The Relationship between Technology, Innovation, and Firm Performance: Empirical Evidence on E-Business in Europe

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Keywords: Information technology; e-business, innovation; firm performance, profitability

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1 Introduction

The importance of new technologies and innovations for competitiveness and growth is a truism among managers, policy makers, and researchers. However, not all new technologies and innovations lead to success. Given the manifold technological opportunities and types of innovations from which firms can potentially choose, it is desirable to know which innovative activities and technologies are most clearly associated with improved competitiveness and growth. Arguably even more important is an understanding of the factors that make the success of new technologies and innovative activities more or less likely in general. The aim of this article is to provide some new insights regarding this topic.

A conceptual framework is developed that assists in analyzing the relationship between technology, innovation, and firm performance. It is argued that the performance implications of new technologies, such as information and communication technologies (IT), are mediated by innovative activities that result from the adoption of these technologies. Furthermore, the performance implications can vary across different types of innovation, depending on firm-internal and market-specific factors. This conceptual framework serves as a guide for the empirical investigation and the interpretation of its results.

The empirical part of the study compares the performance of innovative and non-innovative companies. Performance is measured in terms of turnover development, employment development, and profitability. In particular, four different types of innovative activity are distinguished: product innovations or process innovations that were enabled by Internet-based technologies, and product innovations or process innovations that were <u>not</u> related to the use of Internet-based technologies. The article is organized as follows: succeeding this introduction, the theoretical background of this study and a short overview of related literature is provided in Section 2; the conceptual framework that links technology, innovation, and firm performance is introduced in Section 3; the econometric estimation model is explained and derived in Section 4; section 5 describes the data set and reports some descriptive findings; the estimation results are presented in Section 6 and discussed in Section 7; limitations of the empirical analysis are pointed out in Section 8; and finally, Section 9 concludes the paper.

2 Theoretical background

On the conceptual level, the adoption of new technology, such as IT, can be viewed as an enabler of process innovations from the perspective of the adopter if the implementation succeeds, the routines are changed, and the new system is actually utilized. Newly adopted technology can also act as an enabler of product or service innovations from the perspective of the adopter if it is successfully used to offer a new service or to deliver products to customers in a way that is new to the enterprise. For example, a company that adopts and implements new online shop software usually changes the routine of how incoming orders are processed. This is a process innovation. Furthermore, the new online shop software may allow the firm to deliver its products to customers in a new way or to offer additional services, such as tracking orders online or getting immediate information about availability. This would be a service innovation. Both types of innovations (process and product/service) have clear economic implications. In micro-economic terms, a product innovation corresponds to the generation of a new production function (Kamien and Schwartz, 1982), which includes the possibility to differentiate an existing product (Beath et al., 1987; Shaked and Sutton, 1982; Vickers, 1986)[1]. A process innovation, on the other hand, can be viewed as an outward shift of an existing supply function, which corresponds to lower variable costs in the production of an existing product or service, and is therefore a productivity increase (Beath et al., 1995; Dasgupta and Stiglitz, 1980; Reinganum, 1981).

The payoffs of innovative activities in a firm are determined via a market process that involves not only the activities of the innovator, but also the reactions of customers and competitors. Thus, the payoffs of all actors in a market are interrelated. Economic theory suggests that, *ceteris paribus*, both the creation of a new supply function[2] and the outward shift of an existing supply function[3] can lead to higher output levels and thus revenue growth, although via different mechanisms. Thus, both product and process

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[1] The products or services represented by these production functions may be substitutes from the consumer's perspective and/or they may vary in quality. Thus, a new production function does not necessarily reflect a radical innovation.

[2] Assuming the new good or service is not a close substitute to other goods or services offered by the firm.

[3] Assuming the price elasticity of demand is large enough.

innovations can lead to growth of the innovator, independent of the firm's ability to appropriate private profits from the investment that caused the innovation (Götz, 1999; Hannan and McDowell, 1990; Reinganum, 1981; Sutton, 1991).

The relationship between innovation and profitability is more complex because it critically depends on the reaction of competing firms. The fundamental problem for the innovator is to protect its novel process or product from imitation by rivals. As soon as all competitors use the same (improved) process and produce the same product, no single firm in the market will be able to outperform its rivals, including the firm that first brought the innovation to the market (Teece, 1986, 2006). The quicker an innovation is copied by other firms, the less time each innovating firm has to reap additional payoffs from the investment in the innovation. This is known as the appropriability problem (Geroski, 1995). Thus, the timing of an innovation influences the expected payoff. The game-theoretic literature points out that firms that are able to outpace their direct competitors in technological development will capture market shares and profits from their rivals, possibly up to the degree that they drive their competitors out of business. However, profits from innovation are only sustainable until competitors are able to copy the innovation and all associated complementary assets completely. In addition, potential early mover advantages will be limited or even reversed if the technologies on which the innovations are based exhibit either falling prices or rapid technological improvements over time (Beath et al., 1995; Fudenberg and Tirole, 1985; Götz, 1999; Reinganum, 1981). Summarizing, economic theory predicts that successful innovators are more likely to grow and to survive in their markets. Various empirical studies are consistent with this message (Audretsch, 1995; Cefis and Marsili, 2003; Mansfield, 1968). They might also be able to capture excess profits, but this is contingent on the behavior of rivals and on other exogenous factors that are beyond the control of the innovator (Geroski et al. 1993; Stoneman and Kwon, 1996).

Various empirical studies also show that innovating firms fail to obtain competitive advantages from an innovation, while customers, imitators, and other industry participants benefit (Levin et al., 1987; Teece, 1986). To circumvent this problem, firms typically try to appropriate private returns from innovation using a wide range of mechanisms, including patents, secrecy, lead time advantages, and the use of complementary capabilities (Cohen et al., 2000). Methods of appropriability vary markedly across and within industries, and not all methods work well in all cases (Harabi, 1994; Levin et al., 1987; Teece, 1986).

A different vein of the literature analyzes the firm-level impacts of investments in new technologies, often without linking such investments explicitly to innovation. The consequences of investments into IT have especially been subject to an intense debate among scholars because not all studies have demonstrated clear payoffs from IT (Brynjolfsson and Hitt, 1996, 2000, 2003; Hitt and Brynjolfsson, 1996; Carr, 2003; Chan, 2000; Kohli and Devaraj, 2003).

A particular advantage of seeing the adoption of new technologies as an enabler of innovation is that it allows us to identify the firm- and market-specific mechanisms that can lead to different consequences for firms that invested into the same technologies. In addition, it identifies two types of technology-induced changes (process vs. product innovation) with quite different economic implications. For example, one important difference between process and product innovations is their potential impact on employment. The expansion that usually follows both kinds of innovations creates additional demand for both capital and labor production factors, which implies that innovating firms are more likely to increase employment. This is called the compensation effect (Pasinetti, 1981). However, there can also be a labor-reducing effect of innovations. For process innovations, this is likely to occur when productivity increasing effects begin to materialize. Productivity increases imply that a given level of output can be produced by a lower level of input. Thus, if demand and output remain constant, a process innovation will lead to a reduction of labor. This is called the substitution effect (Edquist et al., 2001). This effect is less likely to occur for product innovations, whether they are IT-enabled or not.

3 Conceptual framework

The theoretical considerations discussed above lead to the conceptual framework displayed in Figure 1, which shows that technology and firm performance are mediated by innovative activity. Firm-internal factors affect whether investments into new technologies can be transferred into innovations and whether the innovations can be protected from imitation by rivals. Ultimately, the performance impact of innovations is determined in a market process that depends not only on the behavior of the innovating firm, but also on the behavior of customers, competitors, and suppliers.

Figure 1: Relation between technology, innovation and firm performance – ABOUT HERE

In particular, investments in and the adoption of particular technologies, such as IT, can enable innovations, either by improving processes or by enabling the firm to offer new products (e.g. digital goods) or services to its customers. Technology investments that do not result in innovations are sunk costs that will not improve corporate performance. The ability of firms to transfer technology investments into innovation is likely to be influenced by firm-specific resources such as managerial skills, know-how, experience, the presence of technical experts, and prior technological investments.

Economic theory suggests that the performance outcomes depend on the type of innovation, the intensity of competition, and the timing of the innovation (whether the firm is a first mover, a follower, or a laggard in implementing a particular innovation), as well as the price-elasticity of demand, the absolute size of the market, and the negotiation power of the innovating firm vis-à-vis suppliers and customers. While demand and supply conditions in a market are often exogenously given, firms can influence the extent to which competitors can imitate their innovation by employing one or a combination of various appropriation tactics, including: secrecy, lead-time, patents, particular sales and service efforts, and achieving a good fit between technology-related innovations and complementary rare assets of the firm (Teece, 1986, 2006). Thus, choosing an adequate appropriation tactic can help the firm to gain private profits from innovations. However, the success of these tactics is likely to vary across industries and with the type of innovation carried out.

The relationship between technology, innovation, and performance is not necessarily unidirectional. Firms that perform well may have easier access to capital to finance further investments and innovations (Abel and Blanchard, 1986; Hubbard and Kashyap, 1992). Furthermore, previous investments into technology and innovation may positively affect the absorptive capacity of firms (Cohen and Levinthal, 1989), the availability of complementary resources such as skilled labor (Acemoglu, 2002; Brynjolfsson and Hitt, 2002), and learning-by-doing effects may occur (Arrow, 1962). Thus, there might be a positive feedback mechanism between technology investments, performance, investment opportunities, and innovation potentials. This is indicated by the dashed line in Figure 1 that links performance to technology and innovation.

The conceptual framework outlined above offers numerous possibilities for interesting empirical research questions. The empirical part of this study does not aim to resolve the question of causality between innovation and performance. Rather, the objective is to compare different types of innovations based on their association with different measures of firm performance.

Due to the data available for this study, the analysis focuses on traditional product or process innovations, and product or process innovations that are enabled by or related to a subset of IT, namely e-business technologies. These are technologies that use the Internet and the TCP/IP computer network protocol to support at least one internal or external business process each, such as sales, procurement, or knowledge management. The associated Internet-related innovations are viewed as a subset of IT-related innovations.

Given the available data, two questions can be empirically analyzed: Are there qualitative differences between Internet-enabled and non-Internet-enabled ("traditional") innovations and their relation to performance? Also, do we find differences between process and product innovations?[4]

The management literature recognizes numerous concepts and variables to measure performance. For example, March and Sutton (1997) mention profits, sales, market share, productivity, debt ratios, and stock prices. Ittner et al. (1997) differentiate between financial and non-financial measures of performance. Obviously, many of these different measures are correlated. Which of the measures is given priority is essentially a matter of perspective – management, employees, and stakeholders will likely emphasize different performance measures as most relevant to them. In empirical studies, the choice of the performance measure is often limited by the availability of data. In this study, organizational performance is measured in terms of profitability and growth. The latter is quantified as changes in revenue and number of employees.

[4] A positive correlation between innovative activity and performance clearly does not imply causality. However, given a sufficiently large sample, an insignificant relationship between innovative activity and performance would at least suggest that this particular innovative activity is unlikely to be a direct cause of superior performance.

4 An error component model of firm performance

It is obvious that, besides innovative activities, numerous other factors also influence the performance of an enterprise. These can include: the market in which a firm operates (Dunne et al., 1988, 1989); the presence of economies of scale and the size of the firm; the prevailing market structure and the market share of the enterprise; and firm-internal structures and resources including the technology the firm uses; its organizational structure; human resources; and managerial competence. Lenz (1981) provides an interdisciplinary summary of numerous "determinants" of organizational performance.

Hence, in order to identify the relationship between innovation and firm performance, one needs to control for alternative factors that influence performance. The challenge in this study (as well as in most other studies with a similar objective) is that not all factors that could play a role are actually observable in the data.

Because not all relevant factors are observable, some preferably non-critical assumptions have to be made. For this purpose, an error component model of firm performance is introduced here that makes it possible to control separately for firm-specific and market-specific unobserved effects when estimating the relationship between observable characteristics and performance variables. This enables the disentanglement of the effects of unobservable market characteristics and the effects of the observable firm level characteristics, for which coefficients are estimated.

The dataset is a cross-section of a large number N of heterogeneous firms with the index $i = 1,...,N$. Each firm operates primarily in one market, and there are J different markets with the index $j = 1,...,J$. Interest lies in the performance of firm i in market j, which is recorded with the dependent variable y_{ij}. Performance depends on a vector of observable firm-specific characteristics $\overline{x}_{ij}$. In addition, performance also depends on unobservable market-specific effects u_j and unobservable firm-specific effects ε_{ij}. Thus, performance is a function of various firm-specific characteristics and two unobservable error terms:

$$y_{ij} = f(\overline{x}_{ij}, u_j, \varepsilon_{ij}) \quad (1)$$

In this study, $\overline{x}_{ij}$ consists of the following variables:

x_1 = dummies indicating four different kinds of innovative activity – the association of these four variables with performance is the main point of this study;

x_2 = firm size (measured by number of employees in four categories) – this controls for possible economies of scale;

x_3 = market share (measured in % in six categories) – this controls for the possible effects of market power on performance;

x_4 = % of employees with a university degree – this is a proxy for the average skill level of employees;

x_5 = number of e-business technologies installed by the firm – this is a proxy to measure how advanced a firm is in using e-business.[5]

The technologies that are included in x_5 and their relative frequency of occurrence are listed in Table 1.[6] A more detailed description of the data follows in Section 5.

Table 1 - Relative frequencies of 7 e-business technologies, Nov 2003 – ABOUT HERE

The economic conditions within one market are comparable for all firms operating in that market, but they can vary greatly among markets. Hence, u_j is equal for all firms operating in market j, but u_j can vary. All relevant firm-specific unobserved effects

[5] Many studies alternatively approximate the level of IT endowment of firms based on IT investments or IT capital stock. The measure used in this study, the count of installed e-business technologies, is conceptually narrower by focusing only on a subset of IT applications. Nevertheless, the measure is closely related to IT capital stock: having installed a high number of e-business applications or having accumulated a high IT capital stock are proxies for how advanced a firm is in using IT.

[6] 57.8% of firms in the sample had not adopted any of the seven e-business technologies in 2003. The mean value of x_5 is 0.67. Only 0.6% of all firms had adopted more than 3 technologies.

are captured in ε_{ij}. The assumption that ε_{ij} is independent of all observable factors $\overline{x}_{ij}$ is required because otherwise the effects of $\overline{x}_{ij}$ cannot be identified.

Yet, the advantage of the model is that the market-specific effect u_j is not assumed to be independent of the firm specific effect ε_{ij}, $E[u_j | \varepsilon_{ij}] \neq 0$. Furthermore, no independence is assumed of u_j from the observable firm-specific characteristics $E[u_j | \overline{x}_{ij}] \neq 0$. Clearly, such an assumption would violate basic economic reasoning. For example, consider the relationship of market structure and the observed market share of an individual enterprise: if a market is characterized by perfect competition, obviously there will be no firm with a high share in that market. In contrast, a highly concentrated market may include a low number of firms with high market shares. Hence, the market structure and the market share of each firm are correlated. In the dataset used for this study, it is possible to observe the market share of each firm in the data, but not the exact market structure in which each firm operates. However, this unobservable market structure, which is captured within u_j, is very likely to affect firm performance. Similar arguments can be made with respect to the other observable characteristics. Thus, not assuming independence of firm-specific characteristics and u_j is crucial for obtaining consistent regression estimates.

We consider a qualitative indicator variable y for firm performance that takes a value of $y = 1$ if a specific criteria is observed, and $y = 0$ otherwise. For example, y could be profitability taking a value of $y = 1$ if the firm has been profitable over the last year and $y = 0$ otherwise. Hence, y is a Bernoulli-distributed random variable and the occurrence of y is conditional on various observable and unobservable characteristics, as defined in (1). Assuming that the influence of the conditional characteristics is linear, the probability that a firm observes $y = 1$ can be written as

$$p_{ij} = \Pr[y_{ij} = 1 | \overline{x}_{ij}, u_j] = E(y_{ij} | \overline{x}_{ij}, u_j) = F(\overline{\beta' x_i} + u_j) \tag{2}$$

where F is the cumulative distribution function (cdf) of the individual specific error term ε_{ij} that maps $(\overline{\beta' x_i} + u_j)$ in the (0;1) range. In order to get consistent estimates for

β in (2), it is necessary to eliminate the unobserved market-specific effects u_j from the equation. Following Chamberlain (1980), the solution to this problem lies in specifying F as the logistic cdf and writing the likelihood function based on the conditional distribution of the data, conditioned on a set of sufficient statistics for u_j. By the definition of a sufficient statistic, the distribution of the data given this sufficient statistic will not depend on u_j anymore.

Chamberlain (1980) showed that a sufficient statistic for u_j is $\sum_j y_{ij}$ and that the conditional log-likelihood function will only depend on β, $\overline{x}_{ij}$, and y_{ij}:

$$\ell_j = \sum_j \ln[\exp(\overline{\beta}'\sum_i \overline{x}_{ij} y_{ij}) / \sum_{d \in B_j} \exp(\overline{\beta}'\sum_i \overline{x}_{ij} d_i)] \tag{3}$$

where

$$B_j = \left\{ d = (d_1, ..., d_{n_j}) \mid d_i = 0 \text{ or } 1 \text{ and } \sum_i d_i = \sum_i y_{ij} \right\}$$

and n_j is the number of firms in market j. The estimator only considers groups where either at least one firm observes a positive outcome or at least one firm does not observe a positive outcome, because the likely contribution of a group j with either no or all positive observations is zero according to (3). The sample log-likelihood summed across j can be used to obtain a $\sqrt{N}$ -asymptotically normal estimator of β, and all inference follows directly from conditional MLE theory (Wooldridge, 2002). Thus, by conditioning the log-likelihood function on $\sum_j y_{ij}$, the u_j are swept away and a consistent estimator is obtained that does not place any restrictions on the distribution or co-variance of the unobservable group-specific effect. Thus, equation (3) is a market-fixed-effects estimator that allows us to estimate the average effect of $\overline{x}_{ij}$ on y_{ij} independent of unobserved market-specific characteristics that might influence corporate performance.

5 Data

The dataset used for this study originates from the Nov/Dec 2003 enterprise survey of the e-Business Market W@tch, a large scale observatory initiative that is sponsored by the European Commission DG Enterprise and Industry. The e-Business Market W@tch monitors the adoption, development, and impact of electronic business practices in different sectors of the European economy. The initiative was launched in late 2001 with the goal of providing reliable and methodically-consistent empirical information about the extent, scope, and factors affecting the speed of e-business development at the sector level in an internationally comparative framework; information that was previously not available from other sources, such as the official register-based statistics or market research studies.[7] The e-Business Market W@tch database has been used by various official institutions, including the European Commission and the OECD (2004).

For the Nov/Dec 2003 decision maker survey, participating firms were randomly selected from 10 sectors and 25 European countries, but not all sectors were covered in each country[8]. Table A1 in the Annex shows the definition of the sectors included in the study, Table A2 provides the numbers of successfully completed interviews in each country-sector cell. The fieldwork was carried out by specialized polling companies that mostly used computer-aided telephone interview (CATI) technology. The decision-maker in the enterprise targeted by the survey was normally the person responsible for IT within the company, typically the IT manager. Alternatively, particularly in small enterprises without a separate IT unit, the managing director or owner was interviewed (European Commission, 2004a).[9]

The number of enterprises sampled in each country-sector cell was large enough to be approximately representative of the underlying population. The economic conditions within each sector can be very different depending on the country. In addition, market structures and economic conditions can vary greatly between the sectors of each country. However, the economic conditions for firms operating in the same country and the same sector can be assumed to be reasonably comparable. In the dataset, each firm belongs unambiguously to a specific country-sector group of enterprises, which defines the relevant market in this study. Overall, the sample contains 101 markets (the market

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[7] Further information about the project can be found at http://www.ebusiness-watch.org.

[8] This heterogeneous coverage requires the use of the market-fixed-effects estimator (equation 3) instead of including dummy variables. Among other statistical problems, sector or country dummies would confound sampling and real effects.

[9] The complete dataset is available for academic research purposes free of charge. For further information, contact info@ebusiness-watch.org.

index in the regression model is defined as $j = 1,...,101$). On average, there are approximately 60 firms surveyed per market, with a total of 7,302 firms.

The dataset contains qualitative information about firm performance. In particular, firms were asked the following questions relating to their performance:

- Has your company been profitable over the past 12 months? (yes / no / don't know, not applicable)
- Has the turnover[10] of your company increased, decreased or roughly stayed the same when comparing the last financial year with the year before? (increased / decreased / roughly stayed the same / don't know, not applicable)
- Has the number of employees in your company increased, decreased, or roughly stayed the same during the past 12 months? (increased / decreased / roughly stayed the same / don't know)

Answers to these three questions were recorded as three categorical performance variables (profit, turnover, employment). The categorical values were then used to generate seven binary variables that serve as dependent parameters in the analysis[11]. In this study, all seven binary variables are analyzed in separate estimation models. This allows detailed insight into the effects of different kinds of innovation and technological development status on financial performance, employment effects, and firm growth. All models follow the same basic structure; they are only different in the dependent variable.

The advantage of this type of qualitative data is that it provides information about dynamic developments, which are independent of the size of each firm, although only one cross-section is observed. Information about absolute turnovers and the number of employees in the survey is only useful to identify the size of a firm, as it does not provide any information about dynamic developments and performance when no true panel data are available. Alternatively, one could ask firms about the absolute size of

[10] turnover meaning sales in local currency

[11] The resulting seven binary (yes/no) variables are: *profit*, *turnover increase*, *turnover unchanged*, *turnover decrease*, *employment increase*, *employment unchanged*, and *employment decrease*. Observations with missing values or subjects answering “don't know, not applicable“ were dropped from the analysis. This amounts to 14.4% of the sample for turnover development, 11.8% for profitability, and 1.2% for employment development.

changes (Δ_t), but such detailed information is usually not obtainable in telephone interviews.

In addition to the above questions relating to the performance of enterprises, the survey also contained questions relating to different kinds of innovative activities of firms. In particular, the following two questions were asked:

- Has your company introduced new or substantially improved products or services to your customers during the past 12 months? (yes / no / don't know, not applicable)
- Has your company introduced new company internal processes during the past 12 months? (yes / no / don't know, not applicable)

These two questions were adopted from the European Community Innovation Survey, which is the official initiative at the European level to measure the extent and impact of innovative activity in a panel study (European Commission, 2004b).

A particular goal of the survey was to find out the current importance of Internet-based technology for innovative activity. Therefore, a follow up question was asked to companies that said "yes" to the first innovation question:

- Have any of your product/service innovations over the past 12 months been directly related to or enabled by Internet-based technology? (yes / no / don't know, not applicable)
- Have any of your company's internal process innovations been directly related to or enabled by Internet-based technology? (yes / no / don't know, not applicable)

96% of the survey respondents (N = 7,302) provided valid responses on the product/service innovation questions, and 97% on the process innovation questions. The relative frequencies of affirmative responses to these questions are displayed in Figure 2.

Figure 2: Innovative activities of companies 2002-2003 – ABOUT HERE

In all, 52% of enterprises in the sample introduced substantially improved products or services to their customers in 2003. Of these, 41% report that they have used Internet-based technologies to enable product or service innovations. This corresponds to 22% of enterprises in the sample in 2003. The importance of Internet-based technologies is even more pronounced for process innovations: 43% of enterprises say that they introduced new internal processes in 2003. About half of these firms state that Internet-based technologies have been related to or directly enabled their process innovations. Thus, it can be concluded that a substantial amount of innovative activity in the European Union was related to or enabled by Internet-based technologies in 2003.

Table 2 shows the descriptive summary statistics for the dependent variables. 44% of enterprises in the sample experienced increasing turnover from 2002-2003, 82% report profitability for this period, and 23% report increasing employment. Less than one fifth of the sample recorded decreasing turnover, decreasing employment, or no profits.

Table 2: Performance indicators of companies 2002-2003 – ABOUT HERE

Table 3 shows correlation coefficients of the performance indicators. Not surprisingly, firms that experience turnover growth are significantly more likely to be profitable and to increase employment and vice-versa. Noticeably, the development of turnover and employment are measures indicating whether a company is growing, declining, or stagnating. According to Table 3, growth is positively related to profitability; however, it is not a prerequisite of profitability. A significant proportion of firms in the sample are profitable although they did not increase employment. Additionally, some firms are profitable although they experienced a decline in turnover.

Table 3: Pearson correlations of performance indicators – ABOUT HERE

6 Estimation results

The error component model of equation (3) was estimated using the e-Business Market W@tch data. Table 4 reports the estimation results.

Table 4: Fixed effect logistic regression results – ABOUT HERE

The results in Table 4 indicate that all four types of innovation are positively associated with turnover and employment growth and negatively associated with stagnating turnover and employment development. Yet, there are also some differences between product and process innovations: while product innovations are positively associated with profitability, internal process innovations do not show a significant relation with profits. This holds for both Internet- and non-Internet-enabled process innovations. Also, product innovations are negatively associated with decreasing turnover, while non-Internet-enabled product innovations are negatively associated with decreasing employment. Thus, firms that conduct product or service innovations are less likely to be in the group of firms experiencing decline. However, this does not hold for internal process innovations. Enterprises engaged in improving internal processes are not less likely to exhibit decreasing employment or turnover levels. This corresponds with the view that process innovations are a defensive strategy, aimed at defending or increasing market shares in existing markets; whereas product innovations represent an offensive, growth-oriented strategy, which aims at entering new markets. Also, it implies that process innovations are more likely to have a labor-substituting effect at the firm level than product innovations, meaning that firms facing decline might invest in a labor-saving process innovation to reduce costs.

Interestingly, Internet- and non-Internet related innovations only reveal small differences in estimated coefficients. In other words, whether firms use the Internet or not to innovate is less important than whether they innovate at all. Furthermore, the differences between process and product innovations are greater than the differences between Internet- and non-Internet-related innovations.

In addition, it is interesting to observe that firms that are more advanced in the use of e-business technologies (i.e., firms having adopted a higher number of e-business technologies) have a greater chance of exhibiting increasing turnover. However, no significant effect can be reported for profitability. Furthermore, firms that are endowed with a higher number of e-business technologies have a higher chance of being in the group of firms that decrease employment, suggesting that IT may have a labor substituting effect in the long term.

The results also support standard economic predictions: small firms with a small market share are less likely to be profitable, and they are also less likely to exhibit increasing turnovers. On the other hand, firms with high market shares are significantly more likely to be profitable, suggesting that they can exploit a certain degree of market and price setting power. Firms with a low market share have a higher chance of exhibiting shrinkage in turnover and employment development, suggesting a decline of enterprises that were not able to capture larger shares of their respective markets.

In all regressions, the proxy variable for the average skill level of employees (% of employees with a university degree) did not turn out to be significant, possibly suggesting that it was an improper proxy to measure the relevant types of skills required in different kinds of firms.

7 Discussion

There are four key messages arising from the empirical analysis:

1. Internet-based technologies are currently important enablers of innovation.
2. All four types of innovation are positively associated with turnover and employment growth at firm level.
3. Only product/service innovations are positively associated with profitability. Process innovations do not show significant inter-relation with profits.
4. Internet-enabled innovations are at the very least not “inferior” to other kinds of innovations in terms of positive correlation with performance indicators.

Although the direction of the causality between innovative activities and performance is ambiguous, it may be surprising to find that only product/service innovations are positively associated with profitability, while process innovations are not. However, the results can be rationalized using the conceptual framework outlined in Section 3: a simple explanation could be that process innovations take longer to generate positive returns than product innovations. Process innovations are organizationally embedded and have to be routinized. Such lagged effects are obviously not observable in this cross-sectional dataset. Additionally, process innovation might be interdependent with other technologies and firm-specific resources and may therefore not yield optimal returns if those complementary assets are not available or not advanced enough.

In addition, strategic advantages of conducting process innovations are only sustainable (thus increasing the chance that a company exhibits positive profits in the long run) if direct rivals have not imitated the innovation yet (Reinganum, 1981; Götz, 1999; Stoneman and Kwon, 1996). According to this view, the adoption of generic "best practice" solutions or technologies, often suggested by process re-engineering consultants and standard business software packages, generates only temporary excess returns at best, lasting only as long as competitors do not successfully copy the same practice. The empirical result that product innovations are positively associated with profitability but process innovations are not could suggest that the firms included in this sample are more successful in differentiating their products and services than their production processes.

Assuming reverse causality, in which innovation follows performance and not the other way around, the empirical results also have an interesting interpretation: it would suggest that profitable firms are more likely to invest in product than in process innovation, which would imply that profitable firms are more customer-oriented, focusing on new products and services to satisfy customer needs rather than on cost leadership.

In any case, the results emphasize the strategic importance of innovation. Innovative firms are significantly more likely to grow than non-innovative firms. This holds for all types of innovations included in this study. However, excess profits from innovations additionally require that the innovator can limit imitation from competitors.

8 Limitations

It should be recalled that appropriability methods vary greatly in their kind and effectiveness among industries (Levin et al., 1987; Cohen et al., 2000). Thus, the empirical results of this study with respect to profitability could be sensitive to the industries included in the sample. Consequently, the result of this study that process innovation (whether Internet-enabled or not) does not correspond to higher profitability should not be generalized. Furthermore, it would be interesting to conduct similar studies in other countries (outside of Europe) and in other industries (for example, in the banking and financial services industry, which is a leading user of e-business technologies).

Furthermore, although the data used for this analysis are unique and interesting in various ways, they also have shortcomings. Obviously, it would be desirable to have panel data to observe the causality of innovation on firm performance, as well as the effects of past performance and other lagged variables. In addition, panel data would enable controlling for unobserved heterogeneity at the firm level. Quantitative instead of qualitative performance variables would be desirable because they contain a greater amount of information. Furthermore, one might question the precision of the performance variables. Yet, as long as the potential imprecision of the answers is not systematically related to the explanatory variables, the direction of the regression results will remain unaffected. For most variables, this seems to be a plausible assumption. However, there is one exception: it could be argued that the profitability variable in this dataset is not an objective variable (indicating whether a firm has made positive profits in the last financial year), but is rather a subjective variable, measuring the profits of a firm vis-à-vis some aspiration level that depends on past performance. For example, firms that experience growth could have higher aspiration levels regarding their profits than firms that experience a decline. Thus, it could be that some firms that were actually objectively profitable did not report it as such and vice-versa, because they were making reference to their aspiration levels, which are unobservable in the data. If past growth is positively associated with current growth and innovative activities, and also with higher aspiration levels for profitability, the results could be biased, underestimating the positive relation between innovative activity and profitability. Thus, if such a bias indeed exists, the main messages of this study would be unaffected, with the possible exceptions that a significant positive relation between process innovation and profitability might exist.

9 Conclusion

The conceptual framework and the empirical results presented in this article provide some new insights on the relation between technology, innovation, and firm performance. It is argued here argued that the adoption of new technologies that were invented and produced elsewhere could enable process or product innovations in the adopting firm. The empirical results show that this is currently very common for Internet-based technologies. In addition, it is also argued that innovation is mediating the effect of technology investments on performance. Logically, the simple purchase of or investment in new technology without any subsequent qualitative change in production processes or product offers cannot be a source of improved performance. Furthermore, the actual performance implications of such investments are contingent upon firm- and market-specific factors that influence the ability of a company to successfully transform technology investments into innovations, the reaction of customers, and the ability to protect these innovations from imitation by competing firms. From this perspective, the largely inconclusive empirical literature on the performance implications of IT investments (Kohli and Devaraij, 2003) no longer appears so surprising since most of these studies focused on how much firms invested in IT instead of focusing on how these IT investments qualitatively change production processes, products or service offers.

The empirical results of this study showed that innovative firms are more likely to grow, but not necessarily more likely to be profitable. Furthermore, it was found that firms that rely on Internet-enabled innovations are at least as likely to grow as firms that rely on non-Internet-related innovations. Nevertheless, the differences between process and product innovations turned out to be greater than the differences between Internet-enabled and non-Internet-enabled innovations. To put it bluntly, what a firm innovates is more important than how it innovates, but most important is that it innovates at all.

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ANNEX – Data description

The survey questionnaire is available online at http://www.ebusiness-watch.org/about/documents/eBiz_Questionnaire_2003b.xls; aggregated and weighted survey results can be downloaded at http://www.ebusiness-watch.org/resources/DB2003_X_Sectors.xls. On average, every fifth contact (~20%) led to a successfully completed interview. The number of attempted contacts varied among sectors and countries in order to achieve the required sampling quota (>10% of large companies with >250 employees, >30% of medium-sized companies with 50-249 employees, and >25% of small companies with <50 employees). Samples were drawn based on acknowledged business directories and databases, such as Dun & Bradstreet.

Table A1 - Sector definition of e-Business W@tch survey Nov/Dec 2003

	Sector short name	**NACE Rev. 1 Codes**
01	Textile	17 – Manufacture of textile and textile products 18.1 – Manufacture of leather clothes 18.2 – Manufacture of other wearing apparel and accessories 19.3 Manufacture of footwear
02	Chemicals	24 – Manufacture of chemicals, chemical products and man-made fibers 25 – Manufacture of rubber and plastic products
03	Electronics	30 – Manufacture of office machinery and equipment 31.1 – Manufacture of electric motors, generators and transformers 31.2 – Manufacture of electricity distribution and control apparatus 32 – Manufacture of radio, television and communication equipment and apparatus
04	Transport Equipment	34 – Manufacture of motor vehicles, trailers and semi-trailers 35 – Manufacture of other transport equipment
05	Crafts & trade	17 – Manufacture of textiles and textile products 18.1-2 – Manufacture of wearing apparel and dressing 19.3 – Manufacture of leather and leather products (footwear only) 30 – Manufacture of office machinery and computers 31.1-2 – Manufacture of electrical machinery and apparatus 32 – Manufacture of radio, television and communication equipment and apparatus 34 – Manufacture of motor vehicles, trailers and semi-trailers 35 – Manufacture of other transport equipment 20 – Manufacture of wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials 36.1 – Manufacture of furniture 45.2-4 – Construction (Building of complete constructions, building installation and completion)
06	Retail	52.11 – Retail sale in non-specialized stores with food, beverages or tobacco predominating 52.12 – Other retail sales in non-specialized stores 52.4 – Other retail sale of new goods in specialized stores, except motor vehicles and motorcycles
07	Tourism	55 – Hotels and restaurants 62.1 – Scheduled air transport 63.3 – Activities of travel agencies and tour operators;

		tourist assistance activities n.e.c. 92.33 – Fair and amusement park activities 92.52 – Museum activities and preservation of historical sites and buildings 92.53 – Botanical and zoological gardens and nature reserve activities
08	ICT Services	64.2 - Telecommunications 72 – Computer-related activities
09	Health Services	85.1 – Health activities 85.3 – Social work activities
10	Business Services	74.1 – Legal, accounting, book-keeping and auditing activities; tax consultancy; market research and public opinion polling, business and management consultancy; holdings 74.2 – Architectural and engineering activities and related technical consultancy 74.3 – Technical testing and analysis 74.4 – Advertising 74.5 – Labor recruitment and provision of personnel 74.6 – Investigation and security activities 74.7 – Industrial cleaning 74.8 – Miscellaneous

Table A2 - Country-sector coverage e-Business W@tch survey Nov/Dec 2003

	Sector									
Country	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**
Austria				68			132		100	
Belgium		101				100				100
Cyprus						64				
Czech Republic		60		60			60	60	60	
Denmark						67	67		66	
Estonia	50	50	50	21	65	50	50	50	50	50
Finland	75		75					76		
France	100				101				100	100
Germany	100				100				100	100
Greece	84		76	89	75		75			
Hungary			80	80						80
Ireland		70					70	71		
Italy	100				100				100	101
Latvia	51	49				51				
Lithuania						57				
Malta							51			
Netherlands	100							101	102	
Norway	30					70				
Poland	80	80	80	80	80	80	80	80	80	80
Portugal				104		100				100
Slovakia	50		50			50				60
Slovenia			56				51	53	55	58
Spain	101				108				101	100
Sweden		80	75	79						80
UK	100				100				100	100

Note: Table shows number of successfully completed interviews.

Figure 1: Relation between technology, innovation and firm performance

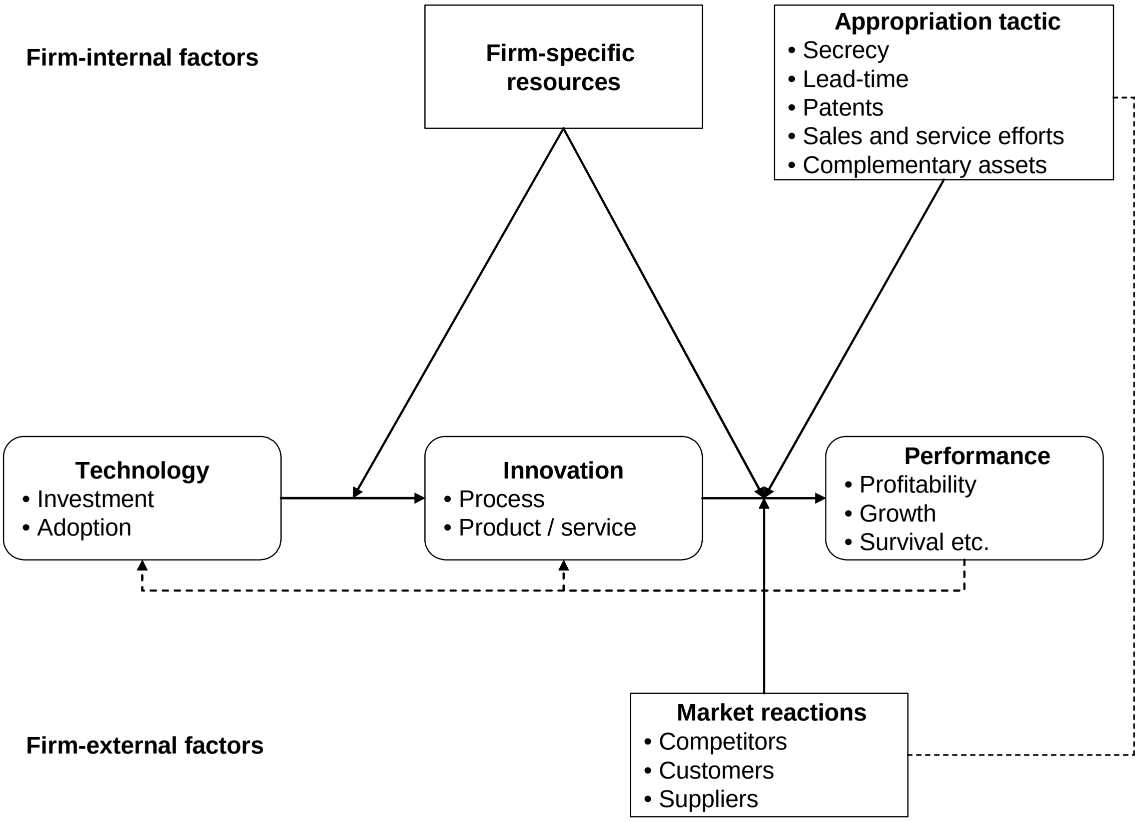
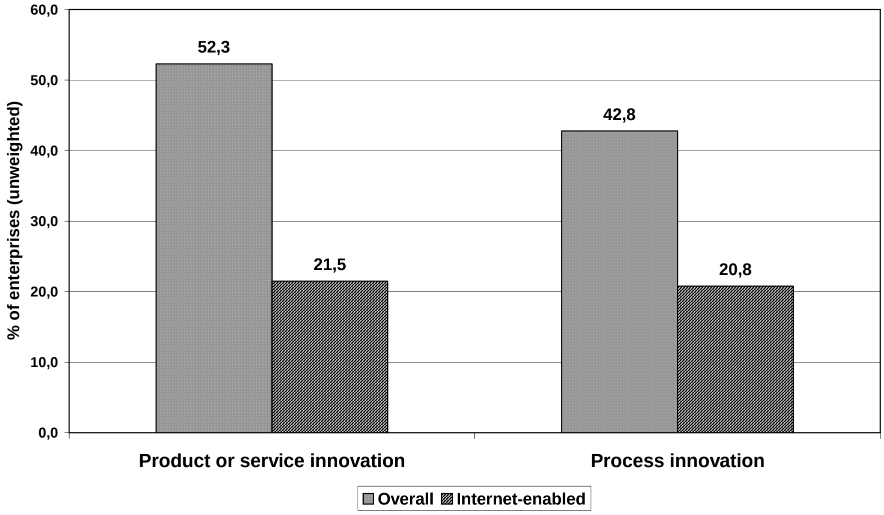


Table 1 - Relative frequencies of 7 e-business technologies, Nov 2003

Technology	**Occurrence in sample**
E-learning	8%
Customer Relationship Management System (CRM)	9%
Online purchasing	38%
Online sales	14%
Enterprise Resource Planning System (ERP)	9%
Knowledge Management System (KMS)	6%
Supply Chain Management System (SCM)	3%
N=7,302. Unweighted results.	

Figure 2: Innovative activities of companies 2002-2003



Note: Unweighted survey results, e-Business Market W@tch Nov/Dec 2003

Table 2: Performance indicators of companies 2002-2003

	Relative frequency	N
Turnover: comparison last financial year with year before		
increased	44%	6,253
decreased	20%	
roughly stayed the same	35%	
Has your company been profitable over the last 12 months?		
yes	82%	6,443
No. of employees: comparison last financial year with year before		
increased	23%	7,218
decreased	18%	
roughly stayed the same	59%	
Note: Unweighted survey results from Nov/Dec 2003.		

Table 3: Pearson correlations of performance indicators

	Profit	Employment (increase)	Employment (unchanged)	Employment (decrease)
Turnover (increase)	0.22* (N=5,887)	0.34* (N=6,226)	-0.12* (N=6,226)	-0.21* (N=6,226)
Turnover (unchanged)	0.01 (N=5,887)	-0.19* (N=6,226)	0.19* (N=6,226)	-0.04* (N=6,226)
Turnover (decreased)	-0.28* (N=5,887)	-0.20* (N=6,226)	-0.08 (N=6,226)	0.31* (N=6,226)
Profit				
Employment (increase)	0.11* (N=6,408)			
Employment (unchanged)	0.09* (N=6,408)			
Employment (decrease)	-0.24* (N=6,408)			

e-Business Market W@tch Nov/Dec 2003.
* denotes significance at the 99% confidence level.

Table 4: Market-fixed-effect logistic regression results

Co-variables	*Turnover increase*	*Turnover unchanged*	*Turnover decreased*	*Profit*	*Employment increase*	*Employment unchanged*	*Employment decreased*
Product or service innovations last year:							
Internet-related	0.40**	-0.20*	-0.29**	0.35**	0.41**	-0.20	-0.17
non-Internet-related	0.44**	-0.28**	-0.22**	0.24**	0.38**	-0.16	-0.17*
Internal process innovations last year:							
Internet-related	0.40**	-0.34**	-0.14	0.03	0.58**	-0.40**	-0.09
non-Internet-related	0.33**	-0.22**	-0.18	0.05	0.50**	-0.40**	0.06
10-49 empl.	0.26**	-0.02	-0.31**	0.05	0.89**	-0.73*	0.23**
50-249 empl.	0.27**	0.13	-0.59**	-0.08	0.88**	-0.88**	0.50**
>250 empl.	0.41**	-0.20	-0.35*	-0.10	0.86**	-1.24**	0.99**
Market share:							
< 1%	-0.29**	-0.13	0.5**	-0.54**	-0.10	-0.20	0.39**
1%-5%	-0.06	-0.15	0.29*	-0.04	-0.03	-0.16	0.27*
6%-10%	0.23*	-0.06	-0.28	-0.01	0.17	-0.20	0.13
11%-25%	0.12	-0.08	-0.07	0.35*	0.32**	-0.35**	0.17
> 25%	0.14	-0.09	-0.09	0.23*	0.08	-0.10	0.08
% empl. w/university degree	0	0	0	0	0	0	0
# e-business technologies	0.15**	-0.16**	-0.06	0.03	0.03	-0.09*	0.08*
Model diagnostics							
N obs	5,697	5,697	5,697	5,796	6,415	6,415	6,415
N groups	101	101	101	100	101	101	101
Log-likelihood	-3,355	-3,328	-2,453	-2,320	-2.905	-3.783	-2,586
Sign. (Prob>chi2)	0	0	0	0	0	0	0

** denotes significance at the 95% confidence level, * denotes significance at 90% confidence.
Reference categories: no innovations last year, 1-9 empl., market share unknown

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