

Engelstätter, Benjamin

Conference Paper

Enterprise Systems and Innovations

Beiträge zur Jahrestagung des Vereins für Socialpolitik 2010: Ökonomie der Familie - Session: Strategic Management, No. F4-V3

Provided in Cooperation with:

Verein für Socialpolitik / German Economic Association

Suggested Citation: Engelstätter, Benjamin (2010) : Enterprise Systems and Innovations, Beiträge zur Jahrestagung des Vereins für Socialpolitik 2010: Ökonomie der Familie - Session: Strategic Management, No. F4-V3, Verein für Socialpolitik, Frankfurt a. M.

This Version is available at:

<https://hdl.handle.net/10419/37215>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Enterprise Systems and Innovations[§]

Benjamin Engelstätter*

Centre for European Economic Research

Abstract

This paper analyzes the relationship between the three main enterprise systems (Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Customer Relationship Management (CRM)) and firms' innovational performance for process as well as product innovations. Using German firm-level data and a two part model, the results reveal that SCM systems foster the firms' likelihood of becoming a potential process innovator. In addition, ERP systems increase the number of process innovations a firm realizes. These results do not only emerge for the short-run of two years or less but remain also stable in the medium-run of two to four years. Concerning product innovational performance, only CRM systems increase the firms' likelihood to acquire product innovations, although the impact emerges for the short-run and vanishes if the long-run perspective is taken into account.

Keywords: Innovation, Product Innovation, Process Innovation, Enterprise Systems, Enterprise Resource Planning, Supply Chain Management, Customer Relationship Management

JEL Classification: L10, M20, O31

[§] I would like to thank Irene Bertschek, Daniel Cerquera, Francois Laisney and Pierre Mohnen for helpful comments and suggestions. All errors are my own.

* ZEW, ICT Research Group, P.O. Box 103443, D-68304 Mannheim, email: engelstaetter@zew.de

1 Introduction

Covering a large range of software products supporting day-to-day business operations and decision-making, company-wide suites of business software, namely enterprise systems in short, are devoted to particular process integration across the value chain. The three main enterprise systems, Enterprise Resource Planning (ERP), Supply Chain Management (SCM) and Customer Relationship Management (CRM), are widespread throughout many industries in numerous areas around the world. The purpose of these systems is to automate operations from supply management, inventory control, manufacturing scheduling, sales force automation and almost any other data-oriented management processes. SAP, the largest global enterprise software vendor, estimates the complete market for core enterprise applications including ERP, SCM and CRM in 2008 at nearly \$39 billion [32].

In general, enterprise systems ought to replace the firms' legacy software systems, which are usually poorly connected and spread out all over the firm. In addition, improvements in operational integration realized through enterprise system adoption can affect the entire organization. Therefore, ERP and SCM systems might positively foster innovational activity as they reduce idle times and save data mining or identify bottlenecks and shortages, thus providing information for process enhancements. With the firm-wide database updated in real time, which both systems provide, the effects of process innovations can be directly pictured, compared and controlled. CRM systems, on the other hand, yield a database of customer preferences, which can be a useful source for product innovations.

Although the usage of information and communication technology (ICT) applications in general is suspected to enhance firms' innovational performance [24], the potential impact of enterprise systems on innovational 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 systems for

innovational activity. Empirical evidence on the basis of firm-level data covering this topic is still lacking at present. Therefore, this study aims to provide the first empirical evidence of the impact of adopting any of the three main enterprise systems on firms' innovational performance. In order to achieve useful results, the present study relies on a unique database consisting of German firms from the manufacturing industry and from service sectors.

Using a two step approach the results provide first evidence of innovational activity fostered through enterprise system usage. The adoption of ERP and SCM systems increases the propensity to realize process innovations. In addition, ERP system usage has a positive impact on the amount of acquired process innovations. These impacts are not only short-term based, in fact they stay also stable in the medium-run of two to four years. The usage of CRM systems, on the other hand, does not have an impact on process innovations but positively impacts the propensity to realize product innovations, although this impact only holds on a short-term basis of two years or less.

The paper proceeds as follows: Section 2 gives an overview of the appropriate literature covering the benefits of enterprise systems in general and their potential effects on innovational performance in particular. Section 3 pictures the estimation approach whereas section 4 presents the dataset. Section 5 contains the estimation results. Concluding remarks are given in section 6.

2 Methodological and theoretical Framework

2.1 Benefits of Enterprise Systems in general

Replacing complex interfaces between different systems with standardized cross-functional transaction automation, ERP systems use a source of data that integrates enterprise functions such as sales and distribution, materials management, production planning, financial accounting, cost control and human resource management [1]. An ERP system is expected to reduce order cycle

times, which in return might lead to improved throughput, customer response times and delivery speeds [9, 27]. Due to automated financial transactions, cash-to-cash cycle times and the time needed to reconcile financial data at the end of a quarter or year can be minimized [25, 26]. The ERP system collects all enterprise data once during the initial transaction, stores the data centrally and performs updates in real time. The standardized firm-wide transactions and centrally stored enterprise data will also greatly facilitate the governance of the firm [28, 33].

IT-based SCM systems coordinate and integrate the complete flow of information, materials and finances and improve operational as well as business planning [11]. The real-time planning capabilities of SCM systems enable firms to react quickly to supply and demand changes [19], serving customers in a timely and comprehensive manner [4]. By reducing inventory levels, holding costs, spoilage and lead times, SCM systems can directly improve inventory management and increase profitability through a reduction of costs, avoiding lost sales and improving customer satisfaction [4]. Lower coordination, sales, general and administrative costs, improved decision-making and forecasting are additional benefits generated through SCM system usage [11]. Based on its ability of information sharing, collaborative planning and forecasting replenishment, a SCM system will also lead to improvements in decisions on order quantity, lowered time and costs of order processing or increased order frequencies combined with reduced lead time.

Providing the appropriate infrastructure, e. g. enabling effective sales force automation, centralized customer data warehousing and data mining paired with decision support and reporting tools, CRM systems facilitate the development of medium-term relationships with customers [22, 35]. A CRM system is also expected to lead to superior customer loyalty, reduced cost of sales and services or improved bottom-line profits [6]. It reduces duplication in data entry and maintenance by providing a centralized firm-wide database of customer information, capturing all their needs and wants. In addition, this database replaces systems maintained by individual sales people, institutionalizes

customer relationships and prevents the loss of organizational customer knowledge, when sales staff leaves the firm [19]. The database might also reduce costs via streamlining repetitive transactions and sales processes [8].

2.2 Effects of Enterprise Systems on Firms' innovational Performance

Enterprise systems might affect the firms' innovational performance through different channels. First of all, enterprise systems foster further innovations directly based on the benefits they provide. The firm-wide database generated and updated by the ERP system, for example, provides every employee with necessary data in real-time, thus making data-mining obsolete and enabling the workers to be more innovative and flexible [10]. ERP systems are also expected to provide strategic benefits and build additional business innovations, for example by enabling new market strategies or building up new process chains [34]. Using a SCM system all departments receive in time information about the resources necessary, therefore bottlenecks and idle time should be reduced to a minimum. Both systems together generate a suitable and more flexible [11, 27] working environment and, with product lifecycles and resource usage shown in real-time, room for process improvements and innovations should be easy to identify. In addition, with the firm wide database updated in real time, the results of the innovations can be directly pictured, controlled and compared, providing even more room for improvements. A CRM system, on the other hand, might be particularly useful for successful product innovations as its data offers a complete picture of the customers' wants and needs. In general, this knowledge of customers' preferences is expected to shape the firms' innovation success [21]. Therefore, firms with CRM systems in use should experience significant advantages in product enhancement and design as they can stick to a rich database of customer information and adjust their production accordingly.

Besides direct effects, enterprise systems might also indirectly increase innovational performance as the systems may foster the introduction of some organizational enhancements which have been

proven to facilitate the generation of more innovations. [37] proclaims that business units are more innovative once they reach a more centralized network position that enables them to access new knowledge generated by other units faster. Enterprise systems fit perfectly into this context as in particular ERP enhances the intern network capabilities of the firms by providing a centralized database with access for every employee and business unit and fastening connections between them. As the communication between the units is accelerated with an ERP system in use, the innovational activity of the firm might, according to [37], also increase. [7] show that firms generate more innovations with established upstream, respectively downstream, contacts to suppliers and customers. [30] support this argument as they emphasize the great value of backwards and horizontal knowledge linkages for process innovations. With their focus on communication with suppliers and customers, SCM and CRM systems are expected to maintain current and generate new upstream and downstream contacts far easier, generating more knowledge linkages in the process. Consequently, firms with SCM and CRM systems in use have access to a large pool of knowledge, which will, according to [7] and [30], be helpful to create more innovations.

3 Research methodology

3.1 Knowledge Production Function

The present study will be based on an innovation respectively knowledge production function as introduced by [15]. The basic assumption is that the output of the innovation process represents a result of several inputs linked to research and ongoing knowledge accumulation, such as, e. g., capital, investment or human capital [14]. [31] augment this function with even more inputs like enterprise characteristics, firm resources and organizational capabilities to take the different routes through which knowledge might influence the firms' innovation activities into account. In addition, I include enterprise systems in the knowledge production function, providing first insights of the

relationship between enterprise system adoption and the firm's innovational activity. To summarize, the probability that a firm will generate either product or process innovations is given by

$$(1) \quad z_i^* = X_i' \beta_1 + ID_i' \beta_2 + ES_i' \beta_3 + \varepsilon_i \quad z_i = 1 \text{ if } z_i^* \geq 0; z_i = 0 \text{ otherwise,}$$

where z_i stands for the i th firm's product or process innovation respectively. X_i covers firm characteristics expected to impact innovations activity, e. g., size, ICT capital, human capital and East German heritage. ID_i includes the control dummies for industry sectors and ES_i contains the enterprise systems used by firm i . ε_i is a standard error term.

3.2 Number of Innovation

As the selection equation (1) shows to which extent enterprise system usage foster the firms' innovation propensity, the next consecutive step will be to reveal the impacts of enterprise systems on the number of innovations realized in the firm. This form of innovational intensity can be specified as

$$(2) \quad y_i^* = Z_i' \lambda_1 + ID_i' \lambda_2 + ES_i' \lambda_3 + \gamma_i \quad y_i = y_i^* \text{ if } z_i = 1; y_i = 0 \text{ if } z_i = 0$$

where y_i^* is the unobserved latent variable accounting for the i th firm's number of process respectively product innovations. Z_i is a set of determinants expected to affect the number of innovations and contains, in general, the same variables as in equation (1). In addition to ES_i picturing enterprise system usage of firm i ID_i contains the industry control dummies and γ_i is a standard error term.

3.3 Estimation Procedure

Estimating equations (1) and (2) via maximum likelihood, count data methods have to be used for inference as the innovation intensity is measured by the number of realized innovations in this study. In general, this two-part model suffers from a selection bias as some information might be available for innovators only. In the current study, however, this selection does not occur as the questionnaire features the appropriate innovation question for every surveyed firm at the end of the questionnaire and contains no exclusive questions for innovators only. This constellation leads to a so called corner solution, featuring a potentially large proportion of zeros in the number of innovations. These zeros might arise for different reasons, e. g. having no need for innovation in general or having failed in introducing new innovations. Therefore, I consider both the hurdle and the zero-inflated model which explicitly allow for a separate treatment of zeros and strictly positive outcomes [39]. Each model is described in the following. The model selection based on appropriate tests takes place in section 5.

In the hurdle or two-part model the zeros are determined by the density $f_1(\cdot)$, so that $\Pr(y = 0) = f_1(0)$ and $\Pr(y > 0) = 1 - f_1(0)$ [5]. The positive counts, however, yield from the truncated density $f_2(y|y > 0) = f_2(y) / \{1 - f_2(0)\}$, which is multiplied by $P(y > 0)$ to ensure that the probabilities sum to 1. Hence suppressing regressors for notational simplicity the density of the hurdle model is

$$(3) \quad f(y) = \begin{cases} f_1(0) & \text{if } y = 0, \\ \frac{1 - f_1(0)}{1 - f_2(0)} f_2(y) & \text{if } y \geq 1 \end{cases}$$

A hurdle model is interpreted as reflecting a two-stage decision-making process, each part being a model of one decision. The two parts of the model are functionally independent. Therefore, the hurdle model can be estimated via maximum likelihood by separately maximizing two terms, one

corresponding to the zeros and the other one to the positives. The first part uses the full sample, the second part uses only the positive count observations.

The zero-inflated model on the other hand differs from the hurdle-model in that, with $p_i = \Pr(y_i = 1)$, y_i is equal to y_i^* for the full range of y_i^* and not just for strictly positive values. Like the hurdle-model, the zero-inflated one combines a count density, $f_2(\cdot)$, and a binary process with a density of $f_1(\cdot)$ [5]. In case the binary process takes on a value of 0, with a probability of $f_1(0)$, then y is equal to 0. In contrary, if the binary process takes on a value of 1, with correspondent probability of $f_1(1)$, then y takes on count values ascending from 0 onwards from the count density $f_2(\cdot)$. Therefore, the zeros occur in two ways in this model. One type of zeros arises as a realization of the binary process, the other type as a realization of the count process when the binary random takes on a value of 1. Suppressing regressors for notational simplicity, the density of the zero-inflated model results in

$$(4) \quad f(y) = \begin{cases} f_1(0) + \{1 - f_1(0)\} f_2(0) & \text{if } y = 0, \\ \{1 - f_1(0)\} f_2(y) & \text{if } y \geq 1 \end{cases}$$

As the zero-inflated model allows for two different types of zeros it is expected to be the better choice for inference in the current analysis. Nevertheless, a vuong test is used in the following to identify whether the hurdle or the zero-inflated model is suitable in the given setup.

For both models, the probability $f_1(0)$ may be a constant or may be parameterized through a binomial model like logit or probit. The second part of both models, i. e. the count process, can either be based on the Poisson or the negative binomial distribution. Allowing for overdispersion, frequently occurring in applied economics, the negative binomial distribution seems to be the more reasonable choice in the present analysis. In section 5, an appropriate likelihood ratio test clarifies which distribution to use.

4 The Data

The dataset used in this study results from two computer-aided telephone surveys conducted in 2004 and 2007 by the Centre for European Economic Research (ZEW). These surveys laid a specific focus on the diffusion and use of ICT in German companies. In general, the interviewee was the chief executive officer of the firms who could also decide to pass on questions to a corresponding employee like, e. g., the head of the ICT department. Each wave of this ICT-dataset originally contains information of about 4,000 firms with five or more employees, representatively chosen from important service and manufacturing sectors in Germany. The data basis for the sample stems from the credit rating agency Creditreform. This agency provides the largest data base on firms available in Germany. Creditreform collects some basic information like address, sector and firm size on all enterprises that ever applied for a bank credit. The selection from the population of German firms was stratified according to industries (seven branches of the manufacturing industry and seven selected service sectors), to three size classes and to two regions (East/West Germany). There have been asked as many firms as needed until all strata were filled.

Besides detailed information on the usage of several other ICT applications, the dataset provides the usage level of the three main enterprise software applications ERP, SCM and CRM. The possible level of usage in the questionnaire was none, minor or complete. For this study, I built a dummy variable for the use of each software application which takes the value one if a firm uses the software at least to a minor degree or completely and zero otherwise¹. In addition, the surveys contain information about the firms' workforce like the share of highly skilled workers and other variables, e. g. organizational practices.

The 2007 survey covers the product and process innovations in the time of 2004 to 2006. However, the answers on enterprise system usage in this survey are related to the year 2007. Since the survey

¹ The interpretation of an impact due to minor software use in comparison to no or complete use is impossible as the questionnaire does not make any distinctions between the levels of usage.

is organized as a panel dataset, I use the software usage reported in 2004 to construct the needed dummy variables. Nevertheless, the impacts of enterprise systems on the firms' innovational performance may to some extent still be biased upward as a few firms might have their enterprise systems reported in 2004 not yet installed by the time they generated their innovations. As the 2004 survey began in April, this source of endogeneity bias should be rather small but despite that, the results should be interpreted carefully. In the following section, the potential size of this bias will be checked via auxiliary regressions. The estimation procedure using enterprise systems reported in 2004 can only capture short-term innovational effects of a time space covering two years or less between the realized innovation and the enterprise system adoption. Therefore, the additional auxiliary regressions will also focus on revealing any innovational impacts of enterprise systems in the medium run.

Suffering from panel mortality and a large proportion of item-nonresponse, matching the data for the two periods returns nearly 1,100 observations. After dropping the banking sector², I had 989 observations left for my final dataset. Table 1³ shows the descriptive statistics for the variables used in this study. To employ a well-defined temporal sequence in line with the reported enterprise system usage, all other explanatory variables also refer to the year 2004. The innovation measures, on the other hand, are taken from the survey of 2007, capturing the innovations in the time of 2004 to 2006. In addition, Table 1 also contains the descriptive statistics for the industry affiliations and the location in the east respectively west part of Germany for the firms in the final sample.

----- Insert Table 1 about here -----

From 2004 to 2006, around 64 percent of the firms reported process innovations and 60 percent realized product innovations. The average number of process innovations a firm has introduced in

² As the enterprise software packages in the German banking sector seem to significantly differ from the ones used in other sectors, I decided to drop that sector completely in order to reduce measurement errors.

³ All Tables are located in the appendix.

the mentioned time space results in 3, for product innovations it turns out to be 5⁴. As innovational performance is highly influenced by former innovational experience [13, 17], the dataset also includes two dummy variables covering whether a firm was process or product innovator in the time span of 2001 to 2003. About 75 percent of the firms in the dataset are former process innovators, 64 percent reported former product innovations. Unfortunately, the number of innovations realized by the firms in the time span of 2001 to 2003 is not available in the database. For 2004, the average firm size amounts to 213 employees and the mean investment is € 2,195.400. The mean share of workers mainly using a personal computer for their work, as a proxy for the ICT intensity of the firm which is suspected to positively affect a firms' innovational performance, e. g. [18], amounts to around 47 percent in the used sample. Human capital is measured via the share of highly skilled workers, including degrees from university and technical college, and the share of medium skilled workers, including finished apprenticeships, in-firm trainings or technical degrees. The mean share of highly skilled workers amounts to around 23 percent in the given sample, for medium skilled workers it results in about 56 percent. The certification of the International Organization of Standardization (ISO) indicates that a firm applies an international standardized strategy in building new products or using new processes. Being ISO certificated values the projects of the certificated firm and, in general, makes them comparable to projects worldwide. In the literature, ISO certification is argued to positively affect innovations to some extent, e. g. [3, 29], making it a viable choice as a control variable in the present study. Around 44 percent of the firms in the used dataset are ISO certificated. Nearly 27 percent of the firms are located in East Germany. Enterprise systems are widely spread in the used sample, only around one quarter of the firms reports no enterprise systems at all. Especially common is the use of ERP, around 64 percent of the observed firms rely on this system. SCM systems are adopted from around 43 percent of the firms and about one half of the firms use CRM systems. All three enterprise systems together are employed by around 28 percent of the firms. Examining the industry affiliation of the firms, the

⁴ To correct for especially high outliers and to reduce potential measurement errors, I use the 95th percentile of the reported quantities for both types of innovations.

biggest share, of around 12 percent, conducts business in metal and machine construction, only a few belong to the automobile or chemical industry (5 respectively 6 percent).

Table 2 reports the descriptives for a group of additional organizational dummy control variables which I expect to positively influence the firms' innovational performance. As shown in [18], the firms' innovation activity is not only influenced by the usage of ICT but also positively affected by certain organizational factors which allow for more employee flexibility. To capture the potential influence of these factors on firms' innovational activity, I include five organizational practices as controls in the estimation procedure. These organizational variables report if a firm has established accounts for working hours, uses job rotation, quality circles or relies on units with own cost and result responsibility or self dependent working groups. The percentage of firms which apply these practices varies from nearly 70 percent using accounts for working hours to 19 percent using job rotation techniques.

----- Insert Table 2 about here -----

To firstly offer descriptive evidence for potential impacts of enterprise systems on innovational performance, Table 3 shows additional statistics of the firms using enterprise systems. In addition, there lies a specific focus on the group of firms using no enterprise systems at all or the full suite of the systems. Comparing the average innovational performance for each group with the entire sample means reported in Table 1, it is easy to see that once the firms use enterprise software, every innovation measure exceeds the sample mean slightly. Firms which use all three enterprise systems together show the highest mean values. In contrast, using no enterprise system at all results in values lower than the sample mean. This result may be viewed as a first clue pointing to the suspected positive impact of enterprise systems on innovational performance. However, it does not provide any descriptive evidence for highly different impacts of specific enterprise systems on one

type of innovations as argued in section 2. CRM users do not show higher mean values concerning product innovations and the mean values of ERP or SCM using firms are only slightly higher than those of CRM users in the case of process innovations.

----- Insert Table 3 about here -----

5 Empirical Results

5.1 Model Selection

As first step of the estimation procedure an appropriate model for the given estimation setup has to be chosen. According to [16], a bivariate model should be used for process and product innovations but the hypothesis of independence of both error terms, given the employed covariates, is not rejected in the current dataset. Therefore, two separate models will be used for inference. In the following estimations, I use two specifications, one parsimonious specification without the mentioned additional organizational control variables and another one capturing the impacts of these control variables as well. For the estimation of the binary process given in equation (1) I choose a probit⁵ model. Deciding the appropriate estimation method for equation (2), a likelihood ratio test evaluating the Poisson model (dispersion parameter $\alpha = 0$) against the negative binomial distributed alternative given the employed covariates rejects the hypothesis of Poisson distribution usage in favor of the negative binomial distribution significantly at the one percent level for both types of innovations. Testing the zero-inflated against the hurdle model the Vuong-Test [38] finally shows that the zero-inflated model describes the data best for process as well as product innovations. The test statistics are pictured in Table 4. Given these results, I stick to the zero-

⁵ A logit specification could also be used to estimate equation (1). However, as the results are virtually the same compared to the ones obtained from the probit approach they are not pictured in this study.

inflated negative binomial model for inference⁶, which indicates that there are two different types of zero innovations reported from the firms. The first type corresponds to the non-innovators, who decide not to innovate at all. The second type of zeros, however, captures potential innovators, who report zero innovations not because they are not willing to innovate but maybe because of failure to introduce the innovations in their firm. Hence, the binary process which is estimated in the probit part of the zero-inflated model is built in the following way: the value one captures all non-innovators, i. e. those firms which are not willing to innovate at all. The complementary event, expressed by the value of zero in the binary process, contains all potential innovators, i. e. those firms which have realized some innovations and those firms willing to innovate but facing zero innovations due to a failure of realizing them. The second negative binomial part of the model uses only potential innovators, hence its coefficients must be interpreted having this condition in mind. Besides allowing for these two different kinds of zeros, the zero-inflated model is also completely identified even if the same covariates are employed in both parts of the model [23].

----- Insert Table 4 about here -----

5.2 Short-Run Impacts of Enterprise Systems on process innovations

Picturing the mentioned short-term relation of two years or less Table 5 presents the estimation results of the zero-inflated negative binomial model for process innovations. Column (1) and (3) of Table 5 display both specifications, the parsimonious one and the one including the organizational control variables, for the propensity of being a non-innovator. Therefore, the event of being a potential innovator is captured in the complementarity probability. Column (2) and (4) of Table 5, on the other hand, report the estimation results for both specifications of the negative binomial part

⁶ Estimating the negative binomial hurdle model as a robustness check offers similar results to the ones obtained from the zero-inflated alternative. The results of the hurdle variant are available from the author upon request.

of the model. As this study focuses especially on the impacts of enterprise systems on innovational performance, I will discuss other factors influencing innovational activity only briefly.

As expected, the parsimonious estimation for process innovations shows that the adoption of a SCM system significantly decreases the probability of being a non-innovator and accordingly increases the probability of being a potential innovator. This result holds also if the specification with all additional control variables is applied, although the coefficient of SCM decreases in size and level of significance. ERP and CRM system usage, on the other hand, shows no impact at all. Considering the other coefficients in Column (3), former process innovators and firms with established quality circles experience a lower probability of non-innovation compared to firms without former process innovational activity or no quality circles. An acquired ISO certification also seems to lower the probability of acquiring no process innovations at all, although only in the parsimonious specification. The share of highly skilled workers, on the other hand, shows a significantly positive impact on the probability of being a non-innovator. This puzzling impact seems to account for the case that in contrast to product innovations, process innovations might, in general, not be initiated by the highly skilled workforce but by low to medium skilled workers working directly in the production line⁷. In addition, a highly proportion of highly skilled workers may reflect knowledge intensive firms, which, in general, do not possess large production processes with much room for optimization.

Conditional on being a potential process-innovator, the adoption of an ERP system is strongly positive related to the number of process innovations in the short-run. This holds for the parsimonious specification as well as for the specification including additional organizational control variables, although the coefficient faces a minor decrease in size in the second specification. SCM systems, on the other hand, fail to significantly increase the number of process innovations a

⁷ In the current dataset this relation seems to hold as the spearman correlation coefficient between product innovations and highly skilled workers amounts to 0.25 significant at the one percent level compared to a slightly negative but non-significant coefficient between process innovations and highly skilled workers.

potential innovative firm realizes. The usage of a CRM system also does not have an impact on the intensity of process innovations. In addition, being a former process innovator and an acquired ISO certification show a highly significant positive influence on the number of process innovations in 2004 to 2006, although both coefficients decrease in size in the second specification with additional organizational variables included.

Connecting both model parts Table 5 also contains the estimated unconditional marginal effects at mean⁸ of enterprise system usage. As expected, the marginal effects of ERP and SCM are positive and significant in both specifications indicating an increase in the number of process innovations on average for firms which adopt either system, although ERP seems slightly more effect as the marginal effect of ERP outmatches the effect of SCM in size. Unsurprisingly, the effect of CRM stays completely insignificant.

----- Insert Table 5 about here -----

5.3 Short-Run Impacts of Enterprise Systems on product innovations

Moving on to product innovations, Column (1) and (3) of Table 6 picture the results of the probit part of the zero-inflated model for both specifications. The short-term impacts of enterprise systems on the probability to acquire no product innovations at all differ completely compared to the impacts on the decision to process innovate. ERP and SCM systems seem to have no effect on the firms' decision to realize product innovations. Firms, which adopt CRM systems, however, face a significantly lower probability to become a non-innovator and are, therefore, more likely to become potential innovators compared to firms without CRM software systems. This impact stays robust even if one controls for additional organizational practices. Considering the other coefficients in

⁸ Marginal effects at mean are only reported for the enterprise software systems as they are the main focus of this study. All other marginal effects are available from the author upon request.

both columns, the results show that former product innovators and firms with an acquired ISO certification face a lower probability of being a non-innovator as firms without product innovations in the last period or no ISO certification. A high proportion of skilled workers also seems to lower the probability of realizing no product innovations at all, although the coefficient is based on a weak significance level in the parsimonious specification.

Concerning the negative binomial part of the model, the results of Table 6 confirm, as already expected, that both process orientated enterprise systems, i. e. ERP and SCM, have no impact on the number of realized product innovations. Surprisingly though is the non-existence of an impact due to CRM system usage. All three enterprise system coefficients turn out to be insignificant in both specifications, as shown in Column (3) and (4) of Table 6, indicating no impact of enterprise systems on product innovation intensity at all. Moving on to the other coefficients, only firm size and the usage of self dependent workgroups show a positive and significant impact on the intensity of product innovations.

Regarding the unconditional overall marginal effects it turns that the impact of an adopted CRM systems stays only significant in the parsimonious specification. Although this indicates an increase in the number of product innovations due to CRM system usage on average, this impact vanishes if additional organizational factors are controlled for and should therefore be handled carefully. The marginal effects of SCM and ERP stay, as expected, completely insignificant.

In addition, the dispersion coefficient alpha stays highly significant throughout all estimations for process as well as product innovations in Table 5 and Table 6. The magnitude of these particular coefficients indicates a high overdispersion in the data and therefore strengthens the choice of the negative binomial distribution against the alternative of an underlying Poisson distribution. The overdispersion turns out to be larger in case of process innovations.

----- Insert Table 6 about here -----

5.4 Medium-Run Impacts and Robustness Checks

To identify potential medium-term impacts and ensure the validity of the results so far, I apply additional regression procedures⁹. Besides revealing medium-term influences of enterprise systems on innovational activities, these checks also provide information concerning the size of the possible endogeneity bias mentioned in section 4. In the first step, the estimation procedure is completely repeated using the enterprise software adoption reported in the 2002 survey instead of the one from the survey in 2004, cutting the number of observation in half as now three surveys are used for estimation. Table 8 and Table 9 picture the results of the zero-inflated models for process as well as product innovations. As before, both specifications, the parsimonious one and the one employing additional organizational control variables, are considered. Concerning ERP, the obtained results are roughly the same, i. e. showing a significant impact of ERP on the number of process innovations, although this impact is based on a weaker significance level compared to the former estimation in Table 5 and stays insignificant in the parsimonious specification, exceeding the threshold for significance at ten percent level slightly (13 percent). Nevertheless, the positive marginal effect of ERP stays highly significant in both specifications and shows roughly the same size as in the short-run relationship indicating that the size of the mentioned bias might be negligible small in the case of ERP. These results also offer a clue of a positive medium-term impact of ERP on the firms' process innovational performance as the time difference between the adoption of the ERP and the realized process innovation covers two to four years in this regression.

Compared to the estimation of the short-term relationship with CRM usage increasing the probability of being a potential innovator, the results in the medium-term relationship captured in Table 9 show a different impact of CRM systems on product innovational performance. Based on a

⁹ The results of these auxiliary regressions are located in the second part of the appendix.

significance level of ten percent in both specifications CRM system usage fosters the number of realized product innovations in the medium-run but has no impact on the probability of innovating itself. Concerning the unconditional marginal effects, however, the impact of CRM systems on product innovational performance seems to vanish as the effects fail to prove significant in both specifications. Therefore, a potential bias due to endogeneity cannot be ruled out completely. Hence, the results of the medium-run relationship between CRM and firms' product innovational performance might be biased or even nonexistent and should, therefore, be handled and interpreted with appropriate care.

As the first robustness check fails to provide any clue about potential medium-term impacts of SCM systems on the firms' innovational performance, a second robustness check procedure is carried out to fill this gap. This second procedure regresses the same explanatory variables as used before on the percentage of sales spent by the firms for research and development (R&D) in 2006, additionally controlling for former process as well as former product innovators. The variable covering R&D spending could not be used as an explanatory variable in the former estimations as its value is only available for the entire year of 2006, making it an unsuitable choice to explain innovations in the time space of 2004 to 2006. R&D spending, in general, is viewed as pre-stage for innovations, indicating ongoing innovational activity. Therefore, explaining R&D spending might reveal additional impacts of enterprise system usage on innovational performance. The estimation equation is given by

$$(5) \quad RD_i = X_i' \beta_1 + ID_i' \beta_2 + ES_i' \beta_3 + PC_i' \beta_4 + PR_i' \beta_5 + \delta_i$$

where RD_i stands for the i th firm's sales spending for R&D. X_i covers the firm characteristics already used in all other regressions, e. g., size, ICT capital, human capital and East German heritage. All these characteristics are, in general, also expected to impact R&D spending. ID_i

includes the control dummies for industry sectors and ES_i contains the enterprise systems used by firm i . PC_i and PR_i indicate whether a firm established process or product innovations in the last period. δ_i is a standard error term.

As R&D spending is not obtained via a count process, equation (5) is estimated via ordinary least squares. Concerning the estimation results pictured in Table 10, SCM shows a highly significant positive impact on R&D spending of at least two years after its adoption, providing a clue towards medium-term effects of SCM adoption on the firms' innovational performance as increased R&D spending will, in general, result in new innovations. This result indicates that a medium-term impact of SCM on innovational activity might not emerge directly but takes time to build up hints and clues for new innovations indirectly through advanced R&D techniques.

Based on these results it seems that the adoption of enterprise systems positively impacts the innovational performance of firms not only in the short- but also in the medium-run. This indicates that the impacts reported in the short-run analysis might even be underestimated as a part of these impacts is only realized after a few years have passed and accordingly not captured in the short-term analysis. In addition, the enterprise systems used in this study are nowadays quite old (5 to 7 years) and there is no information about updates available. Thus, it may be the case that up to date enterprise systems provide even more functions to improve the firms' innovational performance.

6 Conclusion

Enterprise systems are nowadays widely spread among different industries around the world. Although it is argued that enterprise systems increase firm performance [1, 12, 20], their impact on innovational performance is at the moment only suspected. Empirical evidence concerning a relationship between enterprise systems and innovational performance is still missing at present.

The current study aims at filling this gap by empirically exploring the impact of the three main enterprise systems ERP, SCM and CRM on the innovational performance of firms for process as well as product innovations. Using a zero-inflated negative binomial model consisting of two parts, one explaining the decision to innovate and the other explaining the number of innovators for potential innovators, the results confirm the expected positive impacts of enterprise system usage on the firms' innovational performance for both types of innovations. Concerning process innovations the results reveal that firms with established SCM systems face a lower probability of being a non-innovator compared to firms without SCM systems in use. In addition, the adoption of an ERP system positively affects the numbers of realized process innovations. These positive impacts are not only short-term based in a time horizon of two years but emerge as well if a medium-run perspective covering two to four years is taken into account. However, the medium-run impacts are, in general, based on a lower significance level and arise in case of SCM only indirectly through positively affected R&D spending. CRM system usage, on the other hand, shows no impact on process innovation performance at all. In the case of product innovations, ERP and SCM systems completely fail to influence the firms' innovational performance. Firms using a CRM system, on the other hand, face a lower probability of realizing no production innovations at all compared to firms without CRM systems running. This positive impact is only short-term based though and vanishes if a medium-run perspective covering two to four years is taken into account.

The results reveal a new aspect of benefits through enterprise system usage as besides expected productivity and efficiency gains enterprise systems also foster the firms' innovational performance for both types of innovations. Emerging for the short and the medium-run, these results have several practical implications: First of all, managers should not only focus on costs and expected fast evolving performance benefits when deciding to buy or upgrade enterprise systems, as the innovational performance increase due to enterprise software usage takes time to develop. Especially the increased process innovational performance via ERP and SCM adoption might, after

a few years, even cut down costs for the firm in a larger amount overall compared to the investments in enterprise systems. On the other hand, new product innovations developed from CRM data might directly increase firms' financial performance via opening up new market segments or simply increasing sales.

A potential short-coming of the analysis, as the current study contains short- and medium-term perspectives, is a timing issue. The current dataset offers no way to control for the age of the enterprise systems in use as the purchase time was not asked for. In line with that, there is also no information concerning the firms' legacy system usage and potential implementation problems. Future availability of new data may provide evidence even for these cases.

Although there is no suspicion, no case study evidence and neither a theoretical argument that a complementarity relationship among the enterprise systems, as shown for their impact on labor productivity in [12], could foster the innovational impact of enterprise systems, an effect based on potential complementarity cannot be ruled out completely. However, as the current analysis forms a starting point concerning the relationship between innovational performance and enterprise systems, revealing any complementarity aspects was no aim of this study and is accordingly passed on to future research.

7 References

1. Aral, S., Brynjolfsson, E., and Wu, D. J. Which came first, IT or productivity? The virtuous cycle of investment and use in enterprise systems. In *ICIS 2006 Proceedings*, Paper 110, 2006.
2. Bach, D., and Sallet, J. The challenges of classification: emerging VoIP regulation in Europe and the United States. *IE Working Paper* 05-19, 2005.
3. Benner, M. J., and Tushman, M. Process Management and Technological Innovation: A Longitudinal Study of the Photography and Paint Industries. *Administrative Science Quarterly* 47 (2002), 676–706.
4. Cachon, G., and Fisher, M. Supply chain inventory management and the value of shared information. *Management Science* 46, 8 (2000), 1032-1048.
5. Cameron, A. C. ,and Trivedi, P. K. *Microeconometrics Using Stata*. College Station Texas: Stata Press, 2009.
6. Chen, I. J. Planning for ERP systems: analysis and future trends. *Business Process Management* 7, 5 (2001), 374-386.
7. Criscuolo, C., Haskel, J., and Slaughter, M. Why are some firms more innovative? Knowledge inputs, knowledge stocks and the role of global engagement. *NBER working paper*, No. 11479, 2005.

8. Cohen, M. A., Agrawal, N., and Agrawal, V. Winning in the Aftermarket. *Harvard Business Review* 84, 5 (2006), 129-138.
9. Cotteleer, M. J., and Bendoly, E. Order lead-time improvement following enterprise-IT implementation: An empirical study, *Management Information Systems Quarterly* 30, 3 (2006), 643-660.
10. Davenport, T. H. Putting the Enterprise into the Enterprise system, *Harvard Business Review* 76, 4 (1998), 121-132.
11. Dehning, B., Richardson, V. J., and Zmud, R. W. The Financial Performance Effects of IT-Based Supply Chain Management Systems in Manufacturing Firms, *Journal of Operations Management* 25, 1 (2007), 806-824.
12. Engelstätter, B. Enterprise Systems and Labor Productivity: Disentangling Combination Effects. *ZEW Discussion Paper* 09-040, 2009.
13. Flaig, G., and Stadler, M. Success breeds success. The Dynamics of the Innovation Process. *Empirical Economics* 19 (1994), 55-68.
14. Fritsch, M. Measuring the quality of regional innovation systems - A knowledge production function approach. *International Regional Science Review* 25, 1 (2002), 86-101.
15. Griliches, Z. Issues in assessing the contribution of R&D to productivity growth. *Bell Journal of Economics* 10 (1979), 92-116.

16. Hall, B. H., Lotti, F., and Mairesse, J. Innovation and productivity in SMEs: empirical evidence for Italy. *Small Business Economics* 33 (2009), 13-33.
17. Hempell, T. Does Experience Matter? Innovations and the Productivity of ICT in German Services. *Economics of Innovation and New Technology* 14, 4 (2005), 277-303.
18. Hempell, T., and Zwick, T. New Technology, Work Organisation, and Innovation. *Economics of Innovation and New Technology* 17, 4 (2008), 331-354.
19. Hendricks, K. B., Singhal, V. R., and Stratman, J. K. The Impact of Enterprise Systems on Corporate Performance: A Study of ERP, SCM and CRM System Implementations, *Journal of Operations Management* 25, 1 (2007), 65-82.
20. Hitt, L. M., Wou, D. J., and Zhou, X. Investment in Enterprise Resource Planning: Business Impact and Productivity Measures. *Journal of Management Information Systems*, 19, 1 (2002), 71-98.
21. Joshi, A. W., and Sharma, S. Customer knowledge development: antecedents and impact on new product performance. *Journal of Marketing* 68 (2004), 47-59.
22. Katz, H. *How to embrace CRM and make it succeed in an organization*. Costa Mesa: SYSPRO White Paper, 2002.
23. Lambert, D. Zero-inflated Poisson regression with an application to defects in manufacturing. *Technometrics* 34 (1992), 1-14.
24. Leeuwen, G. van, and Wiel, H. P. van der ICT, innovaties en productiviteit: Een analyse met

Nederlandse bedrijfsgegevens, *CPB memorandum*, no 61, 2003.

25. Mabert, V.A., Soni, A.K., and Venkataramanan, M.A. Enterprise resource planning survey of US manufacturing firms, *Production & Inventory Management Journal* 41, 20 (2000), 52-58.
26. McAfee, A. The impact of enterprise resource planning systems on company Performance, At *Wharton Electronic Supply Chain Conference*, 1999.
27. McAfee, A. The Impact of Enterprise Information Technology Adoption on Operational Performance: An Empirical Investigation, *Productions and Operations Management* 11, 1 (2002), 33-53.
28. McAfee, A., and Upton, D. *Vandelay Industries. Harvard Business School Case # 9-697-037*, Boston: Harvard Business School Publishing, 1996.
29. Rehfeld, K. M., Rennings, K., and Ziegler, A. Integrated Product Policy and Environmental Product Innovations: An Empirical Analysis. *Ecological Economics* 61, 1 (2007), 91-100.
30. Roper, S., Du, J., and Love, J. H. Knowledge sourcing and innovation. *Aston Business School Research Paper* 0605, 2006.
31. Roper, S., Du, J., and Love, J. H. Modelling the innovation value chain. *Research Policy* 37 (2008), 961-977.

32. SAP. *Annual Report*. Mannheim: SAP; 2008.
Available at SAP: <http://www.sap.com/germany/company/investor/reports/index.epx>
33. Scott, J.E., and Vessey, I. Implementing enterprise resource planning systems: The role of learning from failure. *Information Systems Frontiers* 2, 2 (2000), 213-232.
34. Shang, S., and Seddon, P.B. Assessing and managing the benefits of enterprise systems: the business manager's perspective. *Information Systems Journal* 12 (2002), 271-299.
35. Suresh, H. What is customer relationship management (CRM)? *Supply Chain Planet*, April 2004.
36. Terza, J. V. Estimating count data with endogenous switching: Sample selection and endogenous treatment effects. *Journal of Econometrics* 84 (1998), 129-154.
37. Tsai, W. Knowledge transfer in intraorganizational networks: Effects of network position and absorptive capacity on business unit innovation and performance. *Academy of Management Journal* 44 (2001), 996–1004.
38. Vuong, Q. H. Likelihood ratio tests for model selection and non-nested hypothesis. *Econometrica* 57, 2 (1989), 307-333.
39. Winkelmann, R. Count Data Models with selectivity. *Econometric Review* 17, 4 (1998), 339-359.

8 Appendix I – Main Analysis

Table 1: Summary statistics

Variable	Mean	Std. Dev.	DV²
process innovations acquired in 2004 to 2006	0.635		yes
amount of process innovations	3.103	4.057	
product innovations acquired in 2004 to 2006	0.600		yes
amount of product innovations	5.005	9.639	
process innovations in 2001 to 2003	0.755		yes
product innovations in 2001 to 2003	0.654		yes
Labor ¹	213.0	636.4	
ln (labor)	3.954	2.148	
share of computer workers	0.469	0.329	
share of highly skilled employees	0.226	0.259	
share of medium skilled employees	0.557	0.262	
International Organization of Standardization (ISO) certificated	0.444		yes
East German heritage	0.267		yes
no enterprise system	0.231		yes
ERP	0.635		yes
SCM	0.434		yes
CRM	0.524		yes
all three enterprise systems	0.275		yes
Manufacturing Sectors			
consumer goods	0.089		yes
chemical industry	0.047		yes
other raw materials	0.082		yes
metal and machine construction	0.123		yes
electrical engineering	0.084		yes
precision instruments	0.075		yes
automobile	0.058		yes
Service Sectors			
whole sale trade	0.047		yes
retail trade	0.069		yes
transport and postal services	0.069		yes
electronic data transfer	0.089		yes
technical services	0.096		yes
other business-related services	0.074		yes
Number of observations		989	

Source: ZEW ICT survey 2004, 2007 and own calculations.

Notes: ¹ Labor is measured in total number of employees. ² Dummy variable

Table 2: Additional control variables – summary statistics

Variable	Mean	DV ¹
accounts for working hours	0.704	yes
job rotation	0.191	yes
quality circles	0.425	yes
units with own cost and result responsibility	0.386	yes
self dependent workgroups	0.623	yes

Source: ZEW ICT survey 2004, 2007 and own calculations. ¹ Dummy variable

Table 3: Descriptive analysis

	No system	All systems	ERP	SCM	CRM
recent process innovator	0.478	0.790	0.726	0.767	0.726
number of process innovations mean	1.783 (2.774)	4.039 (4.252)	3.764 (4.402)	3.935 (4.424)	3.590 (4.274)
recent product innovator	0.408	0.728	0.667	0.700	0.681
number of product innovations mean	2.142 (5.045)	7.167 (10.82)	6.002 (10.15)	6.859 (10.87)	6.197 (10.45)

Notes: Standard errors in parentheses.

Source: ZEW ICT survey 2004, 2007 and own calculations.

Table 4: Model selection

	Process innovations	Product innovations
Llhd.-ratio Test	449.220***	2864.020***
Vuong-Test	6.050***	7.830***

Notes: *** p<0.01; ** p<0.05; * p<0.1. Parsimonious specification used for testing.

Source: ZEW ICT survey 2004, 2007 and own calculations.

Table 5: Determinants of the number of process innovations, zero-inflated neg. binomial estimates

	Specification 1		Specification 2	
	Probit Model	Neg. Bin. Model	Probit Model	Neg. Bin. Model
ln (labor)	-0.032 (0.048)	0.037 (0.031)	0.009 (0.052)	0.026 (0.333)
share of computer workers	-0.352 (0.253)	0.102 (0.170)	-0.360 (0.259)	0.106 (0.170)
share of high skilled workers	0.755* (0.410)	-0.257 (0.258)	0.727** (0.421)	-0.294 (0.264)
share of medium skilled workers	0.351 (0.301)	-0.071 (0.203)	0.312 (0.308)	-0.119 (0.205)
ISO certificated	-0.270** (0.136)	0.230** (0.093)	-0.137 (0.143)	0.196** (0.099)
firm had process innovations last period	-0.377*** (0.136)	0.262** (0.104)	-0.310** (0.136)	0.243** (0.107)
ERP	-0.141 (0.136)	0.282*** (0.097)	-0.110 (0.139)	0.279*** (0.097)
SCM	-0.318** (0.140)	0.064 (0.087)	-0.284* (0.148)	0.059 (0.091)
CRM	-0.181 (0.131)	0.068 (0.087)	-0.198 (0.136)	-0.103 (0.089)
accounts for working hours	-	-	-0.149 (0.132)	-0.059 (0.096)
job rotation	-	-	-0.001 (0.176)	-0.007 (0.101)
quality circles	-	-	-0.485*** (0.143)	0.076 (0.087)
units with own cost and result responsibility	-	-	-0.115 (0.142)	0.106 (0.090)
self dependent work groups	-	-	0.125 (0.132)	0.063 (0.091)
constant	0.337 (0.356)	1.11*** (0.261)	0.312 (0.377)	1.129*** (0.273)
alpha	0.489*** (0.061)		0.489*** (0.062)	
control variables	Industry, East		Industry, East	
overall marg. effect ERP	0.972*** (0.278)		0.923*** (0.280)	
overall marg. effect SCM	0.624** (0.288)		0.556* (0.293)	
overall marg. effect CRM	0.057 (0.274)		-0.024 (0.278)	
number of observations	890			
nonzero observations	547			
zero observations	343			

Notes: *** p<0.01; ** p<0.05; * p<0.1. Standard errors in parentheses.

Source: ZEW ICT survey 2004, 2007 and own calculations.

Table 6: Determinants of the number of product innovations, zero-inflated neg. binomial estimates

	Specification 1		Specification 2	
	Probit Model	Neg. Bin. Model	Probit Model	Neg. Bin. Model
ln (labor)	-0.021 (0.054)	0.136*** (0.046)	-0.029 (0.058)	0.159*** (0.052)
share of computer workers	0.010 (0.272)	0.253 (0.260)	0.155 (0.273)	0.310 (0.255)
share of high skilled workers	-0.884* (0.503)	-0.231 (0.363)	-1.037** (0.506)	-0.329 (0.363)
share of medium skilled workers	0.019 (0.342)	0.040 (0.314)	-0.063 (0.340)	0.069 (0.313)
ISO certificated	-0.364** (0.157)	-0.135 (0.136)	-0.345** (0.164)	-0.109 (0.137)
firm had product innovations last period	-1.067*** (0.145)	-0.010 (0.151)	-1.051*** (0.147)	0.031 (0.150)
ERP	-0.085 (0.156)	0.027 (0.141)	-0.144 (0.158)	-0.091 (0.143)
SCM	0.135 (0.170)	0.116 (0.128)	0.153 (0.171)	0.070 (0.130)
CRM	-0.296** (0.150)	0.084 (0.118)	-0.326** (0.152)	0.012 (0.121)
accounts for working hours	-	-	-0.281* (0.151)	-0.252 (0.145)
job rotation	-	-	-0.126 (0.192)	-0.019 (0.133)
quality circles	-	-	-0.135 (0.155)	-0.004 (0.120)
units with own cost and result responsibility	-	-	0.011 (0.155)	0.172 (0.126)
self dependent work groups	-	-	0.242* (0.145)	0.343*** (0.116)
constant	1.227*** (0.380)	1.074*** (0.388)	1.107*** (0.408)	0.833** (0.396)
alpha	1.186*** (0.116)		1.148*** (0.110)	
control variables	Industry, East		Industry, East	
overall marg. effect ERP	0.345 (0.705)		-0.084 (0.725)	
overall marg. effect SCM	0.232 (0.680)		-0.035 (0.683)	
overall marg. effect CRM	1.156* (0.618)		0.866 (0.626)	
number of observations	886			
nonzero observations	490			
zero observations	396			

Notes: *** p<0.01; ** p<0.05; * p<0.1. Standard errors in parentheses.

Source: ZEW ICT survey 2004, 2007 and own calculations.

9 Appendix II – Auxiliary Regressions

Table 7: *Robustness-check 1:* Model selection

	Process innovations	Product innovations
Llhd.-ratio Test	175.900***	1517.570***
Vuong-Test	4.800***	5.930***

Notes: *** p<0.01; ** p<0.05; * p<0.1. Parsimonious specification used for testing.

Source: ZEW ICT survey 2004, 2007 and own calculations.

Table 8: Robustness-check 1: Determinants of the number of process innovations, zero-inflated neg. binomial estimates using enterprise system adoption in 2002

	Specification 1		Specification 2	
	Probit Model	Neg. Bin. Model	Probit Model	Neg. Bin. Model
ln (labor)	-0.026 (0.067)	0.055 (0.0447)	0.067 (0.079)	0.062 (0.048)
share of computer workers	-0.081 (0.336)	0.277 (0.219)	-0.036 (0.368)	0.383* (0.231)
share of high skilled workers	0.733 (0.545)	-0.418 (0.344)	0.852 (0.614)	-0.520 (0.362)
share of medium skilled workers	-0.168 (0.436)	-0.319 (0.282)	-0.184 (0.465)	-0.412 (0.288)
ISO certificated	-0.285 (0.189)	0.306** (0.122)	-0.134 (0.208)	0.324** (0.132)
firm had process innovations last period	-0.355* (0.201)	0.247** (0.150)	-0.282 (0.215)	0.251* (0.153)
ERP	-0.219 (0.198)	0.222 (0.146)	-0.110 (0.231)	0.302* (0.156)
SCM	0.046 (0.230)	0.164 (0.129)	0.082 (0.246)	0.130 (0.130)
CRM	-0.192 (0.218)	-0.044 (0.132)	-0.196 (0.231)	-0.075 (0.134)
accounts for working hours	-	-	-0.160 (0.208)	-0.249* (0.138)
job rotation	-	-	-0.083 (0.252)	0.057 (0.132)
quality circles	-	-	-0.510** (0.205)	0.165 (0.116)
units with own cost and result responsibility	-	-	-0.357* (0.214)	0.047 (0.118)
self dependent work groups	-	-	0.040 (0.194)	-0.096 (0.123)
constant	0.697 (0.565)	1.53*** (0.432)	0.494 (0.618)	1.594*** (0.455)
alpha	0.410*** (0.073)		0.417*** (0.076)	
control variables	Industry, East		Industry, East	
overall marg. effect ERP	0.856** (0.362)		0.913** (0.362)	
overall marg. effect SCM	0.415 (0.454)		0.271 (0.447)	
overall marg. effect CRM	0.122 (0.402)		0.019 (0.401)	
number of observations	457			
nonzero observations	284			
zero observations	173			

Notes: *** p<0.01; ** p<0.05; * p<0.1.

Source: ZEW ICT survey 2004, 2007 and own calculations.

Table 9: Robustness-check 1: Determinants of the number of product innovations, zero-inflated neg. binomial estimates using enterprise system adoption in 2002

	Specification 1		Specification 2	
	Probit Model	Neg. Bin. Model	Probit Model	Neg. Bin. Model
ln (labor)	-0.051 (0.077)	0.157*** (0.059)	-0.055 (0.083)	0.170** (0.071)
share of computer workers	0.574 (0.384)	0.663* (0.329)	-0.023 (0.373)	0.503 (0.328)
share of high skilled workers	-1.49** (0.755)	-0.607 (0.503)	-1.450** (0.731)	-0.543 (0.505)
share of medium skilled workers	-0.115 (0.493)	-0.082 (0.439)	-0.031 (0.493)	0.112 (0.438)
ISO certificated	-0.272 (0.218)	-0.011 (0.179)	-0.198 (0.216)	0.083 (0.179)
firm had product innovations last period	-1.111*** (0.221)	-0.277 (0.203)	-1.040*** (0.210)	-0.217 (0.201)
ERP	-0.161 (0.220)	-0.149 (0.199)	-0.181 (0.222)	-0.203 (0.196)
SCM	-0.197 (0.279)	-0.161 (0.180)	-0.150 (0.264)	-0.136 (0.177)
CRM	0.070 (0.248)	0.305* (0.180)	0.053 (0.242)	0.297* (0.182)
accounts for working hours	-	-	0.102 (0.217)	-0.171 (0.207)
job rotation	-	-	0.001 (0.257)	0.154 (0.200)
quality circles	-	-	-0.248 (0.216)	-0.230 (0.186)
units with own cost and result responsibility	-	-	0.057 (0.221)	0.044 (0.192)
self dependent work groups	-	-	0.168 (0.664)	0.371** (0.162)
constant	1.853*** (0.660)	1.664*** (0.632)	1.736*** (0.650)	1.444** (0.622)
alpha	1.128*** (0.156)		1.058*** (0.143)	
control variables	Industry, East		Industry, East	
overall marg. effect ERP	-0.385 (1.132)		-0.611 (1.138)	
overall marg. effect SCM	-0.390 (0.994)		-0.344 (0.982)	
overall marg. effect CRM	1.544 (1.171)		1.522 (1.156)	
number of observations	451			
nonzero observations	259			
zero observations	192			

Notes: *** p<0.01; ** p<0.05; * p<0.1. Standard errors in parentheses.

Source: ZEW ICT survey 2004, 2007 and own calculations.

Table 10: Robustness-check 2: R&D spending and enterprise system usage**dependent variable: R&D spending in share of total sales¹**

	(1)	(2)
ln (labor)	0.004 (0.005)	0.006 (0.005)
share of computer workers	0.017 (0.025)	0.014 (0.025)
share of high skilled workers	0.115*** (0.040)	0.120*** (0.040)
share of medium skilled workers	0.013 (0.021)	0.015 (0.022)
ISO certificated	-0.012 (0.014)	-0.009 (0.015)
firm had process innovations last period	-0.018 (0.016)	-0.017 (0.015)
firm had product innovations last period	0.029** (0.013)	0.030** (0.013)
ERP	0.012 (0.014)	0.011 (0.014)
SCM	0.031** (0.015)	0.031** (0.015)
CRM	-0.013 (0.015)	0.013 (0.015)
accounts for working hours	-	-0.009 (0.013)
job rotation	-	-0.001 (0.016)
quality circles	-	-0.006 (0.014)
units with own cost and result responsibility	-	-0.021 (0.015)
self dependent work groups	-	0.030*** (0.011)
constant	-0.017 (0.028)	-0.031 (0.029)
control variables	Industry, East	Industry, East
R ²	0.196	0.205
number of observations	729	

Notes: *** p<0.01; ** p<0.05; * p<0.1; Standard errors robust to heteroscedasticity in parentheses.

¹ mean: 0.096, maximum: 1.

Source: ZEW ICT survey 2004, 2007 and own calculations.