155)
competitors $0-5$			−0.028	0.018
			(0.078)	(0.089)
competitors > 20			−0.055	−0.040
			(0.071)	(0.077)
highly qualified employees			0.026	−0.002
			(0.124)	(0.137)
medium qualified employees			0.018	−0.128
			(0.165)	(0.178)
employees $30-55$ years			−0.468***	−0.184
			(0.172)	(0.194)
employees > 55 years			−0.368*	−0.189
			(0.221)	(0.244)
prior service innovation				0.259***
				(0.080)
prior process innovation				−0.033
				(0.074)
dummies		Sector East	Sector East	Sector East
observations	336	298	240	179
pseudo R^2	0.046	0.103	0.147	0.206

Significance levels: *: 10%, **: 5%, ***: 1%.
Reference categories: competitors 6-20, unqualified employees, employees <30 years.

mate all specifications without the industry sector and regional fixed effects. The results regarding the use of sector-specific and customised enterprise software do not change qualitatively in all these robustness checks.

In order to further investigate the population of the reduced sample with 179 observations, we analyse some descriptive statistics and the distribution of the industry sector. Table 6 and 7 in the Appendix of Chapter 2 picture the corresponding results. The descriptive statistics in Table 6 show that there are no big differences in the population of the reduced sample compared to the whole sample. The mean values are very similar for all variables. Especially firm size and firm age deliver almost the same values. The most important variables which lead to slightly different mean values are the share of firms realising service innovations, the share of firms using customised enterprise software and the share of firms having realised process innovations in the past. For service innovations, the mean value of the reduced sample is about 0.36 compared to the mean value of the whole sample of 0.38. The share of firms using customised enterprise software is 0.42 in the reduced sample and 0.38 in the whole sample. The mean value of prior process innovations is 0.42 in the reduced sample in contrast to 0.44 in the whole sample. Nevertheless, these small differences do not affect the estimation results with the reduced sample qualitatively. The distribution of industry sectors in the reduced sample (see Table 7) does not show any big differences either compared to the distribution of the whole sample pictured in Table 3.

Our last robustness check covers the firm size in our sample. As it could be the case that especially some big enterprises drive the results we decide to restrict our sample to those enterprises with a number of employees at or below the mean in size for the complete sample, i.e. 37 employees or less. As this robustness check reduces our sample to 262 small and medium sized enterprises (SMEs) we estimate all specifications as before except the last one controlling for prior innovations. Adding prior innovations to this reduced sample results in a number of observations too small for the model to achieve convergence. The results generated from analysing our SMEs sample do not change qualitatively compared to the results obtained before. Accordingly, we suspect that big enterprises do not drive our empirical results indicating that customised enterprise software is useful for innovative activity in firms of any size class.

2.7 Conclusion

This paper analyses the relationship between different types of enterprise software systems and innovation in services. In the service sector, enterprise software is an essential tool for providing services. Therefore, it may represent a crucial contribution to a firm's innovation performance. We analyse the innovative impact of two different kinds of enterprise software, i.e. business sector-specific and completely customised enterprise software. In essence, sector-specific enterprise software is off-the-shelf software designed and standardised for certain industries whereas customised software is designed and adopted to the needs of a single firm thereby implying unique features. The analysis is based on a knowledge production function constituted by an innovation equation with data of German firms in ICT- and knowledge-intensive service sectors.

Our results suggest that ICT- and knowledge-intensive service firms using customised enterprise software that fulfills their specific requirements realise positive impacts in innovative activity. Firms using business sector-specific software on the other hand do not receive any positive impacts. The results stay robust to several specifications and robustness checks proposing that not only big enterprises drive this positive impact but SMEs may also realise gains in innovative performance. With customised enterprise software positively impacting firms' innovative performance our results support the technologist as well as the service-oriented approach of explaining service innovation as adopting recent ICT as well as exchanging information paired with improved knowledge handling drives service innovation.

However, it is important to mention here that customised enterprise software can only support service innovation if it is developed and applied properly, if the firm has complete knowledge of its organisational structure and processes and is aware of the goals it wants to achieve by using customised enterprise software. These facts ensure an enterprise software system that is perfectly suitable for all business requirements. Only given these circumstances, service firms are able to profit from the quick delivery of information, enhanced knowledge processing, the strengthened connections of information sources or reflection of all needed business processes customised enterprise software is linked to. Another benefit that arises for firms using customised enterprise software is the increased IT know-how, especially when developing the software themselves. This know-how is an essential tool for innovation which is especially useful to IT-intensive service providers as these firms could generate benefits out of it given that software development, for instance, is a major task in these industries.

In contrast, firms that use sector-specific enterprise software cannot exploit the benefits outlined. Although this type of enterprise software is very supportive by providing frequently updated databases or presenting information in an adequate manner, these advantages by themselves seem, based on our results, insufficient to support service innovation. Accordingly, relying on off-the-shelf software applications seems to be no adequate strategy when aiming for innovations.

However, the current study is not without its limitations, one of these being the establishment of a causality relationship as already mentioned above. Restrained to the available data, we also have no information about other unobserved factors potentially influencing the software adoption decision like management quality or implementation problems and costs of the enterprise systems installed. Accordingly, we have to use dummy proxy variables instead, possibly resulting in unobserved heterogeneity the estimation procedure cannot completely account for. Another aspect one should be aware of is the timing dimension. As our analysis is based on a lagged cross-section we are unable to picture long-term impacts of enterprise software on firms' innovation activity. However, as we argue in Section 2.3, these long-term impacts may possibly be negative as relying on the software might generate processes and solutions too homogenous to allow for worker creativity thereby hampering innovation activity. Future availability of new data might offer the opportunity to control even for the mentioned special cases of firm heterogeneity and allow to picture long-term impacts on innovation activity. Exploring in detail the determinants driving the adoption of different types of enterprise software forms another valid aim for future research.

2.8 Appendix Chapter 2

Questions:

1. Service Innovation: Did your firm introduce a new or essentially improved service during the last 12 months?

2. Enterprise Software: Which types of enterprise software are used within your firm?

The ZEW quarterly business survey among service providers of the information society includes the following industries (NACE Rev. 1.1 Codes of European Community in parenthesis): software and IT services (71.33.0, 72.10.0-72.60.2), ICI-specialised trade (51.43.1, 51.43.3-3.4, 51.84.0, 52.45.2, 52.49.5-9.6,), telecommunication services (64.30.1-0.4), tax consultancy and accounting (74.12.1-2.5), management consultancy (74.11.1-1.5, 74.13.1-3.2, 74.14.1-4.2), architecture (74.20.1-0.5) technical consultancy and planning (74.20.5-0.9), research and development (73.10.1-73.20.2) and advertising (74.40.1-0.2). Table 3 shows the distribution across industries in the sample of 336 observations.

Table 3: Distribution of Industries in the Sample

Industry	**Observations**	**Percentage**
software and IT services	43	12.80
ICT-specialised trade	33	9.82
telecommunication services	13	3.87
tax consultancy and accounting	56	16.67
management consultancy	37	11.01
architecture	54	16.07
technical consultancy and planning	34	10.12
research and development	38	11.31
advertising	28	8.33
sum	336	100

Source: ZEW Quarterly Business Survey among service providers of the information society, own calculations.

Table 4: Probit Estimation Results: Coefficient Estimates

	dependent variable: dummy for service innovation			
	(1)	(2)	(3)	(5)
sector-specific software	−0.151	0.078	−0.036	−0.022
	(0.164)	(0.191)	(0.226)	(0.277)
customised software	0.633***	0.630***	0.767***	0.586**
	(0.144)	(0.166)	(0.194)	(0.234)
log. firm size		0.139**	0.082	0.071
		(0.060)	(0.072)	(0.087)
log. firm age		−0.192	−0.463**	−0.337
		(0.164)	(0.201)	(0.251)
IT intensity		0.166	−0.203	0.216
		(0.325)	(0.405)	(0.531)
competitors $0-5$			−0.088	0.063
			(0.245)	(0.300)
competitors > 20			−0.170	−0.136
			(0.219)	(0.263)
highly qualified employees			0.082	−0.008
			(0.383)	(0.468)
medium qualified employees			0.058	−0.438
			(0.512)	(0.610)
employees $30-55$ years			−1.445***	−0.629
			(0.554)	(0.667)
employees > 55 years			−1.136	−0.646
			(0.692)	(0.839)
prior service innovation				0.816***
				(0.250)
prior process innovation				−0.114
				(0.259)
constant term	−0.426***	−0.410	1.794*	0.520
	(0.156)	(0.667)	(0.929)	(1.119)
observations	336	298	240	179
pseudo R^2	0.046	0.103	0.147	0.206

Significance levels: *: 10%, **: 5%, ***: 1%.

Reference categories: competitors 6-20, unqualified employees, employees <30 years.

Table 5: Probit Estimation Results: Average Marginal Effects, Reduced Sample

	dependent variable: dummy for service innovation			
	(1)	(2)	(3)	(4)
sector-specific software	−0.040	0.007	−0.001	−0.003
	(0.079)	(0.083)	(0.084)	(0.081)
customised software	0.290***	0.250***	0.239***	0.182**
	(0.071)	(0.074)	(0.074)	(0.075)
log. firm size		0.030	0.026	0.020
		(0.025)	(0.026)	(0.025)
log. firm age		−0.167**	−0.158**	−0.098
		(0.069)	(0.072)	(0.072)
IT intensity		0.108	0.096	0.063
		(0.139)	(0.157)	(0.155)
competitors $0 - 5$			0.048	0.018
			(0.094)	(0.089)
competitors > 20			−0.014	−0.040
			(0.078)	(0.077)
highly qualified employees			0.007	−0.002
			(0.142)	(0.137)
medium qualified employees			−0.065	−0.128
			(0.181)	(0.178)
employees $30 - 55$ years			−0.285	−0.184
			(0.199)	(0.194)
employees > 55 years			−0.279	−0.189
			(0.251)	(0.244)
prior service innovation				0.259***
				(0.080)
prior process innovation				−0.033
				(0.074)
dummies		Sector	Sector	Sector
		East	East	East
observations	179	179	179	179
pseudo R^2	0.071	0.145	0.157	0.206

Significance levels: *: 10%, **: 5%, ***: 1%.

Reference categories: competitors 6-20, unqualified employees, employees <30 years.

Table 6: Summary Statistics of Reduced Sample

Variable	**Mean**	**Min.**	**Max.**	**N**
service innovation	0.357	0	1	179
sector-specific software	0.754	0	1	179
customised software	0.424	0	1	179
number of employees	39	1	449	179
log (number of employees)	2.672	0	6.107	179
firm age	20	4	108	179
log (firm age)	2.849	1.386	4.682	179
0-5 competitors	0.229	0	1	179
6-20 competitors	0.329	0	1	179
more than 20 competitors	0.441	0	1	179
share of employees working with PC	0.799	0.01	1	179
share of highly qualified employees	0.424	0	1	179
share of medium qualified employees	0.153	0	1	179
share of low qualified employees	0.373	0	1	179
share of employees younger than 30 years	0.181	0	1	179
share of employees between 30 and 55 years	0.652	0	1	179
share of employees older than 55 years	0.159	0	1	179
prior service innovation	0.418	0	1	179
prior process innovation	0.418	0	1	179
East Germany	0.376	0	1	179

Source: ZEW Quarterly Business Survey among service providers of the information society, own calculations.

Table 7: Distribution of Industries in the Sample

Industry	**Observations**	**Percentage**
software and IT services	24	12.80
ICT-specialised trade	16	9.82
telecommunication services	4	3.87
tax consultancy and accounting	34	16.67
management consultancy	18	11.01
architecture	36	16.07
technical consultancy and planning	16	10.12
research and development	16	11.31
advertising	15	8.33
sum	179	100

Source: ZEW Quarterly Business Survey among service providers of the information society, own calculations.

3 Why Adopt Social Enterprise Software? Impacts and Benefits*

Abstract

This paper explores the performance impacts and benefits of the adoption of social enterprise software (SES). SES forms a nested innovation, given that its adoption requires an already established infrastructure of information and communication technology. To control for induced sample selection, we use a two-step estimation procedure. Based on German firm-level data our results confirm that firms which use business-to-business (B2B) e-commerce applications are more likely to adopt SES. The estimated correlations also provide weak evidence for complementarity between B2B e-commerce and SES. We show that two measures of firm performance, i.e. sales and labour productivity, are highest for firms using SES and B2B e-commerce applications in conjunction.

Keywords: adoption of ICT, social enterprise software, nested innovation, complementarity
JEL-Classification: D00, L10, O31

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3.1 Introduction

In recent years, social software, e.g. wikis, blogs, microblogs or social networks, has increasingly appeared in both public dialogues and press releases. Social software is already extensively used in private households and increasingly adopted by firms. As for firms, more than 80 percent of the top 100 companies in the Fortune 500 maintain a presence on social network sites (Gartner 2012). However, currently a new type of business software is emerging, which interrelates recent social software and firms' established enterprise systems, e.g. Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Customer Relationship Management (CRM). This so called social enterprise software (SES) links firms' enterprise software systems and social software applications as in, e.g., social CRM solutions.

Overall, SES offers benefits in the areas of business-to-customer (B2C) and business-to-business (B2B). For B2C, SES supports tracking data from customer surveys, customer feedback, reviews or user profiles on social networks or blogs, thereby enabling firms to identify new customers, new market segments and observe recent trends. SES packages additionally feature various communication channels allowing for a two-way interaction between companies and their customers, by offering them a direct channel for providing their feedback. With specific customer data collected and direct customer interaction SES might facilitate the development of new products as it allows firms to observe customer tastes and build up meaningful customer profiles.

In the B2B segment benefits of SES emerge in form of enhanced collaboration and communication as employees and partners are connected in a way they can exchange information fast and freely. Stakeholders have real-time access to all areas they are interested in and can monitor and directly access interactions and inputs of others. SES further enhances process management and knowledge sourcing as knowledge consumers, like sales teams, can access information from knowledge providers, like product developers, in real-time saving time for each employee. With partners and clients of the utilising firm connected, the benefits of SES are not limited to the boundary of the firm but may spread on to other business contacts.

Up to now there are no empirical studies on the emerging phenomenon of SES although these software packages began to come up in 2008 (Chess Media Group 2010). Consequently, as SES is still an uncertain new technology in its infancy state, empirical evidence about determinants of its adoption and its potential impacts on firm performance is still lacking. Also, up to now it is still unclear which distribution segment, i.e. B2B or B2C, benefits the most once SES is adopted.

We aim at filling this research gap by empirically evaluating the determinants of SES adoption and exploring its impacts on firm performance. In the analysis, we distinguish between benefits and impacts in the area of B2B and B2C. Our analysis is based on a unique database consisting of German manufacturing and service firms. Since SES requires a firm to first adopt particular information and communication technology (ICT) before it can upgrade them to SES, it represents a so-called "nested innovation" (Greenstein and Prince 2007). This "nested" structure induces sample selection which has to be taken appropriately into account in the estimation procedure.

Our study adds to the empirical literature in a number of ways. To our knowledge we are the first to explore the performance impacts of most recent SES and investigate the determinants of its adoption. Second, considering that ICT might act as complements (Aral et al. 2012) or even substitutes (Kretschmer et al. 2012) in their impact on performance our results offer a weak test for complementarity based on correlations between the usage of established ICTs, i.e. B2B e-commerce applications, and the adoption of most recent ICTs, i.e. SES. Third, our paper presents a valid empirical method with which to model the data generating process in the case of a "nested innovation", i.e. the probit with sample selection (Berinsky 2004; Gourieroux and Jasiak 2007)

Our results show that firms using B2B e-commerce applications are more likely to adopt SES. B2C e-commerce applications fail to impact the adoption decision. The estimated correlations also provide weak evidence for complementarity between B2B e-commerce applications and SES. Concerning impacts on firm performance, we show that mean sales and labour productivity are highest for firms using SES and B2B e-commerce applications in conjunction.

The paper proceeds as follows: Section 3.2 summarises the empirical literature of ICT, its complementarities and performance impacts and explains SES, its classification as a "nested" ICT innovation and its benefits. Section 3.3 presents the dataset whereas Section 3.4 highlights the empirical model. Section 3.5 provides a detailed explanation of the selected exogenous variables and the necessary exclusion restriction. The estimation results and additional robustness checks used to clarify the validity of the results are presented in Section 3.6. Finally, Section 3.7 concludes.

3.2 Background

3.2.1 Complementarities in and Performance Impacts of Information and Communication Technology

In general, ICT is expected to enable productivity and performance gains by supporting the optimization of firms' business processes (Brynjolfsson et al. 2000). Such performance gains are often documented for IT-intensive firms (Brynjolfsson et al. 2003). Thus, there is firm-level based evidence of performance impacts for many different measures of IT-intensity, e.g., the usage of B2B e-commerce applications (Bertschek et al. 2006), different enterprise software systems (Hitt et al. 2000; Shin 2006; Aral et al. 2006) or broadband internet (Bertschek et al. 2012). As for the impact of ICTs on innovation as a crucial prerequisite for productivity gains (Hall et al. 2009), empirical analyses at the firm level usually report positive and significant impacts (Gera and Gu 2004; Hempell et al. 2008; Engelstätter 2012; Engelstätter et al. 2013). Still, the returns of ICT are not the same for all firms as there are substantial variations shown across firms (Brynjolfsson et al. 1995). These variations are most likely due to performance premiums which firms with higher returns on ICT realise as they adopt complementary organisational practices (Bresnahan et al. 2002; Caroli et al. 2001; Aral et al. 2007; Bloom et al. 2008). However, not only organisational practices might complement ICTs in their impact on performance. Recent ICT applications might act as complements among themselves regarding their impact on firm performance (Aral et al. 2012; Engelstätter 2013) or even function as substitutes (Kretschmer et al. 2012).

Although expected, potential performance impacts of recent SES have not yet been explored at all. Offering benefits in the areas of B2C and B2B this new kind of business software might as well form complementary benefits regarding its impact on firm performance with already established B2C or B2B e-commerce software solutions. Therefore, we examine performance impacts, potential complementarities with established e-commerce applications and the determinants of SES adoption.

3.2.2 Social Enterprise Software: Benefits, Complementarities and Impacts

In general, SES links and combines the firms' established enterprise software systems with its social software applications in use. Thereby, SES seems particularly useful for managing customer relations, e.g., a so-called social CRM system can directly implement and exploit data and information from customer surveys, commentaries, reviews or user profiles on social networks or blogs. If these data are processed via SES, the firm can monitor recent trends and customer demands quickly, helping with the elaboration of sales forecasts, market development expectations or the development of new products. Appropriate targeting of customers based on their interests, so-called hyper-targeting (Shih 2010), also becomes feasible. SES systems can add value back to the customer as they offer different channels like email, instant messaging or chat applications for him to interact with the firm. Direct customer feedback on their ideas, wants, and needs may also contribute to the development of new or improved products and services or the observation of new trends and purchase intentions (Gartner 2012). In addition, the established two-way interaction between the customer and the firm via SES might allow engaging with non-traditional industry influencers like bloggers, independent analysts and customers passionate about brands (Chess Media Group 2010) resulting in a positive attitude towards the firm's products potentially attracting more customers. However, communication channels like blogging or profile pages in social networks also provide platforms for visible critique or customer displeasure. Accordingly, if firms do not attend and manage the direct contact to the customer properly, open communication may end up in a social media disaster which could in severe damage of the brand as experienced by, e.g., South West Airlines (McCarthy 2010a) or Nestle (McCarthy 2010b).

Overall, not only firms focused on private customers will benefit from the adoption of SES, as utilising firms will also receive benefits in collaboration, communication, knowledge sourcing, innovation, social linkages or process management (blueKiwi 2011). Collaboration and communication are particularly enhanced, given that employees and partners are connected so that they can exchange information in real-time with no boundaries through the cloud. With applications like, e.g., many-to-many communication, task management, idea sharing or document co-creation continued engagement of contributing individuals is assured, especially as stakeholders can see and directly access interactions and inputs of others. As for knowledge sourcing and process management, SES enhances both as knowledge consumers, e.g. a sales team, can access information from knowledge providers, e.g. product experts, rapidly and in real-time which saves time for each employee resulting in more efficient processes (blueKiwi 2011). Because partners and clients of the utilising firm are also connected, these benefits are not limited to the boundaries of the firm but may spread out to other business contacts, thereby greatly enhancing B2B effectiveness. As every stakeholder, may it be a complete team or an individual, can access each discussion he takes an interest in at any time, appropriate experts on each topic will meet, and thereby most likely germinate ideas, fostering process or even product innovations.

In sum, SES is not necessarily bounded to facilitating and enhancing the area of B2C, but also enables numerous improvements in the B2B segment of firms. Given its benefits in B2C and B2B, one can expect that firms will exhibit complementary benefits once they add SES to their B2B or B2C e-commerce solutions. However, it remains unclear nowadays which segment benefits the most if firms adopt SES. Nevertheless, there is first evidence that the potential benefits of SES seem to be more interesting for B2B as up to today 15 percent of companies engaged in B2B e-commerce already implemented SES (Gartner 2012). This number is expected to grow up to 70 percent by 2014 (Gartner 2012). In our analysis, we identify complementarities of SES and a particular e-commerce solution as we explore if either established B2B or B2C e-commerce applications drive the adoption decision.

Even though SES applications are expected to benefit firms in various areas, no empirical studies have yet established whether these benefits translate into increased firm performance, e.g. increased sales or productivity. Most likely, with SES being a very recent technology just on its way to embark on the diffusion process, this research gap is due to lacking data availability. Given our data, we are unable to present an all-embracing final analysis of the performance impacts of SES over time. However, as our data features the firms' sales and labour productivity as contemporaneous performance measures we start filling this research gap by offering first descriptive and correlation based evidence.

3.2.3 The Process of Adopting Social Enterprise Software

A firm can implement SES in two ways, by either linking its enterprise and social software already in use with the appropriate SES upgrade or via installing a full SES solution providing the complete software without prior experience with enterprise or social software. Chronologically, the possibility of linking both applications via the appropriate software upgrade occurred first. Installing a complete solution was offered later for firms newly starting out in the adoption of ICT infrastructure or for firms wanting to change their service provider or vendor. With upgrades, enterprise and social software must already exist before SES can be used making SES a "nested innovation". With "nested innovations", one primarily adopts a prerequisite tool, e.g. a personal computer, and builds the more advanced tool, e.g. internet usage, upon the existing infrastructure (Greenstein et al. 2007). As explained in Section 3.4, we model this nested structure empirically using a Heckman (1979) selection model.

Although potentially profitable, the adopting firm bears some costs of enhancing its current ICT infrastructure with SES. In general, costs occur per user making it possible even for smaller firms to adopt SES. Heck (2009) provides an overview of pricing schemes and cost levels of some SES providers. However, researchers still have to have the costs in mind when focusing on the adoption of SES and should adequately control for each firm's ICT budget situation.

3.3 Description of Data

The dataset used in this study stems from two computer-aided telephone surveys conducted in 2007 and 2010 by the Centre for European Economic Research (ZEW). These ZEW ICT surveys lay a specific focus on the diffusion and use of ICT in German companies. In addition, the surveys contain detailed information about the firms' economic characteristics and performance, e.g. qualification or age structure of the workforce, competitive environment, innovation performance, exports and e-commerce. Usually, the interviewee was the chief executive officer of the firm, but he could also decide to pass on questions to a corresponding employee, e.g., the head of the ICT department. Each wave of this dataset originally contains information of about 4400 firms with five or more employees, representatively chosen from service and manufacturing sectors in Germany.

The ZEW ICT surveys are organised as a panel dataset. However, as the question on the usage of SES was first included in the survey in 2010, a panel data analysis cannot be provided in this paper. Thus, we employ a cross-section which consists of a combination of the survey waves conducted in 2007 and 2010 for inference. Combining these two surveys is necessary as we need a well-defined temporal sequence between the usage of SES and appropriate prior experience. We explain the selection of these variables in detail in Section 3.5.

For this study, we construct a dummy variable measuring the adoption of SES which takes the value one if a firm establishes a link between its enterprise systems in use and its employed social software applications in the year 2010 and zero otherwise. This dummy variable represents the dependent variable in our analysis. The questionnaire was structured such that only firms who already have established social software and enterprise software were asked if they link both software types. Accordingly, we presume that the firms adopt SES in the form of an upgrade of their existing software infrastructure and not as a completely new solution. This assumption is strengthened as 92% of the firms that reported using enterprise software in 2010 had already used enterprise software in 2007. If these firms adopt SES they most likely use the appropriate upgrade.

In order to analyse the adoption of SES, we built three dummy variables for the usage of social software applications, the usage of enterprise software systems and the usage of both social software and enterprise software in the year 2010. The dummy variable representing the use of social software applications takes the value one if at least one social software application such as a blog, wiki, social network, collaboration platform, podcast, RSS-feed or tagging is used in the year 2010. Figure 2 shows that at least one social software application is employed by about 40 percent of the firms. The dummy variable for the usage of enterprise software systems, on the other hand, takes the value one if a firm uses at least one of the enterprise software systems ERP, CRM or SCM and zero otherwise. Nearly 80 percent of the firms use at least one of the mentioned enterprise software applications, see Figure 2.[16] Furthermore, about one third of the firms employ both social software and enterprise software applications. SES is adopted by about 22 percent of all firms.[17]

[16] Overall, a share of 80 percent of the surveyed firms using enterprise software seems quite high. However, one has to keep in mind that enterprise software has been available for more than thirty years now resulting in a vast reduction of complexity and making recent applications useful even for smaller firms. Also, there are nowadays cheap applications available like open source or freeware solutions and software as service applications in the cloud. Hence, even small firms with a restricted budget can adopt enterprise software.

[17] Given these adoption rates we cannot exclude the possibility that our analysis only features early adopters with SES being widely diffused and perhaps used by nearly every firm in several years.

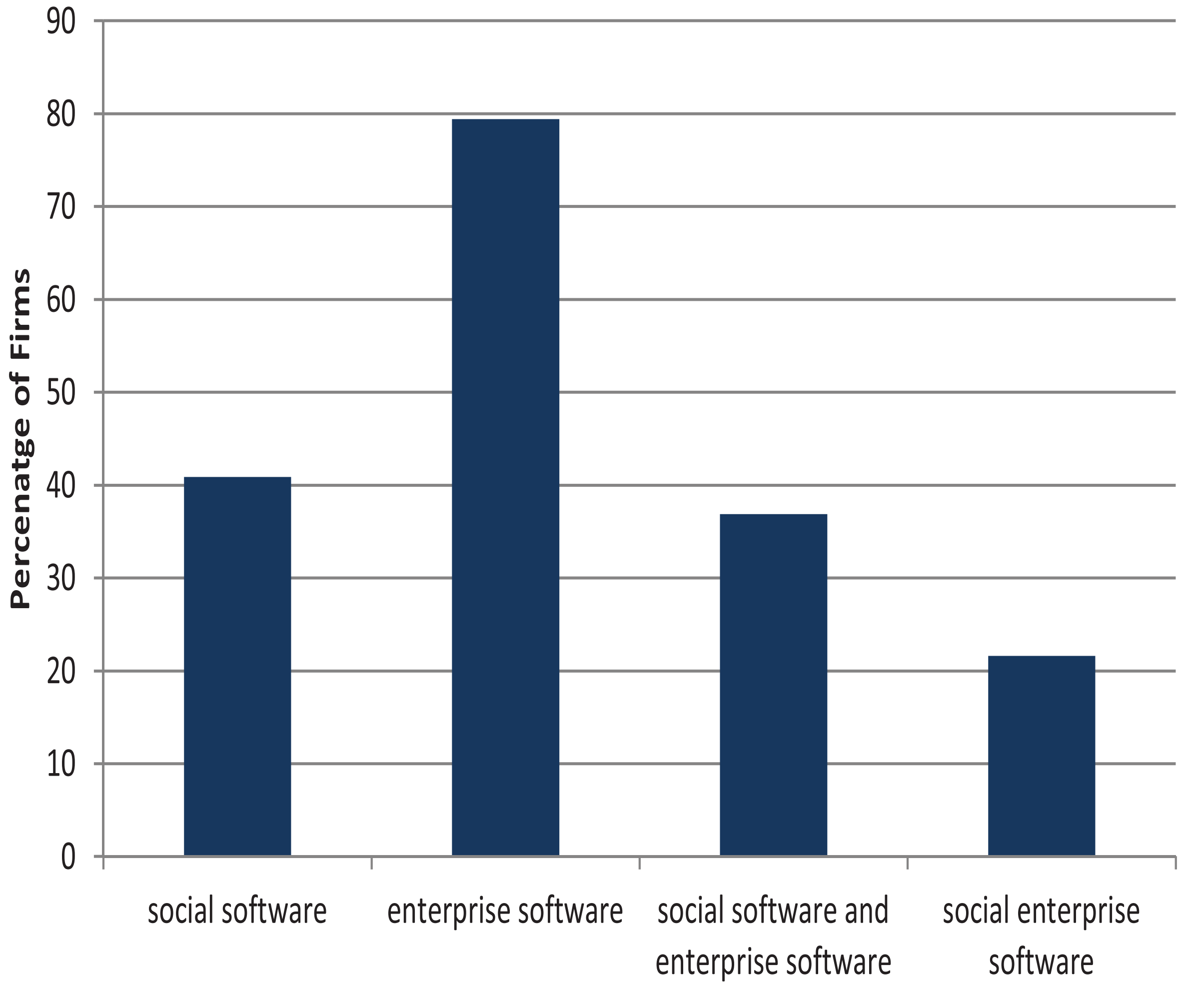

Figure 2: Use of Software Applications

Note: ZEW ICT Survey 2010, own calculations, 1523 observations, descriptive statistics.

3.4 Analytical Framework and Estimation Procedure

As our dataset only contains firms suspected to upgrade their existing ICT infrastructure to SES we face sample selection in our analysis. First, firms have to decide about using both social software and enterprise software applications. In a second step firms then decide to link both software types, i.e. upgrading them to SES. This "nested innovation" structure with one prerequisite innovation needing to be adopted before the next innovation can be used results in a two stage decision process. We model this structure adequately as we employ the Heckman selection model (Heckman 1979) for inference in our empirical analysis. The first part of the decision process is modeled by the selection equation

$$ES_i^* = X_i\beta_1 + ID_i\beta_2 + Z_i\beta_3 + \epsilon_i \qquad ES_i = 1 \text{ if } ES_i^* \geq 0; ES_i = 0 \text{ otherwise} \tag{2}$$

with ES_i^* being a latent variable reflecting the use of both social software applications and enterprise software for firm i. Both types of software applications are used by firm i but not linked with each other at this point in time. X_i contains firm characteristics expected to influence the decision of firm i to use social software and enterprise software, e.g. lagged innovation activity, firm size, characteristics of the workforce or ICT intensity. ID_i includes common control dummies for business sector and East Germany. Z_i reflects the necessary exclusion restriction needed to identify the model. We assume a standard identically and independently distributed error term.

As the selection equation (2) shows which firm characteristics foster the unlinked use of social software applications and enterprise software, the next step will be to explain the firms' decision to link both software types via SES. We model the second part of the decision process being the outcome equation as

$$SES_i^* = X_i\gamma_1 + ID_i\gamma_2 + u_i \qquad SES_i = 1 \text{ if } SES_i^* \geq 0; SES_i = 0 \text{ otherwise} \tag{3}$$

where SES_i^* is the unobserved latent variable accounting for the usage of social enterprise software for firm i. In the outcome equation, we use the same explanatory variables X_i as in the selection equation without the mentioned exclusion restriction. u_i is again a standard identically and independently distributed error term.

Equations (2) and (3) are estimated via maximum likelihood. As ES_i and SES_i are both variables reflecting a binary choice we use a probit with sample selection (Berinsky 2004; Gourieroux et al. 2007), the so called heck-probit, as the estimation procedure for the Heckman selection model. The probit structure of our employed model also provides a test for complementarity based on its observed correlations (Aral et al. 2012). The employed explanatory variables as well as the exclusion restriction and their temporal sequence are explained in detail in the following section.

3.5 Selection of Exogenous Variables and Exclusion Restriction

In exploring if firms perceive more benefits of SES in the B2B or the B2C segment our main explanatory variables for explaining the adoption of SES are the usage of B2B or B2C e-commerce practices. We measure the usage of either B2B or B2C by two dummy variables, each one taking the value one if a firm adopted the appropriate e-commerce practice in the year 2007. However, the first SES solutions were available in 2008 (Chess Media Group 2010). Before that enterprise and social software were only obtainable separately. The adoption of e-commerce practices in 2007 occurred before SES adoption was possible providing a clear temporal relation between our two e-commerce explanatory variables and SES. We elaborate more on the upcoming of social software and SES as we explain our exclusion restriction at the end of this section.

The adoption of SES will most likely not only be determined by adopted e-commerce practices. Therefore, we add a number of additional control variables to our analysis. As SES fosters innovation activity due to enhanced communication and information handling, already innovative firms may install SES to further increase their innovation performance. Overall, SES can also be interpreted as a process innovation itself based on its provided knowledge sourcing and process management capabilities. Thus, firms already successful in realising process innovations might be more likely to engage in SES, experiencing the "success breeds success" phenomenon (Flaig and Stadler 1994) with successful innovations yielding more innovations in the future. In our analysis, we control for success in innovations in the form of two dummy variables. Each dummy variable takes the value one if a firm realised at least either one product or process innovation during 2007 to 2009 and zero if no innovation was realised. We feature both types of innovations as controls in our analysis as product innovations and process innovations are often interrelated (Hall et al. 2009).

We control for typical firm characteristics expected to drive the adoption of a new technology like, e.g., firm size (Bertschek et al. 2002). However, with SES being a rather new technology, its adoption and usefulness might also depend on the availability of appropriate human capital (Lo et al. 2010) or a younger workforce (Meyer 2010). We measure firm size by the logarithm of the number of employees in the year 2009. As for the availability of human capital, we consider the qualification structure of the workforce by creating three control variables: the share of highly qualified (holding a university or university of applied science degree), medium qualified (technical college or vocational qualification) and low qualified (other) employees measured in the year 2009. The share of low qualified employees is taken as the reference category. Additionally, we control for the age structure of the work force with three different variables. The first one represents the share of employees younger than 30 years, the second one the share of employees between 30 and 50 years (reference category) and the third one the share of employees over 50 years. The age structure of employees refers to the year 2009.

Aghion et al. (2009) stress the impact of the competitive environment on the incentives to adopt innovations. As adopting SES could also be interpreted as a process innovation itself we additionally control for competitive pressure in our analysis. We employ three dummy variables capturing the number of main competitors in the year 2009 according to the firms' self-assessment as additional controls. The first variable indicates 0 to 5 competitors, the second one 6 to 50 competitors (reference category) and the last one more than 50 competitors. We also control for international competition and trade activity as a driver of technology adoption (Bertschek 1995). We measure the trade activity of firms by a dummy variable that takes the value one if the firms exported or imported goods or services during the year 2009.

We also include some general controls that might affect the adoption of SES, e.g., ICT budget constraints or business sector classification. Since the adoption of SES might induce substantial costs the firm has to bear, we control for the firms' ICT budget by taking the expenditures for ICT (components plus staff) per employee in the year 2009 into account in our analysis. Another part of the firms' ICT budget is captured in ICT outsourcing measured as the share of ICT expenditures allotted to external service providers during the year 2009. We employ the logarithm of the expenditure measures to make this measure comparable to the number of employees measure. We also capture an additional workforce characteristic common for German firms in the general controls, i.e. the establishment of a works council. Such a council enables employees to participate in the decision making (Zwick 2003), for example, the decision to adopt huge sophisticated software applications and presents a proxy for firm strategy and aims. In addition, we use dummy variables to control for 17 business sector-specific effects. A dummy variable for East Germany accounts for potential regional differences.

An appropriate exclusion restriction requires an explanatory variable which is highly correlated with the selection variable but is not correlated to SES adoption. The exclusion restriction we use is ICT training measured as the share of employees who received specific ICT-related training in the year 2006. We expect this exclusion restriction to be correlated with the common use of social software and enterprise software but showing no correlation with the linkage of both software types. Firms engaging in ICT training in the year 2006 might do so to get first insights into the use of social software applications and possibly prepare the use of these software applications at a later point in time. Social software applications were a new technology in the year 2006, especially for private users, and not yet broadly adopted by firms. Thus, ICT training would have been necessary for firms' adoption of social software applications. Firms' adoption of new enterprise software systems usually also requires ICT training as these systems are sophisticated and it is hardly possible to adopt and use them properly without appropriate training. SES applications, however, arose in 2008 for the first time (Chess Media Group 2010). Accordingly, we can discard the possibility that SES may be part of the ICT training measures conducted by the firms in 2006. This timing argument allows us to conclude that our ICT training measure is not correlated to the adoption decision and represents a suitable exclusion restriction in our empirical setup.

For an overview, Table 8 presents the summary statistics for all variables, including endogenous and exogenous variables as well as the exclusion restriction. We also include the firms' sales and labour productivity of 2009 as mentioned in Section 3.2 in Table 8. Table 9 pictures all 17 industry sectors our data stems from.

Table 8: Summary Statistics

Variable	**Mean**	**Min.**	**Max.**	**N**
social enterprise software	0.216	0	1	1523
enterprise software	0.794	0	1	1516
social software	0.409	0	1	1458
social software and enterprise software	0.369	0	1	1521
number of employees	245.71	1	45000	1523
log (number of employees)	3.701	0	10.714	1523
share of highly qualified employees	0.247	0	1	1408
share of medium qualified employees	0.596	0	1	1406
share of low qualified employees	0.105	0	1	1413
share of employees younger than 30 years	0.216	0	1	1415
share of employees between 30 and 50 years	0.554	0	1	1420
share of employees older than 50 years	0.230	0	1	1425
B2B e-commerce	0.556	0	1	1514
B2B e-commerce	0.266	0	1	1515
0-5 competitors	0.431	0	1	1523
6-50 competitors	0.311	0	1	1523
more than 50 competitors	0.257	0	1	1523
trade activity	0.600	0	1	1518
prior product innovation	0.557	0	1	1505
prior process innovation	0.632	0	1	1510
ICT outsourcing	0.358	0	1	1183
ICT expenditures per employee (in 1000 €)	629.06	0.004	300000	1195
log. ICT expenditures per employee	0.919	-5.480	12.611	1195
works council	0.302	0	1	1517
East Germany	0.328	0	1	1523
ICT training 2006	0.140	0	1	1458
sales (in 1000000 €)	86.13	0.030	15.000	1161
labour productivity (sales per employee in 1000000 €)	0.273	0.012	13.333	1161

Source: ZEW ICT Survey 2007, 2010 and own calculations.

Table 9: Distribution of Industries in the Sample

Industry	**Observations**	**Percentage**
Manufacturing		
electrical engineering	172	11.29
consumer goods	129	8.47
metal and machine construction	103	6.76
precision instruments	93	6.11
other raw materials	89	5.84
chemical industry	73	4.79
automobile	68	4.46
Services		
wholesale trade	93	6.11
retail trade	79	5.19
transportation and postal services	117	7.68
banks and insurances	39	2.56
computer and telecommunication services	140	9.19
technical services	95	6.24
real estate und leasing services	37	2.43
management consultancy and advertising	42	2.76
media services	118	7.75
services for enterprises	36	2.36
sum	1523	100

Source: ZEW ICT Survey 2007, 2010 and own calculations.

3.6 Results

3.6.1 Main Results

Table 10 contains our main estimation results for the selection equation (2) and the outcome equation (3) in two different specifications. In the first specification, we estimate the model with a parsimonious set of baseline variables representing firm characteristics like firm size, qualification and age structure of the workforce, the competitive situation, an established works council and B2B as well as B2C of e-commerce applications. In the second specification of Table 10, we augment the baseline specification with additional controls like trade activity, ICT budget, prior innovation success as well as business sector and regional dummies. In general, the two-step model is well specified as the selection parameter Rho is significant in both specifications. Concerning the exclusion restriction, the coefficient estimate of ICT training is positive and also highly significant in both specifications.

Overall, the estimation results show that the usage of B2B e-commerce positively and significantly affects the probability of SES adoption. B2C e-commerce practices fail to impact the decision to adopt SES. The same pattern also holds for the selection equation. As for other controls, significant drivers of the adoption of SES are firm size, a high share of young and highly qualified workers, activity in trading and prior success in process innovations.[18] Overall, similar firm characteristics drive the adoption of social and enterprise software in the selection equation. The most prominent differences between the selection and the adoption equation emerge in the positive and highly significant effect of ICT budget and firm size on the selection probability. This may indicate that, despite available low cost solutions, the adoption of enterprise software might still be subject to budget constraints with larger firms being potentially more capable of bearing the initial fixed costs of adoption.[19] Also, for larger firms the tools of SES to enhance and improve communication might be more useful as efficient communication schemes are difficult to obtain given the high number of employees in numerous different areas and departments.

In the outcome equation nearly all significant coefficients of both regression specifications translate to significant marginal effects as shown in Table 11. As for our main explanatory variables, firms that use B2B e-commerce practices face a probability of adopting SES which is about 14 respectively 11 percentage points higher compared to firms not employing these applications.

The estimated coefficients in our probit approach generate pairwise correlations and provide, if positive, weak evidence for complementarity between the drivers of the adoption and the adoption itself. Thus, our results suggest that B2B e-commerce adoption form

[18] The share of highly qualified workers only shows a significant impact in specification 2, but is nearly significant in specification 1. Both coefficients translate to significant marginal effects.

[19] A simple probit checking for a positive correlation between the probability to adopt enterprise software and ICT budget as well as firm size shows highly significant positive coefficient estimates confirming this presumption. These estimations are available from the authors upon request.

a complementarity system with SES adoption. No such evidence arises for B2C. In sum, our results indicate that firms perceive more complementary benefits from SES in the segment of B2B compared to the area of B2C. However, without sufficient measures available in our data which picture the development of firm performance over time we cannot stress the suggested complementary relationship any further.

Additionally, to validate the robustness of our results we conduct several different checks focusing on different estimation techniques.[20] We estimated both specifications using the classical two-stage heckman selection model. As expected, the results remain qualitatively similar with only marginal changes in coefficients and standard errors. Ignoring a possible selection bias, we also estimated a simple probit model to explain SES adoption and take only those firms into account that use both enterprise software and social software. Overall, the results remain mostly the same compared to the heck-probit although the coefficients are less precisely estimated. Using B2B e-commerce applications still forms a highly significant driver of SES adoption. However, some coefficients that are based on a lower significance level in our main estimation, especially prior process innovation success, fail to reach significance in this robustness check. All other coefficients keep their level of significance and sizes. Being appropriately careful in case of a potential bias we repeat our estimations, i.e. the heck-probit and the simple probit, using standard errors obtained via bootstrap (50 replications) and find no mentionable coefficient changes. We also conduct a likelihood ratio test comparing the models with and without selection. As expected, we reject the null hypothesis of the simple probit model (p-value less than 0.01) in favor of the heck-probit. Thus, we conjecture, based on these checks, that a simple probit model seems to produce biased results as it does not appropriately model the data generating process in the case of a selection based on a "nested innovation".

[20] All regressions conducted as robustness checks are available from the authors upon request.

Table 10: Bivariate Probit with Sample Selection: Coefficient Estimates of Selection Equation

dependent variable: dummy for usage of social and enterprise software				
	Specification 1		Specification 2	
	Selection Equation	Outcome Equation	Selection Equation	Outcome Equation
log. firm size	0.302***	0.127*	0.283***	0.091
	(0.030)	(0.066)	(0.042)	(0.102)
highly qualified employees	1.009***	0.622	1.062***	0.775*
	(0.250)	(0.408)	(0.288)	(0.412)
medium qualified employees	0.262	0.094	0.365	0.219
	(0.225)	(0.376)	(0.259)	(0.380)
employees < 30	0.375	0.887***	0.332	1.003**
	(0.236)	(0.338)	(0.280)	(0.488)
employees > 50	0.013	0.358	0.064	0.322
	(0.227)	(0.355)	(0.262)	(0.383)
B2B e-commerce	0.353***	0.415***	0.325***	0.411***
	(0.085)	(0.126)	(0.097)	(0.128)
B2C e-commerce	0.057	0.124	0.098	0.148
	(0.096)	(0.136)	(0.112)	(0.151)
competitors $0-5$	−0.156*	0.070	−0.185*	0.140
	(0.092)	(0.132)	(0.104)	(0.185)
competitors > 50	−0.145	−0.035	−0.025	0.013
	(0.108)	(0.159)	(0.126)	(0.162)
prior product innovation			0.181*	0.098
			(0.102)	(0.143)
prior process innovation			0.436***	0.310**
			(0.099)	(0.141)
trade activity			0.315***	0.390***
			(0.112)	(0.151)
ICT outsourcing			−0.192	0.047
			(0.154)	(0.226)
log. ICT expenditures			0.065***	0.036
per employee			(0.024)	(0.033)
constant	−2.372***	2.332***	−2.582***	−2.664***
	(0.373)	(0.732)	(0.429)	(0.765)
exclusion restriction:	0.657***		0.410**	
ICT training 2006	(0.174)		(0.212)	
controls	Industry, Work Council		Industry, Work Council, Region	
Rho	0.691 (0.268)		0.872 (0.308)	
LR-Test (Rho=0)	3.01*		3.27*	
num. of obs. (cens/uncensored)	1305 (852/453)		1042 (672/370)	

Significance levels: *: 10%, **: 5%, ***: 1%.
Reference categories: competitors 6-20, unqualified employees, employees 30–50 years.
Source: ZEW ICT Survey 2007, 2010 and own calculations.

Table 11: Bivariate Probit with Sample Selection: Average Marginal Effects

dependent variable: dummy for social enterprise software (outcome equation)		
	(1)	(2)
log. firm size	0.043***	0.025
	(0.016)	(0.022)
highly qualified employees	0.210*	0.216**
	(0.125)	(0.104)
medium qualified employees	0.032	0.061
	(0.126)	(0.103)
employees < 30	0.299**	0.280
	(0.138)	(0.201)
employees > 50	0.121	0.090
	(0.128)	(0.119)
B2B e-commerce	0.138***	0.112**
	(0.043)	(0.049)
B2C e-commerce	0.042	0.043
	(0.049)	(0.050)
competitors $0-5$	0.024	0.039
	(0.046)	(0.061)
competitors > 50	-0.012	0.004
	(0.053)	(0.046)
prior product innovation		0.027
		(0.037)
prior process innovation		0.084**
		(0.036)
trade activity		0.105*
		(0.055)
ICT outsourcing		0.013
		(0.065)
log. ICT expenditures per employee		0.010
		(0.008)
controls	Industry, Works Council	Industry, Works Council, Region
observations	1305	1042

Significance levels: *: 10%, **: 5%, ***: 1%.

Reference categories: competitors 6-50, unqualified employees, employees 30–50 years.

3.6.2 Potential Performance Impacts of SES

In Table 12, we present a first exploration of potential firm performance impacts of SES by taking a deeper look at the mean of two measures of firm performance, i.e. sales and labour productivity, for firms using SES together with B2B or B2C applications. Forming additional descriptive evidence Table 12 also reports the correlation to sales for the respective groups of firms. Overall, mean sales and mean labour productivity are highest for firms using SES and B2B applications together. As for correlations, SES usage and especially the usage of SES applications together with already established B2B applications feature a significant correlation with firm sales.[21] The correlation for SES together with already established B2C practices in use fail to reach significance. Corroborating our conjectures that B2B e-commerce and SES usage act as complements, the highest performance means as well as the highest correlation coefficient to sales manifests for firms which use SES as well as B2B applications.

Table 12: Impacts of SES–Correlations and Descriptive Evidence

	Mean of Sales (in €1000000)	Mean of Labour Productivity (sales per employee in €1000000)	Correlation to Sales (pairwise correlation coefficient)
SES in general	253.46	0.289	0.135***
SES and B2B e-commerce usage	369.46	0.301	0.144***
SES and B2C e-commerce usage	202.51	0.206	0.020

Significance levels: *: 10%, **: 5%, ***: 1%.
Source: ZEW ICT survey 2007, 2010 and own calculations.

We can, however, offer no further causal analyses here. Any regressions of SES adoption on sales or labour productivity would be heavily biased due to endogeneity and measurement error as the firms' SES adoption refers to 2010 with sales and labour productivity being reported for 2009. Also, performance impacts of SES will most likely need time to emerge and can therefore only be identified once new long-term data is available.

[21] The same pattern also holds for the correlation to labour productivity. However, we decided only to report the correlation to sales for convenience.

3.7 Conclusion and Discussion

Based on the most recent German firm-level data, our study provides insights into the benefits of adopting the most recent business software, i.e. SES. We estimate a heck-probit using ICT training as an exclusion restriction to model the adoption of SES appropriately as a "nested innovation". We find that the usage of B2B e-commerce leads to the adoption of SES. The adoption of B2C e-commerce shows no impact on the adoption decision. The estimated correlations in our model provide weak evidence for a complementary relationship between B2B e-commerce usage and SES. Our results remain robust to several model specifications and estimation procedures. For descriptive evidence of performance impacts of SES we additionally explore correlations to and the mean of firm sales for SES, B2B and B2C users. The results show that the correlation and the mean are highest for firms using SES and B2B e-commerce application in conjunction.

Overall, our results have several implications. First, based on our evidence of complementarity between B2B e-commerce and SES adoption, the benefits of SES in the B2B segment seem to outweigh the benefits in the B2C area. Secondly, although descriptive, we confirm these results offering first evidence of positive performance impacts of SES, which seem to be particularly high for firms who adopt SES in addition to already established B2B e-commerce solutions. Third, modeling the data generating process in case of SES adoption as a "nested innovation" adequately takes the selection process into account resulting in biased coefficients otherwise. Overall, as B2C seems to not benefit from SES overall, we conjecture that for firms the potential benefits of SES do, at this stage, not outweigh the potential costs of a possible social media disaster as mentioned in Section 3.2. However, exploring this issue in detail we have to pass on to further research as our data does not permit us to stress this any further.

Our analysis faces a few potential short-comings which are primarily related to data constraints and unobserved heterogeneity. As stated before, our analysis of any performance impacts of SES must be interpreted very carefully as the analysis is merely descriptive. These results need to be stressed and investigated further once new long-term data including firm performance measures are available. Besides that, we do not observe management decisions of the surveyed firms as we only take an established works council into account. It may be the case that some firms simply adopt new technologies because they want to be on the fast lane in terms of technology, sending out a positive signal. A part of this phenomenon may be captured in the ICT expenditures we control for as those firms can be expected to spend more money on ICT in comparison to firms which are not as prone to the technology frontier. Availability of new data might do away with this potential drawback. Furthermore, our exclusion restriction is not without concern about its exogeneity. It may be the case that ICT intensive firms invest more in ICT training and expect their trained employees to adopt and utilise SES more eagerly. As SES solutions are sophisticated software tools, even particularly eager employees may not be able to utilise the software according to its full potential without specific training. However, as such additional training and further education is definitely not captured in our exclusion restriction general ICT training, we expect the aforementioned eagerness to produce a bias of negligible magnitude.

4 Does Social Software Increase Labour Productivity?*

Abstract

Social software applications such as wikis, blogs or social networks are being increasingly applied in firms. These applications can be used for external communication as well as knowledge management, enabling firms to access internal and external knowledge. Firms can potentially increase their productivity by optimising customer relationship management, marketing and market research as well as project management and product development. This paper analyses the relationship between social software applications and labour productivity. Using firm-level data of 907 German manufacturing and service firms, this study examines if these applications have a positive impact on labour productivity. The analysis is based on a Cobb-Douglas production function. The results reveal that social software has a negative impact on labour productivity. They stay robust for different specifications and alternate measure for social software.

Keywords: social software, Web 2.0, social software intensity, labour productivity
JEL-Classification: L10, M20, O33

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4.1 Introduction

A large range of web-based applications, which are also known as Web 2.0 applications, are not only extremely prevalent in the private internet usage, but are furthermore increasingly applied in firms. Social software is a particular category of Web 2.0 applications that serves to facilitate communication, cooperation and information sharing between individuals. Examples for social software applications include wikis, blogs, social networks or instant messaging. The common feature of all social software applications is that they are supposed to be self-organised, transparent and potentially make the communication process more efficient by interconnecting users and their knowledge. Thus, their use might lead to a wide array of benefits for firms.

Social software can be applied by firms either for external or for internal purposes. It helps strengthen external communication with other firms and thereby improves customer relationship management, marketing and market research. In addition, the access of external knowledge plays a crucial role when using social software. The second field in which social software can be utilised is internal knowledge management. Used as a knowledge management tool, social software can facilitate internal communication. This may result in more efficient knowledge and project management, as well as product development. A possible consequence of the usage of social software is greater flexibility, as firms can operate faster leading to more efficient time management and thus to a higher labour productivity. In addition, the application of social software is more cost-saving for the firms than the application of content management systems (Raabe 2007).

Apart from that, social software can be used to support e-commerce within a firm by opening up new communication channels with customers (Döbler 2008). Firms have the opportunity to achieve business deals at a faster pace and more efficiently. Based on these various benefits for firms, social software has the potential to increase labour productivity. However, there are only few studies analysing this relationship empirically.

The already established studies on social software and firm performance are either theoretical or descriptive and find ambiguous impacts. Kaske et al. (2012) reveal in a study that firms can profit from social media resulting in higher customer retention, better communication with customers and sales increases. Thus, a positive return on investment is at least achievable by using social media. Ferreira and du Plessis (2009) describe explicitly social networking as a technology that increases collaboration between individuals who share a common interest or goal leading to knowledge sharing with the possible effect of increased productivity. At the same time they note the risks associated with social networking which are, for instance, the loss of privacy, bandwidth and storage space consumption, and exposure to malware. The consequence might be lower employee productivity.

Coker (2011) finds a positive effect of social software on labour productivity. Employees who frequently take short breaks during their work time to surf the internet for private purposes are more productive than those who do not. The reason for that might be that employees feel a greater autonomy at their workplace by having the opportunity to use the internet privately which increases employees' motivation. Moreover, private internet surfing during work time results in a better concentration of employees by taking short breaks from work. In contrast, Peacock (2008) emphasizes the so-called shirking effect which has a negative influence on labour productivity as social software rather distracts employees from their work. Van Zyl (2009) also finds that social software applications might affect employee productivity in a negative way when employees spend too much time using these applications for private purposes.

Using data from 907 German firms belonging to the manufacturing industry and the service sector, this paper tests the hypothesis whether the usage of social software applications increases labour productivity. As analytical framework, I employ a Cobb-Douglas production function with social software being an input in the production process. The production function is estimated by ordinary least squares (OLS) and instrumental variable (IV) regression to reduce the potential endogeneity of social software. The instrumental variables for the IV-regression are the private use of wikis, blogs and social networks by the interviewees.

The results reveal that social software has a negative impact on labour productivity. These results stay robust to different specifications controlling for several sources of firm heterogeneity like firm size, IT intensity, qualification and age structure, export activity, e-commerce as well as training of employees and consulting. The negative effect of social software on labour productivity points towards a suboptimal usage among employees caused for instance by the shirking effect. In addition, several robustness checks such as an alternative measure for social software confirm the results.

The paper is organised as follows: Section 4.2 provides an overview of the literature on social software and derives the main hypothesis. Section 4.3 describes the database whereas Section 4.4 presents the analytical framework and establishes the estimation approach. The estimation results and several robustness checks to clarify the validity of the results are presented in Section 4.5. Finally, Section 4.6 concludes and gives an outlook on further possibilities for research.

4.2 Background Discussion and Hypothesis Derivation

This section classifies the present paper into the literature and provides a definition of social software applications as well as an overview of the theoretical and empirical studies concerning social software and labour productivity. This paper is related with the literature on the productivity impact of information and communication technologies (ICT). Kretschmer (2012) provides a survey on the relationship between ICT and productivity and concludes that ICT has a positive and robust impact on firms' productivity which is increasing over time. ICT has to be embedded in complementary organisational investments in order to lead to productivity gains. My analysis fits into this literature since social software is one type of ICT applications. Thus, the current analysis departs form the literature by focusing specifically on social software as ICT application and thus investigating whether or not the impact on labour productivity is consistent with the general literature.

The applications named social software are a rather new phenomenon and are often referred to as Web 2.0 applications. Summarising the existing literature on social software reveals that social software encompasses web-based applications which connect people and support communication, interaction and cooperation as well as information sharing (e.g. Raabe 2007, Back and Heidecke 2012) and thus harness collective intelligence (O'Reilly 2005). It uses the potential, contributions and knowledge of a network of participants (Back and Heidecke 2012). Beck (2007) argues that social software has had a profound effect by changing the nature of efficiency of communication processes in both business and private life. Social software is supposed to be self-organised, transparent and should support social feedback (e.g. Hippner 2006, Raabe 2007). Social software applications are for instance wikis, blogs, web forums (discussion forum, internet forum), instant messaging services (Skype), social bookmarking, podcasts and social networks sites like Facebook or LinkedIn. Nielson (2010) mentions that social media account for nearly one quarter of all internet activity in the USA in the year 2010.

Within a firm, social software can be applied for different purposes. On the one hand, it can be used to strengthen external communication with other firms and partners or enhance customer relationship management, marketing and market research (Döbler 2007; Raabe 2007). In line with that, firms have access to external knowledge by using social software (Döbler 2008). On the other hand, it can be utilised for internal purposes as a knowledge management tool to facilitate internal communication, including for example knowledge and project management or product development. Information sharing and communication between employees, customers and business partners can be faster and more efficient in these areas by using social software. Knowledge sourcing, which is closely related to knowledge management, is essential for the productivity of firms. Kremp and Mairesse (2004) find that different knowledge management practices such as information sharing and internal and external knowledge acquisition contribute to the innovative performance and productivity of firms in a positive way.

Social software applications can impact labour productivity of firms in various different ways. Koch and Richter (2009) provide an overview of various case studies among firms concerning the usage of social software. They picture different implementation fields for social software and describe the possible benefits emerging for firms in case social software is efficiently adopted. Firms have greater flexibility and can operate faster by using social software compared to the usage of content management systems which serve similar purposes. A content management system is a special type of software that enables users to jointly create, edit and organise content such as web sites as well as text documents or multimedia files. The positive aspects of social software may make firms even more productive as being faster and more flexible results in a better time management leaving more time capacities for other work. Furthermore, firms using social software applications face lower costs as their adoption and usage in firms is usually cheaper compared to content management systems (Döbler 2008). The consequence of lower costs is also a higher labour productivity.

Döbler (2008) mentions another important aspect of social software that might influence labour productivity. Social software can be utilised as a tool supporting e-commerce in a firm. It opens up new communication channels with customers leading faster and more efficiently to business deals. Moreover, e-commerce can be integrated into social software applications allowing customers to directly purchase firms' products via social software. Combining e-commerce and social software applications might lead to more purchases in the same time span and thus to a higher labour productivity. Bertschek et al. (2006) show that B2B e-commerce has a positive impact on labour productivity.

Having all capabilities of social software in mind as well as the different ways of contributing to an improvement of labour productivity, I hypothesise that its usage might increase labour productivity in a firm. While the literature on this topic is either theoretical or descriptive, this study analyses this subject using firm-level data.

A few previous studies investigated the usage of social software and its impact on firm performance. A study by McKinsey Quarterly (2009) describes the impact of social software on labour productivity as an S curve. At the beginning of the adoption process, labour productivity does not increase or only slightly. Not until several years later, labour productivity starts to rise very fast before reaching a higher level and slowing down again afterwards. A further study conducted by McKinsey (2010) indicates that Web 2.0 usage in firms increases their performance as those firms are more likely to gain market share and higher profit margins. The reason for that is that Web 2.0 ensures more flexible processes inside the firm as the information flow is optimised and thus management practices are less hierarchical.

Ferreira and du Plessis (2009) provide a descriptive analysis about online social networking with an ambiguous impact on employee productivity. On the one hand, they describe social networking as a technology that can be used to increase collaboration between individuals who share a common interest or goal. The increased collaboration between employees in a firm leads to knowledge sharing with the possible effect of increased productivity. On the other hand, they note the risks associated with social networking such as loss of privacy, bandwidth and storage consumption, exposure to malware, possibly leading to lower employee productivity.

Kaske et al. (2012) analyse the benefits of social media usage in firms for the return on investment by comparing different case studies. The results reveal that firms can indeed profit from social media resulting in higher customer retention, better communication with customers and sales increases. Thus, a positive return on investment is at least achievable by using social media.

Aguenza et al. (2012) analyse the impact of social media on labour productivity based on a conceptual overview of empirical studies concerning this topic. They find ambiguous effects investigating different studies. The first study is conducted by Coker (2011) and shows that employees who frequently take short breaks during their work time to surf the internet for private purposes are more productive than those who do not. The reason for that might be that employees feel a greater autonomy at their workplace by having the opportunity to use the internet privately which increases employees' motivation. Moreover, private internet surfing during work time results in a better concentration of employees by taking short breaks from work.

A theoretical study conducted by Wilson (2009) concludes that social software enables organisations to extend their business opportunities by finding new customers and thus increasing sales. In addition, it can help monitoring new trends by collecting information. Firms are able to extend their product or service offers which may also boost sales. Social software also acts as an application tool to recruit new employees. This might contribute to higher labour productivity. Nevertheless, several other studies included in the overview of Aguenza et al. (2012) found the opposite result. For instance, Peacock (2008) mentions the so-called shirking effect as a negative influence on labour productivity as social software could distract employees from their work. The shirking effect could thus have a negative impact on labour productivity. Van Zyl (2009) addresses the shirking effect in a theoretical study on social networking in firms as well. Social software applications as wikis, blogs and social networks might affect employee productivity in a negative way when employees spend too much time using these applications for private purposes instead of work-related.

Meyer (2010) investigates the relationship between social software and innovation activity among service firms. The empirical study shows that service firms experience higher innovation activity if they rely on social software applications. The result is consistent with a descriptive study conducted by Andriole (2010). The study shows that the social software application wiki improves knowledge management, customer relationship management and innovation more than all other social software applications. A large amount of literature claims that innovation activity is a prerequisite for productivity gains and thus innovative firms experience a higher level of labour productivity (see for example Crépon et al. 1998 or Hall et al. 2009).

The summary of the studies on the possible effects of social software on labour productivity support the hypothesis of a positive impact of social software on labour productivity. Nevertheless, there are also hints that the use of social software might have the opposite effect on labour productivity under certain conditions.

4.3 Description of Data

The dataset used in this study stems from two computer-aided telephone surveys conducted in 2007 and 2010 by the Centre for European Economic Research (ZEW). These ZEW ICT surveys lay a specific focus on the diffusion and use of ICT in German companies. In addition, the surveys contain detailed information about the firms' economic characteristics and performance such as the qualification or age structure of the workforce and other characteristics like exports and e-commerce. In general, the interviewee was the chief executive officer of the firms who could decide to pass on questions to a corresponding employee like the head of the ICT department. Each wave of this dataset originally contains information of about 4.400 firms with five or more employees, representatively chosen from various service and manufacturing sectors in Germany.[22] The selection from the population of German firms was stratified according to seven branches of the manufacturing industry and ten service sectors, to five employment size classes and to two regions being East and West Germany.[23]

The ZEW ICT surveys are organised as a panel dataset. As the questions on the usage of social software were included for the first time in the last survey of 2010, a panel data analysis cannot be provided in this paper. Thus, I employ a specific cross-section which consists of a combination of the survey waves conducted in 2007 and 2010 for inference. Combining these two surveys is necessary as I need a well-defined temporal sequence between the dependent variable labour productivity and the explanatory variables to minimize potential endogeneity problems. The variables collected in 2010 mostly refer to the year 2009 and the variables of the wave of 2007 to the year 2006. Matching the data of both waves and considering item non-response for social software, sales, labour and investments leads to 907 observations.

[22] The data set used for this analysis is accessible at the ZEW Research Data Centre: `http://kooperationen.zew.de/en/zew-fdz/home.html`

[23] Table 17 in the Appendix of Chapter 4 contains the distribution of industries in the sample.

Total sales and the number of employees are needed to construct labour productivity. There are no data available to measure the physical capital stock of the firm. Thus, I use gross investment in the year 2009 as a proxy for the capital stock. Bertschek et al. (2006), for example, also use this method in their study.

The data refers to the use of social software in the year 2010. In order to capture this usage, the firms were offered a list of different applications and they were asked if they use them. The firms had the opportunity to answer the question for every application with either yes or no. With this information, I construct a dummy variable for the usage of social software which takes the value one if at least one of the following social software application is used in the year 2010: wiki, blog, social network or collaboration platform. This dummy variable represents the main explanatory variable of my empirical analysis.

The fact that social software was partly adopted later than total sales and the number of employees were measured leads to a problem for my analysis as social software should be adopted before labour productivity is measured. To ensure at least the same time period for the adoption of social software and sales as well as the number of employees, I drop all observations in which social software was introduced in the year 2010 leaving only firms which introduced social software until the year 2009 in the sample. Overall, only 10 observations were dropped. All other explanatory variables are related to the years 2007 and 2006.

An alternative measure for the usage of social software I use in this study is the so-called social software intensity of the firms. It measures how many different social software applications are used by the firms taking values from 0 to 4. One major drawback of this variable is that it does not measure how much time the employees spend on using them. It measures only the variety of these applications used by the firms and thus the openness of the firms towards social software. I use social software intensity as a robustness check to analyse the effects of variety and openness towards social software on labour productivity.

Table 13 shows the descriptive statistics for the variables included in the production function. The average sales amount in 2009 results in € 63.13 mio. while the average firm size is about 170 employees. Labour productivity is calculated as the ratio of total sales to the total number of employees and takes an average value of € 0.22 mio. For 2009, the mean gross investment is about € 2.03 mio. Comparing firm size and gross investments with the values of the year 2006, I observe that both values were higher in the past. The average firm size in 2006 was 190 while gross investments amounted to about € 3.07 mio on average. One possible explanation for the decrease of both values might be the financial crisis that arose in the year 2008.

Table 13: Summary Statistics

Variable	**Mean**	**Min.**	**Max.**	**N**
sales 2009 (in mio)	63.13	0.03	15000	907
number of employees 2009	170	1	25000	907
log. number of employees 2009	3.56	0	10.13	907
investments 2009 (in mio)	2.03	0	500	907
log. investments 2009	-1.92	-8.52	6.21	907
labour productivity 2009	0.22	0.01	13.33	907
log. labour productivity 2009	-2.13	-4.46	2.59	907
number of employees 2006	190	1	35000	907
log. number of employees 2006	3.56	0	10.46	907
investments 2006 (in mio)	3.07	0	600	907
log. investments 2006	-1.53	-6.90	6.40	907
share of firms using social software in 2009	0.33	0	1	907
social software intensity 2009	0.48	0	4	904
share of employees with PC 2007	0.47	0	1	903
share of export sales 2006	0.13	0	1	898
share of high qualified employees 2006	0.22	0	1	882
share of medium qualified employees 2006	0.60	0	1	880
share of low qualified employees 2006	0.12	0	1	881
share of employees < 30 years 2006	0.23	0	1	887
share of employees $30 - 50$ years 2006	0.57	0	1	886
share of employees > 50 years 2006	0.20	0	1	887
share of firms using B2B e-commerce 2007	0.56	0	1	905
share of firms using B2C e-commerce 2007	0.25	0	1	905
share of firms with training 2006	0.81	0	1	905
share of firms with consulting 2006	0.68	0	1	905
share of firms in East Germany 2010	0.37	0	1	907

Source: ZEW ICT Survey, own calculations.

The descriptive statistics of the usage behaviour of the firms concerning social software are pictured in Table 14. About 33 percent of the firms use at least one of the above mentioned social software applications in 2009. The most frequently used applications are collaboration platforms which are used by about 16 percent of the firms. 14 percent of the firms employ social networks while wikis are used by about 13 percent of the firms. 11 percent of the firms use blogs. These descriptive numbers indicate that social software is rather applied for communication and cooperation purposes, as applications which serve these aims are slightly more common. The average number of social software applications used by the firms, which represents social software intensity, is about 0.48.

The data set contains information on the interviewee's private usage of social software. This variable was measured by asking the interviewed person, the CEO in most cases, if he or she currently uses wikis, blogs or social networks in private life. Table 14 indicates that 42 percent of the interviewed persons use at least one of these social software applications privately. Thus, the private usage is slightly more diffused than the usage in the firm. Social networks are used by about one third of the interviewed persons privately while the second most frequently used application privately are wikis used by 20 percent of the interviewed persons. Private blogs are only used by 12 percent. The intensity of the private usage shows hardly any difference compared to the usage within the firm. The average number of applications that are used privately is also 0.62. Figure 3 illustrates the above mentioned descriptive statistics.

Table 19 in the Appendix of Chapter 4 pictures the correlation structure between the social software applications used in the firm and privately. The strongest correlations between the various social software applications are between social networks and blogs used in the firm as well as collaboration platforms and wikis with correlation coefficients of 0.55 and 0.34 respectively. Concerning the private usage of social software, the usage of wikis and blogs exhibit the highest correlation with a correlation coefficient of 0.31.

Table 14: Descriptives: Use of Social Software Applications

Variable	Mean	N
social software 2009	0.33	907
social software intensity 2009	0.48	907
wiki 2009	0.13	907
blog 2009	0.11	907
social network 2009	0.14	905
collaboration platform 2009	0.16	906
private use of social software 2010	0.42	902
intensity of private use of social software 2010	0.62	897
private use of wiki 2010	0.20	902
private use of blog 2010	0.12	902
private use of social network 2010	0.31	904

Source: ZEW ICT Survey, own calculations.

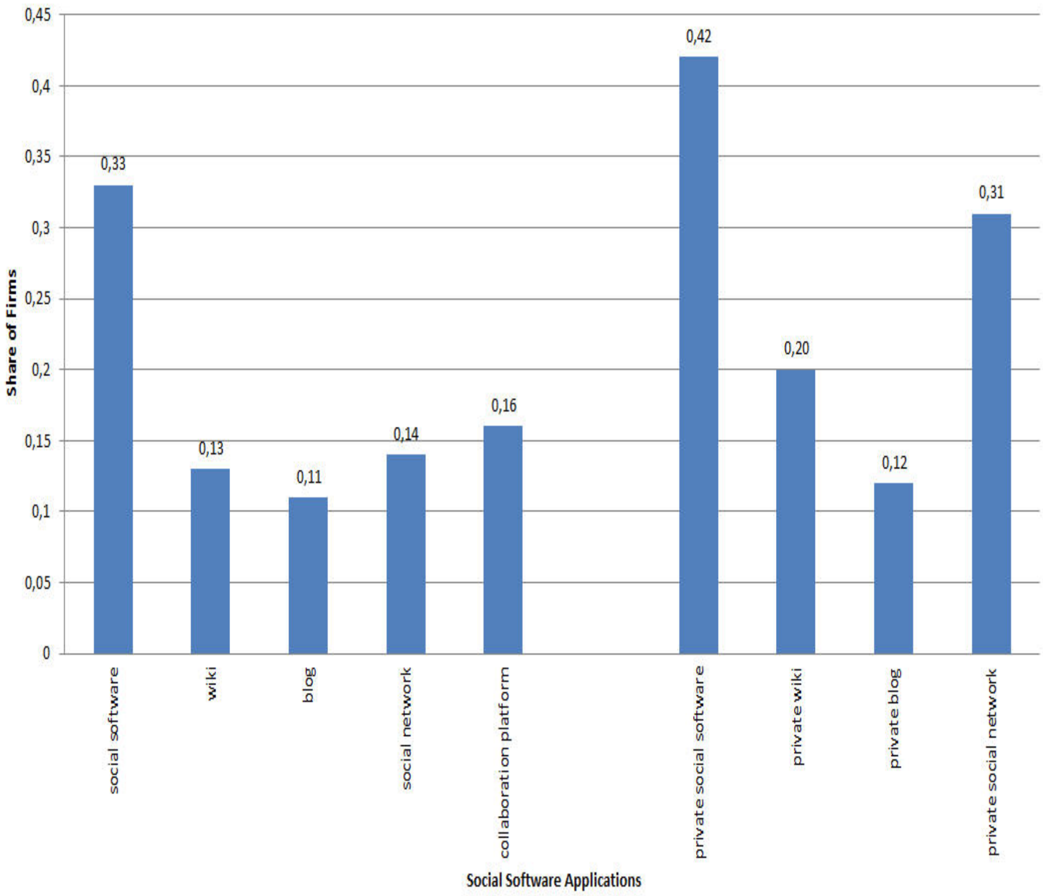

Figure 3: Use of Social Software Applications in the Firm and Private Usage

Note: ZEW ICT Survey 2010, own calculations.

Exploring the relationship between social software and labour productivity descriptively in detail, I first compare the difference between labour productivity for firms using social software and for firms which do not use this type of software. The comparison (see Table 18 in the Appendix of Chapter 4) shows that labour productivity for firms using social software is about 0.20 while it is about 0.24 for firms not using social software. This points to a small difference in productivity. Descriptively, firms using social software face a lower labour productivity than firms not using it. In a second step, I analyse how the usage of social software is related to different firm characteristics. Table 18 shows these relationships. Firms that are engaged in training of employees, consulting, B2B e-commerce, B2C e-commerce and export activity have a slightly lower labour productivity when they use social software than firms not using these applications. A remarkable difference occurs especially for B2C e-commerce. Firms not using any type of social software have a labour productivity that is 15 percentage points higher while using B2C e-commerce at the same time than firms using social software. The descriptive analysis hints at a negative relationship between social software and labour productivity.

4.4 Analytical Framework and Estimation Procedure

In order to investigate the impact of social software usage on labour productivity, I assume that a firm i produces according to a production technology. The production process of the firm i is represented by a function $f(.)$ that relates the inputs of the firm to the output:

$$Y_i = f(A_i, L_i, K_i, S_i) \tag{4}$$

where Y_i denotes the output of firm i. The inputs are capital and labour (K_i, L_i) as well as social software (S_i). The parameter A_i measures total factor productivity and reflects the efficiency of production. In order to specify the production technology, I assume a Cobb-Douglas production function. Social software enters the logarithmic version of the function in a linear way. The error term denoted by ϵ_i is assumed to be independent and identically distributed

$$ln(Y_i) = ln(A_i) + \alpha ln(K_i) + \beta ln(L_i) + \gamma S_i + \epsilon_i. \tag{5}$$

In econometric estimations labour productivity measured by the logarithm of sales per employee is used as a dependent variable:

$$ln\left(\frac{Y_i}{L_i}\right) = ln(A_i) + \alpha ln(K_i) + (\beta - 1)ln(L_i) + \gamma S_i + \epsilon_i. \tag{6}$$

I estimate the model first by a common OLS estimation and afterwards by an instrumental variable regression with robust standard errors in order to instrument labour and gross investments in 2009 with their values in 2006 to reduce potential endogeneity. The fact that the usage of social software and labour productivity are both measured in the year 2009 could also lead to an endogeneity problem. It might be the case that already successful firms are more inclined to use social software pointing towards a reverse causality. To account for the potential endogeneity of this explanatory variable I also run the estimation with social software instrumented by the private use of wikis, blogs and social networks.

There are three reasons why the private usage of social software applications by interviewees are valid instruments for the usage within the firm. The first one is that both types of usage exhibit a high correlation which is necessary for instrumenting (see Table 19 in the Appendix of Chapter 4). The interviewed person who is the CEO of the company in most cases has the power to introduce social software applications in the firm if he or she had good experiences with the private usage and expects benefits from the usage in the firm. The second reason is that the private usage of social software is exogenous from the firms' point of view. The last reason is that the private usage has a similar variability like the usage of social software in the firms and thus sufficient explanatory power.

For the econometric analysis, I add some further control variables which might also have an impact on labour productivity. The controls comprise different firm characteristics such as IT intensity, export activity, qualification and age structure of employees, e-commerce, training, consulting, as well as region and industry dummies. The following section describes the measures of all variables used in the estimations.

Starting out with the explanatory variables, I measure labour and thus firm size by the logarithm of the number of employees in the year 2006. There is no information about the capital stock of the firms in the data. Thus, I consider gross investments in euro of the year 2006 as proxy for capital.

I proxy the IT intensity of the firms by the share of employees working with a computer in the year 2007. At the same time this variable measures workers' technological skills (Bertschek et al. 2010). In general, a higher IT intensity leads to higher labour productivity. Draca et al. (2007) indicate that ICT has a positive and robust impact on firms' productivity.

I also consider the qualification structure of the workforce by creating three control variables: the share of highly qualified (university or university of applied science), medium qualified (technical college or vocational qualification) and low qualified (other) employees measured in the year 2006. The share of low qualified employees is taken as the reference category. I expect a higher labour productivity in firms with a higher share of highly qualified employees as a certain high level of education is necessary to perform more productively. Hempell (2003) shows that the educational level contributes directly to productivity.

Three variables control for the age structure of employees. The first one represents the share of employees younger than 30 years, the second one the share of employees between 30 and 50 years (reference category) and the third one the share of employees over 50 years. The age structure of employees was measured in the year 2006. It is important to include the age structure of employees in the model as there might be differences in productivity for different age categories. The ability to process information and adapt to new situations decreases with age while verbal competence and experience increase (see Börsch-Supan et al. 2006). Bertschek et al. (2009) found that employees younger than 30 years are less productive than prime age workers between 30 and 50 years.

I measure the export activity of the firms by a variable that comprises the share of export sales of the firms during the year 2006. Several studies show that exporting firms are more productive than otherwise identical firms (see Bernard et al. (2007) for the U.S.; Mayer et al. (2007) for European countries and Fryges et al. (2008) for an analysis of exports and profitability in German firms). Wagner (2011) provides a survey of empirical studies that were done on the topic of international trade and firm performance since 2006.

The usage of e-commerce is measured by two dummy variables, each of them taking the value one if a firm applies business-to-business or business-to-consumer e-commerce respectively and zero otherwise. Both e-commerce applications were measured in the year 2007. Bertschek et al. (2006) found a positive impact of B2B e-commerce on labour productivity in German firms when B2B e-commerce is accompanied by ICT-investment. Firms' labour productivity is thus enhanced by using B2B e-commerce.

I include training of employees measured by the share of employees who received training in the year 2006 in my analysis. ICT training is included in this variable. Training is important for firms as ICT investments are often complemented by changes in the contents and the organisation of workplace. These changes require a continuous update of employees' skills. Hempell (2003) shows that firms boosting training of employees after investing in new ICT perform significantly better concerning labour productivity.

Another relevant aspect contributing to labour productivity is consulting. Therefore, I include in the empirical analysis a variable controlling for consulting in general which also includes IT consulting. Cerquera (2008) highlights a positive impact of IT consulting on firms' observed productivity.

In addition, dummy variables control for industry-specific fixed effects and sector-specific variation in labour productivity. A dummy variable for East Germany accounts for potential regional differences. East German firms are generally less productive than West German firms.

4.5 Results

4.5.1 Main Results

Table 15 shows the results of the OLS estimation of equation (6). In the first specification I include only labour and capital measured in the year 2007 in the estimation equation. While capital is positive and highly significant, the coefficient of labour is not exactly plausible. It is rather small and insignificant showing the incorrect sign as well. This points towards increasing returns to scale, but could also point to potential endogeneity of this variable. In the second specification I add the dummy variable for social software to the estimation equation. The relationship of social software and labour productivity is not significant indicating that social software has no effect on labour productivity. The coefficients of labour and capital remain qualitatively unchanged.

In the third specification, labour productivity is regressed on production input factors, social software, IT intensity, export activity as well as age and qualification structure. In addition, industry dummies are included to control for potential sectoral differences and a dummy for East Germany controls for regional differences. Again, social software has no significant impact on labour productivity. The coefficients of labour and investments remain qualitatively unchanged as well. The coefficient of IT intensity is positive and significant at the one percent level. This indicates a positive relation between labour productivity and the share of employees working with a computer. Firms selling their products or services abroad are more productive than firms which do not. The higher the share of export sales is, the more productive the firms are. The result is significant at the one percent level. The results also reveal that employees over 50 years have a labour productivity that is about 34.1 percentage points lower than for prime age workers between 30 and 50 years. The result is significant at the five percent level.

In the fourth specification of Table 15, I augment the specification with the variables B2B e-commerce, B2C e-commerce as well as training and consulting. The effects of the input factors and older employees as well as exports and IT intensity do not change qualitatively by controlling for additional unobserved heterogeneity by including the mentioned variables. The effect of social software on labour productivity remains insignificant in the last specification as well as the variables B2B e-commerce, B2C e-commerce, training and consulting.

Table 16 reports the second stage estimation results of equation (6) using 2SLS with robust standard errors.[24] Labour and investments of the year 2009 are instrumented with their lagged values of the year 2007 to reduce potential endogeneity. I estimate the specifications 2 to 4 of the econometric model which are the same as the ones estimated by OLS in Table 15. The results show that social software reduces labour productivity by about 18.7 percent. The result is significant at the one percent level. The input factors show the expected positive signs and coefficients with this estimation method.[25]

[24] The results of the first stage regression, with investments and labour instrumented by their lagged values, are available from the author upon request.

[25] The coefficient of labour is negative since it reflects the production elasticity of labour minus one. The estimated coefficients of the various categories of labour plus one reflect the productivity of the respective labour category relative to its reference group.

Table 15: OLS Regression

	dependent variable: labour productivity			
	(1)	(2)	(3)	(4)
social software		−0.082	−0.076	−0.077
		(0.058)	(0.057)	(0.059)
log. labour	0.042	0.042	0.026	0.020
	(0.028)	(0.028)	(0.024)	(0.026)
log. investments	0.114***	0.114***	0.082***	0.083***
	(0.021)	(0.021)	(0.020)	(0.020)
employees with PC			0.398***	0.390***
			(0.127)	(0.128)
export activity			0.471***	0.471***
			(0.155)	(0.156)
highly qualified employees			0.246	0.232
			(0.176)	(0.174)
medium qualified employees			0.010	−0.002
			(0.121)	(0.120)
employees $<$ 30			−0.138	−0.135
			(0.150)	(0.151)
employees $>$ 50			−0.341**	−0.325*
			(0.167)	(0.168)
B2B e-commerce				0.030
				(0.056)
B2C e-commerce				0.035
				(0.066)
training				0.071
				(0.065)
consulting				−0.035
				(0.056)
East Germany			−0.326***	−0.328***
			(0.056)	(0.057)
constant term		−2.080	−2.630***	−2.781***
		(0.128)	(0.215)	(0.221)
industry dummies	no	no	yes	yes
number of observations	907	907	858	854

Significance levels: *: 10%, **: 5%, ***: 1%. Standard errors in parentheses. Reference categories: unqualified employees, employees 30–50 years.

The results of the second specification indicate that the relationship between social software and labour productivity is also negative. Firms using social software have a

16.6 percent lower labour productivity than firms not using this type of software. This result stays significant at the one percent level. The effect of IT intensity is also positively significant reflecting a positive relationship between labour productivity and ICT that is found in several other studies. If the share of employees working on a computer rises by one percentage point, labour productivity is 0.33 percent higher. Exporting firms are more productive than non-exporting firms. Furthermore, the results reveal that highly qualified employees are more productive than low qualified employees. The productivity is 36.2 percent higher for employees with university or university of applied science degree. The coefficient is significant at the ten percent level. The estimation results also show that employees above 50 years are less productive than prime age workers. Their labour productivity is 31.7 percent lower.

In the third specification of Table 16 the effects of the input factors, the share of highly qualified and older employees as well as exports and IT intensity do not change qualitatively by controlling for additional unobserved heterogeneity via including further variables. The effect of social software remains also qualitatively unchanged with a decrease in productivity of 15.7 percent. The significance level drops from one to five percent. The variables B2B e-commerce, B2C e-commerce as well as training and consulting are insignificant and do not point towards an impact on labour productivity.

Due to potential endogeneity of social software usage, I estimate the model as a 2SLS regression with private usage of wikis, blogs and social networks as instruments for social software. The results of the first stage regression can be found in Table 21 in the Appendix of Chapter 4. The private usage of blogs and social networks is highly significant in the third specification while the private usage of wikis is significant at the five percent level. The F-statistic takes a value over 10 in every specification suggesting that all instruments are relevant for instrumenting social software. In order to investigate the validity of the instruments I run the Hansen-Sargan test of overidentifying restrictions (see Table 21 in the Appendix of Chapter 4) as the number of instruments exceeds the number of endogenous variables concerning social software. The null hypothesis that all instruments concerning social software and thus the overidentifying restriction are valid cannot be rejected.

Table 16: 2SLS Regression

	dependent variable: labour productivity					
	(1)	(2)	(3)	(4)	(5)	(6)
social software	-0.187^{***}	-0.166^{***}	-0.157^{**}	-0.323^{*}	-0.475^{**}	-0.469^{**}
	(0.064)	(0.064)	(0.064)	(0.172)	(0.205)	(0.220)
log. labour	-0.224^{***}	-0.181^{**}	-0.179^{**}	-0.197^{**}	-0.154^{**}	-0.158^{**}
	(0.084)	(0.077)	(0.074)	(0.080)	(0.074)	(0.072)
log. investments	0.373^{***}	0.285^{***}	0.285^{***}	0.356^{***}	0.280^{***}	0.281^{***}
	(0.079)	(0.077)	(0.076)	(0.075)	(0.075)	(0.074)
employees with PC		0.334^{**}	0.343^{***}		0.357^{***}	0.356^{***}
		(0.132)	(0.132)		(0.137)	(0.137)
export activity		0.470^{***}	0.479^{***}		0.464^{***}	0.468^{***}
		(0.151)	(0.152)		(0.151)	(0.152)
highly qualified emp.		0.362^{*}	0.354^{*}		0.424^{**}	0.411^{**}
		(0.185)	(0.185)		(0.197)	(0.197)
medium qualified emp.		0.124	0.121		0.148	0.139
		(0.144)	(0.144)		(0.148)	(0.147)
employees < 30		-0.082	-0.092		-0.043	-0.045
		(0.159)	(0.159)		(0.165)	(0.166)
employees > 50		-0.317^{*}	-0.308^{*}		-0.353^{**}	-0.340^{*}
		(0.169)	(0.171)		(0.174)	(0.176)
B2B e-commerce			-0.002			0.021
			(0.059)			(0.063)
B2C e-commerce			0.017			0.024
			(0.070)			(0.072)
training			0.016			0.044
			(0.072)			(0.074)
consulting			-0.049			-0.040
			(0.059)			(0.061)
East Germany		-0.290^{***}	-0.286^{***}		-0.292^{***}	-0.291^{***}
		(0.060)	(0.062)		(0.063)	(0.064)
constant term	-0.552	-1.510^{***}	-1.505^{***}	-0.637	-1.555^{***}	-1.562^{***}
	(0.461)	(0.441)	(0.445)	(0.438)	(0.428)	(0.433)
industry dummies	no	yes	yes	no	yes	yes
number of observations	907	858	854	897	848	844

Significance levels: *: 10%, **: 5%, ***: 1%. Standard errors in parentheses. Reference categories: unqualified employees, employees 30–50 years. Labour and investments instrumented in all specifications, social software instrumented in specification 4 till 6.

The columns 4 to 6 of Table 16 show the results of the 2SLS regression with social software instrumented by the private usage of the interviewee, besides labour and investments being instrumented with their lagged values. The impact of social software on labour productivity in this IV-regression is negative but much bigger than in the estimation result when social software is not instrumented. Firms using social software experience a decrease in productivity of 46.9 percent in the third specification. The significance level is five percent. The comparison of the coefficient of social software with the one without instrumentation of social software shows a rather big difference pointing towards an endogeneity of social software. While a negative effect of social software is plausible, the size of the coefficient suggests that the validity of the instruments may be problematic. The Hausman test rejects the null hypothesis that social software is exogenous (see Table 21 in the Appendix of Chapter 4). All other variables remain qualitatively unchanged.

The negative impact of social software on labour productivity points towards a suboptimal usage of social software within the firms. I addressed this issue in Section 4.2 and found evidence in other studies that firms can only benefit from social software if they use these applications efficiently. There are various possible reasons why firms apparently face difficulties using social software in a way that generates productivity gains. The most important reason might be the shirking effect. Social software could have a distracting impact upon employees. They might decide to spend a part of their working time for instance in social networks using them privately. This leads to less working time available and thus to a productivity loss (Peacock 2008 and van Zyl 2009).

Some employees might feel the need to interact and communicate more due to the simple availability of social software applications. The emerging flood of information and interaction associated with this fact might lead to an overwhelming of employees. They might not be able to handle their normal workload as they are distracted by social software activities resulting in a decrease of labour productivity.

Another important reason is that the adoption of social software is recent for most of the firms that adopted social software in the year 2007 while labour productivity was measured in 2009. As the time lag is relatively short, social software can be regarded as a new technology used by the firms. A large amount of literature covers the topic of the adoption of new technologies in general and the short-term productivity loss that is often associated with it, see Aghion et al. (2009) for instance.

According to this literature, labour productivity increases in the long run when the new technologies are integrated in the IT-infrastructure and employees adapted their working routine to them.

One explanation for this short-term productivity loss is that the adoption of social software applications in a firm comprises organisational changes. Those changes could imply coordination costs leading to a decrease in labour productivity especially if the firms fail to consider these costs before the adoption. Such coordination costs might be for instance bandwidth and storage space consumption as well as exposure to malware as argued by Ferreira and du Plessis (2009). In order to use social software applications efficiently after their adoption, firms might have to invest in special training for their employees as well. Usually it takes a certain amount of time until employees are able to use social software in a productive way following the corresponding training. Thus it might be the case that my analysis measures only the short-term impact on productivity. Due to the lack of availability of long-term data, I have to pass an analysis of long-term effects of social software on labour productivity on to further research.

A further aspect which I consider quite relevant is the lack of acceptance of social software among employees, customers and the management board of firms. Employees could use social software applications only reluctantly as they see no benefit in including these applications in fields like marketing, internal or external communication or project management. The rare usage of social software could lead to an insufficient know-how among employees about its handling and thus to a suboptimal usage in case it is needed.

The customers of the firms may not accept the use of social software when they interact with a firm due to security reasons. It is possible that customers might not want the firms to have access to all customer information available in social software applications, especially private information. If firms decide to manage external communication with customers or cooperation partners via social software but face a lack of acceptance among customers and partners, this might lead to a decreasing labour productivity within the firms. The cooperation or interaction can only be managed in a suboptimal way as it might take longer using alternative communications tools.

The lack of acceptance among the management board of a firm might be an additional problem. This is often the case when the management board has second thoughts about security risks or shows little interest in the usage of social software. By using social software, the management board might lose control over the contents provided to customers or cooperation partners in these applications. The consequence might be that sensible data about the firm are accessible to other parties which might be harmful for the firm and thus to its productivity. On the other hand, if the management board uses social software only rarely, employees might not feel encouraged to use it either. The lack of acceptance of all three parties can be traced back partially to the fear of losing privacy which is also an important aspect of the usage of social software mentioned in Section 4.2 and motivated by Ferreira and du Plessis (2009).

In order to explore the negative impact of social software on labour productivity in detail, I estimate equation (6) with dummy variables for every single social software application to see which applications drive this negative impact in particular. Table 20 in the Appendix of Chapter 4 presents the estimation results with each social software application dummy for the formerly mentioned specifications. Labour and capital are once again instrumented by their lagged values of 2007. The impacts of all social software applications except blogs are insignificant (see last column of Table 20). In contrast, blogs have a rather large negative impact on labour productivity. Firms using blogs experience a decrease of labour productivity of about 27.2 percent, a result significant at the one percent level. The results indicate that the productivity loss of the firms concerning social software is mainly driven by the application blog. The reason for that might be the fact that it takes a certain amount of time to read all relevant blog postings and write own postings. This is rather detracting from productivity instead of increasing it (see Back and Heidecke 2008). The coefficients of all other variables in the third specification remain qualitatively unchanged compared to the results in Table 16.

4.5.2 Robustness Checks

For the purpose of testing the validity of the results I employ some further estimation approaches as robustness checks. In all following robustness checks, labour and investments are the only variables instrumented with their lagged values. As already mentioned in Section 4.3, especially firms using social software and being active in B2C e-commerce face a lower labour productivity than firms not using social software. There is a certain possibility that the negative impact of social software runs mainly through B2C e-commerce and therefore, B2C e-commerce in combination with social software drives the negative impact on labour productivity. Thus, this descriptive result demands further investigation considering the negative result of the general usage of social software. I construct an interaction term between social software and B2C e-commerce and add it to the former model specifications of the main results. Table 22 in the Appendix of Chapter 4 contains estimation results including the interaction term. The second stage results of the third model specification show that the negative overall impact of social software on labour productivity remains unchanged by including the interaction term.[26] The impact of B2C e-commerce remains insignificant in this model specification as well. The interaction term between social software and B2C e-commerce shows no significant impact on labour productivity. This result implies that the decrease in labour productivity caused by social software does not run mainly through B2C e-commerce. All other variables remain qualitatively unchanged in this robustness check.

An alternative measure for the usage of social software in the firms is the so-called social software intensity. The estimation of the former main specifications with social software intensity as explanatory variable leads to similar results. Social software intensity has a negative effect on labour productivity. The second stage results are depicted in Table 23 in the Appendix of Chapter 4. If a firm uses one further social software application, labour productivity decreases by 8.9 percent in the third specification. Firms that are active in many different channels concerning social software and use it in this way more intensively suffer from productivity losses. The result is consistent with the main result.

The consideration of all control variables in the estimation equation reduces the sample size to 854 observations. All specifications of the main results have also been estimated using this reduced sample. Table 24 in the Appendix of Chapter 4 contains the second stage results of these estimations. The coefficients in the third specification do not change qualitatively compared to the main results. The usage of social software reduces labour productivity by 15.7 percent. The significance level remains at the five percent level.

In summary, firms using social software experience a decrease in labour productivity. This result is robust across all model specifications and suggests that firms do not benefit from social software concerning labour productivity in an early stage of adoption when the usage is not efficient or they face shirking among employees or a lack of acceptance from different sides. The decrease in labour productivity is mainly driven by the social software application blog. In contrast to social software, IT intensity and export activity

[26]All results of the first stage regressions are available from the author upon request.

have a positive impact on labour productivity. Furthermore, highly qualified employees face a higher labour productivity than low qualified employees while employees who are older than 50 years are less productive compared to prime age employees between 30 and 50 years. As a further robustness check I estimate the model with the alternative variable social software intensity. The results remain qualitatively unchanged across all specifications and support the main results.

4.6 Conclusion

Although the current analysis sheds light on the relationship between social software and labour productivity, the question whether the usage of social software leads to a higher labour productivity needs further research. In particular, the long-term effects of social software need to be investigated since the current data covers a time period that is too short to solve this question econometrically.

The results of this study have several practical implications for firms. In general, social software has the potential of helping firms to be more productive. But in order to achieve that, social software should be channelled in an effective way to get optimal gains for employees and firms. Firms of all sizes should define strategies regarding social software and rules for employee engagement in order to possibly achieve benefits from the usage. They should monitor and control the social software usage as it might result in a security risk otherwise, which could lead to sales decreases and thus to productivity losses.

4.7 Appendix Chapter 4

Table 17: Distribution of Industries in the Sample

Industry	**Observations**	**Percentage**
consumer goods	81	8.93
chemical industry	48	5.29
other raw materials	57	6.28
metal and machine construction	72	7.94
electrical engineering	97	10.69
precision instruments	62	6.84
automobile	31	3.42
retail trade	55	6.06
wholesale trade	50	5.51
transportation and postal services	65	7.17
media services	28	3.09
computer and telecommunication services	80	8.82
financial services	45	4.96
real estate and leasing services	23	2.54
management consultancy and advertising	24	2.65
technical services	67	7.39
services for enterprises	22	2.43
sum	907	100

Source: ZEW ICT Survey, own calculations.

Table 18: Social Software and Different Firm Characteristics

Industry	**Social Software: Yes**	**Social Software: No**
labour productivity	0.24	0.20
training	0.21	0.27
consulting	0.21	0.26
B2B e-commerce	0.19	0.26
B2C e-commerce	0.16	0.31
export	0.25	0.36

Source: ZEW ICT Survey, own calculations.

Table 19: Correlations between Social Software Applications

	wiki	**blog**	**social network**	**collaboration platform**	**private wiki**	**private blog**	**private social network**
wiki	1.00						
blog	0.19	1.00					
social network	0.19	0.55	1.00				
collaboration platform	0.34	0.13	0.13	1.00			
private wiki	0.19	0.14	0.18	0.18	1.00		
private blog	0.17	0.27	0.18	0.18	0.31	1.00	
private social network	0.18	0.21	0.25	0.21	0.28	0.29	1.00

Source: ZEW ICT Survey, own calculations.

Table 20: 2SLS Regression with all Social Software Dummies

	dependent variable: labour productivity		
	(1)	(2)	(3)
wiki	−0.008	0.010	0.008
	(0.080)	(0.079)	(0.080)
blog	−0.330***	−0.266***	−0.272***
	(0.093)	(0.087)	(0.087)
social network	0.041	−0.029	−0.021
	(0.089)	(0.079)	(0.079)
collaboration platform	−0.157**	−0.108	−0.092
	(0.077)	(0.076)	(0.077)
log. labour	−0.214**	−0.169**	−0.168**
	(0.083)	(0.075)	(0.073)
log. investments	0.365***	0.275***	0.276***
	(0.078)	(0.076)	(0.075)
employees with PC		0.330**	0.337**
		(0.132)	(0.133)
export activity		0.435***	0.447***
		(0.154)	(0.154)
highly qualified employees		0.364**	0.355*
		(0.184)	(0.184)
medium qualified employees		0.115	0.111
		(0.143)	(0.143)
employees < 30		−0.097	−0.106
		(0.156)	(0.156)
employees > 50		−0.308*	−0.300*
		(0.171)	(0.174)
B2B e-commerce			−0.001
			(0.059)
B2C e-commerce			0.027
			(0.069)
training			0.011
			(0.072)
consulting			−0.045
			(0.058)
East Germany		−0.293***	−0.290***
		(0.060)	(0.061)
constant term	−0.608	−1.569***	−1.562***
	(0.455)	(0.432)	(0.437)
industry dummies	no	yes	yes
number of observations	904	855	851

Significance levels: *: 10%, **: 5%, ***: 1%. Standard errors in parentheses. Reference categories: unqualified employees, employees 30–50 years. Labour and investments instrumented.

Table 21: First-Stage Regression with Instrumented Labour, Investments and Social Software

	dependent variable: dummy for use of social software		
	(1)	(2)	(3)
employees with PC		0.125**	0.104
		(0.063)	(0.063)
export activity		−0.053	−0.065
		(0.078)	(0.080)
highly qualified employees		0.195**	0.181*
		(0.094)	(0.094)
medium qualified employees		0.078	0.065
		(0.066)	(0.066)
employees < 30		0.054	0.071
		(0.085)	(0.084)
employees > 50		−0.056	−0.041
		(0.090)	(0.089)
B2B e-commerce			0.072**
			(0.031)
B2C e-commerce			−0.001
			(0.037)
training			0.034
			(0.035)
consulting			0.036
			(0.031)
East Germany		0.023	0.018
		(0.031)	(0.031)
industry dummies		yes	yes
log. labour 2006	0.061***	0.068***	0.056***
	(0.013)	(0.013)	(0.014)
log. investments 2006	−0.001	0.004	0.005
	(0.009)	(0.009)	(0.009)
private use of wiki	0.113***	0.092**	0.086**
	(0.041)	(0.042)	(0.042)
private use of blog	0.243***	0.220***	0.208***
	(0.054)	(0.055)	(0.055)
private use of social network	0.223***	0.172***	0.167***
	(0.037)	(0.037)	(0.037)
constant term	−0.009	−0.140	−0.169*
	(0.055)	(0.101)	(0.100)
observations	897	848	844
F-statistic	40.21 ($p = 0.000$)	14.47 ($p = 0.000$)	13.79 ($p = 0.000$)

Hansen-Sargan test: Hansen's J $Chi^2(2)$: 2.93304 ($p = 0.2307$)
Hausman test: robust score $Chi^2(3)$: 15.2048 ($p = 0.0016$)
Hausman test: robust regression $F(3, 810)$: 4.99168 ($p = 0.0020$)

Significance levels: *: 10%, **: 5%, ***: 1%. Standard errors in parentheses. Reference categories: unqualified employees, employees 30–50 years.

Table 22: 2SLS Regression with Interaction Term for Social Software and B2C E-commerce

	dependent variable: labour productivity		
	(1)	(2)	(3)
social software	-0.187^{***}	-0.166^{***}	-0.171^{**}
	(0.064)	(0.064)	(0.070)
log. labour	-0.224^{***}	-0.181^{**}	-0.179^{**}
	(0.084)	(0.077)	(0.074)
log. investments	0.373^{***}	0.285^{***}	0.285^{***}
	(0.079)	(0.077)	(0.076)
employees with PC		0.334^{**}	0.346^{***}
		(0.132)	(0.133)
export activity		0.470^{***}	0.477^{***}
		(0.151)	(0.152)
highly qualified employees		0.362^{*}	0.354^{*}
		(0.185)	(0.185)
medium qualified employees		0.124	0.123
		(0.144)	(0.145)
employees < 30		-0.082	-0.089
		(0.159)	(0.158)
employees > 50		-0.317^{*}	-0.311^{*}
		(0.169)	(0.172)
B2B e-commerce			-0.002
			(0.059)
B2C e-commerce			-0.001
			(0.092)
training			0.017
			(0.072)
consulting			-0.047
			(0.059)
social software*B2C e-commerce			0.053
			(0.139)
East Germany		-0.290^{***}	-0.287^{***}
		(0.060)	(0.062)
constant term	-0.552	-1.510^{***}	-1.503^{***}
	(0.461)	(0.441)	(0.456)
industry dummies	no	yes	yes
number of observations	907	858	854

Significance levels: *: 10%, **: 5%, ***: 1%. Standard errors in parentheses. Reference categories: unqualified employees, employees 30–50 years. Labour and investments instrumented.

Table 23: 2SLS Regression with Social Software Intensity

	dependent variable: labour productivity		
	(1)	(2)	(3)
social software intensity	-0.111^{***}	-0.094^{***}	-0.089^{**}
	(0.034)	(0.036)	(0.036)
log. labour	-0.224^{***}	-0.179^{**}	-0.177^{**}
	(0.084)	(0.077)	(0.074)
log. investments	0.372^{***}	0.283^{***}	0.284^{***}
	(0.079)	(0.077)	(0.075)
employees with PC		0.330^{**}	0.340^{**}
		(0.133)	(0.134)
export activity		0.464^{***}	0.474^{***}
		(0.152)	(0.153)
highly qualified employees		0.387^{**}	0.378^{**}
		(0.187)	(0.186)
medium qualified employees		0.122	0.119
		(0.144)	(0.144)
employees < 30		-0.085	-0.095
		(0.158)	(0.158)
employees > 50		-0.315^{*}	-0.306^{*}
		(0.172)	(0.174)
B2B e-commerce			-0.001
			(0.059)
B2C e-commerce			0.015
			(0.069)
training			0.013
			(0.072)
consulting			-0.049
			(0.059)
East Germany		-0.294^{***}	-0.289^{***}
		(0.060)	(0.062)
constant term	-0.564	-1.526^{***}	-1.520^{***}
	(0.460)	(0.441)	(0.445)
industry dummies	no	yes	yes
number of observations	904	855	851

Significance levels: *: 10%, **: 5%, ***: 1%. Standard errors in parentheses. Reference categories: unqualified employees, employees 30–50 years. Labour and investments instrumented.

Table 24: 2SLS Regression: Reduced Sample

	dependent variable: labour productivity		
	(1)	(2)	(3)
social software	-0.181^{***}	-0.159^{**}	-0.157^{**}
	(0.065)	(0.064)	(0.064)
log. labour	-0.236^{***}	-0.184^{**}	-0.179^{**}
	(0.084)	(0.077)	(0.074)
log. investments	0.367^{***}	0.287^{***}	0.285^{***}
	(0.080)	(0.078)	(0.076)
employees with PC		0.347^{***}	0.343^{***}
		(0.132)	(0.132)
export activity		0.473^{***}	0.479^{***}
		(0.151)	(0.152)
highly qualified employees		0.358^{*}	0.354^{*}
		(0.185)	(0.185)
medium qualified employees		0.121	0.121
		(0.144)	(0.144)
employees < 30		-0.082	-0.092
		(0.159)	(0.159)
employees > 50		-0.303^{*}	-0.308^{*}
		(0.170)	(0.171)
B2B e-commerce			-0.002
			(0.059)
B2C e-commerce			0.017
			(0.070)
training			0.016
			(0.072)
consulting			-0.049
			(0.059)
East Germany		-0.283^{***}	-0.286^{***}
		(0.061)	(0.062)
constant term	-0.536	-1.505^{***}	-1.505^{***}
	(0.462)	(0.444)	(0.445)
industry dummies	no	yes	yes
number of observations	854	854	854

Significance levels: *: 10%, **: 5%, ***: 1%. Standard errors in parentheses. Reference categories: unqualified employees, employees 30–50 years. Labour and investments instrumented.

5 Determinants of Flexible Work Arrangements*

Abstract

Flexible work arrangements such as allowing employees to work at home are used in firms, especially since information and communication technologies have become so widespread. Using individual-level data from 10,884 German employees, this paper analyses the determinants of working at home as a form of flexible work arrangements. The analysis is based on descriptive analyses and a discrete choice model using a probit estimation approach. The results reveal that men have a higher probability to work at home but women are more likely to work at home intensively. Education, tenure and the use of computers increase the probability of working at home while firm size and a young age of employees reduce it. Having children less than six years old, overtime and work time have a positive impact on both working at home and on working at home intensively.

Keywords: work at home, telecommuting, home office, workplace organisation
JEL-Classification: J01, J10, J20

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5.1 Introduction

Flexible work arrangements such as the opportunity to work at home are increasingly widespread among firms and employees, especially in the U.S. (e.g. Noonan et al. 2012). Since information and communication technologies (ICT) have been applied in nearly every firm, it is now easier than ever for firms to offer these arrangements to their employees or for employees to make use of them. Taking regular work home from time to time is the most common way of working flexibly. If work output is delivered to the firm by ICT, the work arrangement is known as telecommuting. Telecommuters usually maintain a traditional office in the firm but have the opportunity to work at home or in telecentres around one to three days a week (Hill et al. 1998). Telecommuting arrangements are usually agreed by contract. A special form of telecommuting is the case where employees work all their hours at home without having an office in the firm.

By making use of flexible work arrangements, women can work and provide child care at the same time (Noonan et al. 2012). Another important benefit of telecommuting is the reduction of commute time and commute stress for employees as well as the associated reduction in road congestion and pollution (Mokhtarian 1991). In line with that, telecommuting may reduce firm expenses and enhance work-life balance at the same time leading to higher employee productivity (Hill et al. 1998). Furthermore, firms can organise teamwork across different locations more efficiently by online collaboration (TNS Infratest and ZEW 2014).

Most of the studies carried out so far on the factors that influence working at home or telecommuting show mixed results. A large amount of studies point towards the fact that married female employees are more likely to telecommute compared to married male employees (e.g. Yap et al. 1990). According to Mokhtarian et al. (1998) and Popuri et al. (2003), the presence of young children in the household is also an important determinant of telecommuting. Many studies suggest that education plays a crucial role regarding telecommuting as well as the work time. The higher the education levels of employees, the higher the share of telecommuters of a firm (Perez et al. 2004 or Peters et al. 2004). According to Peters et al. (2004) and Noonan et al. (2012), telecommuters work more hours compared to non-telecommuters. In contrast, IT skills in particular have no significant impact on telecommuting (Belanger 1999; Peters et al. 2004). The studies of Mokhtarian et al. (1997) or Popuri et al. (2003) and Perez et al. (2004) show that the need for interaction or teamwork with colleagues at the workplace are factors that reduce telecommuting. The distance from home to the workplace is found to be irrelevant for the decision to telecommute by Mannering et al. (1995) while Popuri et al. (2003) and De Graaff et al. (2003) find that age and tenure have mixed impacts. The newest study on this topic conducted by Brenke (2014) is a descriptive analysis which shows that working at home depends very much on the vocational field and qualification level. Moreover, age has no impact on working at home in his study while men work slightly more often at home than women. The presence of children leads to more working at home as well. Employees working in a full-time job work more often at home than employees working only part-time.

Using individual-level data from the BIBB/BAuA employee survey of 2006, containing information on 10,884 German employees, this paper analyses the determinants of flexible work arrangements such as working at home and working at home intensively. Both variables are dummy variables. Working at home takes the value one if employees work at home at least rarely and zero if they do not work at home at all. Working at home intensively takes the value one if employees work always or frequently at home and zero if they work sometimes, rarely or never at home. As an analytical framework, I employ a discrete choice model with working at home and working at home intensively being the outcome variables. The explanatory variables comprise employee and firm characteristics such as gender, the presence of children under six years old, education, vocational field, firm size and computer use.

The results reveal that men have a higher probability of working at home while women are more likely to work at home intensively. The presence of children less than six years old is positively related to both working at home and working at home intensively without dividing the sample by gender. A higher qualification level of employees and the use of computers encourage working at home, while employees who work in middle-sized or large firms are less active in this work arrangement. Younger employees aged less than 30 years also have a lower probability to work at home. Tenure, overtime and work time are associated with working at home while overtime and work time are positively associated with working at home intensively as well. Employees aged 50 or older are more likely to work at home frequently or always than employees between 30 and 50 years while employees younger than 30 years are less likely to work at home. Firm size reduces the probability of working at home intensively.

The paper is organised as follows: Section 5.2 provides an overview of the literature on flexible work arrangements. Section 5.3 describes the database and gives a first insight into the determinants of flexible work arrangements whereas Section 5.4 presents the analytical framework and establishes the estimation approach. The estimation results are presented in Section 5.5. Finally, Section 5.6 concludes and gives an outlook on possibilities for future research.

5.2 Literature Review

This section positions the present paper in the literature and provides definitions of the different forms of flexible work arrangements as well as an overview of the theoretical and empirical studies completed so far on this topic. Most of the existing literature focuses on the determinants of telecommuting, leaving aside other forms of flexible work arrangements like flexitime where employees have the opportunity to schedule their work hours flexibly. Moreover, most economic studies on this topic use data from U.S. firms or employees. This is because U.S. firms were the pioneers of telecommuting for a long time. In 2011, 50 million employees in the U.S. who wanted to work at home have jobs that are at least compatible with telecommuting (Harnish et al. 2011). Matthews et al. (2005) estimated for the year 2012 that over 50 million U.S. workers, which is around 40 percent of the working population, could work from home at least part of the time while in the year 2010, 24 percent of employed Americans reported that they worked at least several hours per week at home (U.S. Bureau of Labor Statistics 2011).

In comparison to the USA, around 21 percent of German firms offered their employees the opportunity to telecommute (Statista 2012) while 4.7 million employees, being 13 percent of the workforce, worked predominantly or sometimes at home in the year 2012, although this number is decreasing since the year 2008 (Brenke 2014). A recent study conducted among ICT companies shows that 57 percent of firms offered their employees the opportunity to work at home in the year 2013 while only 12 percent of employees in the ICT sector made actually use of this opportunity (TNS Infratest and ZEW 2014).

There are various forms of flexible work arrangements. Let us first define the opportunity to work at home in general. For the purposes of this paper, working at home as an arrangement is when a part of the work of an employee is done at home. Working at home is not necessarily fixed in employees' contracts. It is instead often a verbal agreement between employers and employees. The opportunity to work at home can be specified in different ways. Employers can offer their employees the possibility of telecommuting or to work at home full time. In both cases, firms can fix these work arrangements in employees' contracts or they can simply agree verbally. There are various definitions of telecommuting. The most common one is that employees work some hours of their work time or some days per week at home or at other suitable places like telecentres (Hill et al. 1998). The most common workplace for telecommuters is at home. Employees deliver work output to the firm by using information and communication technologies. For instance, employees are able to access the server of the office, personal files and emails as well as to participate in video conferences and thus work almost as if they were in the office (De Graaff et al. 2003).

Telecommuting may enable women to more efficiently compete in the workplace in a way that facilitates child care at the same time (Noonan et al. 2012). Menezes et al. (2011) describe the rise of flexible work arrangements in the UK and mention that parents of young and disabled children gained the legal right to work flexibly in the UK in 2003. The law was extended to carers in 2007 and to parents with children under the age of 16 years in 2009 which points towards children being an important factor for promoting flexible work politically. Another key reason for telecommuting is the reduction of commute time for employees as well as the associated reduction in road congestion and pollution as a consequence (see Mokhtarian 1991 or Handy 1995). A special form of telecommuting is that employees work both their regular work time and overtime exclusively at home. This form might also be contractually fixed. In general, telecommuting can be performed best in the service sector in general, but especially in the financial sector or high-tech sectors as the technical requirements are provided best in these industries (Noonan et al. 2012; Tung et al. 1996; TNS Infratest and ZEW 2014).

A large amount of research has been completed especially on the adoption of telecommuting in firms. First studies on this topic emerged in the mid-eighties. As information and communication technologies are crucial for telecommuting and those technologies have changed a lot since the 1980s, the meaning of telecommuting is different today. In the 1980s and 1990s, when information and communication technologies were far less evolved, employees could carry out simple tasks at most, but did not have the opportunity to deliver their work through those technologies to the firm. Only in the 1990s, they could access their emails at home and could deliver work output still in a very limited way, by sending small email attachments. Only since around the year 2000 have the technologies developed to the point where the delivering of work output is possible by accessing the server of the firm with help of a client and uploading content. Thus, the evolving meaning of telecommuting must be considered in the review of the current literature on the topic.

An early analysis by DeSanctis (1984) investigates descriptively the attitudes towards telecommuting of managers and programmers of anonymous computer service firms. The study finds that the presence of children has no significant relationship with telecommuting, but women prefer telecommuting compared to men. Distance to the workplace and tenure play no significant role for telecommuting while overtime, supervisory duties and the need to interact with colleagues are relevant factors that do not support telecommuting.

Kraut (1989) focuses in an econometric study on the trade-offs of telecommuting in the U.S. This study finds the result that older workers are more likely to work at home. Kraut (1989) argues that this might be the case because they are less physically vigorous and prefer shorter commutes. Workers who live in rural areas and have work- or transportation-limiting disabilities are also more likely to telecommute. Women who are married and have young children have a higher propensity to work at home than unmarried women without children.

A small descriptive study among female computer professionals in Singapore conducted by Yap et al. (1990) reveals that telecommuting is considered as an alternative work arrangement if women are married, have a relatively high proportion of work that can be done at home and are stressed by commuting to the regular workplace. In addition, women who have a study room at home prefer to telecommute.

An econometric study conducted by Mannering et al. (1995) with different U.S. data sets analyses the factors that favour the frequency of telecommuting. They find that household size, the degree of control over scheduling job tasks and the possibility to borrow a computer from the firm as well as having children less than five years old for women are factors positively related to the frequency of telecommuting in all their models. Moreover, employees with more vehicles in the household telecommute more frequently as well as employees who supervise other employees. In contrast, factors like distance to work, hours worked, managerial and professional occupation and the amount of time spent in face to face communication are not significant for the frequency of telecommuting.

A further econometric study is conducted by Mokhtarian et al. (1997). The study analyses the preference for telecommuting using U.S. individual-level data. The estimation results show a positive and significant relation between the preference for telecommuting and parental leave, commute stress as well as leisure and commute time. On the other hand, the need for interaction with colleagues in the workplace as well as distraction at home has a negative impact on the preference for telecommuting. Gender is insignificant for the preference for telecommuting in this study, although the results show that women feel more stressed by commuting.

Mokhtarian et al. (1998) use econometric methods to investigate employees' preferences for working in the office, in telecentres or at home. The main finding is that the presence of children younger than two years of age triggers the preference of home-based telecommuting. In contrast, household size is negatively correlated with the preference of telecommuting at home. Employees who have worked for a long time in their current position are less likely to prefer home-based telecommuting. Mokhtarian et al. (1998) argue that they might be more resistant to changes of workplace. Regarding telecommuting at telecentres, employees' age plays a significant role. Older employees prefer telecommuting at telecentres rather than at home as they might be more risk-averse or have a preference for a workplace similar to the office.

Belanger (1999) analyses descriptively workers' propensity to telecommute in a high-tech organisation. The case study finds that women have a greater propensity to telecommute than men. In contrast, the age of employees, tenure as well as computer skills show no difference between telecommuters and non-telecommuters.

De Graaff et al. (2003) investigate the determinants of at-home and out-of-home work econometrically. They find that possessing a modem increases the probability of working at home. Furthermore, the results indicate that the propensity of working at home rises with educational level and falls with age.

Popuri et al. (2003) estimate a joint model of telecommuting choice and telecommuting intensity. The results show that women are less likely to telecommute if they have no children. If there are children in the household, women have a higher probability to telecommute intensively than men. Moreover, the study indicates that older employees are more likely to telecommute frequently. Marital status plays an important role for telecommuting as well. Employees who are married have a higher propensity to telecommute and do it more frequently. According to the authors, the explanation might be that married employees are more committed to household obligations than unmarried employees. Education has a small but significant impact on telecommuting. Employees who possess a college degree are more likely to work at home. Other job-related factors such as tenure and working full-time have a positive effect on telecommuting and its frequency while the need to interact with colleagues lowers the propensity of telecommuting.

A theoretical paper by Perez et al. (2004) discusses the adoption of telecommuting in firms by using a technology adoption model. Factors that are relevant for the adoption decision of telecommuting in firms in a positive way are the intensity of information and communication technologies used in the firm, the educational level of employees, training, geographical decentralisation, outsourcing and tenure of employees. Teamwork of employees has a negative influence on adopting telecommuting while firm size and gender of employees play no significant role for the adoption decision.

Peters et al. (2004) analyse econometrically the opportunity, preference and practice of telecommuting with a representative sample of the Dutch labour force. The study reveals that telecommuters work more hours and have a greater commuting time than non-telecommuters. On average, employees who practice telecommuting are highly educated compared to those who would only prefer to do so. Regarding organisational characteristics of the firms, employees who work in firms with at least one subsidiary are more likely to telecommute.

A recent econometric study on telecommuting was conducted by Noonan et al. (2012). The central result of this study is that telecommuting in U.S. workplaces is linked to long working hours and overtime. This might lead to an intensification of work demands instead of relieving employees. In general, parents are only slightly more active in telecommuting than non-parents. Furthermore, the study shows that mothers do not telecommute more than fathers. Thus, it seems that telecommuting is not used primarily by women to improve child care without taking a complete break from work. In addition, college-educated employees have a higher probability of telecommuting than the population as a whole.

The newest descriptive analysis on this topic which is until now the only one using German individual-level data is done by Brenke (2014). Brenke (2014) considers a time period from 1992 to 2012. The results of his study indicate that the share of employees working at home has hardly changed over the years. Moreover, he shows that vocational field and qualification level are crucial determinants for working at home. Moreover, age is no determinant for working at home while men work slightly more often at home than women. The presence of children increases working at home as well. Employees working full-time also work more often at home than employees working only part-time. My study differs from Brenkes (2014) study by using econometric methods for the analysis with German individual-level data.

The summary of the studies on the determinants of working at home and telecommuting in particular shows the following results: most studies point towards the fact that being a woman and married has a positive influence on telecommuting. The presence of small children in the household also represents a crucial determinant for telecommuting. A large amount of studies also suggest that education plays an important role regarding telecommuting as well as the vocational field and the work time. The higher the educational level of employees, the higher the share of telecommuters. On the other hand, the need for interaction with colleagues at the workplace and teamwork are factors that have a negative impact on telecommuting. Commute time as well as age and tenure have mixed impacts on the decision to telecommute.

5.3 Description of Data

The dataset used in this study is the Employee Survey of the Federal Institute for Occupational Safety and Health (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, BAuA) and the Federal Institute for Vocational Education and Training (Bundesinstitut für Berufsbildung, BIBB) conducted in 2006. It is a representative survey of about 20,000 employees who are between 15 and 70 years old and work at least 10 hours per week in Germany. The survey was conducted via computer-assisted telephone interviews (CATI).[27] The survey contains detailed information about employees and their workplaces. It focuses on job characteristics, skill requirements, education, training and

[27] BIBB/BAuA 2012 is the most recent of the BIBB Employee Surveys, which were conducted in a similar way in 1979, 1986, 1992, 1999 and 2006. See Hall (2009) for further information about the 2006 survey.

conditions of work. I use the survey of 2006 for my analysis as the information about flexible work arrangements is only included in this wave.

The central research question of this paper treats the factors which trigger working at home and working at home intensively. Based on the results of the previous literature, I expect the most important determinants to be gender, the presence of children, age, education, firm size, computer use, tenure as well as commute time, overtime, work time and industry. I use these factors for a descriptive analysis in a first step. I then investigate the determinants with econometric methods. The difference between this study and the previous studies concerning this topic is that I investigate this research question econometrically with a German data set while most of the previous studies were done with U.S. data sets. Only one recent study is done descriptively by Brenke (2014) using German data until now.

Flexible work arrangements are measured in the BIBB/BAuA survey of 2006 via four variables. The first measures if the employees work at home at least rarely. With this information I construct a dummy variable that takes the value one if the employees work at home at least rarely and zero if they do not work at home at all. The second variable represents working at home intensively. It is a dummy variable that takes the value one if employees work always or frequently at home and zero if they work sometimes, rarely or never at home. The third variable represents telecommuting if working at home consists in telecommuting agreed by contract. Again, the dummy variable for telecommuting takes the value one if the opportunity to work at home is related to telecommuting agreed by contract, and zero otherwise. Only employees who work always or frequently at home are considered as potential telecommuters in the survey as working at home rarely or only from time to time is considered an exception. The last form of flexible work arrangement is represented by a dummy variable for working at home completely. The variable takes the value one if the employees who have the opportunity to work entirely at home as agreed by contract and zero otherwise.

Table 25 shows summary statistics for all variables that measure flexible work arrangements as well as the potential determinants. 30 percent of the employees work at home. Table 25 further indicates that 12 percent of employees work at home frequently or always. Telecommuting is done by 1.4 percent of employees and 0.6 percent of employees have an agreement by contract to work only at home. Due to the fact that the share of employees who telecommute and work entirely at home is so low that the dummy vari-

Table 25: Summary Statistics

Variable	Mean	N
work at home (share of employees)	0.30	10,884
intensive work at home (share of employees)	0.12	10,884
telecommuting (share of employees)	0.014	10,884
work at home entirely (share of employees)	0.006	10,884
male (share of employees)	0.47	10,884
female (share of employees)	0.53	10,884
children $<$ 6 years (share of employees)	0.14	10,884
no degree (share of employees)	0.005	10,884
only secondary school (share of employees)	0.03	10,884
secondary school and vocational education (share of employees)	0.55	10,884
only Abitur (share of employees)	0.02	10,884
Abitur and vocational education (share of employees)	0.30	10,884
Abitur and studies (share of employees)	0.09	10,884
age (years)	41.79	10,884
share of employees $<$ 30 years	0.13	10,884
share of employees 30–50 years	0.63	10,884
share of employees $>$ 50 years	0.24	10,884
work with computers (share of employees)	0.82	10,884
tenure (years)	12.50	10,884
overtime (hours per month)	14.62	10,884
work time (hours per week)	39.17	10,884
commute time (minutes)	24.46	10,884
firm with 1 - 19 employees (share of employees)	0.24	10,884
firm with 20-99 employees (share of employees)	0.28	10,884
firm with $>$ 100 employees (share of employees)	0.48	10,884

Source: BIBB/BAuA Employee Survey 2006, own calculations.

able has hardly any variation, I focus in this study on the first two measures of flexible work arrangements. Concerning gender, 47 percent of employees in the sample are male while only 14 percent have children in pre-school age. The qualification structure of employees reveals that most of the employees have either secondary school and vocational education (55 percent) or Abitur[28] and vocational education (30 percent).

The average age of employees is around 42 years. 82 percent of employees work with computers showing that computers were integrated in most work tasks in the year 2006.

[28]The German Abitur is the qualification gained in Germany by students completing their secondary education, usually after twelve or thirteen years of schooling. It is comparable to GCE Advanced Levels, the International Baccalaureate or Advanced Placement tests.

Employees worked in their current jobs for 12.5 years on average and they work around 15 hours of overtime per month. The average work time of employees is about 39 hours per week including overtime and additional part-time jobs while the average commute time is around 25 minutes. Concerning firm size, the three size classes show that almost half of the employees are employed in large firms with at least 100 employees.

Table 26: Descriptives I

Variable	**Working at Home**	**No Working at Home**	**T-Test**
share of men	0.47	0.47	0.0002 (0.023)
share of women	0.53	0.53	0.0002 (0.023)
share of men with children < 6 years old	0.17	0.16	-0.015 (-1.380)
share of women with children < 6 years old	0.13	0.12	-0.005 (-0.554)
average age (years)	43.29	41.15	-2.139*** (-10.214)
share of employees < 30 years	0.08	0.15	0.070*** (10.048)
share of employees 30–50 years	0.64	0.62	-0.012 (-1.214)
share of employees > 50 years	0.28	0.23	-0.057*** (-6.406)
average tenure (years)	12.93	12.32	-0.609*** (-2.980)
average commute time (minutes)	25.05	24.20	-0.849*** (-2.044)
average overtime (hours per month)	19.22	12.69	-6.543*** (-16.499)
average work time (hours per week)	41.49	38.19	-3.295*** (-13.923)
share of employees working with a computer	0.86	0.80	-0.063*** (-7.831)
firm with 1 - 19 employees	0.27	0.22	-0.044*** (-4.957)
firm with 20 - 99 employees	0.34	0.26	-0.206*** (-15.632)
firm with > 100 employees	0.39	0.52	0.208*** (14.203)

Source: BIBB/BAuA Employee Survey 2006, own calculations. T-statistics in parentheses. Significance levels: *: 10%, **: 5%, ***: 1%.

Other studies often show differences between men and women concerning work at home. Table 26 shows that 47 percent of the employees who work at home are men while 53 percent of employees who work at home are women. The shares of employees who do not work at home are the same for men and women. Both shares are the same as the share of men and women in the whole sample. The t-test that serves the purpose of testing the difference between employees working at home and those who do not is insignificant for both genders.

The presence of children is often mentioned as a reason for why women prefer telecommuting. As women are involved in child care more intensively than men, telecommuting might be a good way of providing work and being able to care for children at the same time (Mokhtarian 1997). Table 26 presents the shares of employees with children less than six years old by gender and engagement in working at home. 17 percent of all men who work at home have children less than six years old while the share of men who do not work at home and have children in this age group is 16 percent. The corresponding shares for women are 13 and 12 percent. The t-tests of differences in mean for men and women who have children in this age group with respect to working at home is insignificant in both cases. The results show that a higher share of men has children less than six years old than women. This result might be driven by the fact that a part of the women having children in this age group does not work at all and is therefore not included in the sample. The result that there is no significant difference for both genders is surprising as the opportunity to work and provide childcare at the same time is discussed as one main reason for working at home in the literature on this topic. On the other hand, the fact that many women in the sample work full-time might explain this result.

In order to analyse if the age of employees plays an important role for flexible work arrangements, Table 26 also lists the average age of employees as well as the share of employees in different age groups with respect to working at home. Employees who work at home are about 43 years old on average, while employees who do not work at home are about 41 years old. The age difference is rather small for these two categories but nonetheless significant. The share of employees over 50 years old is larger among those working at home while the share of employees under 30 years old is larger among those not working at home. Both differences are significant suggesting that with an increasing age, working at home occurs more often which is consistent with the result of the average age.

I investigate if the tenure of employees might have an influence on working at home as well. Employees who have worked for a longer time in a firm and are more experienced might get the opportunity to work at home more readily than newer employees (Belanger 1999). Employees who work at home are employed in the firms for around 13 years on average. Employees who spend all their work time in the office are employed for 12 years on average. The difference in tenure is only a few months, but significant.

A large literature, e.g. Peters et al. (2004), dealing with the topic of telecommuting mentions the distance to the workplace as a relevant determinant. Table 26 shows that the average commute time to the workplace is 25 minutes for employees who work at home and around 24 minutes for employees who work entirely at the office. According to the t-test, this difference is significant suggesting that employees with a shorter commute time work more seldom at home than employees who have a longer commute time, although a difference in commuting of about one minute is negligible for employees.

Several studies on the topic of telecommuting argue that overtime might play a role for telecommuting (e.g. Noonan 2012). Additional hours of work beside the regular work time represent overtime. Table 26 sheds some light on this issue. Employees who work at home have around 19 hours of overtime per month on average while employees who do not work at home have around 13 hours. Concerning regular work time, Table 26 indicates that employees who work at home work about 41 hours per week on average while employees who do not work at home work 38 hours per week. The differences are both significant.

In conjunction with overtime, the regular work time which is contractually fixed might be relevant. It may be the case that employees who have a full-time job are supposed to work more additional hours than employees who work only a part-time job. Table 33 in the Appendix of Chapter 5 shows that employees who work overtime have a contractually fixed work time of about 40 hours. In contrast, employees who do not work additional hours have an average work time of about 33 hours. It seems that employees who have longer working hours are indeed the ones who tend to work more additional hours.

Many empirical studies about telecommuting, e.g. Noonan et al. (2012) argue that this work arrangement is best deployable in jobs where employees work with computers. In IT-intensive sectors, telecommuting is particularly well established. Table 26 shows that the share of employees who work with computers is 86 percent for those who work at home and 80 for those who work completely at the firm. The t-test indicates that the difference between both mean values is significant.

A further factor which may be relevant but at the same time ambivalent for working at home is firm size. It may be the case that employees who work for larger firms have more opportunities to work at home. The reason for that is that large firms' technical and organisational structure leaves them more disposed to offer flexible forms of work arrangements. The Monitoring Report conducted by TNS Infratest and ZEW (2014) shows that flexible work arrangements are indeed diffused especially in large firms in the ICT sector. On the other hand, smaller firms may have a more familial business culture. The idea behind a familial business culture is that it is built on trust towards employees concerning their work. Firms trust them to fulfil their work tasks outside the workplace without being supervised. Thus, employees in small firms may work at home more often. Table 26 indicates that 27 percent of employees who work at home are employed in small firms with one to 19 employees while 34 percent are employed in middle-sized firms with 20 to 99 employees. The corresponding shares of employees who do not work at home and are employed in firms of those size are 22 and 26 percent. The t-tests indicate that the shares of employees working in small and middle-sized firms are higher for employees who work at home. The results for large firms with more than 100 employees are reversed. The share of employees working in large firms is 39 percent for employees who work at home and 52 percent for employees who do not work at home. The results are again significant.

Table 27: Descriptives II

Variable	**Working at Home Intensively**	**No or Rarely Working at Home**	**T-Test**
share of men	0.41	0.48	0.070*** (4.760)
share of women	0.59	0.52	-0.070*** (-4.760)
share of men with children < 6 years old	0.17	0.16	-0.015 (-0.926)
share of women with children < 6 years old	0.13	0.12	-0.011 (-0.935)
average age (years)	44.76	41.38	-3.372*** (-11.430)
share of employees < 30 years	0.06	0.14	0.078*** (7.925)
share of employees 30–50 years	0.58	0.63	0.051 (3.564)
share of employees > 50 years	0.36	0.23	-0.129*** (-10.183)
average tenure (years)	14.28	12.26	-2.019*** (-7.011)
average commute time (minutes)	24.74	24.42	-3.266 (-0.557)
average overtime (hours per month)	19.46	13.96	-0.027*** (-2.728)
average work time (hours per week)	41.72	38.82	-2.900*** (-8.642)
share of employees working with a computer	0.83	0.81	-0.015 (-1.313)
firm with 1 - 19 employees	0.24	0.24	-0.002 (-0.0184)
firm with 20 - 99 employees	0.46	0.26	0.134*** (12.956)
firm with > 100 employees	0.30	0.50	0.208*** (14.203)

Source: BIBB/BAuA Employee Survey 2006, own calculations. T-statistics in parentheses.
Significance levels: *: 10%, **: 5%, ***: 1%.

Table 27 shows descriptive statistics for the category working at home intensively. The results do not differ much in comparison with Table 26. Only the results concerning gender, commute time and firm size are slightly different. 41 percent of the employees working at home frequently or always are male. In contrast, 48 percent of employees who work at home only sometimes, rarely or never are men. The corresponding shares for women are reversed and take the values 59 and 52 percent indicating that women are more active in working at home intensively. The t-test are for both genders significant compared to the gender differences in Table 26. Concerning working at home intensively, the average commute time hardly shows any differences compared to Table 26 and is even insignificant for working at home intensively.

The results concerning firm size are also slightly different than in Table 26. The shares of employees working in small firms do not show any significant differences for employees who work at home intensively and those who do not. In contrast, 46 percent of employees who work at home intensively are employed in middle-sized firms while the corresponding share is 26 percent for employees who do not work at home intensively. 30 percent of employees working at home at least frequently work in large firms while 50 percent of employees who do not work at home intensively are employed in large firms. The t-test shows that the differences for middle-sized and large firms are significant. All other results show only minor differences compared to Table 26 and remain qualitatively unchanged.

Table 28: Descriptives III: Share of Employees in Educational Categories Working at Home by Gender

	Men		Women	
Variable	**Share Working at Home**	**Share Working at Home Intensively**	**Share Working at Home**	**Share Working at Home Intensively**
no degree	0.08	0.05	0.12	0.04
only secondary school	0.10	0.02	0.11	0.02
secondary school and vocational education	0.19	0.04	0.19	0.06
only Abitur	0.20	0.07	0.21	0.05
Abitur and vocational education	0.45	0.19	0.44	0.24
Abitur and studies	0.56	0.24	0.53	0.28

Source: BIBB/BAuA Employee Survey 2006, own calculations.

Education plays a crucial role regarding opportunities for working at home. Employees who have higher qualifications tend to be more often engaged in flexible work arrangements (Noonan et al. 2012). In contrast to the former tables, the values in Table 28 are interpreted the other way around: in Tables 26 and 27 I displayed the share of men, young employees, employees in small firms, etc. *within the population working at home.* Now I show the share of people working at home *within educational categories.*

Thus, Table 28 displays the shares of employees working at home and working at home intensively by gender. The same argument and interpretation is also valid for industries and vocational fields in Table 29.

Since gender is often considered as an important determinant of working at home, I additionally consider differences by qualification for men and women separately. The results indicate that working at home is related to qualification in a similar way for men and women. In general, the higher the degree, the higher the shares of employees working at home. The highest shares of work at home for both genders occur for employees with Abitur and vocational education and Abitur and further studies. The corresponding shares are 45 and 56 percent for men and 44 and 53 percent for women. The shares do not differ much between genders, although they are slightly higher for men.

Working at home intensively shows similar results. Again, the highest shares for both genders can be found for employees with Abitur and either vocational education or further studies. While only 19 percent of men who have Abitur and vocational education work at least frequently at home, 24 percent of men who have Abitur and further studies do so. The shares for women are 24 and 28 percent, respectively. Comparing the shares for men and women, the results indicate that once women decide to work at home, they do it slightly more frequently which is consistent with the results in Table 27.

There are certain jobs that are more suitable for the opportunity to work at home. In particular, IT-related jobs or jobs that belong to the service sector are often considered as suitable for working flexibly. The results of Table 29 show that the public sector delivers, with 38 percent, the highest share of employees working at home followed by the service sector without craft and trade with a share of 31 percent. It seems that the industry in which employees work plays a crucial role for working at home. The public sector is also leading concerning working at home intensively. Nearly one quarter of employees report to work at home frequently or always.

In order to analyse the relationship between working at home and different jobs, Table 29 also shows the shares of employees working at home and working at home at least frequently with respect to vocational field.[29] Table 29 reveals that the teaching profession in particular is by far the most suitable for working at home. 90 percent of teachers work at home. As teaching belongs to the public sector, the result is consistent with the

[29] Table 32 in the Appendix of Chapter 5 shows the distribution of industries and vocational fields in the sample.

Table 29: Descriptives IV: Share of Employees with Flexible Work Arrangements by Industry and Vocational Field

Variable	**Share Working at Home**	**Share Working at Home Intensively**
Industry		
public sector	0.38	0.22
manufacturing industry	0.22	0.05
craft	0.24	0.06
trade	0.18	0.04
other services	0.31	0.08
Vocational Field		
mining	0.39	0.07
manufacturing and restoring	0.13	0.03
manufacturing and maintenance	0.05	0.01
trade	0.19	0.05
traffic and logistics	0.10	0.02
gastronomy and cleaning	0.25	0.05
commercial services	0.23	0.05
mathematics and natural sciences	0.35	0.09
law, business and economics	0.60	0.19
humanities and art	0.48	0.12
health and social sciences	0.32	0.10
teaching	0.90	0.79

Source: BIBB/BAuA Employee Survey 2006, own calculations.

finding that the public sector has the highest shares of employees who work at home. The vocational fields law, business and economics as well as humanities and art are also quite fitting for working at home. The shares of employees who work at home are 60 and 48 percent. Both fields are either part of the public sector or the service sector in general which is again consistent with the former results concerning industries.

Working at home intensively has the same tendencies among vocational fields. The shares of employees working at home at least frequently are 79 percent for teaching, 19 percent for law, business and economics and 12 percent for humanities and art. Those are the highest shares among all vocational fields.

5.4 Analytical Framework and Estimation Procedure

In order to investigate the determinants of working at home econometrically, I assume that the way employees choose these work arrangements can be described by a discrete choice model. The outcome of the choice of employee i is represented by a dummy variable WH_i that relates the determinants of the decision to work at home to the outcome of the decision which is determined jointly by the employer and the employee:

$$WH_i = \alpha X_i + \beta ED_i + \gamma Y_i + \delta Z_i + \phi VF_i + \theta ID_i + \epsilon_i \tag{7}$$

where WH_i denotes the choice of employee i to work at home. WH_i is measured by two dummy variables: work at home and intensive work at home. The determinants are represented by the following explanatory variables: X_i contains personal characteristics of employee i. It comprises gender, age and the presence of children less than six years old. The variable ED_i represents the qualification structure while Y_i includes tenure, overtime, work time and commute time of employee i. Firm characteristics are represented by Z_i which contains firm size as well as IT intensity of the work tasks of employee i. VF_i and ID_i reflect control dummies for vocational field and industry. The error term denoted by ϵ_i is assumed to be independent and identically distributed. Due to the binary character of the outcome variables, I use a probit estimation.[30] The following section describes the measures of all variables used in the estimations. All variables were measured in the year 2006.

The gender of employees is measured by a dummy variable that takes the value one if the employee is male and zero if female. The variable representing the presence of children less than six years old is constructed in the same way. It takes the value one if employees have children under the age of six years and zero if they do not have children in this age group. The age of employees is measured by three dummy variables: the first one takes the value one if employees are less than 30 years old and zero otherwise, the second one takes the value one if employees are between 30 and 49 years old (reference category) and zero otherwise while the third one takes the value one if employees are aged 50 or older and zero otherwise.

[30] For more details on the probit estimation see Wooldridge (2010).

I also consider the qualification structure of employees by creating six dummy variables: the first one takes the value one if employees have no degree at all and zero otherwise (reference category), the second variable takes the value one if employees have only secondary school degree and zero otherwise, the third dummy is one if employees have secondary school and vocational education while the fourth variable takes the value one if employees have only Abitur and zero if they do not. The last two variables take the value one if employees have Abitur and vocational education or Abitur and studies and zero otherwise.

Tenure, the amount of overtime and work time as well as the commute time to the workplace are relevant issues for flexible forms of workplace organisation. I control for tenure of employees by the number of years they spent working for the firm. Overtime is measured by the number of additional work hours per month while I control for the work time by the number of work hours per week. Commute time to the workplace is quantified by the time measured in minutes employees need to get to their workplace. Overtime might lead to an endogeneity problem, as it is not clear if overtime leads to working at home or if working at home results in a higher workload for employees which in turn leads to overtime as firms know that employees have the opportunity to work at home at any time.

In order to control for firm size, I create three dummy variables representing the number of employees in the firm. The first variable takes the value one if the firm where the employee works has one to 19 employees and zero otherwise. This is the reference category. The second dummy takes the value one if the firm has 20 to 99 employees and zero otherwise while the third variable takes the value one if the firm has 100 or more employees and zero if they have less.

I proxy the IT intensity of employees' work tasks by using a dummy variable that takes the value one if employees work with computers and zero otherwise. At the same time this variable measures workers' technological skills (Bertschek et al. 2010). In addition, dummy variables control for industry-specific fixed effects and vocational field.

5.5 Results

Table 30 shows the marginal effects of the probit estimation of equation 7.[31] The dependent variable is working at home. In the first specification I include only gender and children less than six years old as explanatory variables in the estimation equation, the most frequently discussed reasons for working at home. Both variables are insignificant.

In the second specification I add dummy variables for education, age of employees and firm size to the estimation equation. In addition, industry dummies and dummy variables for vocational field are included in order to control for potential sectoral and occupational differences. The impact of gender becomes highly significant when including the mentioned variables. Men have a probability of working at home that is about 8.5 percentage points higher than women. The presence of children less than six years old remains insignificant. The combination of Abitur with either vocational education or studies has a positive influence on working at home. The probability of working at home rises for both degrees by 25.7 and 33.0 percentage points compared to employees with no degree. Employees less than 30 years old have a 10.5 percentage points lower probability of working at home compared to prime age workers between 30 and 49 years old. In contrast, the impact of employees being at least 50 years old is not significant. Larger firm size reduces the probability of working at home. Employees who work in middle-sized firms with 20 to 99 employees have a 4.5 percentage point lower probability of working at home than employees working in small firms. The propensity to work at home decreases by 10.7 percentage points for employees who work in large firms with at least 100 employees. All results are significant at the one percent level.

In the third specification, further control variables are included. The estimation equation is extended by a dummy variable for computer use and discrete variables for tenure, overtime, work time and commute time. The impact of gender on working at home remains qualitatively unchanged. Men are with 4.0 percentage points more likely to work at home than women which is a surprising result as women are generally rather expected to work at home. The impact of children less than six years old turns significant at the five percent level indicating that employees who have children in this age group have a 3.4 percentage point higher propensity to work at home. The qualification structure leads to similar results as well. The only difference is that the effect of employees with only Abitur becomes significant at the ten percent level. The results concerning education

[31] The coefficients of the first stage regression can be found in Table 34 in the Appendix of Chapter 5.

indicate a 17.6 percentage points higher probability to work at home for employees with only Abitur, a 23.5 percentage point higher probability for employees with Abitur and vocational education and a 29.2 percentage point increase for employees with Abitur and studies. These three educational levels lead to the highest probability increase on working at home of all variables in the regression equation.

Being younger than 30 years is once again highly significant and decreases the probability of working at home by 10.0 percentage points. Firm size remains for middle-sized and large firms qualitatively unchanged. The probabilities of working at home decrease by 6.2 and 13.6 percentage points respectively pointing towards the fact that working at home occurs more often in small firms with a familial business culture built on trust. Furthermore, the results show that computer use is a relevant determinant for working at home. It increases the propensity to work at home by 5.6 percentage points. Tenure, overtime and work time are also important factors that influence working at home. Tenure increases the probability of working at home by 0.1 percentage points per year while overtime and work time lead to an increase of the probability of working at home by 0.2 and 0.3 percentage points per hour. Although the impacts of tenure, overtime and work time are highly significant, the probability increase is rather small. In contrast, commute time is insignificant.

Table 31 reports the marginal effects of the probit estimation with an alternative outcome variable.[32] The dependent variable is now working at home intensively. The explanatory variables are the same as in Table 30. Most results of the third specification lead to similar and qualitatively unchanged results as in Table 30 concerning the variables children less than six years old, firm size, overtime and work time. In contrast to Table 30 where men have a higher probability of working at home, they have a 1.0 percentage points lower probability of working at home intensively compared to women. Therefore, women are more likely to work at home frequently or always once they decide to work at home although the difference is not very high compared to men. Furthermore, education is insignificant for all qualification levels indicating that the formerly high impact of education on working at home disappears for working at home intensively. Computer use and tenure are not significant as well for working at home intensively compared to the results in Table 30. On the other hand, age plays a noticeable role for working at home intensively. While employees younger than 30 years old have a 3.9 percentage points lower probability of working at home frequently or always compared to prime age

[32]The coefficients of the first stage regression are in Table 35 in the Appendix of Chapter 5.

Table 30: Probit Estimation I: Marginal Effects on Average

	dependent variable: work at home		
	(1)	(2)	(3)
male	-0.001	0.085^{***}	0.040^{***}
	(0.008)	(0.011)	(0.011)
children $<$ 6 years	0.017	0.019	0.034^{**}
	(0.012)	(0.014)	(0.014)
only secondary school		0.044	0.042
		(0.091)	(0.092)
secondary school and vocational education		0.105	0.090
		(0.077)	(0.078)
only Abitur		0.140	0.176^{*}
		(0.102)	(0.106)
Abitur and vocational education		0.257^{***}	0.235^{***}
		(0.087)	(0.088)
Abitur and studies		0.330^{***}	0.292^{***}
		(0.094)	(0.097)
employees $<$ 30 years		-0.105^{***}	-0.100^{***}
		(0.012)	(0.013)
employees $>$ 50 years		0.006	0.001
		(0.011)	(0.012)
firm with 20 - 99 employees		-0.045^{***}	-0.062^{***}
		(0.012)	(0.012)
firm with $>$ 100 employees		-0.107^{***}	-0.136^{***}
		(0.012)	(0.012)
computer use			0.056^{***}
			(0.013)
tenure			0.001^{*}
			(0.000)
overtime			0.002^{***}
			(0.000)
work time			0.003^{***}
			(0.001)
commute time			0.001
			(0.001)
dummies for vocational field	no	yes	yes
industry dummies	no	yes	yes
number of observations	10,844	10,844	10,844

Significance levels: *: 10%, **: 5%, ***: 1%. Standard errors in parentheses. Reference categories: unqualified employees, employees 30-50 years, small firms.

workers, employees aged 50 or older have a 1.3 percentage points higher probability. The results concerning age indicate that the older employees are the higher is the probability of working at home intensively.

Table 31: Probit Estimation II: Marginal Effects on Average

	dependent variable: intensive work at home		
	(1)	(2)	(3)
male	-0.030^{***}	0.009	-0.010^{*}
	(0.006)	(0.005)	(0.005)
children < 6 years	0.011	0.026^{***}	0.033^{***}
	(0.009)	(0.008)	(0.008)
only secondary school		-0.038	-0.037
		(0.026)	(0.023)
secondary school and vocational education		-0.020	-0.026
		(0.041)	(0.040)
only Abitur		0.003	0.015
		(0.047)	(0.051)
Abitur and vocational education		0.028	0.017
		(0.046)	(0.042)
Abitur and studies		0.035	0.017
		(0.053)	(0.046)
employees < 30 years		-0.041^{***}	-0.039^{***}
		(0.006)	(0.006)
employees > 50 years		0.014^{**}	0.013^{*}
		(0.006)	(0.007)
firm with 20 - 99 employees		-0.012^{*}	-0.018^{***}
		(0.006)	(0.006)
firm with > 100 employees		-0.041^{***}	-0.050^{***}
		(0.006)	(0.006)
computer use			0.007
			(0.006)
tenure			0.001
			(0.001)
overtime			0.001^{***}
			(0.000)
work time			0.001^{***}
			(0.000)
commute time			0.001
			(0.001)
dummies for vocational field	no	yes	yes
industry dummies	no	yes	yes
number of observations	10,844	10,844	10,844

Significance levels: *: 10%, **: 5%, ***: 1%. Standard errors in parentheses. Reference categories: unqualified employees, employees 30-50 years, small firms.

Men are more likely to work at home. The same result is also found by Brenke (2014), while some earlier studies point to a higher prevalence of working at home among women. The presence of children has a positive and robust impact on working at home that is confirmed by almost all studies so far on this topic. Kraut (1989), Mannering et al.

(1995), Mokhtarian et al. (1998) as well as Noonan et al. (2012) support the result concerning the presence of small children. Concerning working at home intensively, the study by Mannering at al. (1995) confirms the results of Table 31: the presence of small children favours more frequent working from home. The results for the qualification levels are also consistent with former studies. De Graaff et al. (2003), Popuri et al. (2003), Perez et al. (2004) as well as Peters et al. (2004) and Noonan et al. (2012) find that employees who are highly educated have a higher propensity to be active in flexible work arrangements. One explanation might be that a high qualification level is related to higher positions in a firm wherein working at home occurs more often (Noonan et al. 2012).

The relevance of computers or information and communication technologies for flexible work arrangements is also confirmed by Mannering et al. (1995), De Graaff et al. (2003) and Perez et al. (2004). As the literature finds mixed results on the impact of tenure on telecommuting, the slightly positive effect I find in this study is confirmed only by Popuri et al. (2003). The positive impact of overtime and work time on working at home is also found by Popuri et al. (2003), Peters et al. (2004) and Noonan et al. (2012) showing that telecommuters have longer working hours compared to non-telecommuters.

A sensitivity check splitting the sample up by gender was done in order to find out if there are gender-based differences in the results. The comparison of the marginal effects listed in Tables 36 and 37[33] in the Appendix of Chapter 5 indicates that there are no differences concerning education, overtime and work time. While Abitur and vocational education and Abitur and studies have the biggest positive and significant impacts on working at home, overtime and work time have very small but highly significant effects for both genders. Differences between both genders occur in age, computer use and tenure. While computer use and tenure are significant for men, they remain insignificant for women. Men aged 50 or older have a higher probability to work at home compared to male prime age workers between 30 and 50 years old. For women, age plays a completely different role. Women under 30 years old as well as women aged 50 or older have both a lower probability to work at home compared to prime age women. All other variables are insignificant for both genders.

In summary, men have a higher probability of working at home in general while women are more likely to work at home frequently or always. The presence of small children

[33] The coefficients of the first stage regression are available from the author upon request.

also increases employees' probability of working at home and working at home intensively. While the probability of working at home increases with the qualification level, employees in large or middle-sized firms are less likely to work at home. Employees younger than 30 years have a lower probability to work at home while employees who work with computers are more likely to work at home. Tenure, overtime and work time are positively associated with working at home while overtime and work time are relevant determinants for working at home intensively.

5.6 Conclusion

The current analysis sheds light on the determinants of flexible work arrangements, specifically working at home and working at home intensively. Most determinants for German employees are consistent with those of other studies where individual-level data from other countries is used.

The results in this study reveal that working at home and working at home intensively occur mainly in small firms. A possible practical implication for middle-sized and large firms might be to support flexible work arrangements in order to enable their employees to benefit from the advantages linked to those work arrangements and benefit themselves from cost-savings concerning office equipment and more efficient organisation structures. The most surprising result of this study is that men are more likely to work at home than women. The reason might be that women work more often part-time or not at all compared to men. Children also influence the probability to work at home, but the effect is similar for women and men. Education plays a far larger role for the probability to work at home than gender.

However, the topic of this paper needs further research. A panel data analysis or an adequate instrument for working at home might solve the potential endogeneity problem between overtime and working at home. I leave this to future research. Furthermore, the impacts of flexible work arrangements on employee satisfaction would be interesting to investigate.

5.7 Appendix Chapter 5

Table 32: Distribution of Industries in the Sample

Variable	Observations	Percentage
Industry		
public sector	3852	35.39
manufacturing industry	2496	22.93
craft	754	6.93
trade	1125	10.34
other services	2064	18.96
other sectors	593	5.45
sum	10,884	100
Vocational Field		
mining	72	0.66
manufacturing and restoring	920	8.45
manufacturing and maintenance	700	6.43
trade	959	8.81
traffic and logistics	864	7.94
gastronomy and cleaning	204	1.87
commercial services	2927	26.89
mathematics and natural sciences	1028	9.45
law, business and economics	505	4.64
humanities and art	300	2.76
health and social sciences	1586	14.57
teaching	819	7.52
sum	10,884	100

Source: BIBB/BAuA Employee Survey 2006, own calculations.

Table 33: Descriptives: Average Hours of Work per Week by Overtime

Variable	Mean	N
overtime: yes	40.13	9370
overtime: no	33.21	1514
total	39.17	10,884

Source: BIBB/BAuA Employee Survey 2006, own calculations.

Table 34: Probit Estimation I: Coefficient Estimates

	dependent variable: dummy for work at home		
	(1)	(2)	(3)
male	−0.001	0.258***	0.123***
	(0.025)	(0.032)	(0.035)
children < 6 years	0.049	0.059	0.103**
	(0.036)	(0.040)	(0.041)
only secondary school		0.130	0.125
		(0.259)	(0.265)
secondary school and vocational education		0.325	0.279
		(0.241)	(0.246)
only Abitur		0.388	0.483*
		(0.264)	(0.270)
Abitur and vocational education		0.735***	0.678***
		(0.242)	(0.247)
Abitur and studies		0.883***	0.788***
		(0.244)	(0.250)
employees < 30 years		−0.351***	−0.335***
		(0.046)	(0.048)
employees > 50 years		0.020	0.003
		(0.034)	(0.038)
firm with 20 - 99 employees		−0.140***	−0.197***
		(0.039)	(0.040)
firm with > 100 employees		−0.327***	−0.423***
		(0.038)	(0.039)
computer use			0.179***
			(0.043)
tenure			0.003*
			(0.001)
overtime			0.008***
			(0.001)
work time			0.010***
			(0.001)
commute time			0.001
			(0.001)
dummies for vocational field	no	yes	yes
industry dummies	no	yes	yes
constant term	−0.542***	0.779***	0.254
	(0.017)	(0.072)	(0.267)
observations	10,884	10,884	10,884
χ^2-statistic	1.91 ($p = 0.385$)	2779.48 ($p = 0.000$)	3078.21 ($p = 0.000$)

Significance levels: *: 10%, **: 5%, ***: 1%. Standard errors in parentheses. Reference categories: unqualified employees, employees 30-50 years, small firms.

Table 35: Probit Estimation II: Coefficient Estimates

	dependent variable: dummy for intensive work at home		
	(1)	(2)	(3)
male	-0.152^{***}	0.068	-0.079^{*}
	(0.031)	(0.044)	(0.047)
children $<$ 6 years	0.057	0.181^{***}	0.236^{***}
	(0.044)	(0.053)	(0.055)
only secondary school		-0.368	-0.399
		(0.345)	(0.353)
secondary school and vocational education		-0.153	-0.205
		(0.304)	(0.311)
only Abitur		0.027	0.109
		(0.341)	(0.348)
Abitur and vocational education		0.202	0.129
		(0.305)	(0.311)
Abitur and studies		0.230	0.123
		(0.308)	(0.314)
employees $<$ 30 years		-0.387^{***}	-0.383^{***}
		(0.072)	(0.075)
employees $>$ 50 years		0.102^{**}	0.099^{*}
		(0.045)	(0.051)
firm with 20 - 99 employees		-0.095^{*}	-0.150^{**}
		(0.052)	(0.053)
firm with $>$ 100 employees		-0.309^{***}	-0.397^{***}
		(0.051)	(0.053)
computer use			0.065
			(0.058)
tenure			0.002
			(0.002)
overtime			0.007^{***}
			(0.001)
work time			0.011^{***}
			(0.002)
commute time			0.001
			(0.001)
dummies for vocational field	no	yes	yes
industry dummies	no	yes	yes
constant term	-1.121^{***}	0.693^{**}	0.214
	(0.021)	(0.319)	(0.334)
observations	10,884	10,884	10,884
χ^2-statistic	24.47 ($p = 0.000$)	2789.68 ($p = 0.000$)	2934.68 ($p = 0.000$)

Significance levels: *: 10%, **: 5%, ***: 1%. Standard errors in parentheses. Reference categories: unqualified employees, employees 30-50 years, small firms.

Table 36: Probit Estimation: Marginal Effects on Average, Only Men

	dependent variable: work at home		
	(1)	(2)	(3)
children < 6 years	0.023	0.033	0.029
	(0.017)	(0.018)	(0.019)
only secondary school		0.083	0.071
		(0.136)	(0.136)
secondary school and vocational education		0.142	0.111
		(0.103)	(0.105)
only Abitur		0.118	0.184
		(0.141)	(0.150)
Abitur and vocational education		0.295**	0.250**
		(0.124)	(0.126)
Abitur and studies		0.374***	0.317**
		(0.130)	(0.136)
employees < 30 years		−0.063***	−0.029
		(0.020)	(0.023)
employees > 50 years		0.045***	0.034*
		(0.016)	(0.018)
firm with 20 - 99 employees		−0.017	−0.030
		(0.020)	(0.019)
firm with > 100 employees		−0.066***	−0.089***
		(0.019)	(0.020)
computer use			0.090***
			(0.017)
tenure			0.002**
			(0.001)
overtime			0.002***
			(0.000)
work time			0.005***
			(0.001)
commute time			0.001
			(0.001)
dummies for vocational field	no	yes	yes
industry dummies	no	yes	yes
number of observations	5119	5119	5119

Significance levels: *: 10%, **: 5%, ***: 1%. Standard errors in parentheses. Reference categories: unqualified employees, employees 30-50 years, small firms.

Table 37: Probit Estimation: Marginal Effects on Average, Only Women

	dependent variable: work at home		
	(1)	(2)	(3)
children < 6 years	0.010	0.006	0.034
	(0.018)	(0.020)	(0.021)
only secondary school		0.016	0.014
		(0.126)	(0.128)
secondary school and vocational education		0.078	0.066
		(0.114)	(0.117)
only Abitur		0.174	0.188
		(0.149)	(0.154)
Abitur and vocational education		0.229*	0.213*
		(0.125)	(0.128)
Abitur and studies		0.287**	0.249*
		(0.138)	(0.142)
employees < 30 years		−0.134***	−0.142***
		(0.016)	(0.163)
employees > 50 years		−0.031*	−0.028*
		(0.015)	(0.017)
firm with 20 - 99 employees		−0.066***	−0.083***
		(0.016)	(0.016)
firm with > 100 employees		−0.138***	−0.167***
		(0.015)	(0.016)
computer use			0.022
			(0.019)
tenure			−0.001
			(0.001)
overtime			0.003***
			(0.001)
work time			0.002***
			(0.001)
commute time			−0.001
			(0.001)
dummies for vocational field	no	yes	yes
industry dummies	no	yes	yes
number of observations	5765	5765	5765

Significance levels: *: 10%, **: 5%, ***: 1%. Standard errors in parentheses. Reference categories: unqualified employees, employees 30-50 years, small firms.

6 Conclusion and Limitations

6.1 Overall Summary

The thesis explores the impact of various software applications on firm performance, the adoption of new software applications and the determinants of flexible work arrangements. The impact of enterprise software on innovation in the service sector is analysed in Chapter 2, the determinants of the adoption of social enterprise software in Chapter 3, the effect of social software applications on labour productivity in Chapter 4 and the determinants of flexible work arrangements in Chapter 5.

In summary, enterprise software is a special business software which is designed to serve the process integration across the value chain. Enterprise software contains software products which support decision-making and day-to-day business operations. Social software applications like wikis, blogs and social networks facilitate communication, cooperation and information sharing between individuals. Social enterprise software links enterprise software with social software applications and serves the purpose of providing several benefits in information storing and handling, knowledge acquisition, management and customer relations.

Positive impacts of enterprise software applications on firm performance are already shown in the literature (Hitt et al. 2002; Aral et al. 2006; Engelstätter 2012). Chapter 2 contributes to this research area focusing on different types of enterprise software being customised and business sector-specific software and service innovations in particular. Based on a survey among "service providers of the information society" conducted by the ZEW, the results estimated by a probit model show that customised enterprise software is connected to service innovations. A relationship between sector-specific enterprise software and innovation in the service sector could not be confirmed. Thus, innovative activity seems to be related to the use of appropriate enterprise software.

Chapter 3 goes one step further and analyses the benefits and performance impacts of the adoption of social enterprise software as special ICT application. SES is a nested innovation as its adoption requires an established ICT infrastructure. Using the ZEW ICT survey and relying on a two step bivariate probit model controlling for sample selection, the results reveal that firms which use B2B e-commerce are more likely to adopt SES. The correlations also reveal weak evidence for complementarity between B2B e-commerce and SES. In addition, sales and labour productivity, are highest for firms using SES and B2B e-commerce applications in conjunction.

The impact of social software applications on service innovation has already been investigated by Meyer (2010). The next chapter deals with a further aspect of the influence of social software on firm performance and focuses on labour productivity. Relying again on the ZEW ICT survey and using OLS as well as an IV-regression, the results in Chapter 4 show that using social software makes firms less productive in an early stage of adoption as the use is not efficient yet or they face shirking among employees or a lack of acceptance from different sides.

Chapter 5 moves away from the firm level to the individual level and explores forms of work organisation in firms which are provided by ICT. Flexible work arrangements like the opportunity to work at home or to telecommute are popular forms of work organisation. Using individual-level data of the BIBB/BAuA employee survey and applying a probit estimation approach, the results indicate that men have a higher probability to work at home but women are more likely to work at home intensively. Education, tenure and the use of computers increase the probability of working at home while firm size and a young age of employees under 30 years reduce it. Having children less than six years old, overtime and work time have a positive impact on both working at home and its frequency. Firm size also reduces the probability of working at home intensively.

Overall, the results confirm that ICT leads to benefits for firms, increasing innovative activity and labour productivity as well as for employees offering new forms of work organisation and work arrangements.

6.2 Limitations and Further Research

The analyses presented in this thesis face some limitations that are mostly data driven. Both the ICT survey and the survey among the "service providers of the information society" feature high panel mortality as several firms do not respond regularly in consecutive survey waves. The only way to analyse the research questions is to use cross-sections which cannot exclude biases due to reverse causality completely. A new panel data set which is larger and more detailed could possibly solve this causality problem in the future. In addition, adequate or better instruments for enterprise software, social software and social enterprise software might also help to solve this problem. Then, the future research might check the robustness of the results in this thesis as well. Concerning social enterprise software, its impact on productivity and innovation activity is still not investigated offering additional opportunities for future research.

The BIBB/BAuA employee survey has similar limitations concerning the data. Information about flexible work arrangements are only included in the survey wave of 2006. Thus, a panel data analysis is not possible either and leads to potential reverse causality. Again, a new and more detailed data set or including questions on this topic in further survey waves of BIBB/BAuA on a regular basis might help to solve the endogeneity problem between overtime and working at home. Finding an adequate instrument for flexible work arrangements might also contribute to future research. A possible research question that could be investigated with new German data is the impact of flexible work arrangements on job satisfaction of employees. Due to a lack of data, this question has not been analysed with German data so far.

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