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# External Technology Supply and Client-Side Innovation

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## Non-Technical Summary

Dynamic market environments and consumer preferences demand firms to assure a high degree of flexibility. At the same time, competitive pressure from globalized markets leads to constantly raising efficiency requirements. Organizations change their design from static to dynamic concepts in order to react adequately to these developments and challenges. A common strategy is to reach beyond the boundaries of the firm to access critical resources. Accordingly, we observe that technology transfer from providers of knowledge intensive business services attracts more and more attention.

A specific case is the external supply of information technology. A major reason why firms outsource IT, is the potential to cut cost. We argue that there is also a potential of knowledge transfer in IT outsourcing relationships, leading to client-side innovation. The aim of this paper is to contribute to resolving an empirical puzzle arising from the prior literature. Some authors find beneficial effects of IT outsourcing, others underline that firms often fail to achieve their expected strategic goals.

Our stylized theoretical model combines a knowledge production function framework and transaction cost economics. We hypothesize that the right balance between internal and external knowledge is critical for innovation. The empirical application is German firm-level data covering a wide range of industries from 2003 to 2006. Our results largely support the theoretical arguments and suggest a positive linear relationship between the level of outsourcing and process innovation. For product innovation we find a hump-shape, indicating a positive relationship only up to a tipping point. Partial outsourcing seems to be more beneficial than complete outsourcing.

## Das Wichtigste in Kürze

Unternehmen agieren in zunehmend dynamischen Märkten. Dies verlangt ein hohes Maß an Flexibilität, wobei gleichzeitig der globale Wettbewerb zu Effizienz zwingt. Um auf diese Entwicklungen und Herausforderungen adäquat reagieren zu können, setzen Unternehmen auf eine dynamische Organisationsstruktur. Eine verbreitete Strategie ist dabei Ressourcen außerhalb der Unternehmensgrenzen zu nutzen. In diesem Sinne spielt Technologietransfer von Anbietern wissensintensiver Dienstleistungen, wie zum Beispiel Informationstechnologie, eine immer wichtigere Rolle.

Der klassische Grund, warum Unternehmen IT Dienste auslagern, ist ein Einsparungspotenzial. Im vorliegendem Papier stellen wir jedoch einen potenziellen Wissenstransfer in den Fokus und untersuchen ob IT Outsourcing Auswirkungen auf die Innovationstätigkeit auf Kundenseite haben kann. In diesem Zusammenhang versuchen wir dazu beizutragen, augenscheinlich widersprüchliche Ergebnisse empirischer Studien in Einklang zu bringen: Während einige Autoren zeigen können, dass IT Outsourcing zu Produktivitätssteigerung führt, heben andere hervor, dass oft langfristige strategische Ziele verfehlt werden.

In einem stilisierten theoretischen Modell kombinieren wir den Ansatz der Wissensproduktionsfunktion mit Transaktionskostenökonomik. Die zentrale Hypothese ist, dass eine Steigerung der Innovationstätigkeit vom richtigen Verhältnis von internem zu externem Wissen abhängt. Die empirische Untersuchung basiert auf einem Datensatz deutscher Unternehmen unterschiedlichster Branchen, der Informationen von 2003 bis 2006 abdeckt. Die Ergebnisse bestätigen die theoretische Argumentation weitestgehend. Wir können zeigen, dass es einen linear-positiven Zusammenhang zwischen dem Grad an Outsourcing und Prozessinnovation gibt. Der Zusammenhang zwischen Outsourcing und Produktinnovation ist umgekehrt-U-förmig, das heißt Outsourcing erhöht die Innovationswahrscheinlichkeit nur bis zu einem bestimmten Punkt. Teilweises Outsourcing scheint in diesem Fall vorteilhafter als vollständiges Outsourcing.

# External technology supply and client-side innovation

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**Abstract**

Flexibility in response to competitive pressure from globalized markets and increasingly individualized customer desires has become vital for firms. A common strategy to address this challenge is to employ a dynamic concept of organization and reach beyond the boundaries of the firm. Accordingly, technology transfer from providers of knowledge intensive business services attracts more and more attention. In this context we focus on external supply of information technology and client-side innovation. The aim of this paper is to contribute to resolving an empirical puzzle arising from the prior literature. Some authors find beneficial effects of IT outsourcing, others underline that firms often fail to achieve expected strategic goals. Our stylized theoretical model combines a knowledge production function framework and transaction cost economics. We hypothesize that the right balance between internal and external knowledge is critical for innovation. The empirical application is German firm-level data covering a wide range of industries from 2003 to 2006. Our results largely support the theoretical arguments and suggest a positive linear relationship between the level of outsourcing and process innovation. For product innovation we find a hump-shape.

*Keywords:* Knowledge Production Function, Transaction Cost Economics, Product Innovation, Process Innovation, KIBS, IT Outsourcing, ZEW ICT survey
*JEL No.:* L24, D23, O31

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# 1 Introduction

Make-or-buy decisions have a long history. For example, already in the ancient Roman Empire tax collection was given in private hands (Kakabadse and Kakabadse, 2002, p. 189). Hence, long before the Industrial Revolution, division of labor has been identified as a source of efficiency enhancement. The literature has addressed this question from a variety of perspectives. One approach is to look at models of two regions with asymmetric factor endowments to explain how firms decide on where to locate different stages of the production process (Krugman, 1991; Antràs and Helpman, 2004; Grossman and Helpman, 2005; Şener and Zhao, 2009). With the advent of new technologies that render transportation costs of information negligible, recently also more knowledge-intensive corporate functions are subject to make-or-buy decisions (Freund and Weinhold, 2002; Amiti and Wei, 2006). As firms seek flexibility in response to globalized markets and increasingly individualized customer desires, research and development (R&D) services and most dominantly computer, information and communication technology (ICT) services are traded (World Trade Organization, 2011). Despite its growing practical relevance, empirical research on external supply of information technology (IT) is still scarce. An IT outsourcing paradox persists in the literature: While a number of large scale firm- and industry-level studies find positive impacts on productivity in the short run (Ohnemus, 2007; Knittel and Stango, 2008; Han et al., forthcoming), client organizations often report to be dissatisfied in terms of long run strategic goals such as innovation (Miozzo and Grimshaw, 2005; Overby, 2007, 2010; Bacheldor, 2010). Evidence from case-study research and insights from simulation models suggests that this is due to myopic management and opportunistic vendor behavior (Barthélemy, 2001; Rouse, 2009; Windrum et al., 2009). In contrast, there is a substantial body of work showing that firms benefit from linkages with related types of knowledge-intensive business services (KIBS) (Bessant and Rush, 1995; Antonelli, 1998; Muller and Zenker, 2001; Czarnitzki and Spielkamp, 2003; Howells, 2006; Tether and Tajar, 2008; Huang and Yu, 2011; Görg and Hanley, 2011).

In this paper, we aim to contribute a differentiated explanation for this prevailing empirical puzzle. We change the focus from cost-cutting to a more strategic perspective by recognizing IT outsourcing as a source of external knowledge and expertise (Scarbrough, 1998). In a stylized theoretical model we extend the knowledge production framework with insights from transaction cost economics. Specifically we ask: Can IT outsourcing impact the innovative capabilities of the client? Our hypothesis is that, depending on the strategic importance of the service subject to outsourcing, firms face a trade-off between make and buy. That is, the optimal mix of internal and external knowledge is critical in order to achieve innovative outcomes (Harrigan, 1984; Arora and Gambardella, 1990; Audretsch et al., 1996; Piga and Vivarelli, 2004; Afuah, 2001; Cassiman and Veugelers, 2006; Grimpe and Kaiser, 2010). Among Weigelt and Sarkar's (2009) paper on vendor-induced knowledge spillovers, ours is one of the first studies to empirically investigate the relationship between IT outsourcing and innovation. The empirical application is German firm-level data spanning a wide range of industries observed 2003-2006.

We find that IT outsourcing is positively associated with cost-reducing process innovation. The impact on demand-enhancing product innovation is found to be hump-shaped. External knowledge embodied in IT services seems to positively contribute to client-side innovation up to a tipping point, after which the relationship becomes steeply decreasing. That is, we can explain negative outcomes with over-outsourcing. The remainder is structured as follows. We start off with a discussion of the related literature, and present a stylized theoretical model of outsourcing and innovation. Data and methodology are described in the next sections, followed by a discussion of our results. Finally, we conclude and give some directions for further research.

## 2 Background discussion

According to the information systems literature, we can define IT outsourcing as a "*significant contribution by external vendors in the physical and/or human resources associated with the entire or specific components of the IT infrastructure in the user organization*"(Loh and Venkatraman, 1992, p. 9). Lacity et al. (2009) distinguish three categories of sourcing decisions: 'total outsourcing' (at least 80% of the IT budget is represented by third-party responsibility), 'total insourcing' (at least 80% of the IT budget is managed and provided internally) and 'selective sourcing' (selected IT functions are provided externally, the remaining 20 to 80% of the budget are provided internally). Ever since Eastman Kodak decided to hand over its entire data center to IBM in 1989 (Loh and Venkatraman, 1992, p. 8), the market for IT outsourcing has grown extensively in all parts of the world (Lacity and Willcocks, 2001, p. 2 sq.). In Germany for example, 66 percent of firms with at least 10 employees have been outsourcing IT activities in 2007. Only Finland and Denmark have a higher percentage share in the EU15 countries (Eurostat data, see figure A.1). According to industry analysts, the global outsourcing market had an average size of $88.4 billion in terms of total contractual value from 2007-2010 (TPI, 2011).

A number of authors have looked at the outsourcing decision from a cost perspective, suggesting that firms consider outsourcing if expected production cost savings outweigh transaction costs (Dibbern et al., 2004). These cost savings can come in the form of vendor buying power in terms of hard- and software, access to specialized human capital, increased capacity utilization, or fixed cost degression. However, empirical research on the outcome is still scarce. Some studies find evidence that IT outsourcing is associated with productivity growth. Ohnemus (2007) for example shows that labor productivity of German firms that outsource basic IT services is significantly higher compared to non-outsourcing firms. Han et al.'s (forthcoming) analysis of US industry-level data suggests an 2-4% increase in productivity. Knittel and Stango (2008) also find a 30% reduction in operating costs for US cooperative banks. Nevertheless, case study research (Miozzo and Grimshaw, 2005) and trade press articles (e.g. Overby, 2007, 2010; Bacheldor, 2010) report that clients often fail to reach innovation as a long term strategic goal. Only 24% of 290 respondents to an online survey of subscribers to the CIO magazine indicate that outsourced activities contributed most to IT innovation (compared to 76% in-house). The discrepancy between expected and actual outcomes of IT outsourcing, at the same time with wide diffusion across industries and countries, is what researchers have called the *IT outsourcing paradox*.

Based on case study research, Rouse (2009) concludes that this is mainly due to myopic management and opportunism. Similarly, Overby (2010) argues that innovation is expected but often not properly defined, and sometimes not recognized because traditional business metrics fail to properly measure innovation outcomes. This suggests a trade-off between cost advantages for (specialized) input and a holdup problem (Klein et al., 1978; Grossman and Helpman, 2002). The simulation model of organizational innovation by Windrum et al. (2009) goes in the same direction. They posit that IT radically expands technical opportunities for the outsourcing of production, and significantly lowers external coordination costs. A short run consequence of outsourcing is a reduction in the depth of hierarchy. This results in a reduction of fixed cost and gains in productivity. Accordingly, because managers have short run objectives this increases the probability that the firm will choose the outsourcing option again. The firm becomes locked-in to an outsourcing trajectory. Innovation in the sense of a recombination of organizational activities in response to changing business needs then is difficult to achieve as it demands coordination with the external supplier. The result is a long run productivity decline.

Given such a trade-off, Hecker and Kretschmer (2010) argue that the hold-up effect dominates unless vendor-side production cost decreasing scale effects increase at an increasing rate. They suggest that this could be the case due to network externalities where the client's utility is increasing in the number of other clients of the supplier. Among gains from modularization, knowledge spillovers can be a type of such network externalities. Vendors accumulate expertise from the combination of explicit and implicit knowledge gained in the interaction with other clients (double loop learning), which finally results in superior solutions to individual problems (Antonelli, 1998). In a sense suppliers can be seen as "bees cross-pollinating between firms, carrying experiences and ideas from one location or context into another" (Bessant and Rush, 1995, p. 102). A relatively large body of literature supports this argument in related settings. It is found that clients benefit from linkages with KIBS[1], and also KIBS themselves are more innovative compared to firms in all service sectors (Muller and Doloreux, 2009). Weigelt and Sarkar (2009) explicitly look at the role of vendors in the innovation adoption of clients in IT outsourcing relationships. The application is US cooperative banks and electronic banking innovations. The core finding is similar: Clients contracting a technically and organizationally more experienced

[1]KIBS are defined as firms from the NACE 72–74 sectors, i.e. *Computer and related activities*, *Research and development*, and *Other business services* such as *Legal services*, *Accounting*, *Advertising*, etc. (Muller and Doloreux, 2009).

vendor have a higher propensity to adopt innovation.

In the following we propose another explanation for the prevailing empirical puzzle. We argue that the scale of outsourcing is crucial to explain both positive and negative outcomes. From a theoretical perspective, our work is related to Windrum et al. (2009). Under certain conditions we can derive similar implications. A central assumption in their paper is that firms face a binary decision between in-house provision and outsourcing. The setting of our study allows for a continuum of cooperative (partial) types of outsourcing decisions. With this, we can replicate the main result that firms are better off without outsourcing, however only when the specificity of the IT service subject to outsourcing is sufficiently high. In all other cases we hypothesize a positive effect on outsourcing compared to in-house provision. From an empirical perspective, the most related papers are Weigelt and Sarkar (2009) and Grimpe and Kaiser (2010). In contrast to Weigelt and Sarkar (2009), we focus on the client-side and do not consider vendor characteristics directly. Further, we are able to observe in-house provision, partial and complete outsourcing. Finally, our dependent variables measure client-induced innovation rather than adoption of new technology. Grimpe and Kaiser (2010) is related in the sense that the authors also observe a range of outsourcing decisions. However, the subject is R&D outsourcing. Interestingly, our analysis partly produces similar results: The main finding of Grimpe and Kaiser (2010) is that outsourcing exerts a curvilinear relationship with product innovation. We additionally look at process innovation and find evidence for a different (increasing) relationship in this case.

## 3 A stylized model of innovation and outsourcing

From a knowledge perspective, organizations may be characterized as "social communities in which individual and social expertise is transformed into economically useful products and services by the application of a set of higher-order organizing principles"(Kogut and Zander, 1992, p. 384). That is, choosing the optimal sourcing strategy implies understanding IT outsourcing not only "as the product of a decision process, but, more fundamentally, as a particular way of organizing knowledge"(Scarbrough, 1998, p. 137). The process of gathering and sharing tacit experience, and articulating and codifying it into explicit knowledge (Nonaka and Takeuchi, 1995) involves exploring and exploiting competencies both internal and external to the firm. Consider this process to be specified as a knowledge production function (Griliches, 1979), such that

$$K_t = K_{t-1} + R(E) - c_\theta E, \tag{1}$$

$$K_t = K_0 + t \cdot [R(E) - c_\theta E], \tag{2}$$

where expertise $E$ can be provided internally, as well as by sources external to the firm. It is assumed that returns increase with expertise, such that $\frac{\partial R}{\partial E} > 0$. This reflects the notion that the more useful expertise is, the more it adds to the knowledge stock of the firm.

Of course, there is a cost to accessing expertise. According to transaction cost economics (Williamson, 1975, 1985, 1991), bounded rationality and opportunism raise issues that lead to heterogenous transaction costs $c_\theta$ among different types of organization $\theta$. We follow Audretsch et al. (1996) and focus on a ceteris paribus analysis of transaction costs as a function of the degree of specificity, leaving other determinants such as uncertainty and complexity aside. Therefore assume that expertise can vary in its specificity s. If s is low, expertise is very generic. If s is high, it is very firm-specific. Williamson (1985) argues that markets provide high-powered incentives and are better able to curtail bureaucratic distortion compared to internal organization and cooperation. However, control of opportunistic behavior is most effective in a hierarchical organization. The risk of holdup rises with specificity. A particular reason is that switching to alternative technologies and modes of provision is costly (Whitten and Wakefield, 2006; Peukert, 2011). Accordingly, we specify transaction costs according to

$$c_{\theta,s} = \left(\frac{1}{\alpha}s\right)^2 + \alpha,\ \alpha = \frac{1}{1+\theta},\ \theta, s \in [0,1] \tag{3}$$

where $\theta$ is the outsourcing level.

The transformation of knowledge into new processes, products and services is finally modeled as the probability that the stock of accumulated knowledge exceeds a certain threshold level $\tau$. Economically this may be interpreted as the net value of an invention: If the invention is promising enough, the firm starts the implementation/places it on the market.[2] Hence, the probability to innovate is given by

$$\text{Prob(Inno)} = \text{Prob}(K_t > \tau) = 1 - \text{Prob}(K_t \leq \tau) = 1 - \int_{-\infty}^{\tau} f(y)dy \quad \forall \tau \in \mathbb{R} \tag{4}$$

where $f : \mathbb{R} \to [0, \infty)$ is the pdf of $K$.

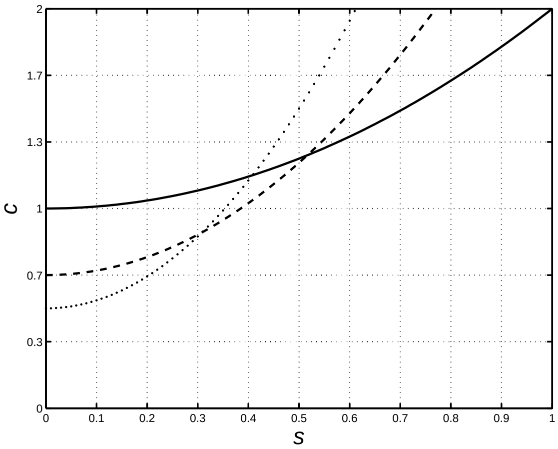
Following Williamson (1991) figure 1 compares the transaction costs of the three types of organization in-house ('hierarchy', $\theta = 0$), partial outsourcing ('hybrid', $\theta = 0.5$) and complete outsourcing ('market', $\theta = 1$). Analogously, in the graphical representation of equation (2) in figure 2, the optimal organizational form is defined by the envelope of the three curves.[3] Sourcing from the market is best when specificity is modest. For semi-specific assets, a hybrid mode of organization is optimal, and in case of high specificity the highest stock of knowledge is achieved in a hierarchical organization. Figure 3 shows the relationship between outsourcing and knowledge production.[4] Holding specificity fixed at

[2] Note that we are not considering any cost of implementation, such as liquidity constraints or advertising. That is, we implicitly assume this cost $C_t$ to be zero in $\text{Prob}(K_t - C_t > \tau)$.

[3] For simplicity we set $K_0 = 0$, and $t = E = 1$, such that $K = 1 - c_{\omega,s}\ \forall \omega \in \{H, X, M\}$.

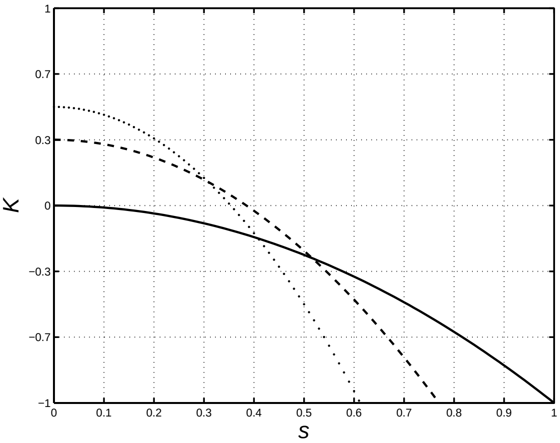
[4] See figure A.2 for a plot of the three dimensions $K$, $s$ and $\theta$.

**Figure 1:** Transaction costs



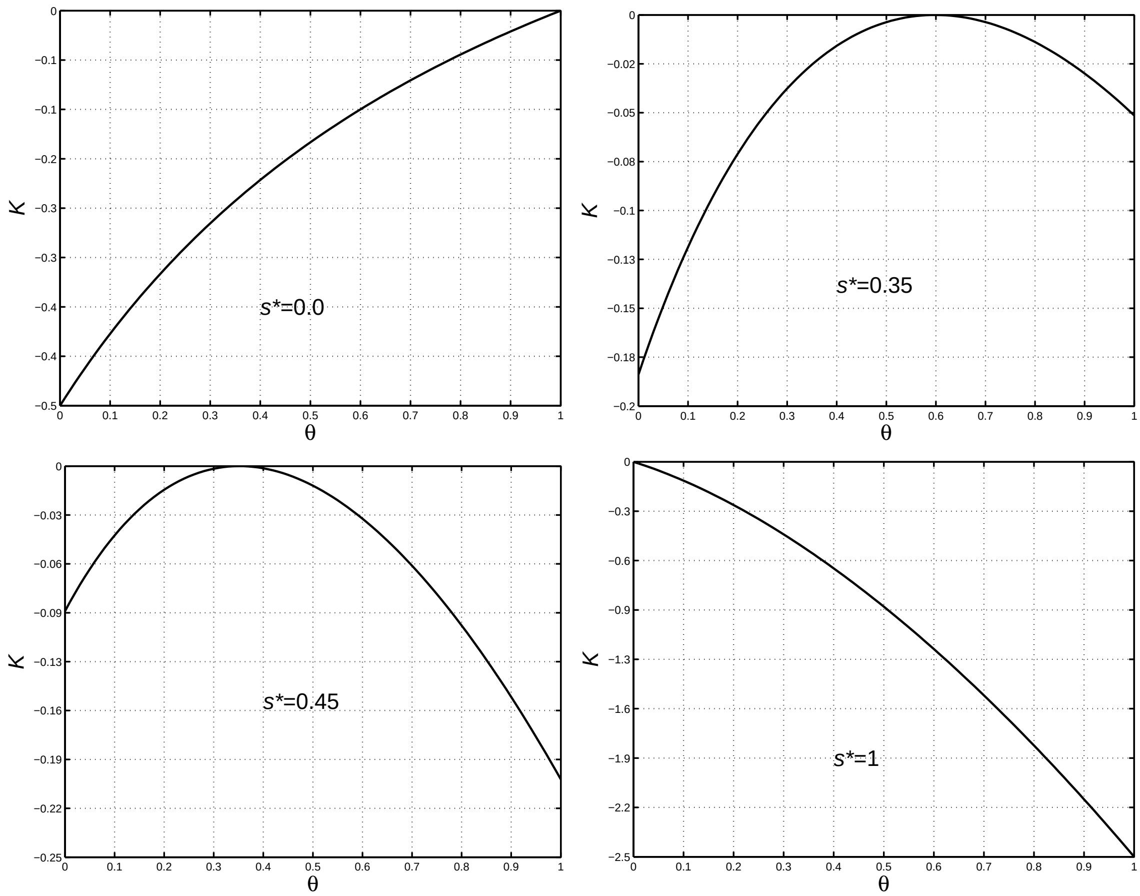

— *Hierarchy* --- *Hybrid* ··· *Market*
*Similar to Williamson (1991), Figure 1, p. 284.*

**Figure 2:** Accumulated knowledge




— *Hierarchy* --- *Hybrid* ··· *Market*

**Figure 3:** Accumulated knowledge as a function of the outsourcing level




*Accumulated knowledge $K$ as a function the outsourcing level $\theta$, holding asset specificity $s$ fixed.*

a low level of $s$, the upper left panel indicates an steadily increasing relationship. Once we increase $s$, this relationship changes. For intermediate values the relationship is inversely U-shaped, for high values of $s$ it is steadily decreasing.

Dependent on the level of specificity, the model suggests different functional forms for the relation between knowledge production and the level of outsourcing. For low levels of specificity the results point to an increasing relation (upper panel of figure 3). For medium levels the model suggests a hump-shape and for high levels of specificity the model predicts a decreasing relation.

# 4 Data and empirical specification

The empirical analysis is based on the ZEW ICT Survey, a telephone survey conducted every three years with a special focus on diffusion and use of ICT in German companies. While the data offer information on the use of ICT in the firm, we also observe variables on innovation, personnel and human capital, export, industry affiliation and location. To incorporate a time-lag needed for innovation to be created and successfully launched, and to cover the potential issue of reverse causality, data from two waves is used. Innovation variables are employed from the 2007 data and refer to the time span of 2004 to 2006. Variables on IT outsourcing and controls are taken from the 2004 data and refer to 2003. Due to item-nonresponse and panel attrition the sample size is 1582 observations. The data allow to distinguish between product innovation and process innovation, where both are defined to be *new or markedly improved*. The majority of firms in the sample has been innovating during 2004 to 2006. About 59 percent report to have launched new products and services, while roughly 66 percent report to have introduced improved or new processes. Correspondingly, about one quarter has done both product and process innovation.

Firms are asked whether they are using specific types of IT services $j$ and indicate the mode of provision: inhouse, partial outsourcing or complete outsourcing.[5] That is, $S_i^j$ is defined as

$$S_i^j = \begin{cases} 0, & \text{not in use} \\ 1, & \text{inhouse} \\ 2, & \text{outsourced partially} \\ 3, & \text{outsourced completely.} \end{cases} \tag{5}$$

From this information we construct a firm-specific measure of the outsourcing ratio, defined

[5]Those IT services are *installation of new hard- and software*, *system support and maintenance*, *support help desk*, *software development*, *internet/web maintenance and design*, *IT training*, *IT security* and *on-demand-computing.*

as the proportion of outsourced IT on total IT,

$$\tilde{\theta}_{i,\gamma} = \frac{\gamma \overbrace{\sum_{j=1}^{J} I(S_i^j = 2)}^{P_i} + \overbrace{\sum_{j=1}^{J} I(S_i^j = 3)}^{C_i}}{\underbrace{\sum_{j=1}^{J} I(S_i^j > 0)}_{T_i}}, \tag{6}$$

where $I(\cdot)$ is the indicator function. Because we do not know if 'partial' is 10% outsourcing or 90% outsourcing, we assume a weight of $\gamma \in (0, 1)$. Another issue becomes evident when considering the following example. Firm $a$ has only one IT service in use ($T_a = 1$), firm $b$ uses the whole range of IT services ($T_b = J$), both are complete outsourcers ($P_a = P_b = 0, C_a = 1, C_b = J$). While those firms are clearly different, both exhibit the same outsourcing ratio $\tilde{\theta}_{i,\gamma} = 1$. In order to consider the firm-specific importance of IT in our measure of outsourcing, we weight $\tilde{\theta}_{i,\gamma}$ with a measure of IT intensity $\eta_i$, such that

$$\theta_{i,\gamma} = \eta_i \cdot \tilde{\theta}_{i,\gamma} \in [0, 1]. \tag{7}$$

We operationalize $\eta_i$ with the percentage of computerized workplaces.[6] In the following we use the term *outsourcing ratio* for $\tilde{\theta}_{i,\gamma}$ and the term *outsourcing level* for $\theta_{i,\gamma}$.

Treating the theoretical construct of the knowledge stock as a latent variable that is indirectly observed in the decision to innovate (see equation 4), we estimate sets of probit models. Two specifications each for product and process innovation and $\gamma \in \{0.1, 0.2, \ldots, 0.9\}$ are used. The first is given as

$$inno_{i,t,\gamma} = f(\alpha + \beta\theta_{i,t-1,\gamma} + \delta' x_{i,t-1} + \varepsilon_{i,t,\gamma}) \qquad \text{(specification A)}$$

where $\alpha, \beta, \delta$ are (vectors of) coefficients and $\varepsilon_i$ is an error term. To test the predictions of our stylized theoretical model, we also estimate a quadratic specification, i.e.

$$inno_{i,t,\gamma} = f(\alpha + \beta_1\theta_{i,t-1,\gamma} + \beta_2\theta^2_{i,t-1,\gamma} + \delta' x_{i,t-1} + \varepsilon_{i,t,\gamma}). \qquad \text{(specification B)}$$

As control variables $x_i$ we include:

*Log employees:* Audretsch and Acs (1991) and Acs et al. (1994), among others, show that firm size is an important determinant of innovative activity.[7] Kretschmer et al. (forthcoming) consider the fact that firm scale (size) is endogenous to the innovation decision. We

[6]Descriptive statistics on IT intensity can be found in table 1.

[7]See Acs and Audretsch (2003) for a summary of key issues in the empirical literature in favor of a firm size effect on innovation.

measure size by the logarithm of the number of employees working for the firm in Germany on average in 2003 (including apprentices and part-time employees and excluding secondary labor force).
*% University, Job training:* A firm's technological competence is crucial to innovation - as a source of ideas, as a direct influence on R&D, and as a way to enable the capability to adopt a new technology (Cohen and Levinthal, 1989; Hoffman et al., 1998). As modeled above, technological competence is created endogenously by accumulation of knowledge in a continuous process of learning in production (Cantwell and Fai, 1999). We control for two types of human capital: Formal education, i.e. the proportion of staff with a university degree, and firm-specific human capital, i.e. a dummy for job training (Bauernschuster et al., 2009).
*Business situation:* Innovation can occur pro- and anticyclically (Mowery and Rosenberg, 1979; Geroski and Walters, 1995). On the one hand, newly introduced products compete for customer spending. Within a boom situation the market grows and can therefore absorb more new products in a given period of time without reducing the profitability of each. Firms will therefore place their innovative products when demand is high or expected to rise. On the other hand, in a recession, a decrease of existing rents relative to expected returns of innovation represents an incentive to innovate. Moreover, the implementation of new processes requires to divert resources from operational to strategic tasks, which is less costly in a recession when current activities are relatively less profitable.
*Export:* The openness of a firm, i.e. access to remote markets, acts as a multiplier of innovation drivers surrounding the firm (Eaton and Kortum, 2006). The firm is faced with increased market pressure resulting from a relative increase in the number of competitors compared to the home market. Moreover, export activity expands the boundaries of the (national) innovation network (cf. Bertschek, 1995). That is, openness adds sources of knowledge (Baldwin and Gu, 2004). It should be noted that export is likely to be endogenous (Kirbach and Schmiedeberg, 2008; Becker and Egger, forthcoming). We neglect this issue since we are more interested in exports as a control variable than in a causal interpretation of the coefficient. Our measure is a dummy variable coded one if firms report to have exported in 2003, zero otherwise.
*East Germany:* Taking a macro location effect into consideration, we aim at controlling for persistent differences between Eastern and Western Germany in terms of resources, innovation and productivity (Lehmann et al., 2004; Audretsch et al., forthcoming; Smolny, forthcoming).
*Industry dummies:* To control for heterogeneity among industries, dummies for 14 industries, classified according to two-digit NACE codes are included.[8]

**Table 1:** Descriptive statistics

| | Outsourcing level | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | In-house $\theta_\gamma < 0.2$ | | Low $0.2 \leq \theta_\gamma < 0.5$ | | Medium $0.5 \leq \theta_\gamma < 0.8$ | | Complete $\theta_\gamma \geq 0.8$ | |
| $\gamma = 0.3$ | | | | | | | | |
| Product innovation | 0.583 | (0.493) | 0.640 | (0.481) | 0.426 | (0.497) | 0.489 | (0.505) |
| Process innovation | 0.659 | (0.474) | 0.661 | (0.474) | 0.585 | (0.495) | 0.702 | (0.462) |
| Log employees | 3.975 | (1.643) | 3.687 | (1.560) | 3.062 | (1.387) | 2.342 | (1.026) |
| % University | 0.135 | (0.225) | 0.162 | (0.235) | 0.225 | (0.300) | 0.154 | (0.273) |
| Job training | 0.824 | (0.381) | 0.880 | (0.325) | 0.798 | (0.404) | 0.872 | (0.337) |
| Business situation | 0.663 | (0.473) | 0.664 | (0.473) | 0.670 | (0.473) | 0.553 | (0.503) |
| Export | 0.510 | (0.500) | 0.482 | (0.500) | 0.277 | (0.450) | 0.213 | (0.414) |
| East | 0.278 | (0.448) | 0.278 | (0.449) | 0.234 | (0.426) | 0.170 | (0.380) |
| IT intensity $\eta$ | 0.393 | (0.325) | 0.657 | (0.272) | 0.831 | (0.163) | 0.971 | (0.067) |
| Observations | 1099 | | 342 | | 94 | | 47 | |
| $\gamma = 0.6$ | | | | | | | | |
| Product innovation | 0.562 | (0.496) | 0.670 | (0.471) | 0.493 | (0.502) | 0.463 | (0.503) |
| Process innovation | 0.637 | (0.481) | 0.696 | (0.461) | 0.642 | (0.481) | 0.685 | (0.469) |
| Log employees | 3.901 | (1.633) | 3.951 | (1.623) | 3.347 | (1.504) | 2.330 | (0.984) |
| % University | 0.119 | (0.216) | 0.179 | (0.240) | 0.221 | (0.291) | 0.150 | (0.258) |
| Job training | 0.803 | (0.398) | 0.895 | (0.307) | 0.845 | (0.364) | 0.889 | (0.317) |
| Business situation | 0.659 | (0.474) | 0.661 | (0.474) | 0.703 | (0.459) | 0.574 | (0.499) |
| Export | 0.495 | (0.500) | 0.538 | (0.499) | 0.324 | (0.470) | 0.204 | (0.407) |
| East | 0.278 | (0.448) | 0.263 | (0.441) | 0.297 | (0.459) | 0.167 | (0.376) |
| IT intensity $\eta$ | 0.337 | (0.308) | 0.636 | (0.260) | 0.852 | (0.152) | 0.975 | (0.063) |
| Observations | 923 | | 457 | | 148 | | 54 | |
| $\gamma = 0.9$ | | | | | | | | |
| Product innovation | 0.546 | (0.498) | 0.678 | (0.468) | 0.557 | (0.498) | 0.479 | (0.502) |
| Process innovation | 0.626 | (0.484) | 0.705 | (0.457) | 0.655 | (0.477) | 0.667 | (0.474) |
| Log employees | 3.827 | (1.620) | 4.067 | (1.631) | 3.635 | (1.638) | 2.737 | (1.213) |
| % University | 0.107 | (0.210) | 0.174 | (0.231) | 0.195 | (0.268) | 0.246 | (0.310) |
| Job training | 0.787 | (0.410) | 0.892 | (0.311) | 0.866 | (0.342) | 0.917 | (0.278) |
| Business situation | 0.644 | (0.479) | 0.674 | (0.469) | 0.711 | (0.454) | 0.635 | (0.484) |
| Export | 0.488 | (0.500) | 0.547 | (0.498) | 0.412 | (0.494) | 0.240 | (0.429) |
| East | 0.282 | (0.450) | 0.264 | (0.441) | 0.278 | (0.449) | 0.208 | (0.408) |
| IT intensity $\eta$ | 0.307 | (0.302) | 0.575 | (0.258) | 0.832 | (0.152) | 0.967 | (0.058) |
| Observations | 811 | | 481 | | 194 | | 96 | |

*Means are reported, standard deviation in parentheses.*
*Product and process innovation between 2004 and 2006 (0/1).*
*Natural logarithm of the average number of employees in 2003 (apprentices and part-timers included).*
*Percentage of employees holding a university degree compared to all employees on average in 2003.*
*Employees have attended any type of job training in 2003 (0/1).*
*Good/rather good business situation (0/1) at the time of the interview (2004).*
*Firm has exported in 2003 (0/1).*

## 5 Results

Table 1 shows some descriptive statistics for a categorization of outsourcing levels. Following Lacity et al. (2009), we distinguish between *In-house* ($\theta_\gamma < 0.2$), *Low* ($0.2 \leq \theta_\gamma < 0.5$), *Medium* ($0.5 \leq \theta_\gamma < 0.8$) and *Complete* ($\theta_\gamma \geq 0.8$). The distribution is skewed to the right. That is, dependent on the assumed weight of 'partial', in between 30% to 50% of the firms in our sample resort to IT outsourcing. Most strikingly, looking at the means reveals that the proportion of innovating firms varies significantly across classes of outsourcing levels. Independent of $\gamma$, the descriptive statistics suggest a non-linear relationship between product innovation and the outsourcing level, where the maximum is at levels in between 0.2 and 0.5. Minima can be found at levels in between 0.5 and 1. The picture for process innovation is less clear, but a general positive correlation with fluctuations is visible. Firms relying on higher levels of outsourcing seem to be smaller in size, report a worse business situation, have a lower propensity to export and are more often located in East Germany. Further, the descriptive statistics reveal a positive correlation between the percentage of employees with an university degree and the outsourcing level. For moderate levels of $\gamma$ maxima are at outsourcing levels in between 0.5 and 0.8. The proportion of firms with employees in on-the-job training varies across classes of the outsourcing level as well. The data suggest an overall positive correlation, however, there is a kink for outsourcing levels in between 0.5 and 0.8.

Estimation results according to specification A are reported in table 2. The coefficients of our control variables are strikingly similar across all values of $\gamma$. Therefore the tables only report coefficients for models with $\gamma = 0.3$, $\gamma = 0.6$ and $\gamma = 0.9$. In figure 4 the coefficient of outsourcing ($\hat{\beta}$) and the corresponding 90% confidence band is plotted as a function of $\gamma$. Regardless of the parameter $\gamma$, there is no significant effect of outsourcing on the probability of product innovation in this specification (see left hand panel of figure 4). Concerning the control variables, the results depicted in the top row of table 2 are intuitive. The estimates suggest that firm size is a significantly positive predictor of product innovation. A higher fraction of employees with an university degree also increases the probability of product innovation. Firm-specific human capital is not significant for higher values of $\gamma$. Our estimates suggest that investment in innovation is pro-cyclical. Export is highly significant and positive. We do not find a significant difference between East and West German firms. Concerning process innovation, the right hand panel of figure 4 indicates a significantly positive effect of outsourcing when setting $0.4 \leq \gamma \leq 0.9$. That is, on a very reasonable interval, independent of how we operationalize 'partial outsourcing', external technology supply has a positive and significant effect on client-side process innovation. Also the estimated coefficients for the control variables reported in the bottom row of table 2 are different compared to the results for product innovation. Formal education does not play a significant role here. At the same time firm-specific knowledge

[8]See Table A.1 in the appendix for an industry classification.

**Table 2:** Probit models for specification A

| | $\gamma = 0.3$ | | $\gamma = 0.6$ | | $\gamma = 0.9$ | |
|---|---|---|---|---|---|---|
| **Product innovation** | | | | | | |
| Outsourcing level | 0.2064 | (1.13) | 0.2160 | (1.28) | 0.2022 | (1.35) |
| Log employees | 0.0961*** | (3.91) | 0.0958*** | (3.92) | 0.0949*** | (3.91) |
| % University | 0.0054*** | (3.20) | 0.0054*** | (3.14) | 0.0053*** | (3.10) |
| Job training | 0.1669* | (1.69) | 0.1627 | (1.64) | 0.1603 | (1.61) |
| Business situation | 0.1906*** | (2.61) | 0.1907*** | (2.61) | 0.1907*** | (2.61) |
| Export | 0.6308*** | (7.77) | 0.6280*** | (7.73) | 0.6261*** | (7.70) |
| East | -0.1132 | (-1.45) | -0.1139 | (-1.46) | -0.1151 | (-1.47) |
| Constant | -0.9906*** | (-5.68) | -1.0004*** | (-5.72) | -1.0016*** | (-5.74) |
| Industry dummies | Yes | | Yes | | Yes | |
| Log likelihood | -9.1e+02 | | -9.1e+02 | | -9.1e+02 | |
| $\chi^2$ | 274.2910 | | 274.8184 | | 275.2097 | |
| Pseudo-$R^2$ | 0.1559 | | 0.1561 | | 0.1562 | |
| Observations | 1582 | | 1582 | | 1582 | |
| **Process innovation** | | | | | | |
| Outsourcing level | 0.2864 | (1.61) | 0.3351** | (2.04) | 0.3369** | (2.31) |
| Log employees | 0.1761*** | (6.95) | 0.1768*** | (7.03) | 0.1761*** | (7.04) |
| % University | -0.0001 | (-0.04) | -0.0002 | (-0.15) | -0.0004 | (-0.22) |
| Job training | 0.3471*** | (3.69) | 0.3390*** | (3.60) | 0.3333*** | (3.53) |
| Business situation | 0.2804*** | (3.90) | 0.2809*** | (3.90) | 0.2812*** | (3.90) |
| Export | -0.0021 | (-0.03) | -0.0072 | (-0.09) | -0.0113 | (-0.14) |
| East | -0.2297*** | (-3.04) | -0.2295*** | (-3.04) | -0.2307*** | (-3.05) |
| Constant | -0.9347*** | (-5.56) | -0.9621*** | (-5.71) | -0.9742*** | (-5.81) |
| Industry dummies | Yes | | Yes | | Yes | |
| Log likelihood | -9.3e+02 | | -9.3e+02 | | -9.3e+02 | |
| $\chi^2$ | 161.5773 | | 162.9138 | | 164.0155 | |
| Pseudo-$R^2$ | 0.0858 | | 0.0866 | | 0.0871 | |
| Observations | 1582 | | 1582 | | 1582 | |

*z statistics in parentheses,* $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.
*The dependent variables are product innovation and process innovation between 2004 and 2006 (0/1).*
*Proportion of outsourced IT on total IT weighted by the percentage of computerized workplaces,*
*where* $\gamma$ *gives the weight of 'partial' (see section 4).*
*See table A.1 for an industry classification, 'other business-related services' is the omitted category.*

(measured by job training) seems to be a significant predictor of process innovation. Also, firms in East Germany have a significantly lower probability of process innovation.[9]

Estimation results according to specification B are reported in table 3. Again, coefficients for control variables are strikingly similar across all values of $\gamma$. Therefore the tables only report coefficients for models with $\gamma = 0.3$, $\gamma = 0.6$ and $\gamma = 0.9$. Figure 5 plots the coefficients of the outsourcing level ($\hat{\beta}_1$, $\hat{\beta}_2$) and the corresponding 90% confidence band as a function of $\gamma$. For product innovation (left hand panel) we find significant effects when setting $0.4 \leq \gamma \leq 0.9$. The corresponding signs of the coefficients indicate an inverse U-shape.[10] The corresponding maximum is at an outsourcing level of about 0.5.

The right hand panel of figure 5 indicates similar, yet insignificant estimates of $\hat{\beta}_1$ and $\hat{\beta}_2$ for process innovation. In consequence, we are unable to confirm an inversely U-shaped relation of outsourcing and process innovation. For both models, coefficient estimates of control variables are not largely different from those in specification A.

Overall, these results are robust to a number of different specifications. First, comparable results can be found when lagged innovation variables are included as independent variables, testing a 'success breeds success' hypothesis (Flaig and Stadler, 1994; Peters, 2009). Second, to account for interdependencies between different types of innovation (Kretschmer et al., forthcoming), we estimated a simultaneous bivariate probit model to allow the error terms of both equations to be correlated. Third, we tried to tackle the possible issue of non-random selection into outsourcing more explicitly. With information on whether the firm has considered consultancy with regard to the Y2K problem in the late 1990s (see Ohnemus (2007) for a detailed description), the dataset offered a reasonably good instrument for our measure of outsourcing. However, we still lacked a second exclusion restriction. Coding the outsourcing variable discretely $((\theta_\gamma < 0.2) = 0, (0.2 \leq \theta_\gamma < 0.8) = 1, (\theta_\gamma > 0.8) = 2)$ and estimating separate bivariate probit models for in-house vs. partial, in-house vs. complete and partial vs. complete allowed us to correct for endogeneity using only one exclusion restriction. Because results obtained in this setting are comparable, we chose to show the most straightforward specification here. We are aware that this doesn't allow to establish causality.

## 6 Discussion

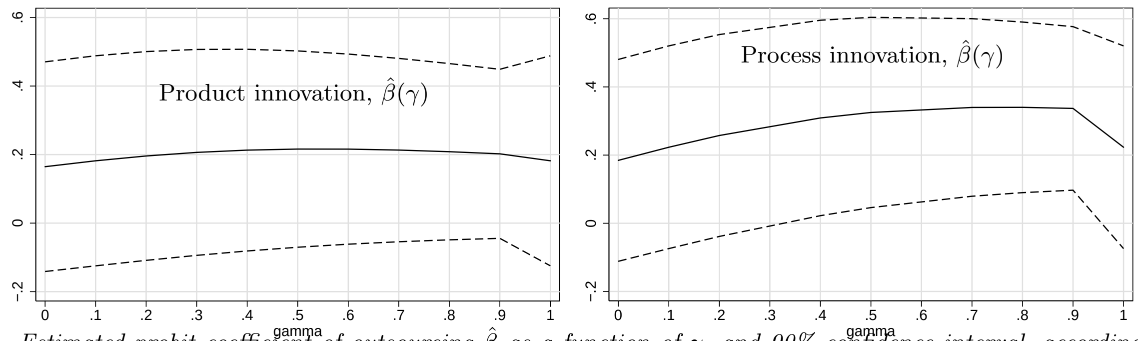
To sum up, we find a positive relation between innovation and the outsourcing level. That is, our specification indicates a positive effect of outsourcing on process innovation and a hump-shaped effect of outsourcing on product innovation.[11]

[9] In some sense, this is in line with the literature on productivity gaps between East and West Germany. See for example Smolny (forthcoming).

[10] A test with the null of a U-shape (negative slope at the lower bound and positive slope at the upper bound) or monotone function (sign of the slope is equal at both bounds) can be rejected for $\gamma > 0.4$. See Lind and Mehlum (2010) for a description of the test.

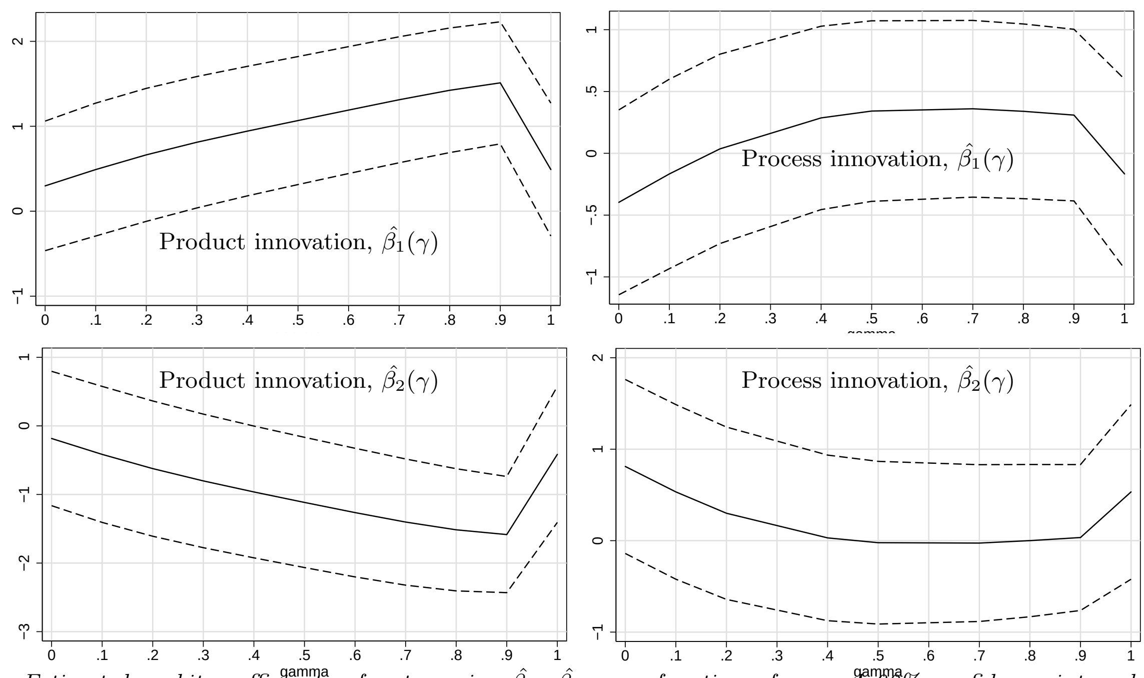
[11] The fact that the coefficients are insignificant in the respective other specification can be explained by looking at the descriptive statistics in table 1. First, the proportion of firms that report product innovation

**Figure 4:** Estimated probit coefficients $\hat{\beta}(\gamma)$, product and process innovation (specification A)




*Estimated probit coefficient of outsourcing $\hat{\beta}$ as a function of $\gamma$, and 90% confidence interval, according to specification A without squared term.*

**Figure 5:** Estimated probit coefficients $\hat{\beta}_1(\gamma)$, $\hat{\beta}_2(\gamma)$, product and process innovation




*Estimated probit coefficients of outsourcing $\hat{\beta}_1$, $\hat{\beta}_2$ as a function of $\gamma$, and 90% confidence interval, according to specification B with squared term.*

**Table 3:** Probit models for specification B

| | $\gamma = 0.3$ | | $\gamma = 0.6$ | | $\gamma = 0.9$ | |
|---|---|---|---|---|---|---|
| **Product innovation** | | | | | | |
| Outsourcing level | 0.8121* | (1.73) | 1.1906*** | (2.62) | 1.5113*** | (3.46) |
| Outsourcing level$^2$ | -0.8017 | (-1.35) | -1.2637** | (-2.22) | -1.5842*** | (-3.08) |
| Log employees | 0.0931*** | (3.77) | 0.0866*** | (3.50) | 0.0797*** | (3.22) |
| % University | 0.0054*** | (3.19) | 0.0054*** | (3.19) | 0.0056*** | (3.29) |
| Job training | 0.1602 | (1.62) | 0.1536 | (1.54) | 0.1520 | (1.52) |
| Business situation | 0.1872** | (2.56) | 0.1849** | (2.53) | 0.1831** | (2.50) |
| Export | 0.6238*** | (7.67) | 0.6128*** | (7.52) | 0.6030*** | (7.38) |
| East | -0.1188 | (-1.52) | -0.1239 | (-1.59) | -0.1256 | (-1.61) |
| Constant | -1.0151*** | (-5.78) | -1.0316*** | (-5.88) | -1.0407*** | (-5.97) |
| Industry dummies | Yes | | Yes | | Yes | |
| Slope lower bound | 0.8121** | (1.73) | 1.1906*** | (2.62) | 1.5113*** | (3.46) |
| Slope upper bound | -0.7913 | (-1.02) | -1.3367** | (-1.80) | -1.6571*** | (-2.60) |
| Extreme point | 0.5065 | | 0.4711 | | 0.4770 | |
| 90% Fieller-CI | *out of range* | | [0.3594, 0.8335] | | [0.3985, 0.6186] | |
| U-test | 1.02 | | 1.81** | | 2.60*** | |
| Log likelihood | -9.1e+02 | | -9.0e+02 | | -9.0e+02 | |
| $\chi^2$ | 274.7983 | | 277.7270 | | 281.6255 | |
| Pseudo-R$^2$ | 0.1569 | | 0.1587 | | 0.1610 | |
| Observations | 1582 | | 1582 | | 1582 | |
| **Process innovation** | | | | | | |
| Outsourcing level | 0.1874 | (0.41) | 0.3634 | (0.83) | 0.3092 | (0.73) |
| Outsourcing level$^2$ | 0.1333 | (0.24) | -0.0374 | (-0.07) | 0.0343 | (0.07) |
| Log employees | 0.1766*** | (6.93) | 0.1765*** | (6.91) | 0.1764*** | (6.90) |
| % University | -0.0001 | (-0.04) | -0.0002 | (-0.15) | -0.0004 | (-0.22) |
| Job training | 0.3481*** | (3.70) | 0.3387*** | (3.59) | 0.3335*** | (3.53) |
| Business situation | 0.2809*** | (3.90) | 0.2808*** | (3.90) | 0.2814*** | (3.90) |
| Export | -0.0009 | (-0.01) | -0.0077 | (-0.10) | -0.0107 | (-0.13) |
| East | -0.2289*** | (-3.02) | -0.2298*** | (-3.04) | -0.2305*** | (-3.05) |
| Constant | -0.9308*** | (-5.51) | -0.9629*** | (-5.70) | -0.9736*** | (-5.80) |
| Industry dummies | Yes | | Yes | | Yes | |
| Slope lower bound | 0.1874 | | 0.3633 | | 0.3092 | |
| Slope upper bound | 0.4540 | | 0.2886 | | 0.3777 | |
| Extreme point | -0.7028 | | 4.8600 | | -4.5110 | |
| 90% Fieller-CI | *out of range* | | *out of range* | | *out of range* | |
| U-test | *trivial rejection* | | *trivial rejection* | | *trivial rejection* | |
| Log likelihood | -9.3e+02 | | -9.3e+02 | | -9.3e+02 | |
| $\chi^2$ | 161.5438 | | 163.2040 | | 164.1084 | |
| Pseudo-R$^2$ | 0.0858 | | 0.0866 | | 0.0871 | |
| Observations | 1582 | | 1582 | | 1582 | |

*z statistics in parentheses.* $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

*Slope lower bound* $= \beta_1 + 2\beta_2 \cdot 0$, *slope upper bound*$=\beta_1 + 2\beta_2 \cdot 1$.

*Extreme point* $= -\beta_1/2\beta_2$. *U-test according to Lind and Mehlum (2010).*

Our stylized theoretical model implies both results, dependent on the specificity of knowledge underlying the innovation decision. The upper panel of figure 3, with low values of specificity, suggests a monotonically increasing relation between knowledge growth and the level of outsourcing. A hump-shaped and monotonically decreasing relationship is implied in the lower panel of figure 3, where higher levels of specificity are depicted. Although a limitation of the empirical analysis presented here is that specificity cannot be measured directly, we argue that it provides some evidence for the theoretical reasoning above. Inspired by Barras (1986), innovation can be seen as a cycle that starts with process improvements to increase efficiency to go on with process innovations that increase quality, and finally stimulates the development of new products and services. In each stage, more specific knowledge is needed to reach the next stage. In essence we argue that $s_{proc} < s_{prod}$, i.e. product innovation and process innovation differ in terms of knowledge specificity. Hence, if the knowledge needed to generate IT-enabled product innovation is more specific than the knowledge needed to generate IT-enabled process innovation, the empirical results fit the results of our stylized theoretical model quite well. Our results are in line with the study by Gooroochurn and Hanley (2007) who find that the probability to outsource process innovation is twice as high as product innovation in UK Community Innovation Survey data.

To see why there are different effects on product and process innovation in the specific setting of IT outsourcing, consider the case study discussed by Kumar and Snavely (2004) as an example. A company from the printing industry decided to develop a new internet-based service that allows its customers to individualize their print projects. Mainly due to a lack of internal competence, the implementation was outsourced and became a success. The outsourcing contract implied that the external vendor was integrated in the internal management process, i.e. it was a partial outsourcing relationship. Kumar and Snavely (2004) stress that vendor-client cooperation was the key driver of success in this case. This example shows that IT-enabled product innovation can be very firm-specific. In a recent study using micro-level data on providers of knowledge-intensive business services, Engelstätter and Sarbu (2010) underline this argument from a different perspective. The authors find that enterprise software, specifically developed for the firm, has a positive impact on the probability of service (i.e. product) innovation. Less customized, industry-specific software, however, turns out to have no significant impact on service innovation. A common reason why firms use standardized software aims at improvements in productivity and flexibility instead of increasing demand. If IT is widely used for operational tasks, improvements in technology are very likely to have effects on business processes. Hence, by the nature of expertise needed to develop standardized vs. customized software solutions, IT-enabled process innovation should be easier achieved than IT-enabled prod-

at the lower end of the outsourcing level does not largely differ from those at the upper end. Second, although there is a kink in the proportion of firms reporting process innovation for a medium level of outsourcing, differences between the lower and the upper end are rather substantial. Figures A.3, A.4, A.5 in the appendix further illustrate our findings.

uct innovation. Another explanation why we don't observe a tipping point in our results for process innovation is a difference in the required vendor-client coordination. Weeks and Feeny (2008) argue that in the case of process innovation, soft factors like trust and communication are less critical for success. Hence, outsourcing too much is less harmful.

## 7 Conclusion

While the market for external supply of IT has seen rapid growth during the last decade, scientific research has been largely silent on an important long run aspect of client-side effects so far. It is well known that IT enabled innovation is an important source of value creation for firms operating in globalized markets and increasingly individualized customer desires. However it remains unclear if innovation can be achieved in IT outsourcing relationships.

We employ a stylized theoretical model based on transaction cost economics to explore knowledge creation across the boundaries of the firm. The model suggests that knowledge growth, and therefore innovation, depends on the specificity of knowledge and the scope of outsourcing decisions. When the knowledge needed to generate innovation is not very specific, completely outsourcing knowledge production is always better than cooperation or in-house production. For intermediate levels of specificity, however, the optimal mode of organization is a hybrid one. When required knowledge is more specific, in-house production is optimal. Our empirical strategy involves to test the theoretical predictions with German micro-data. Following a knowledge production function approach, we estimate probit models for product and process innovation. By combining several variables, we construct a measure of the firm-specific importance of IT outsourcing, reflecting both external supply of IT services and firm-specific IT intensity. We find a positive linear effect on process innovation, and a hump-shaped effect on product innovation. We argue that innovation can be seen as a multi-stage process of improvements in efficiency and quality that finally stimulates the development of new products and services. In consequence the specificity of knowledge needed is increasing in each stage. That is, if knowledge needed to generate process innovation is less specific than knowledge required to generate product innovation, the empirical results fit the results of our stylized theoretical model quite well, although we cannot observe asset specificity directly. We are aware that we cannot establish causality in this analysis. Future work should try to address this issue, directly incorporate the underlying specificity of knowledge in the empirical analysis and possibly control for vendor-specific effects. Another extension could be to investigate the performance implications of innovation, i.e. differentiate quantity and quality of innovation.

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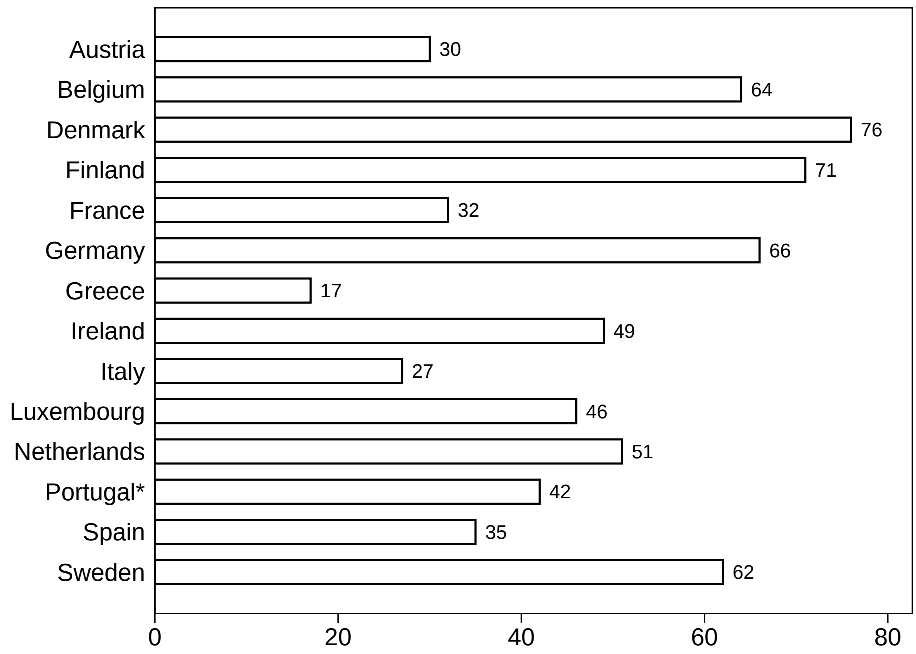
# A Appendix

**Table A.1:** Industry classification

| Industry | NACE |
|---|---|
| Consumer goods | 15–22, 36–37 |
| Chemical industry | 23–24 |
| Other raw materials | 25–27 |
| Metal and machine construction | 28–29 |
| Electrical engineering | 30–32 |
| Precision instruments | 33 |
| Automobile | 34–35 |
| Wholesale trade | 51 |
| Retail trade | 50, 52 |
| Transportation and postal services | 60–63, 64.1 |
| Banks and insurances | 65–67 |
| Electronic processing and telecommunication | 72, 64.2 |
| Technical services | 73, 74.2, 74.3 |
| Other business-related services | 70–71, 74.1, 74.4–74.8, 90 |

**Source:** Ohnemus (2007).

**Figure A.1:** IT outsourcing in the EU15 countries in 2007




*Percentage share of all enterprises with at least 10 persons employed, grouped by sector where external suppliers performed (fully or partly) ICT functions requiring ICT/IT specialists* (IT outsourcing) *during 2007. *Due to data restriction without financial sector, data for the United Kingdom is not available.*
*Source: Eurostat, information society statistics on enterprises 2007.*

**Figure A.2:** Accumulated knowledge as a function of the outsourcing level and specificity

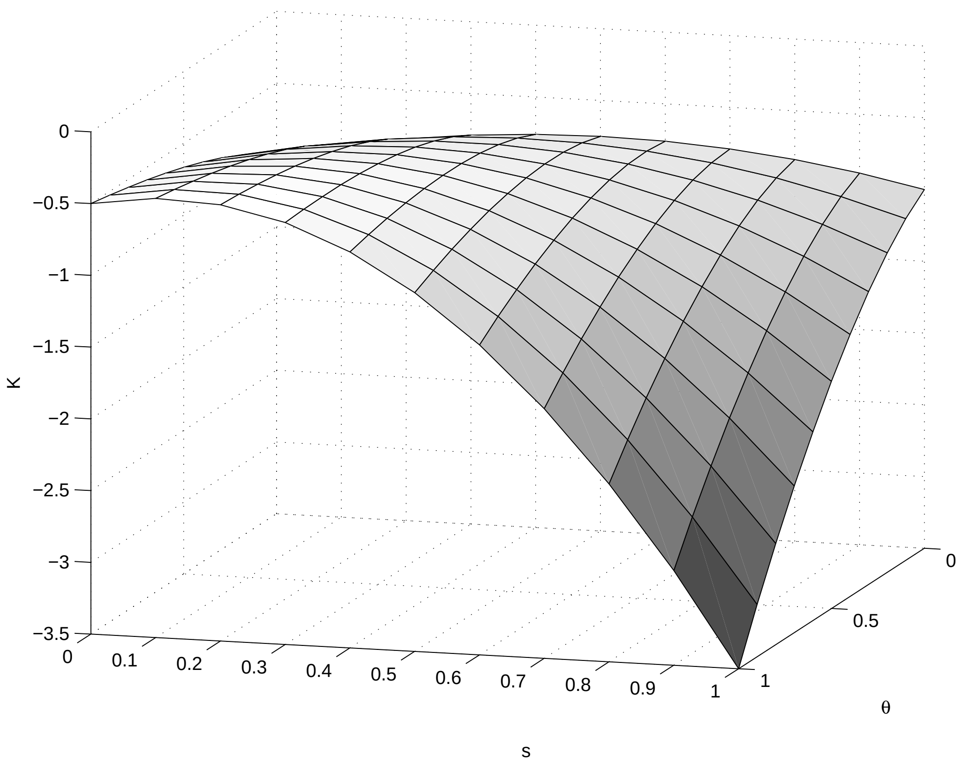
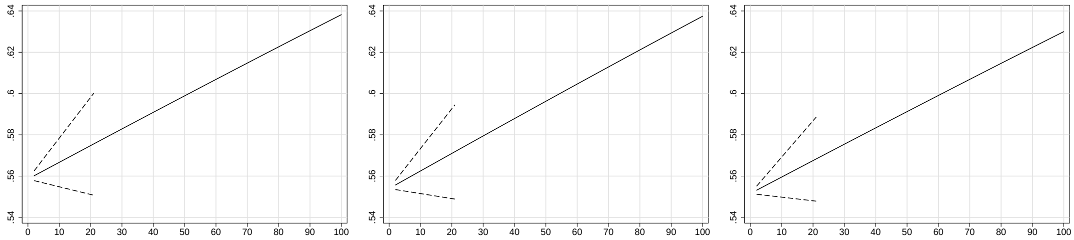
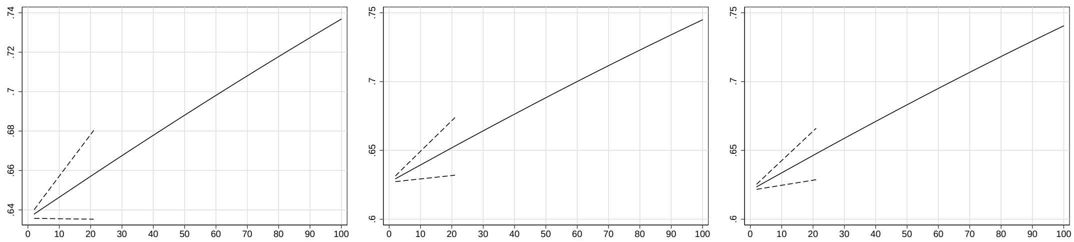


**Figure A.3:** Predicted probability of product innovation, $\gamma$=0.3, $\gamma$=0.6, $\gamma$=0.7



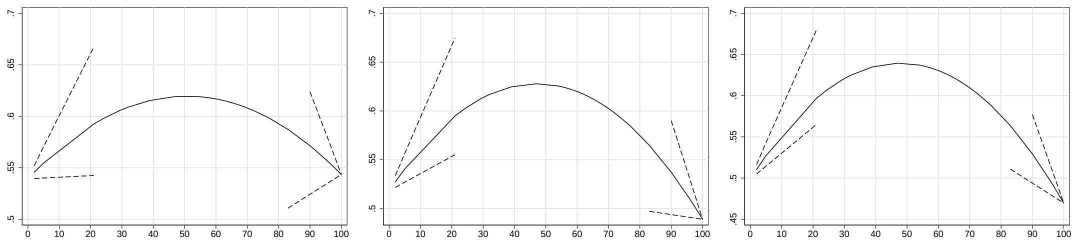

*Predicted probability $\widehat{prod}$ as a function of $\theta$, and 90% confidence interval, according to specification A without squared term. All covariates fixed at the mean.*

**Figure A.4:** Predicted probability of process innovation, $\gamma$=0.3, $\gamma$=0.6, $\gamma$=0.7



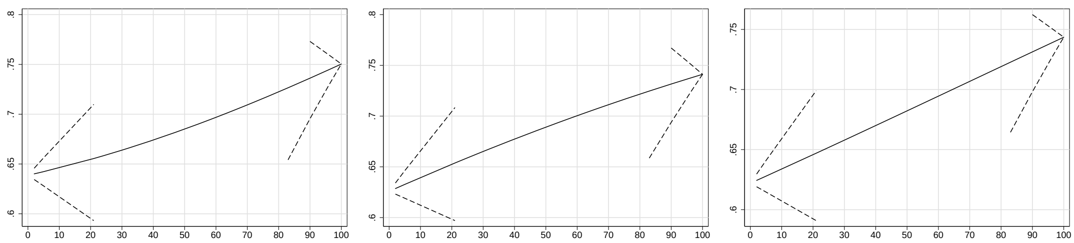

*Predicted probability $\widehat{proc}$ as a function of $\theta$, and 90% confidence interval, according to specification A without squared term. All covariates fixed at the mean.*

**Figure A.5:** Predicted probability of product innovation, $\gamma$=0.3, $\gamma$=0.6, $\gamma$=0.7




*Predicted probability $\widehat{prod}$ as a function of $\theta$, and 90% confidence interval, according to specification B with squared term. All covariates fixed at the mean.*

**Figure A.6:** Predicted probability of process innovation, $\gamma$=0.3, $\gamma$=0.6, $\gamma$=0.7




*Predicted probability $\widehat{proc}$ as a function of $\theta$, and 90% confidence interval, according to specification B with squared term. All covariates fixed at the mean.*