Enterprise Software Adoption and Perceived Business Performance - An Empirical Investigation in Germany and the US

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ENTERPRISE SOFTWARE ADOPTION AND PERCEIVED BUSINESS PERFORMANCE – AN EMPIRICAL INVESTIGATION IN GERMANY AND THE US

Adoption des logiciels d'entreprise et performance perçue – une recherche empirique en Allemagne et aux États-Unis

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Abstract

This work contributes to the ongoing debate on the productivity paradox by considering CIOs' perceptions of IT business value. Applying regression analysis to data from an international survey, we study how the adoption of certain types of enterprise software affects the CIOs' perception of the impact of IT on the firm's business activities and vice versa. Other potentially important factors such as country, sector and size of the firms are also taken into account. Our results indicate a more significant support for the impact of perceived IT benefits on adoption of enterprise software than vice versa. CIOs based in the US perceive IT benefits more strongly than their German counterparts. Furthermore, certain types of enterprise software seem to be more prevalent in the US.

Keywords: IT business value, enterprise software adoption, CIO perceptions, empirical analysis

Résumé

Nous examinons comment l'adoption de certains types de logiciels d'entreprise affecte la perception que les responsables de systèmes d'information (les CIO) ont de la valeur de la technologie de l'information utilisée dans leurs organisations et vice versa. Nos hypothèses sont testées statistiquement sur un échantillon de 262 entreprises allemandes et américaines.

Introduction

In 1987 Nobel Prize winner Robert Solow stated that 'you can see the computer age everywhere except in the productivity statistics' (Solow 1987). The apparent lack of correlation between the degree of Information Technology (IT) adoption and firm performance sounded counter-intuitive back then and surely does today. The finding became known as the 'productivity paradox' and spurred manifold reactions in the information systems community. Since the beginning of the debate on the productivity paradox, a number of researchers have tried to isolate the effect of IT adoption on economic performance and to prove that IT actually does have a positive impact on productivity (e.g. Barua et al. 1995; Dos Santos et al. 1993; Weill 1992). Brynjolfsson and Hitt (1996) were among the first to find empirical evidence proving a positive influence of IT investment on firm performance and shortly afterwards declared the productivity paradox as solved. Although this happened back in 1996, the debate is still ongoing (Bharadwaj et al. 1999; Bharadwaj 2000; Stratopoulos and Dehning 2000). Some of the reasons for its continuation are mentioned in the following.

Results of Brynjolfsson and Hitt (1996) – although pointing out a positive correlation of IT investment and firm-level productivity – also showed that this relationship is characterized by a high degree of variance: some firms that spend a lot of money on IT are outperformed while other firms invest relatively little into IT while showing above-average performance. The variance in the relationship between IT investment and firm-level productivity can be explained in various ways. Firstly, just installing a new IT system in a company does not automatically lead to performance benefits. Rather, IT investment has to be complemented by other activities which lead to whole new ways of doing things in the company. It was found that for every dollar of IT hardware capital a company owns, there is up to $9 of IT-related human and organizational capital such as highly qualified staff and innovative processes (Brynjolfsson 2003). Hence, a negative correlation between investment into IT and firm performance could result from insufficient complementary investments. Secondly, since business processes and the skills of employees need to be constantly aligned with the capabilities of the latest IT, a measurable performance increase is likely to be observed only after a certain time lag. The improvement of work flows also depends on the complexity of the task supported by a corresponding IT solution or the usability of the technology itself. Thirdly, the positive impact of IT has oftentimes been implicated with organizational trends such as decentralization and increasing geographical dispersion. A number of researchers came to the conclusion that in particular organizational decentralization plays a mediating role when it comes to the realization of IT benefits (Bresnahan et al. 2002). Recently it has also been argued that being able to handle enterprise software is becoming a basic necessity for all employees, which coined the assertion that 'IT is shifting from staff to line'. The speed of this development is also expected to influence the effective use of enterprise software (Culnan et al. 1999). Fourth, there seem to be industry-specific particularities that may explain the success or failure of certain IT investment decisions. These are not covered in Brynjolfsson's work for methodological reasons: both IT investment and firm-level productivity are measured relative to the corresponding industry average.

Information technology is a very general term that covers all kinds of hard- and software used to store and process enterprise data. Brynjolfsson and Hitt (1996) measured IT investment in terms of the current replacement cost of IT hardware stock per worker. Other studies focus on the value of a particular kind of software, e.g. Supply Chain Management (SCM) applications (Aral et al. 2006; Baron et al. 2007). Regarding certain types of generally applicable enterprise software (e.g. Enterprise Resource Planning software), the specificity of software is without doubt higher than the specificity of hardware: a personal computer can serve as a platform for all kinds of software applications, while a SCM solution can only be used for a relatively specific purpose. A particular IT asset can be of a more or less strategic importance for a company (Chan et al. 1997, Porter and Millar 1985). For instance, using accounting software is commonplace today and will therefore be highly unlikely to provide competitive advantage to a firm. Hence, we believe that when trying to measure the impact that the adoption of IT has on the performance of organizations, the degree of innovativeness of this technology should be included into the analysis. One possibility to do so is to consider representative types of enterprise software (Aral et al. 2006; Baron et al. 2007; Grover et al. 1998).

Another important determinant in the relationship between IT adoption and firm performance is strategic alignment, i.e. how well the adopted IT supports the strategic goals of an organization (Byrd et al. 2006). Recently, a study by the Economist Intelligence Unit (2006) based on a survey among 288 senior IT executives provided insights into how the role of IT is perceived in today's business environment. A major result of the study was that executive expectations with respect to the returns of IT are changing; in particular IT is expected not only to enable further gains in operational efficiency, but also to support long-term and strategic objectives of the firm. The study also revealed an 'expectation gap' between Chief Information Officers (CIOs) and other executives. Thus, while the questioned CIOs were only to a certain degree convinced that IT's role will shift from an enabler of cost efficiency to

a strategic asset, the executive suite seems to be fully convinced of this development. Recent academic research that investigated the perceptions of executives regarding the impact of IT on firm performance showed that these perceptions oftentimes reflect the facts (Tallon & Kraemer 2007). Thus, the role of IT may indeed be changing as it finds its way into more and more business processes.

Organizational change can also be among the drivers of IT adoption and IT value. Previous research suggests that changes to the IT infrastructure can be related to changes of the organizational structure. For instance, organizational decentralization and geographic dispersion may fuel the need for IT applications that are expected to make the collaboration of employees more efficient (Grover 1993).

Interestingly, the study conducted by the Economist Intelligence Unit (2006) also showed that this expectation gap varies significantly depending on the provenance of the respondents: It is much smaller in Europe and the Asian-Pacific region. These results suggest that the provenience of survey participants may have a crucial impact of the valuation of IT benefits and thus should be included as an independent factor.

Other possible reasons for structural differences regarding the perception and adoption of IT could be the sector affiliation and size of organizations. The service sector is oftentimes regarded as more information intensive which implies that the effective use of modern IT could constitute a more significant success factor for a service company. Regarding the effect of firm size, economic theory suggests that it generally increases transaction costs due to an increased need of task coordination and monitoring (Brynjolfsson 1994). IT is expected to reduce transaction costs by enabling more effective and efficient ways of information transmission (within as well as between firms). Therefore the impact of IT with respect to business benefit should be felt more strongly in larger organizations.

In this paper, we present empirical findings regarding the relationship between perceptions regarding the impact of IT on business performance, organizational change, and the adoption of particular types of enterprise software. The relationship of investment into hardware and the perception of IT benefits is not analyzed although previous research has shown a connection between IT hardware capital and firm productivity (Brynjolfsson 1994). Instead of measuring the actual impact of IT on firm performance, we explicitly ask for the CIOs' assessment of a broad range of possible IT benefits. This approach sets us apart from the more fundamental economics oriented research on the productivity paradox (e.g. Brynjolfsson and Hitt 1996).The impact of IT on organizational change is also not measured directly but through the eyes of the CIOs. Moreover, we consider the influence of a number of basic firm profile variables such as country, sector and organizational size on the perception of IT benefits and the adoption of enterprise software.

In the next section we define our major hypotheses and state the goals of our research. In a follow-up section we provide some background information on the sample that was used to test our hypotheses. The last two sections describe the applied methodology, the statistical results, as well as possible interpretations of the results.

Research Goals and Hypotheses

Our research generally stays in line with the studies conducted on the IT paradox, i.e. we strive to investigate possible connections between the investment into IT and the performance of organizations. However, in contrast to most of the quantitative work cited in the introductory section, we focus on the connection between the *adoption of specific types of enterprise software* and *the impact of IT on specific performance variables as perceived by CIOs*. If causality is added to the link between the adoption of enterprise software and the perceived impact of IT on organizational performance, two general hypotheses emerge:

- The adoption of enterprise software leads to a more positive perception of IT with respect to business performance and strategic knowledge gain (H1).

- A more positive perception of IT with respect to business performance and strategic knowledge gain fosters the adoption of enterprise software (H2).

Apart from testing these two general hypotheses with respect to specific types of software and business performance metrics, our interest lies in considering the effect of a number of the other factors that are likely to influence both the use of enterprise software and perceived IT benefits. To this end we take IT-driven organizational change as well as the firm profile with respect to country, sector and number of employees into account. Based on a number of indicators for these factors, we state four more hypotheses:

- A stronger perception of organizational change ascribed to IT has a positive impact on the adoption of enterprise software (H3).

- A stronger perception of organizational change ascribed to IT leads to a more positive perception of IT with respect to business performance and strategic knowledge gain (H4).

- Sector, country, and number of employees have an influence on the adoption of enterprise software (H5). In particular, the enterprise software adoption rates are higher in the US (H5, country), higher in the services sector (H5, sector), and higher in firms which employ more personnel (H5, #employees) and IT personnel (H5, #IT employees).

- Sector, country, and number of employees have an influence on the perceived impact of IT on business performance and strategic knowledge gain (H6). In particular, the perception of IT benefits is higher in the US (H6, country), higher in the services sector (H6, sector), and higher in firms which employ more personnel (H6, #employees) and IT personnel (H6, #IT employees).

Figure 1 provides an overview of these hypotheses.

Figure 1. Hypotheses
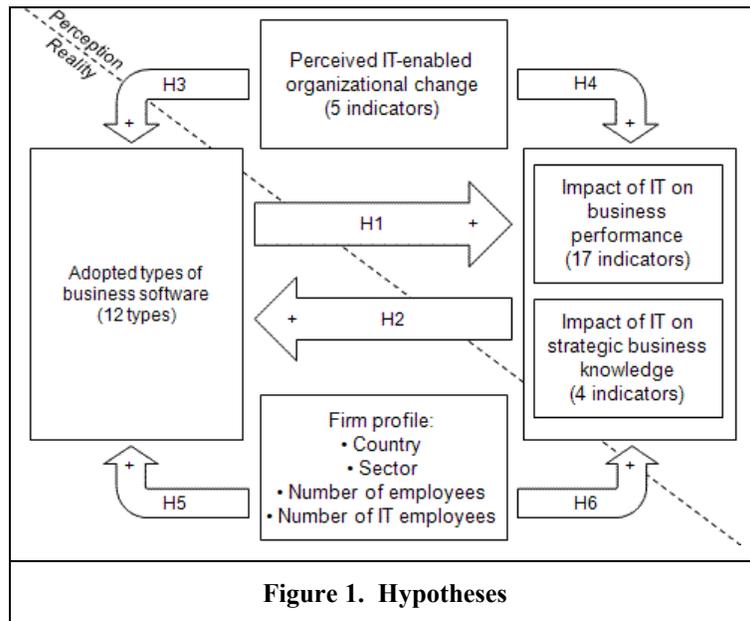
Survey Design and Sample

All results presented in this paper are based on empirical data. This data was collected in the course of an international survey carried out by cooperating research institutions in Germany and the US. The survey was designed to measure current trends in IT usage and the impact of IT on organizations. It targeted the CIOs of organizations from the respective countries. The German data was collected during Fall 2006 using both a paper-based questionnaire and a web-based survey tool. The US data was collected online between Fall 2005 and Winter 2006. The raw sample consisted of 165 data records collected in Germany (5.6% response rate) and 210 records collected in the US (1% response rate). 49 out of the 165 German and 64 out of the 210 US responses had to be dropped from the sample due to too many unanswered questions in the sections of the questionnaire that were relevant for the research presented in this paper. The remaining sample for Germany consisted of 116 observations (46 manufacturing and 70 service firms). The US sample consisted of 146 observations (44 manufacturing and 102 service firms). The total net sample size thus was 262. The samples were dominated by medium-sized firms: more than 85% of the companies had revenues less than $100 million and the rest had revenues between €100 million and €1 billion. Thus, despite differences in the response rates and absolute numbers of the responses, the German and the US samples are comparable in both the distribution of the firm size as well as the manufacturing to services ratio.

The questionnaire consisted of eight sections containing around 200 specific questions in total. In order to produce the results presented in this paper, we used only a fraction of the empirical data in terms of the measured variables. Tables 1 and 2 provide an overview and the required semantics of the variables which were used in this study.

Table 1. Description of the variable types and names			
Variable types	**Variable names**	**Value domain and encoding**	**Questionnaire**
Types of enterprise software adopted	a_i; $A = \{a_1,...,a_{12}\}$	Not adopted (0), adopted (1)	Sections I & V
Perceived IT-enabled organizational change	b_j; $B = \{b_1,...,b_5\}$	Strongly disagree (1), disagree (2), neutral (3), agree (4), strongly agree (5)	Section II
Perceived impact of IT on business performance	c_k; $C = \{c_1,...,c_{17}\}$	Decreased significantly (1), decreased (2), unchanged (3), increased (4), increased significantly (5)	Section VI
Perceived impact of IT on strategic business knowledge	d_l; $D = \{d_1,...,d_4\}$	Declined significantly (1), declined (2), same (3), improved (4), improved significantly (5)	Section VI
Country of origin	e	Germany (0), US (1)	-
Sector affiliation	f	Manufacturing (0), Service (1)	Section VIII
Numbers of employees (total and IT)	g_m; $G = \{g_1,g_2\}$	Very small (0), small (1), medium (3), large (4), very large (5)	Section VIII

Table 2. Detailed variable descriptions			
Types of Enterprise Software Adopted: *Adoption of ...*			
a_1	… Groupware and productivity tools	a_2	… Enterprise Resource Planning (ERP) software
a_3	… website and E-Commerce software	a_4	… Business Intelligence (BI) tools
a_5	… Business Process Modeling (BPM) software	a_6	… Content Management software
a_7	… E-learning environments	a_8	… Enterprise Instant Messaging software
a_9	… Supply Chain Management (SCM) software	a_{10}	… E-Procurement
a_{11}	… E-Payment	a_{12}	… Electronic Data Interchange (EDI)
Perceived IT-enabled Organizational Change: *CIO's perception that IT has lead to an increase/decrease of ...*			
b_1	… collaboration of employees	b_2	… demand for information at the executive level
b_3	… the shift of IT functions from staff to line	b_4	… organizational decentralization
b_5	… geographical dispersion of the firm		
Perceived Impact of IT on Business Performance: *CIO's perception that IT has lead to an increase/decrease of ...*			
c_1	… research and development costs	c_2	… market research costs
c_3	… advertising and direct marketing costs	c_4	… promotional and loyalty costs
c_5	… commercial costs	c_6	… customer service costs
c_7	… technology costs	c_8	… human resources costs
c_9	… consultancy and collaboration costs	c_{10}	… internal communication costs
c_{11}	… new products' time to market	c_{12}	… new products' risk of failure
c_{13}	… number of new products	c_{14}	… market share
c_{15}	… revenue	c_{16}	… profit
c_{17}	… margin		
Perceived Impact of IT on Strategic Business Knowledge: *CIO's perception that IT has lead to an increase/decrease of knowledge regarding ...*			
d_1	… customer buying behavior	d_2	… customers' expectations
d_3	… customers' satisfaction	d_4	… competitors' products/services

The choice of variables picked from the original data depended on the hypotheses being tested as well as the completeness of the corresponding data. For instance, since our focus is on the adoption of enterprise software rather than IT hardware, we did not consider any of the hardware adoption variables featured by the original survey. Neither did we include variables with too many missing observations. For example, questions relating to the degree of workforce reduction and increased productivity monitoring using IT were oftentimes left unanswered and thus could not be considered.

All variables in the category 'types of enterprise software adopted' are binary, meaning that their values either state adoption or non-adoption of a particular type of enterprise software. Each variable of the type 'perceived IT-enabled organizational change' is measured on a 5-point ordinal scale. The same applies to variables belonging to the categories 'perceived impact of IT on business performance' and 'perceived impact of IT on strategic business knowledge'. The country and sector variables take on binary values with the two sectors and countries coded as 0 or 1 respectively. The numbers of employees (total and IT) was transformed from an absolute value to an ordinal value on a 5-point scale. The interval boundaries were determined in a way such that the total number of data records is distributed equally across the five intervals.

Methodology and Results

In this section we describe the methodology applied and interpret the results of our statistical analysis of the survey data. In the first part, we present a number of descriptive results in order to make the general structure of the data more transparent. In the second part, we explain and apply a regression-based method to test our hypotheses.

Descriptive Results

Figure 2 provides the adoption percentages for the different types of enterprise software. This percentage is provided based on the whole sample as well as for the sub-samples we consider, i.e. all manufacturers in the German sample, all manufacturers in the US sample, all service firms in the German sample, and all service firms in the US sample. The types of software are ranked by the total adoption percentage in descending order. For some types of enterprise software the Figure 2 already indicates a difference of software adoption depending either on the sector affiliation (e.g. ERP software and E-Learning environments) and the country of origin of the organization (E-Learning environments and Enterprise Instant Messaging software).

Figure 2. Enterprise software adoption

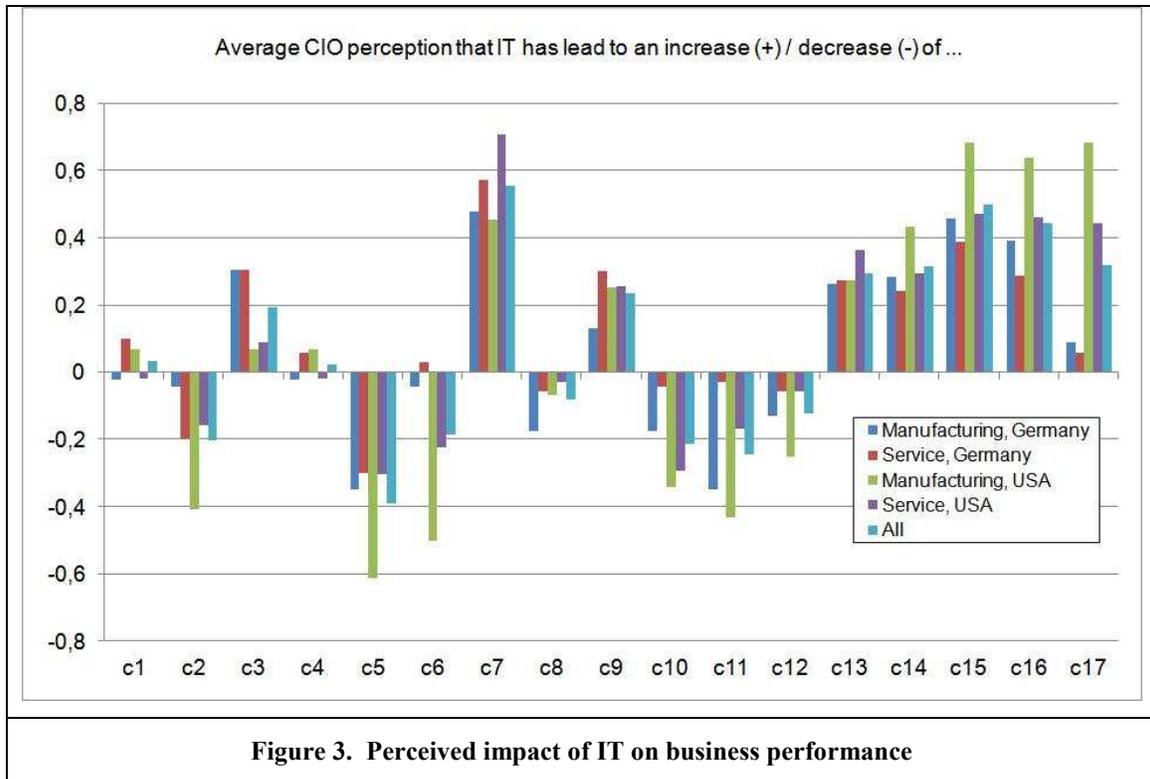**Figure 3. Perceived impact of IT on business performance**
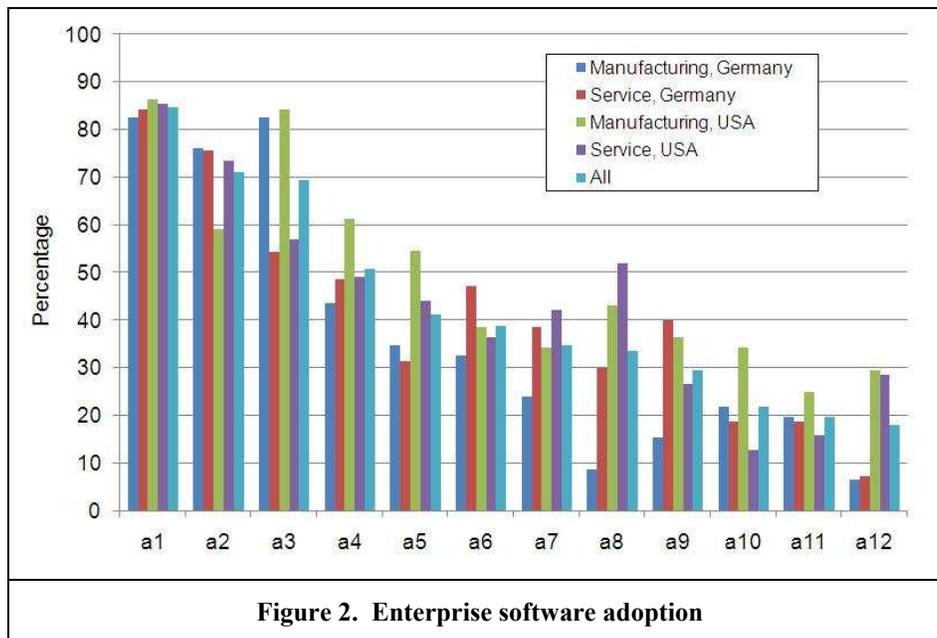
Figure 3 shows how the impact of IT on the 17 indicators of business performance was assessed on average. In the case of indicators c_1 to c_{12} negative values signify a positive average assessment by CIOs. For indicators c_{13} to c_{17}, positive values signify a positive perception. As the chart shows, the perceived impact of IT varies depending on the business performance indicator which the respective assessment is based on. Interestingly, the average values indicate a relatively strong support for IT having a positive influence on indicators related to competitive and long-term success such as time to market (c_{11}), market share gain (c_{14}) and revenue (c_{15}). Furthermore, the average values already indicate potentially significant differences regarding the perception of IT benefits. For instance, the US manufacturers judged the impact of IT more positively on average than the comparison groups based on almost all indicators. In addition, the CIOs of US organizations seem to perceive the impact of IT more positively in general (see for instance customer service costs or margins).

Figure 4 shows the average measurement results for the different business performance indicators. The scales of the indicators has been adapted to the interval (-2; +2) for presentation purposes. The CIOs on average perceive a positive impact of IT on the availability of strategic business knowledge. However, there again exist some remarkable differences across the comparison groups. Compared to German CIOs, the CIOs of US organizations see a stronger contribution of IT to understanding their customers' buying behavior and expectations. For these types of business knowledge our data also shows a difference with respect to sector affiliation: manufacturers perceive a more positive impact of IT on the understanding of customers' buying behavior than service organizations, while this relationship is reversed in the case of the impact of IT on the understanding of customers' expectations.

Figure 5 shows how CIOs have judged the influence of IT on organizational change measured by five different indicators. The scales again have been adjusted by subtracting 2. Again some remarkable differences between the average perceptions across countries and sectors are discernible. On average, U.S. CIOs see a stronger rise in the use of IT-based collaboration between employees (e.g. Microsoft's Net Meeting). Furthermore, the impact of IT on the geographical dispersion of organizations is more strongly felt in the manufacturing sector.

Figure 4. Perceived impact of IT on strategic business knowledge

Figure 5. Perceived organizational change due to IT
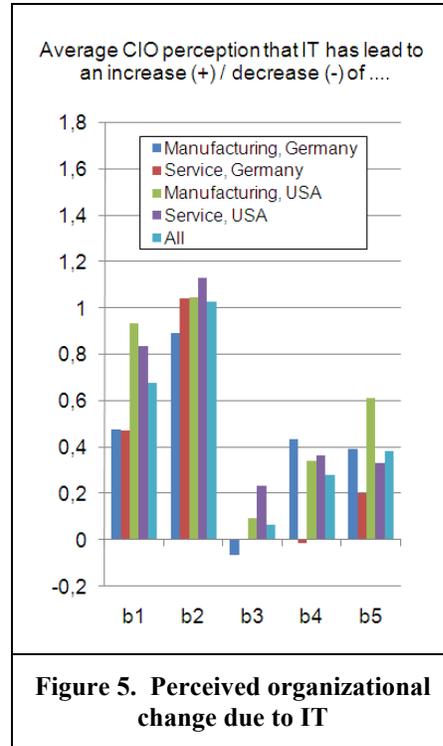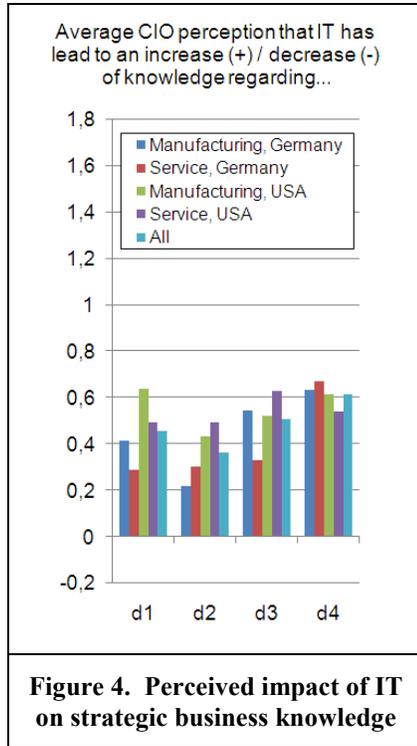
Regression Analysis

In order to test our hypotheses with the available data, we conducted regressions of one dependent variable on multiple independent ones. Each variable of the enterprise software adoption types (a_i) as well as each variable of the business performance (c_k) and business knowledge types (d_l) were used as the dependent variable in a corresponding regression. In order to take all presumed influences on these dependent variables into account, we used the following regression models:

$$a_i = \sum_j x_{ibj} * b_j + \sum_k x_{ick} * c_k + \sum_l x_{idl} * d_1 + x_{ie} * e + x_{if} * f + \sum_m x_{igm} * g_m \qquad (1)$$

$$c_k = \sum_i x_{kai} * a_i + \sum_j x_{kbj} * b_j + x_{ke} * e + x_{kf} * f + \sum_m x_{kgm} * g_m \qquad (2)$$

$$d_l = \sum_i x_{lai} * a_i + \sum_j x_{lbj} * b_j + x_{le} * e + x_{lf} * f + \sum_m x_{\lg m} * g_m \qquad (3)$$

In formulas (1-3) the factor x denotes the regression coefficient associated with the respective independent variable. The application of these formulas results in a total of 33 multivariate regressions. The regression models described by formula (1) feature 30 independent variables, thereof 28 measured on ordinal ($b_1, ..., b_5; c_1, ..., c_{17}; d_1, ..., d_4; g_1, g_2$) and 2 ($e$ and f) measured on binary scales. The models described by formulas (2) and (3) feature 21 independent variables of which 7 ($b_1, ..., b_5; g_1, g_2$) are measured on an ordinal scale and 14 ($a_1, ..., a_{12}; e; f$) are measured on a binary scale.

We denote the models described by formulas (1-3) as 'initial models'. Beginning with these initial models, we apply a simple algorithm based on the Akaike Information Criterion (AIC) to eliminate insignificant independent variables from the models. Judging models by the AIC implies to trade off the complexity of an estimated regression model against how well this model fits the data (Akaike 1973). A lower AIC indicates that the model achieves a 'better' trade-off. The algorithm eliminates the independent variables present in the initial models one by one and in ascending order of significance until the AIC cannot be diminished by eliminating more variables. We refer to the outcome of this process as the 'optimal model'. The statistical computations required to execute the algorithm were conducted using Zelig. Zelig is statistical software based on the open source platform R (Imai et al. 2007). From the Zelig package we applied the 'ologit' model for the multivariate regression of dependent variables measured on an

ordinal scale and the 'logit' model for the multivariate regression of dependent variables measured on a binary scale. Detailed results of the statistical computations can be obtained from the authors on special request.

The regressions reveal the dependency of single dependent variables on multiple independent variables. For instance, they show a significant dependence of the adoption of business intelligence software on the perceived impact of IT on the time to market. Since the hypotheses that we want to test are more general (e.g. 'the adoption of enterprise software is fostered by a positive perception of the impact that IT has on firm performance'), the regression results need to be aggregated. A statistically rigorous method for measuring a more general concept using several indicators is Structural Equation Modeling (SEM), which can either be based on the analysis of the covariance (Jöreskog 1977)[1] or the analysis of the variance (Wold 1982)[2]. Unfortunately, these techniques are very demanding in terms of survey design and the statistical properties of the measured variables. In order to fulfill these requirements, surveys usually have to be designed for the unique purpose of testing well-defined hypotheses. Since the nature of the original survey was explorative and designed primarily to get an overview of IT adoption trends and IT-driven organizational changes, our dataset did not fulfill the requirements necessary to conduct a SEM analysis. Therefore, we use a different approach to assess the validity of our hypotheses. Based on the 33 multivariate regressions, we define additional variables which serve as aggregate measures. These aggregate measures indicate the empirical support for acceptance and rejection of hypotheses H1 through H6 based on our data. They take into account the sign and the value of the estimated regression coefficients, the significance levels of independent variables (10%, 5%, 1%, and 0.5%), as well as the fit of each regression model (based on the AIC). The exemplary formulas used to compute the metrics indicating the support for acceptance and rejection of hypothesis H1 are given below.

$$accept_{H1}(c_k) = \frac{1}{AIC(c_k)} * \sum_i (I_{accept}(c_k, a_i) * |x_{kai}| * SIG(c_k, a_i)); \; k = 1,...,17 \qquad (4)$$

$$reject_{H1}(c_k) = \frac{1}{AIC(c_k)} * \sum_i (I_{reject}(c_k, a_i) * |x_{kai}| * SIG(c_k, a_i)); \; k = 1,...,17 \qquad (5)$$

$$accept_{H1}(d_l) = \frac{1}{AIC(d_l)} * \sum_i (I_{accept}(d_l, a_i) * |x_{lai}| * SIG(d_l, a_i)); \; l = 1,...,4 \qquad (6)$$

$$reject_{H1}(d_l) = \frac{1}{AIC(d_l)} * \sum_i (I_{reject}(d_l, a_i) * |x_{lai}| * SIG(d_l, a_i)); \; l = 1,...,4 \qquad (7)$$

$$accept_{H1} = \sum_k accept_{H1}(c_k) + \sum_l accept_{H1}(d_l) \qquad (8)$$

$$reject_{H1} = \sum_k reject_{H1}(c_k) + \sum_l reject_{H1}(d_l) \qquad (9)$$

The expressions used in formulas (4-7) have the following meanings:

- *AIC(y)* stands for the Akaike Information Criterion of the regression where *y* is the dependent variable.

- $I_{accept}(y, x)$ is equal to 1 if the impact of the independent variable *x* on the dependent variable *y* supports the corresponding hypothesis and equal to 0 otherwise.

- $I_{reject}(y, x)$ is equal to 1 if the impact of the independent variable *x* on the dependent variable *y* contradicts the corresponding hypothesis and equal to 0 otherwise.

- *SIG(y, x)* stands for the reciprocal value of the significance level of the independent variable *x* when *y* is the dependent variable in the regression.

Formulas (4-7) allow for the calculation of the support of acceptance and rejection of H1 based on the regressions that are relevant for hypothesis H1 (i.e. all models where the dependent variable is contained in the variable sets *C* or *D*). These 'support metrics' are weighted by the AIC of each regression in order to accommodate the fact that the different regressions exhibited differences regarding their explanatory power. Formulas (8) and (9) yield the final

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[1] A popular software package used to carry out this kind of analysis is LISREL.

[2] This approach is also referred to as Partial Least Squares (PLS).

aggregate support for the acceptance and rejection of H1 based on all available regression models which explain hypothesis H1.

Regression Results

The calculated support metrics are presented in Table 4. To improve readability, the metrics are expressed as percentage relating to each hypothesis. For instance, 4.02% out of all regression results explain hypothesis H1. 95.82% thereof support the acceptance of H1, whereas 4.18% support its rejection. The last column of Table 4 shows a breakdown of the explanatory power into single regression results. Each listed item indicates the relative support for either acceptance (upper row) or rejection (lower row) of a specific hypothesis. For instance, the support for acceptance of H1 found in our data is to a degree of 65.65% due to the regression where c_{17} is the dependent variable. We believe that this preparation of our statistical results provides an accessible overview of how our data supports the acceptance or rejection of the hypotheses made. It allows us to determine how the aggregate support for the acceptance and rejection of each hypothesis depends on the single regressions we conducted in the first step.

As the results summarized in Table 4 show, the method yields a higher support in favor of hypotheses H1 through H4. Regarding the impact of the firm profile on software adoption and perceived IT benefits (H5 and H6) the data supports our hypotheses only partly.

Although the data supports the acceptance of hypotheses H1 and H2, there are some significant differences regarding the relative strength of this support. While the support for the acceptance of hypothesis H1 in relation to the whole explanatory power of the data is 3.85% (equal to 95.82% of 4.02%), the support in favor of H2 is 22.96% (equal to 72.46% of 31.68%) for H2, i.e. approximately 6 times as high. Thus, based on our regression results and the selected aggregation method, *there exists more statistical support for the impact of perceived business benefits of IT on the adoption of enterprise software* than vice versa. In other words, we find more evidence for the statement 'enterprise software is introduced because CIOs have a good feeling about its impact' than for the statement 'CIOs have a good feeling about the impact of IT because certain types of enterprise software have been introduced'. One possible explanation for this result is the organizational adaptation process, which usually takes place after new enterprise software has been adopted. A closer look at the regression results that explain the statistical support for the acceptance and rejection of hypothesis H1 provides a starting point for justifying this interpretation: the adoption of BI tools (a_4) accounts for most of the support confirming hypothesis H1. Since the introduction of BI software has no direct influence on operative processes taking place in the firm, it should cause relatively little organizational effort in terms of process adaptation. On the other hand, the only type of enterprise software which seems to be related to a negative assessment of IT is SCM software (a_9). Compared to BI software, the introduction of SCM software can be expected to involve a rather high degree of organizational adaptation since it affects many operational processes (e.g. order tracking, warehouse operations, etc.).

Based on our results, hypothesis H2 should be accepted rather than rejected (72.46% versus 27.54%). It is interesting to see which perceptions of the CIOs account for the acceptance of H2. Table 4 shows that this support is primarily due to three types of enterprise software: E-Commerce software (a_3: 32.1%), SCM software (a_9: 28.65%) and BI tools (a_4: 19.36%). According to the selection of detailed regression results provided in Table 5,[3] the adoption of E-Commerce software seems to at least partly result from the perception of CIOs that it reduces consultancy and collaboration costs (significance level 0.5%). The adoption of SCM software can be explained by the CIOs' perception that it provides more knowledge about customer satisfaction (significance level 0.5%) and also reduces promotional costs (significance level 1%). The adoption of BI tools seems to be related to the CIO's belief that these tools reduce the time to market of new products (significance level 0.5%), that their adoption increases the margin (significance level 1%), and that they help to gain market share (significance level 5%).

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[3] Table 5 contains only a selection of the detailed regression results. A document containing all regression results can be obtained from the authors upon request.

Hypothesis	Relative explanatory power of hypothesis	Relative support for acceptance/ rejection of hypothesis		Relative importance of regression results regarding the support for acceptance/rejection of hypothesis
H1	4.02%	**accept**	**95.86%**	c_{17}: 65.65%; c_{12}: 8.13%; c_6: 5.91%; c_{14}: 5.11%; c_{11}: 4.95%; c_{16}: 4.37%; d_4: 3.72%; c_9: 2.16%
		reject	4.14%	c_9: 100%
H2	31.68%	**accept**	**72.46%**	a_3: 32.10%; a_9: 28.65%; a_4: 19.36%; a_5: 5.63%; a_7: 5.34%; a_6: 2.76%; a_{10}: 2.26%; a_{12}: 1.51%; a_{11}: 0.80%; a_8: 0.54%; a_1: 0.53%; a_2: 0.51%
		reject	27.54%	a_4: 34.33%; a_9: 29.60%,; a_3: 13.40%; a_6: 6.21%; a_8: 3.12%; a_1: 3.06%; a_{10}: 2.92%; a_{12}: 2.32%; a_5: 2.20%; a_2: 1.72%; a_7: 1.12%
H3	15.04%	**accept**	**66.54%**	a_8: 42.60%; a_3: 35.31%; a_1: 17.87%; a_{11}: 1.75%; a_{10}: 1.39%; a_4: 0.54%; a_{12}: 0.54%
		reject	33.46%	a_3: 95.06%; a_9: 4.05%; a_6: 0.89%
H4	0.23%	**accept**	**68.06%**	d_3: 53.18%; c_{13}: 27.04%; c_7: 19.79%
		reject	31.49%	c_8: 100%
(H5, country)	14.08%	**accept**	**99.29%**	a_8: 64.23%; a_7: 35.77%
		reject	0.71%	a_{10}: 100%
(H5, sector)	14.84%	accept	26.68%	a_7: 97.62%; a_{11}: 2.38%
		reject	**73.32%**	a_9: 54.97%; a_2: 45.03%
(H5,# employees)	5.41%	**accept**	**100%**	a_7: 40.19%; a_{10}: 34.96%; a_{12}: 19.88%; a_5: 2.37%; a_4: 2.05%; a_2: 0.55%
		reject	0%	-
(H5, # IT employees)	3.22%	**accept**	**100%**	a_3: 90.40%; a_9: 4.24%; a_6: 3.18%; a_4: 1.29%; a_{11}: 0.89%
		reject	0%	-
(H6, country)	6.2%	**accept**	**100%**	c_{17}: 61.69%; c_6: 29.77%; d_2: 3.84%; d_1: 3.49%; c_{16}: 1.21%
		reject	0%	-
(H6, sector)	2.41%	accept	0%	-
		reject	**100%**	c_{11}: 100%
(H6, # employees)	2.85%	accept	0%	-
		reject	**100%**	c_{11}: 53.18%; c_{12}: 45.66%; c_{14}: 1.16%
(H6, # IT employees)	0%	accept	0%	-
		reject	0%	-

Table 4. Support for acceptance and rejection of hypotheses H1-H6

Since our data supports the rejection of hypothesis H2 by 8.72% (27.54% of 31.68%), we will also have a closer look at which perceptions regarding the impact of IT have a negative influence on enterprise software adoption. Interestingly, the exact same types of enterprise software – albeit in reversed order and due to different perceived business benefits – explain most of the support for the rejection of hypothesis H2 (a_4: 34.33%, a_9: 29.60%, and a_3: 13.4%): Regarding the adoption of BI tools, the detailed regression results in Table 5 suggest that firms use BI software although their CIOs have not yet observed its positive impact on revenue generation (significance level

1%).[4] Regarding SCM software our results indicate that firms use it despite the fact that their CIOs do not believe that it can decrease the failure probability of new products (significance level 1%). The same applies to E-Commerce software with respect to revenues (significance level 5%).

Table 5. Selected regression results								
Dependent variable	**Independent variable**	**Regression coefficient**	**Error**	**z-Value**	**Pr(>|z|)**	**Significance level [5]**	**I_{accept}**	**AIC**
a_3	c_9	-1.205	0.353	-3.41	0.00065	***	1	199.1
	b_3	-0.865	0.259	-3.34	0.00083	***	0	
	g_2	0.526	0.162	3.25	0.00116	***	1	
	b_2	0.639	0.216	2.96	0.00309	***	1	
	c_{11}	-0.905	0.359	-2.52	0.01185	*	1	
	c_{16}	-1.097	0.443	-2.47	0.0134	*	0	
	c_1	0.757	0.328	2.3	0.02125	*	0	
	c_{17}	0.733	0.422	1.74	0.08243	.	1	
	c_8	0.519	0.309	1.68	0.09262	.	0	
a_4	c_{11}	-0.723	0.244	-2.96	0.0031	***	1	314.9
	c_{17}	0.82	0.309	2.65	0.008	**	1	
	c_{15}	-1.713	0.659	-2.6	0.0094	**	0	
	c_{14}	0.828	0.353	2.35	0.019	*	1	
	g_1	0.317	0.139	2.28	0.0229	*	1	
	b_3	0.309	0.161	1.92	0.0552	.	1	
	c_{16}	1.1	0.626	1.76	0.0789	.	1	
	g_2	0.237	0.137	1.73	0.0834	.	1	
a_9	f	-1.271	0.377	-3.37	0.00076	***	0	234
	d_3	1.048	0.357	2.94	0.00329	***	1	
	c_3	-0.646	0.245	-2.64	0.00837	**	1	
	c_{13}	0.822	0.313	2.63	0.00863	**	0	
	c_{10}	0.618	0.248	2.49	0.0127	*	0	
	d_4	-0.76	0.338	-2.25	0.02437	*	0	
	b_4	-0.433	0.2	-2.17	0.03034	*	0	
	g_2	0.29	0.134	2.16	0.0306	*	1	
	c_2	-0.52	0.272	-1.91	0.05572	.	1	

In summary, our results with respect to hypothesis H2 indicate that the adoption of mainly BI tools, SCM software and E-Commerce software is related both to positive and negative opinions of CIOs on how they affect firm performance. However, our results suggest that adoption of those types of enterprise software is for the most part supported by the CIOs' beliefs in their positive influence on business activities.

Regarding the impact of perceived IT-enabled organizational change on software adoption and the perceived impact of IT benefits, the regression results support hypothesis H3 more strongly than hypothesis H4. The support for hypothesis H3 is based on three highly significant relationships (all at a significance level of 0.5%): a positive impact of IT-enabled collaboration (b_1) on the adoption of Enterprise Instant Messaging software (a_8), a positive impact of increasing demand for information provision at the executive level (b_2) on the adoption of E-Commerce software (a_3), and finally a positive impact of IT-enabled collaboration (b_1) on the adoption of Groupware solutions (a_1). Since the purpose of both Enterprise Instant Messaging and Groupware solutions is to enable more collaboration among employees, the connection to the perceived impact of IT on collaboration is intuitive. In contrast to that, the usage of E-Commerce software due to the increasing demand for information provision at the executive level leaves more leeway for interpretation. A possible explanation is that instant access to accurate information about customer transactions is becoming more relevant for effective decision making at the executive level. The adoption of E-Commerce and a corresponding software solution among other things allows for logging and processing relevant

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[4] The influence of IT on revenues was almost never perceived to be negative.

[5] Encoding of significance levels: ***=0,05%; **=1%, *=5%, .=10%

customer data. Thus, the increasing demand for information at the executive level may very well be among the drivers of E-Commerce software adoption.

The support for the acceptance of hypothesis H4 is difficult to interpret. The most significant underlying relationship (significance level 5%) is a positive influence of IT-enabled geographical dispersion (b_5) on the gain of knowledge about customer satisfaction (d_3). This connection could be due to the possibility to integrate the CRM databases of different branches. This in turn may have a positive impact on knowledge about the customer. However, the statistical support of hypothesis H4 is probably too low to draw any stringent conclusions along these lines.

Another major result of the study is the role the firm profile plays when it comes to the adoption of enterprise software and the perception of IT benefits. Since our data was collected in the US and Germany, we were able to analyze the impact of a binary variable (e) indicating the nationality of the firm. As it turns out, this variable has a highly significant influence both on the adoption of software and the perception of IT benefits (14.08% and 6.2% respectively). The adoption of enterprise software seems to be systematically higher in the US than in Germany. The same applies to the perception of IT benefits in the US. The support for the acceptance of hypothesis (H5, country) is explained by the adoption of two types of enterprise software, namely Enterprise Instant Messaging (a_8: 64.23%) and E-Learning (a_7: 35.77%). Regarding hypothesis (H6, country), i.e. the impact of the country variable on the perception of IT benefits, two indicators of business performance explain most of the acceptance support: the perception that IT has a positive impact on the margin (c_{17}) as well as that it reduces customer service costs (c_6) seems to be more prevalent in the US (significance level 0.5% in both cases).

Regarding the impact of the affiliation of firms to either the manufacturing or services sector (f), our initial hypotheses are not backed by the data. Rather the opposite, namely that adoption rates are higher in the manufacturing sector, seems to be true: the support of our data for the rejection of hypothesis (H5, sector) is 10.88% (73.32% of 14.84%) compared to 3.96% (26.68% of 14.84%) for its acceptance. Again, it is interesting to see which types of enterprise software explain this outcome. As it turns out, it is SCM (a_9) and ERP software (a_2). This does not come as a surprise since both types of enterprise software were initially targeted at firms managing the production of physical goods, although they are used by firms in the service sector as well (see Figure 2). The support for acceptance is explained by systematic differences in the adoption patterns of E-Learning (a_7), which seem to be more prevalent in the services sector (significance level 0.5%).

Our hypotheses stating that the number of employees (g_1) has a positive influence on the adoption of enterprise software (H5, # employees) is supported by the data (5.41%). This support is explained for the most part by the adoption of E-Learning (a_7: 40.19%), E-Procurement (a_{10}: 34.96%), and EDI (a_{12}: 19.88%). According to our data, the influence of the number of employees on the perceived benefits of IT (H6, #employees) is negative (2.85%). This comes as a surprise since one would expect IT to exhibit economies of scale in terms of organization size. Furthermore, theory suggests that IT has the potential to reduce transaction costs resulting from intra-firm coordination. If one has a closer look at which business performance indicators explain the support for rejection of hypothesis (H6, #employees), the result seems even more surprising: it is mainly due to the performance indicators 'new products time to market' (c_{11}: 53.18%) and 'new products failure risk' (c_{12}: 45.66%). Thus, according to our data, the CIOs of smaller firms perceive the adopted IT to have a more positive impact on innovativeness than the CIOs of larger firms.

The last variable analyzed in this work is the number of IT employees working for the firm (g_2). According to our data, this variable only has a significant positive influence on the adoption of enterprise software (3.22%), whereas no significant support was found for acceptance or rejection of hypothesis (H6, #IT employees), i.e. the impact of more IT employees on the perceived benefits of IT. The type of enterprise software accounting for the acceptance of (H5, #IT employees) is primarily the adoption of E-Commerce software (a_3: 90.4%). Thus, firms which have introduced E-Commerce software usually seem to employ more IT personnel. A possible interpretation of this result is that participating in E-Commerce still requires a relatively high investment into specialized personnel.

Methodological Limitations

Our findings are based on a regression-based analysis of survey data containing the answers of 262 CIOs from Germany and the US. Regarding the data and methodology we used, a number of limitations which may have an effect on the validity of our conclusions have to be mentioned.

Our study can be subject to a sample selection as well as a self-selection bias. The term sample selection bias refers to the way data is collected, especially with respect to the selection of respondents. The very fact that the firms contained in our sample have a CIO already implies that representativeness cannot be assumed. Nevertheless it has to

be noted that the resulting sample distribution comes very close to reality (e.g. regarding firm sizes and the manufacturing to service ratio). Self-selection refers to an overrepresentation of a particular type of respondent in the sample. Applied to our case, it might for instance be possible that CIOs who have been more successful in implementing IT solutions were more likely to take part in the survey. However, regarding company size and the manufacturing service ratio the distribution of our sample comes very close to reality which supports the generalizability of our findings.

Another type of bias that oftentimes limits the validity of survey-based research refers to the respondents' desire to influence survey results. If a significant portion of the respondents have a personal disposition to exaggerate their responses in a certain way, a so-called self-desirability bias may result. Given the type of questions asked and the job of the respondents, this bias may indeed be present in our data. In particular, CIOs could be inclined to overstate the positive impact of IT on the business performance of their firm because they are more technology friendly or savvy than other decision makers in the firm. This potential self-desirability bias in our data would constitute a severe problem if we were interested in measuring the actual performance of firms. However, we explicitly ask for the perceptions of CIOs. Therefore, the self-desirability type of bias should not have a significant influence on the validity of our conclusions.

Last but not least, the method we apply to aggregate the results of the 33 regression and to compare the support for and against our different hypotheses is rather sketchy. However, the intention behind using this method is not to develop a statistically valid test for our hypotheses, but rather to provide an overview of how the results of our extensive regression analysis support the hypotheses. We find the results produced by this method (presented in Table 4) very useful for quickly and effectively separating the more important from the less crucial regression result.

Conclusions

The motivation for the work presented in this paper was to contribute to the ongoing debate on the productivity paradox. We focused on how CIOs perceive the impact of IT on the performance of their firms. Possible influences of IT on firm performance are measured using a broad range of indicators. This range does not only include the potential of IT to reduce operational costs, but also its perceived impact on revenue, market share, the strategic knowledge base and innovativeness. IT investment is not measured in terms of money but rather in terms of particular types of enterprise software adopted by the firms. This allows us to investigate how the use of certain types of software affects the CIOs' perception of IT benefits and also how the perception of IT benefits drives the adoption of enterprise software. Due to the scope and heterogeneity of the sample, we also had the chance to take basic differentiating factors regarding firm profiles into account. In particular, we analyzed the impact of nationality, sector affiliation and firm size in terms of number of employees on adoption patterns and the perception of IT benefits.

Our results confirm the changing role of IT in the enterprise. We show that investments into innovative enterprise software are believed to influence an organization's performance in a very broad manner. Not only is it expected to reduce most types of operational costs, but also to foster innovativeness, increase revenue, gain market share, and extend the strategic knowledge base of a firm. Interestingly, our results indicate that the positive impact of IT, although acknowledged in both Germany and the US, is perceived more strongly by CIOs based in the US. Regarding country-based differences in software adoption patterns our data indicates that two types of rather innovative software (E-Learning environments and Enterprise Instant Messaging) are adopted more frequently by US firms.

A vital contribution of our research can be seen in the empirical investigation of perceived business benefit as a driver of enterprise software adoption. Based on our data, this effect was approximately six times stronger than the inverse relationship, namely the influence of adopted enterprise software on the perception of IT benefits. Based on the combination of our statistical results and background knowledge about the characteristics of certain types of enterprise software, we support the view that this imbalance is due to the challenges involved in the IT-enabled transformation of operational business processes.

Our consideration of different types of enterprise software and benefit indicators allows us to gain a more detailed and thus deeper understanding of the whole enterprise software adoption process. Among other things, our results indicate that the use of Business Intelligence (BI) tools has a decisive impact on the CIOs' positive perception of IT in the enterprise. The same applies to Electronic Data Interchange (EDI), albeit with much less support. In the case of Supply Chain Management (SCM) software, these signals point into the opposite direction. CIOs currently seem to perceive them as a cost driver rather than a source of benefit. We also found that the adoption of enterprise

software is driven by a broad range of possible benefits that CIOs associate with their use. In particular, three types of enterprise software are responsible for most of the statistical support in favor of the statement 'the CIOs' perception of higher IT benefits results in higher adoption rates': E-Commerce software, BI tools and SCM software. Thus, our results indicate that especially with respect to these three types of enterprise software, the CIOs' opinions on how they affect business performance seem to be related to their adoption. Regarding other types of software, the influence of CIO perceptions seems to be less important.

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