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Enterprise Systems and Labor Productivity: Disentangling Combination Effects

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Non-technical summary

Company-wide packages of enterprise software for planning and controlling business processes, referred to as enterprise systems, are widely used in many different industries throughout many countries around the world. The economic literature has provided evidence indicating that the adoption and usage of enterprise systems has positively affected firms' labor productivity. However, the three main enterprise systems Enterprise Resource Planning (ERP), Supply Chain Management (SCM) and Customer Relationship Management (CRM) have different impacts on productivity. In addition, the three systems might function as compliments or substitutes because of interacting functions and the usage of similar databases. Therefore, the productivity effects of the software applications might turn out to be even more heterogeneous if a firm uses more than one system at a given time.

This paper studies the relationship between enterprise systems and labor productivity. The analysis is based on a production function and focuses especially on productivity impacts due to the adoption of more than one enterprise system at a given time. Moreover, the analysis verifies the existence of complementarity or substitutability between the three different enterprise systems. The basis of the analysis is a German enterprise data set, containing enterprises of different industry branches from the manufacturing and service sector.

The results confirm the expected positive influence of the enterprise systems on labor productivity. In addition, a robust significant complementarity relationship between SCM and CRM is confirmed, especially if the necessary IT-infrastructure is provided through an ERP system. Thus firms which use all three enterprise systems together realize the highest productivity gains.

Das Wichtigste in Kürze

Die Nutzung von unternehmensweiten Softwarepaketen zur Planung und Steuerung betrieblicher Prozesse, sogenannte Unternehmenssoftware, ist in verschiedensten Wirtschaftszweigen nahezu weltweit verbreitet und wirkt sich, wie die wissenschaftliche Literatur zeigt, positiv auf die Produktivität der Unternehmen aus. Allerdings beeinflussen die drei größten Unternehmenssoftwarepakete Enterprise Resource Planning (ERP), Supply Chain Management (SCM) und Customer Relationship Management (CRM) die Arbeitsproduktivität in unterschiedlichem Maße. Zusätzlich besteht die Möglichkeit, dass sich die drei Softwareanwendungen aufgrund zusammenwirkender Funktionen und dem Zugriff auf ähnliche Datenbanken wie Komplemente oder gar Substitute verhalten. Dies könnte dazu führen, dass sich die Produktivitätswirkungen der Softwarepakete bei gleichzeitiger Nutzung vergrößern oder gar abschwächen.

Diese Studie untersucht den Zusammenhang zwischen Unternehmenssoftware und der Arbeitsproduktivität von Unternehmen. Die Analyse basiert dabei auf einer Produktionsfunktion und trägt besonders jenen Produktivitätswirkungen Rechnung, die durch die gleichzeitige Nutzung mehrerer Unternehmenssoftwarepakete entstehen. Zusätzlich wird geprüft, ob sich die verwendeten Softwarepakete untereinander komplementär oder substituierend verhalten. Die Grundlage der Analyse bildet ein Unternehmensdatensatz, der deutsche Unternehmen verschiedener Branchen des verarbeitenden Gewerbes und des Dienstleistungssektors umfasst.

Die Ergebnisse bestätigen den vermuteten positiven Einfluss der Unternehmenssoftware auf die Firmenproduktivität. Weiterhin zeigen die Analysen eine robuste, signifikante Komplementaritätsbeziehung zwischen SCM und CRM. Dies gilt besonders dann, wenn die für beide Systeme notwendige IT-Infrastruktur durch ein ERP System bereitgestellt wird. Die größten Produktivitätszuwächse realisieren demnach diejenigen Unternehmen, die alle drei Unternehmenssoftwarepakete nutzen.

Enterprise Systems and Labor Productivity: Disentangling Combination Effects[§]

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Abstract

This study analyzes the relationship between the three main enterprise systems (Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Customer Relationship Management (CRM)) and labor productivity. It reveals the performance gains due to different combinations of these systems. It also tests for complementarity among the enterprise systems with respect to their interacting nature. Using German firm-level data the results show that the highest productivity gains due to enterprise system usage are realized through use of the three main enterprise systems together. In addition, SCM and CRM function as complements, especially if ERP is also in use.

Keywords: Labor Productivity, Enterprise Systems, Complementarity, Enterprise Resource Planning, Supply Chain Management, Customer Relationship Management

JEL Classification: D20, M00.

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1 Introduction

Enterprise systems, company-wide suites of business software devoted to particular process integration across the value chain, encompass a wide range of software products supporting day-to-day business operations and decision-making. The three main enterprise systems, Enterprise Resource Planning (ERP), Supply Chain Management (SCM) and Customer Relationship Management (CRM), serve many industries in numerous areas. They are designed to automate operations from supply management, inventory control, manufacturing scheduling or sales force automation and almost any other data-oriented management process. In 2004, the global market for ERP systems grew by 14 % and accounts for approximately $25 billion. Regarding SCM and CRM systems, the market is estimated to account for nearly $6 billion and $9 billion respectively[1]. SAP, the biggest global enterprise software vendor, estimates the complete market for ERP, SCM and CRM in 2007 at nearly $37 billion (SAP, 2007).

Enterprise systems are often adopted to replace the usually poorly connected legacy software with the aim to reduce infrastructure support costs (Hendricks et al. (2007)). In addition, improvements in operational integration realized through enterprise software can affect the entire organization and therefore might positively affect firm performance. ERP systems provide benefits in the area of transaction automation, adopted SCM systems lead to more sophisticated planning capabilities, and CRM systems simplify customer relationship management.

Despite the fact that enterprise systems are now widely spread among industries around the world their influence on firm performance is still not absolutely clear. The literature is mostly based on case studies[2] which offer concrete and meaningful lessons for implementation strategies but in general fail to provide clues for economy-wide effects. Studies providing evidence on the basis of firm-level data are still quite rare. Most of the studies report positive effects on firm performance through enterprise system adoption. However, existing research puts an exclusive focus on the adoption of one single system[3]. This might turn out to produce biased results as enterprise systems nowadays are often adopted in concert and are expected to interact, to complement or in rare cases even substitute each other to some extent. The goals therefore are to (1) provide econometric evidence on the performance effects generated by adopting any of the three main enterprise systems and to (2) disentangle the performance effects attributed to the combinations and interactions of enterprise systems using a unique database consisting of German firms from the manufacturing

[1] AMR "Market Analytix Report: Enterprise Resource Planning 2004-2007" referenced in Network World, 06/15/05.
[2] E. g. Cotteleer and Bendoly (2006), Tchokogue et al. (2005).
[3] E. g. Hitt et al. (2002), Nicolaou (2004), Dehning et al. (2007).

industry and from service sectors. In addition, as the enterprise systems are assumed to complement each other[4], I (3) check for pairwise complementarity among the systems. The evidence is based on the simple but comparable metric total factor productivity, therefore the difference in the performance of the various enterprise software applications can be tackled.

The results provide empirical evidence about the productivity gains due to enterprise system usage. Contrary to former analysis, the highest productivity gain is achieved by using all three enterprise systems in concert. In addition, a complementary relationship between SCM and CRM is revealed once an ERP is also in use or gotten in conjunction. The results imply that analyzing the influence of the enterprise systems one by one while neglecting possible benefits due to the combination of systems turns out to be insufficient to picture the performance effects of enterprise software.

The paper proceeds as follows. Section 2 gives an overview of the literature and derives hypotheses. Section 3 pictures the basic model and covers the issues concerning pairwise complementarity. Section 4 presents the dataset and Section 5 the estimation results. Section 6 concludes.

2 Background discussion and hypotheses

2.1 Benefits of enterprise systems in theory

This section outlines the benefits of ERP, SCM and CRM discussed in management literature and presents some empirical studies. ERP systems replace complex interfaces between different systems with standardized cross-functional transaction automation. They 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 (Aral et al. (2006)). Through using an ERP system order cycle times can be reduced, which might lead to improved throughput, customer response times and delivery speeds (Cotteleer and Bendoly (2006), McAfee (2002)). In addition, cash-to-cash cycle times and the time needed to reconcile financial data at the end of the quarter or year can be reduced due to automated financial transactions (Mabert et al. (2000), McAfee (1999), Stratman (2001)). With an ERP system all enterprise data are collected once during the initial transaction, stored centrally, and updated in real time. This ensures that all levels of planning are based on the same data allowing the resulting plans to realistically reflect the prevailing operating conditions of the firm (Hendricks et al. (2007)). All in all, standardized firm-wide transactions and centrally stored enterprise data greatly facilitate the governance of the firm

[4] See e. g. Aral et al (2006).

(Scott and Vessey (2000), McAfee and Upton (1996)). Providing managers with a clear view of the relative performance of different parts of the company, ERP reports can be used to identify necessary improvements and to take advantage of market opportunities (AT Kearney (2000), Boston Consulting Group (2000)).

IT-based SCM systems coordinate and integrate the flow of information, materials and finances from the materials supplier to the manufacturer to the wholesaler to the retailer to the end consumer (Dehning et al (2007)). The primary benefit of SCM systems is to improve operational and business planning. With the real-time planning capabilities offered by SCM systems, firms can react quickly to supply and demand changes (Hendricks et al. (2007)) and are able to serve customers in a timely and comprehensive manner (Cachon and Fisher (2000)). In addition, SCM systems can directly improve inventory management by reducing inventory levels, holding costs, spoilage and lead times. This results in increased profitability through reducing costs, avoiding lost sales and improving customer satisfaction (Cachon and Fisher (2000)). SCM systems may also have indirect effects on firm performance due to lower coordination, sales, general and administrative costs and improved decision-making and forecasting (Dehning et al. (2007)). The ability of information sharing, collaborative planning and forecasting replenishment provided by a SCM system can improve decisions on order quantity, lower the time and costs of order processing, increase order frequencies and reduce lead time.

CRM is a synthesis of customer focused management and of many existing principles from relationship marketing (Jancic and Zabkar (2002), Sheth et al. (2000), Morgan and Hunt (1994)). The key focus of CRM systems is to facilitate the building of long-term relationships with customers by 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 (Katz (2002), Suresh (2004)). Offering a complete view of customer needs and wants, a CRM system is also expected to lead to superior customer loyalty, reduced cost of sales and services and improved bottom-line profits (Chen (2001)). A CRM system reduces duplication in data entry and maintenance by providing a centralized firm-wide database of customer information. This database replaces systems maintained by individual sales people, institutionalizes customer relationships, prevents the loss of organizational customer knowledge when sales staff leaves the firm (Hendricks et al. (2007)) and can reduce costs via streamlining repetitive transactions and sales processes (Cohen et al (2006)).

Although there is a vast number of studies on the adoption of ERP systems[5], there is currently little empirical research on the performance implications of the combined use of all three main enterprise systems. Previous evidence on ERP systems often came from qualitative case studies or surveys of self-reported performance. There are relatively few studies that provide evidence based on large firm-level databases or which use objective measures of productivity and performance. In the case of the adoption of SCM or CRM systems empirical evidence is even scarcer. Moreover, most previous studies examine data prior to 1999[6], leaving a gap of up-to-date evidence. In addition, most former studies neglect the fact that the adoption of one enterprise system is nowadays often accompanied by the adoption of other types of enterprise software[7]. A problem arises if all of the enterprise systems are correlated or interacting with each other and are positively associated with performance. In that case, the few available estimates concerning the relationship between a single enterprise software and performance could be biased upward. To provide a structured overview of this literature branch, I start with the studies focusing exclusively on ERP, followed by analyses which include SCM or CRM. The section is closed with an examination of the articles which use a production function to explain the effects of enterprise software on performance since I build my estimations on the same approach.

One of the first statistical studies focusing on the impact of ERP use on firm performance by Poston and Grabski (2001) analyzes four cost and revenue ratios before and after ERP adoption. The study is based on a sample of 50 firms and applies univariate tests. The results indicate an efficiency increase based on a reduction in the numbers of employees and in the ratio of employees to revenues for each year following the ERP implementation. Furthermore, Poston and Grabski (2001) find a decrease in the ratio of the costs of goods sold to revenues three years after the implementation of an ERP system. Nicolaou et al. (2003) conduct a univariate analysis of performance differences across time periods for financial data, comparing firms which adopt enterprise-wide ERP systems and a matched control group. Their results show that firms adopting ERP systems have a significantly higher differential performance in their second year after the completion of the system compared to the matched control group. By comparing return on assets, return on investments and asset turnover for 63 ERP adopters and matched nonadopters, Hunton et al. (2003) verify the impact of ERP adoption on overall firm performance. Although their main results do not show a performance enhancement for ERP adopters, they find that the financial performance of adopters has not declined during the test period while the performance of the

[5] A comprehensive overview of this branch of literature is given by Moon (2007).
[6] E. g. Hendricks et al. (2007).
[7] To the best of my knowledge the only study focussing on the adoption of all enterprise systems together is Aral et al. (2006). However, their study does not concern all possible interactions and complementarities among the different enterprise systems.

nonadopters has decreased in that period. Nicolaou (2004) examines the longitudinal impact of ERP systems. He uses a matched pair design comparing the performance of 242 ERP adopters and matched nonadopters. In addition, evaluating the financial performance of firms, Nicolaou (2004) incorporates various implementation characteristics, e. g. vendor choice, implementation goal, modules implemented and implementation time period into the analysis. The results show that firms adopting ERP systems only exhibit higher differential performance after two years of continued use. Regarding vendor choice, the differential performance effect of ERP adoption is highest for those firms who adopt SAP or Oracle applications. Matolcsy et al. (2005) extend the analysis of ERP adoption on firm performance by using two sets of performance measures: publicly available financial account data and financial performance ratios of core business processes in the value chain. Based on univariate and multivariate tests with a sample of 35 companies and a corresponding control group, their results show sustained operational efficiencies and improved overall liquidity through adoption of an ERP system. They also find some support for improvements in accounts receivable management and for increased profitability two years after the adoption of ERP.

Only a few studies incorporate SCM or CRM adoption as well. Wieder et al. (2006) for example empirically examine the combined impact of ERP and SCM adoption on firm performance using key performance indicators for the overall firm and the business process level. Looking at a small sample of 89 companies including 49 firms ERP using firms of which only six use additional SCM systems, Wieder et al. (2006) are only able to look for significant differences in the grouped samples of adopters and nonadopters and present correlations. Their results show no difference between ERP adopters and nonadopters. By estimating a linear and a third order polynomial trend Wieder et al. (2006) are able to confirm on the other hand that the longer the experience of firms with ERP systems is the higher the overall firm performance. In addition, only those ERP adopters who also adopt SCM systems achieve significantly higher performance at the business process level. The financial benefits of adopting SCM systems are analyzed by Dehning et al. (2007). Their analysis is based on 123 firms of the manufacturing sector. By examining the change in financial performance before and after adoption controlling for industry median changes in performance, their results indicate that SCM systems increase a firm’s gross margins, inventory turnover, market share, return on sales and reduce selling, general and administrative expenses. In high-tech firms the benefits are similar or even greater. The effects of investment in ERP, SCM and CRM systems on a firm’s long-term stock price performance and profitability measures are examined by Hendricks et al. (2007). Using a sample of 406 firms which made an announcement for an investment in one of the three software systems and an appropriate control group their results show an improvement in profitability but not in stock returns for ERP adopters, proving stronger for early adopters. SCM adopters experience higher stock returns as well as improvements in profitability. On the other hand Hendricks et al. (2007) find no evidence of improvements in stock returns or profitability for firms which only invest in CRM systems.

Being the first to utilize a production function approach to explain the impact of enterprise systems on firm performance, Hitt et al. (2002) observe that firms which invest in ERP tend to show higher performance across a wide variety of performance metrics, e. g. value added, sales, output and labor productivity. Their evidence is based on multi-year multi-firm ERP implementation and financial data of 350 firms over several years. Although their results show a decrease in business performance and productivity shortly after the implementation, financial markets consistently reward adopters with higher market valuation measured by Tobin's q. Aral et al. (2006) examine the performance effects of ERP, SCM and CRM based on panel data of 698 firms over a period of eight years by using general specifications and a production function approach. Being able to distinguish between purchasing and go-live events the results of Aral et al. (2006) indicate that ERP system usage causes performance gains and not strong performance leading to the purchase of ERP. Also SCM systems show a significantly larger impact on productivity and other performance measures than ERP. CRM systems on the other hand fail to affect performance when the use of the other enterprise systems is controlled for. Shin (2006) also analyzes the impact of several enterprise software applications, e. g. ERP, SCM, CRM, Knowledge Management, Groupware and Integration Software, on productivity of small and medium sized enterprises (SMEs) based on a production function approach for 525 SMEs. In the estimation procedure Shin (2006) controls only for one enterprise system at a time. The empirical results show that Groupware and SCM significantly raise the SMEs' productivity. These effects are stronger in the manufacturing than in the service sector. Based on the benefits from enterprise software usage and the evidence from former analyses, I hypothesize:

H1 (2 and 3): The Adoption of ERP (SCM or CRM) systems leads to improved overall labor productivity.

2.2 Complementarity between enterprise software applications

Complementarity between the three enterprise software applications seems obvious. For instance, the integrated data, processes and interfaces which an ERP system provides, enable effective implementation of supply chain activities and utilization of customer data. Therefore, both SCM and CRM systems should benefit from a previously implemented ERP system. The planning of internal production activities via ERP can be directly influenced or automated by information inputs from supply chain partners through the use of an SCM system (Aral et al. (2006)). Used in combination with ERP systems, SCM systems partly substitute and partly complement the functionality of the ERP systems, with the level of substitution or complementation being primarily determined by the functionality of either package and partly by the preferences of the organization using them (Davenport and Brooks (2004), Stefanou (2001)). Accordingly, one should expect that the advanced features of SCM systems in conjunction with ERP systems lead to higher firm performance which is shown by the analysis of Wieder et al. (2006).

On the other hand, the centralized customer data provided by CRM systems can be used as source for the ERP and SCM systems and are valuable when multiple product lines are managed (Hendricks et al. (2007)). In addition, the CRM system can utilize the data mining capabilities of ERP systems and data warehousing to reveal the profiles of key customers, customer profitability and purchasing patterns (Conlon (1999)). Also Mithas et al. (2005) find out that firms are more likely to benefit from CRM systems if they have a greater supply chain integration. According to Charkari and Abdolvand (2004), the isolated use of SCM or CRM systems separately might result in missed opportunities and poor performance. To put it short, ERP systems generally determine the business processes, the two other applications optimize these business processes in a specific area, especially by linking the front office (e. g. sales, marketing, customer services) with the back office (e. g. operations, logistics, financials, human resources) of the enterprise. Therefore, firms using more than one enterprise system will probably realize a larger performance increase compared to those which do not rely on enterprise software or on only one enterprise software application:
H4: Complementarity exists between any two enterprise software applications.

H5: Using all three enterprise systems in concert, however, generates the highest productivity gain.

3 Research methodology

3.1 The basic model

Following Hitt et al. (2002), Aral et al. (2006) and Shin (2006) I use a production function specification to estimate the effects of enterprise system usage on firm performance. According to this approach, the production process of firm i is represented by a function $f(\cdot)$ that relates output to the inputs of the firm. Throughout this paper labor productivity Y_i is measured by sales per employee. The inputs are capital and labor (K_i, L_i). I include control dummies for Eastern Germany and industry sectors in the estimation. Labor is measured according to Greenan and Mairesse (2000):

$$
\begin{aligned}
(1) \qquad L_i^* &= L_i^{NC} + \left(1+\gamma_i\right) L_i^C \\
&= \left(L_i^{NC} + L_i^C\right)\left(1+\frac{\gamma_i L_i^C}{L_i^{NC} + L_i^C}\right) \\
&= L_i\left(1+\gamma_i p\right),
\end{aligned}
$$

where L_i^C is the number of employees who use a computer and L_i^{NC} respresents the workers who do not. L_i $\left(=L_i^{NC}+L_i^C\right)$ refers to the total number of employees in firm *i*. The proportion of computer users is represented by the parameter p_i $\left(=L_i^C\ /\ L_i\right)$. γ_i measures the relative labor efficiency between employees working with a computer and those who do not. The production function can be represented as follows:

$$(2) \qquad Y_i = f(A_i, K_i^{\alpha}, L_i^*) = A_i\ K_i^{\alpha} L_i^{*\beta}$$

The exponents α and β in this production function denote the output elasticities with respect to capital and labor. Regarding the calculation of performance differences, this function has the advantages of both simplicity and empirical robustness (Brynjolfsson and Hitt (2000), Varian (1990)). Additional terms to capture differences in performance, e. g. enterprise software adoption, can simply be added to the production function in its log-log form (Hitt et al. (2002)). The coefficients of the added term can be interpreted as percentage differences in productivity. In case of software adoption the coefficient captures the enterprise software's effect on firm-level productivity other things being equal (Shin (2006)). Inserting equation ((1) into ((2), dividing by *L*, taking logs on both sides, adding an i.i.d. error term ε, controls for East Germany and industries and enterprise system usage labor productivity in log output per employee ln (Y/L) results in[8]:

$$
\begin{aligned}
(3) \qquad \ln (Y_i/L_i) = {} & c + \alpha \ln (K_i) + \beta \ln (L_i) + \delta\ \gamma\ p_i + \text{east control} \\
& + \text{enterprise system usage variables} + \text{industry controls} + \varepsilon
\end{aligned}
$$

[8] The approximation ln $(1+\gamma p) \approx \gamma p$ was used. γp is assumed to be small.

3.2 Modeling complementarity

Since pairwise complementarity between the enterprise software systems might exist this section outlines the definition and conditions regarding complementarity and substitutability for the cases of discrete practices. One has to identify a set of inequality constraints and test whether these are rejected by the data.

Throughout this paper each practice represents the use of a different enterprise system. Following Lokshin et al. (2007a) an objective function f is considered a starting point. The value of f is determined by the practices x_p = (p =1,…,n) with n=3 in the present case of enterprise software system use. A cross-term specification of the objective function f allows to test for complementarity or substitutability. This implies the following expression for n equal to 3:

(4) $f(x_1,x_2,x_3) = \theta_0 + \theta_1 x_1 + \theta_2 x_2 + \theta_{12} x_1 x_2 + \theta_3 x_3 + \theta_{13} x_1 x_3 + \theta_{23} x_2 x_3 + \theta_{123} x_1 x_2 x_3$

In the present case of observed enterprise system usage the practices are measured dichotomously, i.e. variables takes the value one if the practice is used and zero otherwise. In that case function (4) can be conveniently rewritten in terms of possible combinations of practices (Mohnen and Röller (2005)). The collection of possible combinations considering three practices is defined in the usual binary order as D = {(0,0,0),(1,0,0),(0,1,0),(0,0,1),(1,1,0),(1,0,1),(0,1,1),(1,1,1)}, with introducing the indicator function for three practices $I_{D=(r,s,t)}$ equal to one when the combination is (r,s,t) and zero else. The function f can be rewritten as:

(5) $f\left(x_1, x_2, x_3\right) = \sum_{r=0}^{1}\sum_{s=0}^{1}\sum_{t=0}^{1} \lambda_{rst} I_{(x_1,x_2,x_3)=(r,s,t)}$

The conditions of pairwise complementarity between practice 1 and 2 then correspond to $\theta_{12} = \lambda_{110} + \lambda_{000} - \lambda_{100} - \lambda_{010} \geq 0$ and $\theta_{12} + \theta_{123} = \lambda_{111} + \lambda_{001} - \lambda_{101} - \lambda_{011} \geq 0$, with at least one inequality holding strictly. Similar inequalities apply for the pairs (1,3) and (2,3). For substitutability the inequalities are reversed.

3.3 Testing for complementarity

Mohnen and Röller (2005) use a Wald type test based on a minimum distance estimator. For this purpose two independent tests are conducted, which test separately for complementarity and substitutability. Mohnen and Röller (2005) also do not report p-values for their tests, instead they use upper and lower bounds as suggested by Kodde and Palm (1986). Lokshin et al. (2007a) advanced this method and derived a test which decides between complementarity and substitability in one run. Their multiple restrictions test is a Likelihood-ratio test which specifically tests for the two inequalities derived above but faces a computational demanding test-statistic. As the test-statistic follows a mixed chi-square distribution under the null hypothesis of no complementarity respectively no substitutability exact p-values need to be computed using specific weights (Shapiro (1985)). The complete testing procedure and its distribution are derived in Lokshin et al. (2007a)[9].

In addition, one can use the standard interaction terms to check for complementarity between the enterprise software applications. As both testing methods do not provide a reliable values in the case of a low R^2 (Lokshin et al. (2007b)), which is common in cross section analysis, I conduct both tests for inference[10].

4 The data

The dataset used in this paper results from two computer-aided telephone surveys conducted in 2004 and 2007 by the Centre for European Economic Research (ZEW). The surveys had a special focus on the diffusion and use of information and communication technologies (ICT) in German companies. Each wave of the dataset originally contains detailed information of more than 4,000 firms with five and more employees, stratified by industry affiliation, size class and location of the company (West/East Germany). Besides detailed information on the use of ICT, the dataset contains additional information about total sales, the firms' workforce, the total investments and various other variables. The questionnaire also covered the usage level of the three main enterprise software applications SCM, ERP, CRM. The level of usage can be none, minor or complete. I constructed 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 otherwise[11].

The 2007 survey covers total sales and the number of employees for 2006 only. However, the

[9] Lokshin et al. (2007b) report a simplified testing method using several standard Likelihood-ratio tests consecutively reducing computational demand. The more complex version of Lokshin et al. (2007a) on the other hand has the advantage of reporting only one p-value and offering better inference as the inequalities are tested jointly. Therefore I use the complex testing method for inference in this study.

[10] The results from Lokshin et al (2007b) reporting a low size of both tests once the R^2 is low should be treated with care since they are based on the first monte carlo simulation in this context. Without more research in this field one is unable to decide which methods produce more useful results or is appropriate in a given context. Therefore, it is far more careful to check both approaches for inference instead of relying on one method.

[11] The interpretation of a productivity effect due to a 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.

answers on enterprise system usage relate to the year 2007. Since the survey is organized as a panel dataset, I use the software usage level reported in 2004 to construct the needed dummy variables. Despite possible software updates or the availability of newer software versions, the two-year difference between software use and firm performance should be adequate to measure the productivity effects of enterprise systems as many other analyses reported that enterprise software needs about two years to generate some kind of performance effects[12]. The two years lag used in the present study should also decrease the potential endogeneity problem.

Matching the data for the two periods results in nearly 1,000 observations. Due to item-nonresponse and by dropping the banking sector[13] I obtained 927 observations for my final data set. As there were no data available to measure the physical capital stock of the firms, I used gross investment figures as an empirical proxy for the capital stock. This is also done by Bertschek et al. (2006) but could turn out to be a potential drawback for my analysis. However, without adequate panel data available it is not feasible to calculate the firms' capital stock using the perpetual inventory method (e. g. OECD (2001)). Another problem with this method arises as some firms report zero investments in 2004, although the occurrence of zero investments is explained by Bond and Van Reenen (2007) and is therefore not surprising at all. However, with an econometric specification of the production function in logarithmic values for the factor inputs these firms must be excluded from the final sample. To take care of this problem and to avoid losing further observations, I follow the approach used in Ohnemus (2007) and determine the value of investment for the firms reporting zero investments as the 10 percent quantile of their respective industry and size class[14].

Table 1[15] shows the descriptive statistics for the variables of the production function estimation in this study. Table 1 also includes two additional variables, namely export activity and works council which I use for some analyses in the next section. Sales, labor and the labor productivity ratio refer to the year 2006, the qualitative inputs capital and share of computer workers as well as all other variables refer to the year 2004. In addition, Table 1 also provides the descriptive statistics for the industry affiliations of the firms in the final sample.

In 2006 mean sales amount to € 46,667,200 and the average firm size results in 246 employees. For 2004 the mean investment (as proxy for capital) is € 2,382,600. The share of computer workers in the sample used for the estimation of the production function is around 47 percent. Nearly 27

[12] E. g. Nicolaou et al. (2003), Nicolaou (2004) and Matolcsy et al. (2005).
[13] 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 error.
[14] 71 replacements were made.
[15] All Tables are located in the Appendix.

percent of the firms are located in East Germany. Export activity is reported by 56 percent of the firms and 47 percent of the sample firms have a works council. Regarding the industry affiliation of the firms, the biggest share of 12 percent does business in metal and machine construction, only a few belong to the whole sale or retail trade industry (both 5 percent). 56 percent of the firms do business in the manufacturing sector.

Table 2 provides the summary statistic for the dummy variables of enterprise system usage and shows additional statistics of the firms using these systems. In addition, it lays a specific focus on the group of firms using no enterprise systems at all or the full suite of enterprise systems. It is striking that more than one quarter of the firms uses all three enterprise systems in concert, nearly 28 percent in the sample, or no enterprise software at all (24 percent). The use of ERP is widespread (64 percent), around 44 percent apply SCM software and about 51 percent of the firms have adopted CRM software. Comparing the average labor productivity for each group with the entire sample mean reported in Table 1 it catches the eye that once the firms use software, their labor productivity exceeds average productivity of € 192.200. Especially firms using all three systems in concert show on average the highest labor productivity of € 234.200. Firms using no enterprise systems at all seem to fall back in terms of labor productivity (€ 167.000). It seems that especially the large firms of the sample choose all three systems together. These firms have on average 566 employees as shown in Table 2. However, in the available sample smaller firms also seem to count on the full suite of enterprise software applications, about 43 percent of the firms which use all three enterprise systems have 100 or less employees (not reported). As expected, firms which use SCM or ERP belong merely to the manufacturing sector (63 respectively 68 percent). In addition, Table 2 shows that many manufacturing firms also tend to buy CRM (54 percent). Regarding the usage of enterprise systems among the different industries, ERP is used most often by electrical engineering companies. Around 81 percent of the enterprises in this sector rely on ERP (not reported). SCM systems are used most frequently in the precision instruments industry sector (57 percent, not reported). CRM are most commonly used by enterprises working in the electronic data transfer sector (74 percent, not reported).

Since enterprise software systems are often adopted together, the correlation between the software systems should also be taken into account. Table 3 reports the Pearson correlation coefficient. Each coefficient turns out to be significant at the 1 percent level and exceeds the magnitude of 0.3. Assuming that firms maximize their profits, this medium correlation may indicate that the firms expect some kind of performance benefits from adopting more than one enterprise system.

5 Empirical results

5.1 Returns to enterprise systems

Table 4 reports the basic estimation results using the regression formulation described in Equation (3). The firm-level labor productivity is regressed on production input variables and an indicator of each enterprise software application controlling for industry and the geographical region of East Germany. At the beginning in order to arrange the estimation in the right context and provide a suitable basis I introduce the three enterprise systems in the regression, one at a time. Overall, I find that the firms using ERP or SCM show greater performance in terms of labor productivity than firms not using these systems. Both point estimates are statistically significant at the one percent level. For instance, the estimate of 0.152 in Column (1) indicates that ERP adopters have on average 15.2 percent greater labor productivity than firms which do not adopt ERP. Both coefficients show a similar order of magnitude, with SCM having the highest impact. The coefficients of CRM, on the other hand turns out to be only weak significant at the ten percent level as shown in Column (3). These results form a first confirmation for the hypotheses one and two. However, as these coefficients do not directly compare ERP, SCM and CRM with each other, I have to estimate them simultaneously to determine which enterprise systems really drive performance.

As the usage of ERP, SCM and CRM are highly correlated with each other and as all three systems are expected to contribute to performance enhancement, omitting one of them could upwardly bias all the returns of the observed one. Aral et al. (2006) reports the first evidence for this. In order to confirm the findings of Aral et al. (2006) and to give a first insight of the interacting nature of the enterprise systems Table 5 reports the regression results taking combinations of the adoption of two enterprise systems into account. It contains the results with all three enterprise systems being simultaneously integrated in the regression as well. If the assumption of omitted variable bias is true one would expect a decrease in significance and in the size of the coefficients[16] provided that the enterprise systems are integrated together in the regression. This is exactly what happens. Overall, ERP and SCM stay significant once I control for the other enterprise software applications in the regression. Abstracting from SCM leads to a higher significance of ERP, as shown in Column (2) of Table 5. The coefficient of CRM stays insignificant in all regressions. Moreover, every coefficient decreases in magnitude once the adoption of another enterprise system is controlled for. This change in the coefficients goes in line with the results reported by Aral et al. (2006). Although their

[16] This is only true if the variables are positive correlated. The positive correlation between the three enterprise systems is confirmed in Table 3.

coefficients of SCM and ERP still remained significant they declined in magnitude and the ERP estimate even turned out to be negative once the adoption of other enterprise systems was included in the regression. Their coefficient of CRM loses significance when SCM and ERP are included in the regression as well. This implies that if the enterprise systems are considered simultaneously in the regressions the performance impact of one enterprise system is to some extent explained by the other one with SCM explaining the major part in the present dataset. The big impact of SCM systems on performance is not surprising having in mind that every study focusing on SCM reports positive impacts of SCM, also when used alone, on firm performance. For CRM usage, however, there is nearly no evidence of such impacts. One should expect that enterprise systems outside the boundary of the firm, e.g. SCM, generate greater performance than internally oriented ERP systems, which is confirmed by the results shown in Table 5. In addition, the performance effect of ERP might already be generated much earlier. Thus, it does not show high significance anymore as most firms install first their ERP system and a few years later SCM and CRM applications. Unfortunately, the data does not provide any information about the date of purchasing or implementing the enterprise system. However, without an already installed ERP system the firms would need to feed their SCM and CRM systems from legacy systems, often in form of spreadsheets spread out over different departments and subsidiaries of the firm. In that case the information from all areas of the company cannot be accessed fast and misses a reliable basis (Wailgum and Worthen (2008))[17].

These results suggest that the omission of two out of these systems creates an upward bias in the estimates. One possible interpretation of this upward bias in the estimates of one enterprise system alone might be that it functions as a proxy for the positive performance impact of the two omitted systems, thus the two other systems may partly explain the performance benefits originally attributed to the first system. This bias might even grow larger if the systems are used in combination because the performance gains resulting from benefits due to combinations of these interacting systems are not explicitly revealed. Therefore, to cover the performance benefits due to different combination of the systems and their potential complementarity relationship will be the next step.

[17] In line with Wailgum and Worthen (2008) the used dataset contains only a few firms which use SCM and CRM individually or in combination but no ERP (13 percent, not reported).

5.2 Complementarity and interaction between the enterprise systems

To reveal complementary benefits due to the use of different combinations of the systems, I at first use the multiple restrictions test of Lokshin et al. (2007a) as described in Section 3.3. In addition, another specification based on interaction terms between the systems capturing the productivity impacts of different combinations of the systems is applied. To the best of my knowledge, complementarity between the enterprise systems has not been tested in the literature before.

Table 6 reports the computed log-likelihood values of the unconstrained and constrained models, the Likelihood-ratio statistics and p-values. I rely on the method developed by Shapiro (1985) to generate the needed weights. Overall, the Likelihood-ratio statistics turn out to be small in the first two cases and the test rejects the hypothesis of pairwise complementarity for the combinations of ERP and either SCM or CRM. However, in the third case the test reports a complementarity relationship between SCM and CRM significant at the one percent level. The complementarity relationship is unconditional on ERP adoption indicating that complementary benefits might be realized even if an ERP system is not installed. This result tends to be a long shot having in mind that SCM and CRM might not be able to generate the desired performance increases without the necessary infrastructure and databases provided through the ERP system as stated by Wailgum and Worthen (2008).

In the next step the standard interaction terms take account of complementarity. Table 7 reports the interaction terms controlling for the adoption of any two systems together in specification (1) to (3). Concerning any two systems together no interaction term turns out to be significant, indicating no complementarity between any two enterprise software applications at the first glance. Even the performance impact of the enterprise systems individually drops down to zero with the exception of ERP having a small impact in specification (2). However, specifications (1) to (3) only control for two systems at a time neglecting influence of the third system. Specification (4) on the other hand controls for all possible interactions between all three software systems. Corresponding to the interactive nature of the software systems mentioned in section 2.2 the results now change. The influence of ERP turns out to be significant indicating an increase in labor productivity for firms using this system. Striking on the other hand is the significance, even only weak, of the interaction term which captures the use of all three software systems together. According to this term firms using ERP and additionally SCM and CRM systems exhibit a considerable increase in labor productivity. Complementarity between the three different systems is not directly realized through the adoption of two of these, but SCM and CRM complement each other once ERP is already in use or implemented in conjunction. Having in mind potential combination benefits outlined in Section

2.2 and the statement of Wailgum and Worthen (2008) indicating that SCM and CRM alone might not be that useful this result seems very plausible. The ERP system provides the necessary infrastructure to feed the needed data to the SCM and CRM system, building a bridge function (Koch and Wailgum (2008)) between the front and the back office. The performance effects generated through the use of an ERP system are increased even further once the firms adopt the other two systems. Therefore, adopting the full suite of enterprise systems turns out to be most useful for firms if they provide the needed data infrastructure based on an ERP system in first place. In addition to the interaction terms I also conducted the testing procedure of Lokshin et al. (2007a) for two practices, namely SCM and CRM, but only if ERP is also in use. Conducting the appropriate one-sided t-test reports a complementarity relationship significant at the one percent level and thus strengthening the results of Table 7. All together firms using SCM and CRM should realize some complementary benefits as reported in Table 6, but the benefits turn out to be especially high if the firms provide the infrastructure for both systems through an ERP system as reported in Table 7.

As specification (3) is rather parsimonious in terms of variables which affect labor productivity, the results might to some extent be driven by unobserved heterogeneity with respect to the firms. Therefore, a reduction of the heterogeneity bias by introducing some more productivity affecting variables seems reasonable, especially as the evidence is based on weak significance. For this kind of robustness check I introduce two additional dummy variables in the estimation, the first one taking the value one if the firm exports, the second one taking the value one if there is a works council in the firm. Compared to firms that are only active in their home market, firms engaged in export activities are more exposed to international market pressure. Those firms are in general used to adjust more quickly to changes in the market environment. They rely on a highly flexible workforce as worldwide demand may change more rapidly and drastically than domestic demand. Therefore, export activity is expected to be positively related to labor productivity[18]. With an established works council on the other hand employees are expected to show a higher identification with their enterprise and the decisions taken, they feel more committed and consequently do a better job. In addition, employee participation in decision-making might balance production more effectively to eliminate bottle-necks or interruptions of the production process. Hence, the establishment of a works council should also lead to higher labor productivity[19]. Specification (5) of Table 7 reports the result once works council and export activity is controlled for. As expected, both estimates show a significant positive impact on labor productivity. Concerning complementarity

[18] Empirical Evidence is given by e. g. Baldwin and Gu (2004) and Bernard and Jensen (2004).
[19] Empirical Evidence is given by e. g. Zwick (2003).

between the enterprise systems the two newly introduced variables do not affect the relationship much. Both relevant coefficients, ERP and the interaction term of all three systems, decrease in size but still show a significant impact on labor productivity. In addition, both multiple restrictions tests, the one conditional on ERP adoption and the unconditional one, stay significant at the one percent level if export activity and works council is controlled for. Therefore, the complementarity relationship between SCM and CRM is not tackled even if unobserved heterogeneity based on export activity and works council is taken care of.

The strong impact of the usage of all three enterprise systems together is not surprising if we bear in mind the benefits each system offers and the potential benefits a firm might realize if it combines the systems. Firms using the complete suite of enterprise systems are able to manage all components of the value chain, such as outbound and inbound logistics, marketing, sales and procurement in real time. Therefore, they can quickly react to changes in supply or demand. The firms can only realize these interaction benefits if they adopt the full suite of systems although ERP should be adopted first in order to provide the appropriate infrastructure.

6 Conclusion

Starting to get adopted by firms in the early 1990s, enterprise systems are now widely diffused among industries and firms of any size category. Their influence on productivity, however, is still not perfectly revealed. Moreover, it is still unknown if the interactions between various enterprise systems affects performance in a different way than the use of a single application.

The present paper approaches this question from a new angle. It does not only focus on the productivity gains generated by the adoption of enterprise systems in general, it also tries to disentangle the productivity impacts caused by the combinations of different enterprise systems. The results shed light on the influence of the combination of enterprise systems on labor productivity. They provide empirical evidence of the impact of the three major enterprise systems and of possible complementarities among these systems. The results indicate that SCM and CRM function as complements, especially if an ERP system provides the necessary IT-infrastructure for both. This turns out to be robust even if a non-parsimonious labor productivity specification is used for inference. Therefore, the productivity gains caused by enterprise system adoption are not only generated by the usage of one single system, they are augmented and increased by adopting the three major enterprise systems together. Therefore, previous estimations of the productivity impacts from enterprise software might be biased as long as any interaction effects of the systems are not taken into account and pictured adequately.

The results imply that it is not sufficient for managers to rely on possible benefits gained through the adoption of one single system, as it might fail to provide the expected benefits on its own. Managers should carefully examine the benefits and advantages of adopting one system compared to the combination of all three systems and adjust their decisions accordingly.

A potential short-coming of this analysis might be the fact that I could only check for the combined effects of adopting the different software systems without controlling for other obstacles interfering with enterprise system usage. This may be a drawback since not only the adoption of other enterprise systems might influence the productivity gains of one system. Special IT-training or the quality of updates and maintenance, to name only a few examples, may also affect the performance effects of enterprise software. In addition, the dataset does not allow for distinguishing between individually developed software applications or acquired generic ones, which might impact the performance as well. The dataset also contains no information about the usage of Enterprise Application Integration software. This software enhances the communication between the different enterprise systems and enables them to check for redundant information thereby increasing the performance of the systems. Future availability of new data may provide evidence for these cases. The availability of data on costs for enterprise software implementation and maintenance would also allow for a richer analysis.

In addition, even if the bias due to the endogeneity of the decision to adopt enterprise systems in the current dataset should be small, as mentioned in Section 4, it cannot be excluded completely. Therefore, finding appropriate instrumental variables for the three enterprise systems is still an issue. Unfortunately, the available dataset of the present study does not provide appropriate instrumental variables. Thus, I pass this task to future research.

7 References

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8 Appendix

Table 1: Summary statistics

Variable	Mean	Std. Dev.	DV[4]
Output (sales)	46,667.2	169,785.8	
labor productivity[1]	192.2	229.7	
capital[2]	2282.6	9843.0	
labor[3]	245.7	916.5	
ln (output)	8.879	1.914	
ln (labor productivity)	4.891	0.811	
ln (capital)	5.366	2.230	
ln (labor)	3.987	1.644	
share of computer workers	0.467	0.328	
East Germany	0.273		yes
export share	0.557		yes
works council	0.368		yes
consumer goods	0.093		yes
chemical industry	0.052		yes
other raw materials	0.081		yes
metal and machine construction	0.118		yes
electrical engineering	0.076		yes
precision instruments	0.066		yes
automobile	0.073		yes
complete manufacturing sector	0.559		yes
whole sale trade	0.054		yes
retail trade	0.051		yes
transport and postal services	0.065		yes
electronic data transfer	0.097		yes
technical services	0.102		yes
other business-related services	0.073		yes
Number of observations		927	

Notes: [1] Sales per employee (in 2006) in €1,000. [2] Capital is proxied by gross investment in €1,000. [3] Labor is measured in amount of total employees.
[4] Dummy variable
Source: ZEW ICT survey 2004, 2007 and own calculations.

Table 2: Means and shares for the enterprise systems

	No system	All systems	ERP	SCM	CRM
Share of entire population	0.236	0.278	0.636	0.442	0.513
Labor Productivity Mean	167.0	234.2	205.6	217.1	204.8
	(269.0)	(245.8)	(215.8)	(219.8)	(229.4)
Size Mean	43.1	566.3	359.5	441.3	357.8
	(70.1)	(1605.1)	(1132.1)	(1319.7)	(1229.6)
share of manufacturing sector	0.457	0.667	0.625	0.676	0.538

Notes: Standard errors in parentheses.

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

Table 3: Enterprise system adoption – correlation structure

	ERP	**SCM**	**CRM**
ERP	1.000		
SCM	0.384 ***	1.000	
CRM	0.350 ***	0.384 ***	1.000

Notes: Spearman correlation coefficient reported
*** p<0.01; ** p<0.05; * p<0.1
Source: ZEW ICT survey 2004 and own calculations.

Table 4: Returns of enterprise systems evaluated individually

Dependent Variable: Labor Productivity	**(1)**	**(2)**	**(3)**
ln (labor)	-0.111***	-0.111***	-0.102***
	(0.026)	(0.026)	(0.026)
ln (capital)	0.125***	0.124***	0.127***
	(0.019)	(0.019)	(0.019)
share of computer	0.584***	0.593***	0.593***
workers	(0.106)	(0.106)	(0.108)
ERP	0.152***	-	-
	(0.055)		
SCM	-	0.164***	-
		(0.051)	
CRM	-	-	0.082*
			(0.049)
Constant	5.697***	5.703***	5.727***
	(0.166)	(0.166)	(0.167)
Control variables	Industry, East	Industry, East	Industry, East
R^2	0.234	0.235	0.230
Number of Observations		927	

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

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

Table 5: Returns to enterprise systems

Dependent Variable: Labor Productivity	**(1)**	**(2)**	**(3)**	**(4)**
ln (labor)	-0.119***	-0.112***	-0.111***	-0.119***
	(0.026)	(0.026)	(0.026)	(0.026)
ln (capital)	0.120***	0.123***	0.123***	0.120***
	(0.019)	(0.019)	(0.019)	(0.019)
share of computer workers	0.584***	0.570***	0.584***	0.566***
	(0.105)	(0.107)	(0.107)	(0.106)
ERP	0.120**	0.138**	-	0.118**
	(0.055)	(0.057)		(0.057)
SCM	0.139***	-	0.152***	0.135**
	(0.051)		(0.054)	(0.053)
CRM	-	0.049	0.034	0.012
		(0.050)	(0.052)	(0.053)
Constant	5.669***	5.688***	5.697***	5.667***
	(0.166)	(0.167)	(0.167)	(0.167)
Control variables	Industry, East	Industry, East	Industry, East	Industry, East
R^2	0.239	0.234	0.236	0.239
Number of Observations	927			

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

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

Table 6: Multiple restrictions test for complementarity[20]

Complementarity Relation	Unconstrained	Inequality Constrained ≥ 0	Inequality Constrained ≤ 0	Equality Constrained	LR-Statistic	P-Value
ERP – SCM	-658.475	*-659.319*	-659.804	-660.653	2.668	0.117
ERP – CRM	-658.475	-659.694	*-659.499*	-660.709	2.420	0.134
SCM – CRM	-658.475	*-658.768*	-662.311	-662.604	7.672	0.010

Note: In the LR tests the null corresponds to the value in italics and the alternative corresponds to the equality constraint. In order to conclude in favor of complementarity or substitability the Log-Likelihood value with the inequality constraints should be significantly larger than the Log-Likelihood value with the equality constraint.
Source: ZEW ICT survey 2004, 2007 and own calculations.

[20] Although this test shows a problematic size if the R^2 is low, it is the most recent method to confirm the existence of complementarity in the case of three or more adopted practices. The other test used by Mohnen and Röller (2005) does not report p-values and turns even out to be inconclusive in some cases. Therefore I use the multiple restrictions test by Lokshin et al. (2007a) for inference.

Table 7: Returns to enterprise systems – interaction between the systems

Dependent Variable: Labor Productivity	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
ln (labor)	-0.120***	-0.112***	-0.110***	-0.121***	-0.146***
	(0.026)	(0.026)	(0.026)	(0.026)	(0.028)
ln (capital)	0.120***	0.123***	0.122***	0.120***	0.110***
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
share of computer workers	0.568***	0.571***	0.582***	0.572***	0.572***
	(0.105)	(0.107)	(0.107)	(0.107)	(0.106)
export activity	-	-	-	-	0.148***
					(0.057)
works council	-	-	-	-	0.171**
					(0.069)
ERP	0.107	0.135*	-	0.185**	0.154*
	(0.068)	(0.072)		(0.084)	(0.085)
SCM	0.103	-	0.072	0.171	0.139
	(0.085)		(0.076)	(0.116)	(0.118)
CRM	-	0.044	-0.023	0.046	0.045
		(0.089)	(0.070)	(0.121)	(0.123)
ERP & SCM	0.049	-	-	-0.196	-0.186
	(0.104)			(0.151)	(0.151)
ERP & CRM	-	0.007	-	-0.179	-0.189
		(0.106)		(0.149)	(0.150)
SCM & CRM	-	-	0.138	-0.134	-0.110
			(0.100)	(0.180)	(0.183)
All three systems	-	-	-	0.419*	0.408*
				(0.219)	(0.220)
Constant	5.678***	5.690***	5.711***	5.664***	5.574***
	(0.169)	(0.168)	(0.167)	(0.169)	(0.171)
Control variables	Industry, East	Industry, East	Industry, East	Industry, East	Industry, East
R^2	0.239	0.234	0.237	0.244	0.255
Number of Observations			927		

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

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