Special Report No. 01/2006

Impact of ICT on Corporate Performance, Productivity and Employment Dynamics

Authored by Dr. Philipp Koellinger

December 2006

European Commission
Enterprise & Industry Directorate General
Technology for Innovation / ICT Industries and e-Business

About *e-Business W@tch* and this report

The European Commission, Enterprise & Industry Directorate General, launched the *e-Business W@tch* to monitor the growing maturity of electronic business across different sectors of the economy in the enlarged European Union, EEA and Accession countries. Since January 2002, the *e-Business W@tch* has analysed e-business developments and impacts in manufacturing, construction, financial and service sectors. All results are available on the internet and can be accessed or ordered via the Europa server or directly at the *e-Business W@tch* website (www.europa.eu.int/comm/enterprise/ict/policy/watch/index.htm, www.ebusiness-watch.org).

This document is an interim report of a Special Report, focusing on the impacts of ICT on corporate performance, productivity and employment dynamics. Analysis is based on a literature review. Descriptive and econometric results based on a Europe-wide survey of enterprises will be added for the final document.

Disclaimer

Acknowledgements

Contact

For further information about this Sector Study or the *e-Business W@tch*, please contact:

DIW Berlin	e-Business W@tch	European Commission
DIW Berlin Königin-Luise-Str. 5 14195 Berlin, Germany Fax: (49-30) 89789-103	**e-Business W@tch** c/o empirica GmbH Oxfordstr. 2, 53111 Bonn, Germany Fax: (49-228) 98530-12 info@ebusiness-watch.org	**European Commission** Enterprise & Industry Directorate-General Technology for innovation, ICT industries and e-business Fax: (32-2) 2967019 entr-innov-ict-ebiz@ec.europa.eu

Rights Restrictions

Table of Contents

Executive Summary

Objectives and scope of the study

This study deals with the impact of Information and Communication Technologies (ICT) on corporate performance, productivity and employment dynamics. Its objective is to summarise recent research results on this topic based on a literature review and to develop and test hypotheses using data from the e-Business Survey 2006 conducted by *e-Business W@tch*.

Impact on corporate performance

In this report, corporate performance is empirically measured in terms of turnover growth. The hypothesised relationship between ICT and turnover growth is straightforward: The implementation of new ICT and complementary investments can lead to innovations, and innovations are positively associated with turnover growth. In other words, innovative firms are more likely to grow. This holds for ICT- and for non-ICT-related innovations, as well as for process- and product-innovations. The empirical results support this view and indicate that innovative firms exhibit increasing turnovers significantly more frequently than non-innovative firms.

The relationship between ICT usage and profitability is more complex and contingent upon firm- and market-specific factors such as the timing of the investment relative to competing firms and the reaction of competing firms in the market. Hence, no general relationship between ICT usage and profitability can be hypothesised because profitability crucially depends on the respective competitive environment of each individual firm and its ability to limit imitation by rivals.

Impact on productivity

Although measurement problems and a debate about the sustainability of ICT-enabled productivity growth remain, there is now a growing consensus that ICT does have positive effects on labour- and total-factor-productivity. However, the effects vary greatly between sectors and countries. Furthermore, the link between ICT-investments and productivity is rather indirect, and positive effects are contingent upon additional complementary investments into innovation and human capital at the firm level. The empirical evidence reported here suggests that innovative firms are more likely to exhibit productivity increases at all stages of ICT development. Also, more advanced users of ICT are more likely to experience productivity gains. These results suggest that intense ICT usage combined with innovate activity are positively related to productivity growth at the firm level.

Impact on employment

Whether the increasing use of ICT creates or destroys jobs remains a subject of debate. Theory suggests that the net impact depends on the relative strength of two competing effects: On the one hand, the use of ICT can lead to innovations, which can result in output growth and a concomitant growth in jobs. On the other hand, process innovation and ICT-related productivity gains imply that a given output level can be produced with less labour input. In addition, there can be substitution effects if new ICT-related products and services replace other, potentially more labour-intensive, products and service. Depending on which of these effects dominates, the net impact of ICT on job growth could be positive or negative. Furthermore, the net effect can vary between the firm level, the industry level, and the macroeconomic level. ICT as investment products can generate additional employment in some sectors and labour displacement in others. This is part of the structural changes that are caused by the diffusion of ICT in the economy, which will ultimately lead to a more efficient allocation of resources in the long run.

New empirical results based on firm-level data from the *e-Business W@tch* 2006 survey suggest a positive relationship between ICT-enabled innovations and employment growth. In addition, more advanced users of ICT in the sample are significantly more likely to increase employment than less advanced users of ICT. Finally, the empirical results suggest that firms with a high share of college-educated employees tend to be more advanced users of ICT, while the opposite holds true for firms with a lower share of college-educated employees. This is consistent with the view that a highly skilled workforce and intense ICT usage complement each other. This could lead to changes in the labour market, which over-proportionately benefit highly skilled individuals. However, because the *e-Business W@tch* 2006 survey does not cover all sectors of the economy, the results reported here cannot be extrapolated to the aggregate level.

Policy implications

This report concludes that ongoing action of public policy is mainly needed in two areas:

- Improving the framework conditions for innovation in general; this includes education, Research and Development (R&D), and market regulation.

- Monitoring and analysing recent technological developments, with the aim to inform governmental institutions, industry and the interested public about implications of these developments.

1   Introduction

This study deals with the impact of ICT on corporate performance, productivity and employment dynamics. Its objective is to summarise recent research results on this topic based on a literature review and to develop and test hypotheses using data from the 2006 *e-Business W@tch* enterprise survey (see Annex I).

The ongoing diffusion of new ICT and e-business technologies among firms is a current example of the dynamics of technological change and economic development (Koellinger 2006). Economic theory suggests that the diffusion of new technologies can have far-reaching consequences. Most fundamentally, it may change the type of products and services that are offered and traded and it may change the production costs of existing products. Hence, virtually all economic spheres can be affected by such changes, including innovation dynamics, productivity and growth, the development of market structures, firm performance, and the demand for (certain types of) labour. Not all new technologies will necessarily lead to disruptive or even measurable changes in any of these variables. Yet, there is good reason to believe that e-business as a technological paradigm, comprised of various tools and applications to optimise the flow and the availability of commercially relevant information based on computer networks, has such a general scope to yield a measurable economic impact.

On the conceptual level, there exists a clear link between the adoption of new e-business technologies and innovation (Koellinger 2005, 2006). E-business and ICT investments in general can enable process innovations if the implementation of new ICT succeeds, the routines are changed and the new system is actually utilised. ICT investments can also enable product or service innovations at the enterprise level. For example, a company that adopts and implements a new online shop software usually changes the routines of how incoming orders are processed. This is an example of a process innovation. Also, 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. This conceptualisation of ICT as an enabler of innovation allows a market-based, economic approach to study the impact of ICT on corporate performance and employment dynamics.

Adopting this market-based, economic perspective, this report focuses on possible consequences of ICT and e-business in three different, although related, areas: (1) corporate performance, empirically measured by turnover development, (2) productivity and (3) employment dynamics. Based on a literature review of recent research findings on these topics, hypotheses are developed that are confronted with the data from the 2006 *e-Business W@tch* survey. The literature review provides a fairly comprehensive overview of the current state of research. Together with the new empirical evidence, this report gives an overview of the current economic impacts of ICT.

2 Corporate performance

The management literature recognises 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. 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 emphasise 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 report, organisational performance is measured in terms of turnover growth.

The effects of ICT on corporate performance are subject to debate because not all studies have demonstrated clear payoffs from ICT investments (Chan, 2000, Kohli and Devaraj, 2003). Also, the results vary depending on how performance and ICT payoffs are measured and analysed. For example, one empirical study finds positive impacts of ICT investments on productivity, but not on profits (Hitt and Brynjolfsson, 1996). Another study did not find positive effects of ICT capital on productivity, while ICT labor positively contributed to output and profitability (Prasad and Harker, 1997).

An analysis of the profitability of ICT investments in an empirical study that explicitly considered the competitive dynamics in a market showed that the profits of non-adopters of ICT are reduced as other firms adopt new ICT. Furthermore, the gross profit gains of ICT adoption are related to firm and industry characteristics and the number of other users of the technology (Stoneman and Kwon, 1996). Along similar lines, another study suggests that early adopters of ICT are likely to benefit, but once the technology becomes common the competitive advantage is lost (Weill, 1992).

These somewhat ambiguous results on the impact of ICT on corporate performance can be explained if we drop the assumption that there is a direct link between ICT investments and corporate performance. In other words, the new economy mantra "*more ICT equals better performance*" must be rejected. Instead, a more comprehensive approach is needed to explain these findings.

The key to understanding the impacts of ICT on performance is to view ICT as an enabler of innovation (Koellinger 2005). This conceptualisation of new technologies as possible enablers of innovation allows a market-based approach to study the relationship between ICT and performance. It also allows investigating why different firms that invest in the same technology may exhibit different payoffs. In addition, this concept allows us to argue that ICT remains of strategic relevance for firms as long as it enables innovation. Innovation is a strategic variable because it allows firms to differentiate their products, services and production processes vis-à-vis their competitors, at least in the short run.

Economists have been studying innovation as a central element of markets' competitive dynamics for a long time, and various scholars have stressed the importance of innovation for corporate performance. An elementary insight from this research is that the payoffs of innovative activities in a firm are determined in 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. Both process and

product/service innovations 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 1986, Vickers 1986). 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 (Dasgupta and Stiglitz 1980). Both types of innovations will lead to growth of the innovator, everything else equal. The positive growth implications of conducting innovations are independent of the firm's ability to appropriate private profits from the investment (Götz, 1999, Hannan and McDowell, 1990, Reinganum, 1981, Sutton, 1991).

Previous empirical studies support the argument that innovation is positively associated with firm-level growth. Positive effects of ICT investments and ICT usage on revenue growth have been demonstrated in the health care sector (Devaraj and Kohli, 2000, 2003). Similar results were found in the insurance industry where top performing firms with high premium income growth had higher ICT expense ratios and lower non-ICT costs (Harris and Katz, 1991). In addition, positive effects of ICT investment on sales growth were found among valve manufacturing firms (Weill, 1992). Koellinger (2005) finds a positive relationship between ICT- and not-ICT-related innovation and turnover growth using data from the 2003 *e-Business W@tch* survey. This leads to Hypothesis 1:

> **Hypothesis 1**
>
> *Firms that conduct innovations, whether they are ICT-related or non-ICT-related, are more likely to exhibit increasing turnover*

Exhibit 1 provides support for hypothesis 1 based on the 2006 *e-Business W@tch* survey. 44% of firms that did not conduct any kind of innovation during the 12 months prior to the survey said that they experienced increasing turnovers that year. The share of growing firms is significantly[1] higher among the innovators. Seventy percent of firms that conducted ICT-enabled innovations reported turnover growth. Also, 60% (63%) of firms that used traditional, non-ICT enabled product (process) innovation said that they experienced turnover growth in the previous year. In addition, innovative firms were significantly less likely to exhibit a decrease in turnover compared to non-innovative firms. These figures clearly suggest that innovative firms are more likely to grow.

---

[1] According to Chi-2 Tests (Sheskin 2003), all group means in turnover development between non-innovative firms and all four kinds of innovative firms are significantly different at >99% confidence.

Exhibit 1 – Turnover development of firms and innovative activity 2005
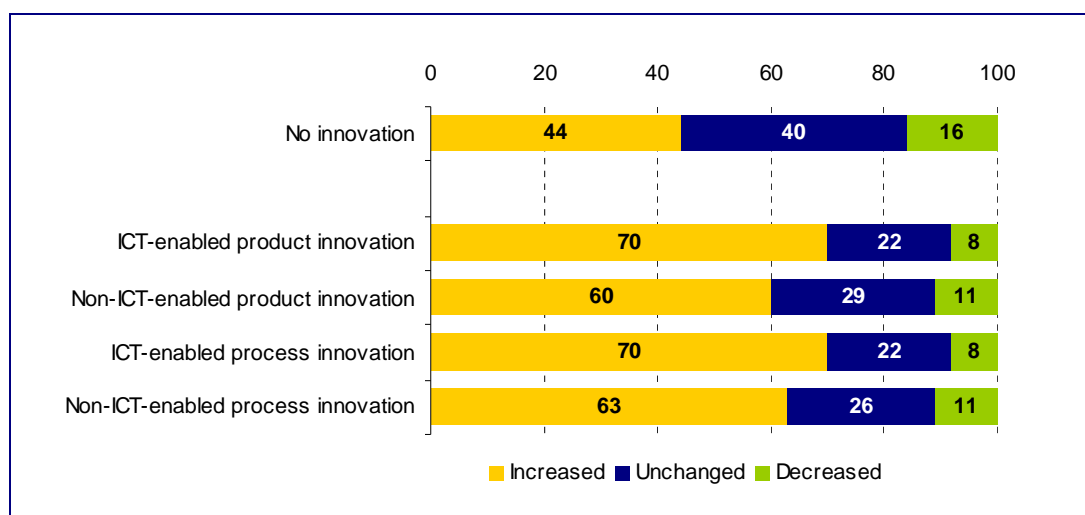
Base (100%): All companies. N = from 12,721 to 12,799 depending on missing values
Questionnaire reference: I1-4, U14

Source: *e-Business W@tch* (Survey 2006)

The relationship between innovation and profitability is more complex because it crucially 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[2]. Instead, all gains will be passed on to consumers who will benefit from lower prices and affluent competing offers. The quicker an innovation is copied by other firms, the less time each innovating firm has to reap additional payoffs from the investment into the innovation. On the other hand, social welfare is usually maximised if new products and technologies diffuse quickly and competition is intense.

Yet, without a clear expectation of – at least temporary – superior profits, firms have no incentive to invest in innovation and new technologies and economic development would stall. This is known as the "appropriability problem" (Geroski, 1995). 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. Yet, 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).

---

[2]   The economic literature points out some conditions under which early mover advantages can exist that might be sustainable even if rivals copy an innovation later on. Examples are network externalities, free entry and exit to markets, reputation effects, asymmetric information in financial markets, or positive returns to scale. Nevertheless, even if sustainable first mover advantages should exist, imitation by rivals still has a negative effect on the profitability of an innovation.

Two main messages can be drawn from the economic literature cited above: First, the timing of an innovation influences the expected payoff. Second, a trade-off exists between social welfare in the short run (which is maximised if new technologies are immediately used by all firms, which implies that no firm can gain a private profit from the investment and all gains are directly passed on to consumers via competitive prices) and social welfare in the long run (which is maximised if firms have the opportunity to gain temporary monopoly positions that allow them to generate profits from their innovative investments, which lead to technological progress and economic development).

Summarising, successful innovators might be able to capture profit gains, but this is contingent on the behaviour of rivals and on other exogenous factors that are beyond the control of the innovator. Hence, no clear relationship between ICT usage and profitability can be hypothesised because profitability crucially depends on the competitive dynamics in a market that are hard to observe in empirical studies. The econometric analysis of Koellinger (2005), using data of the Nov/Dec 2003 *e-Business Market W@tch* survey, suggests that both ICT- and non-ICT-enabled product innovations are positively associated with profitability, while no significant relationship is found for process innovations and profitability.[3]

---

[3]   Unfortunately, these results could not be replicated for this report because the 2006 *e-Business W@tch* survey does not include a variable for profitability.

3 Productivity

The joint emergence of a productivity growth resurgence in the US in the 1990's and the simultaneous massive diffusion of new ICT's has stimulated a debate about a "new economy," where ongoing productivity improvements in ICT were believed to lead to a sustainable and higher rate of total factor productivity growth. Numerous studies have since dealt with two major questions in this context: (1) How much productivity growth is due to ICT, and (2) will ICT be an additional and sustainable source of growth?

Various authors stressed that ICT may be characterised as a typical general purpose technology that, like earlier technological breakthroughs, has a wide range of applications and a large impact on economic activity (Breshnahan and Trajtenberg 1995, Helpman 1998). At the aggregate level, Jorgenson (2001) and Jorgenson and Stiroh (2000) argue that the resurgence of growth in the US is mainly founded on the development and deployment of semiconductors that continuously exhibit a price decline and increasing performance, following Moore's law (Moore 1965, Ruttan 2001 pp. 317-365). Other authors have also demonstrated an increasingly productive use of ICT in the user-sectors, and not only a productivity growth in the ICT producing sector itself (Oliner and Sichel 2000, Baily and Lawrence 2001). Gordon (2000) raised doubts about this productivity growth acceleration story and attributed most of the observed changes in US-productivity to price-measurement problems and cyclical factors. Although measurement problems and a debate about the sustainability of ICT-enabled growth remain, there is now wide consensus that ICT does have positive effects on labour productivity and total factor productivity (Pilat 2005, van Ark 2002).

ICT-induced productivity effects vary significantly between sectors (Nordhaus 2002) and among countries (van Ark 2002). The largest productivity growth effect occurs in the ICT-producing sectors themselves, and only smaller (but still measurable) effects in the well-measured non-farming business sectors. So far, only a few countries, including Australia, Canada and the United States, have clearly seen an upsurge in productivity growth in those sectors of the economy that have invested most in ICT, notably services sectors such as wholesale and retail trade, financial services and business services (van Ark et al. 2003). These industries in Europe experienced much slower productivity growth although they also invested heavily in ICT, but were not able to recoup growth effects, mostly due to structural factors (van Ark 2002, Nordhaus 2002).

In fact, the growth differences in these three industries explain much of the total observed productivity growth gap between the US and Europe at that time (Gordon 2002). Most studies show that the European Union lags behind the United States in experiencing an increase in productivity growth in ICT-using services (O'Mahony and van Ark 2003, van Ark and Inklaar 2005, Denis et al. 2004). The United States has also benefited more from the ICT-producing manufacturing sector than the European Union (O'Mahony and van Ark 2003). Nevertheless, van Ark and Piatkowski (2004) show that increasing ICT-usage has contributed to the restructuring process of manufacturing industries in Central and Eastern European (CEE) countries that contributed to the convergence process of these countries with the old EU-15. Also, they show that ICT capital in CEE countries has contributed as much to labour productivity growth as in the EU-15.

Some authors have also analysed the impact of ICT on firm-level productivity. It is usually stressed that ICT investments must be combined with complementary investments in work practices, human capital and firm restructuring to have an impact on performance (Brynjolfsson and Hitt 2000, David 1990, Greenwood and Jovanovic 1998, Malone and Rockart 1991). These complementary investments that are usually not counted as ICT-specific lead to comparatively high returns to ICT investment (Brynjolfsson and Hitt 2003). Because these complementary investments and organisational changes are highly firm-specific, empirical studies show on average a positive return to ICT investments, but with large variation across organisations (Pilat 2005).

Brynjolfsson and Hitt (2003) provided evidence that the returns to ICT investments usually do not occur immediately, but rather with a significant time lag. They find that computers make a positive and significant contribution to output growth at the firm level, but the implied returns increase if longer time differences are taken into account, which suggests that time-intensive complementary investments into organisational restructuring have to be undertaken. In a similar spirit, Hempell (2002) argues that firms with innovative experience are particularly well prepared to make productive use of ICT by introducing appropriate complementary innovations. Bertschek and Kaiser (2004) show that ICT has indirect effects on productivity by enabling workplace reorganisation and organisational change, stressing strong complementarities between these investments.

Summarising, ICT is indeed a relevant part of current technological change processes and an important factor that contributes towards growth. However, the magnitude of impact varies significantly between firms, sectors and countries and can either be hampered or promoted by external factors. Also, there is growing consensus that the link between ICT-usage and productivity growth is rather indirect and that a positive impact arises only if ICT investments are combined with complementary investments into innovation and human capital.

Since complementary investments into innovation and organisational change seem to be necessary to generate positive effects of ICT investments on productivity, the following hypothesis can be formulated:

> ### Hypothesis 2
>
> *Positive effects of ICT on productivity are more likely to occur in firms that conduct innovations.*

Hypothesis 2 states that ICT-related productivity gains should be more likely to occur in firms that innovate than in firms with a comparable degree of ICT usage but no innovative activity. The hypothesis builds on the above-discussed logic that ICT investments often need to be combined with complementary investments to generate positive impacts on productivity. Complementary investments to ICT are in most cases related to innovation. For example, organisational change or process-redesign are typical complementary investments to the adoption of new ICT that result in process innovation. Thus, whether firms conduct innovation or not is a proxy for whether they carry out complementary investments when adopting new ICT. Hence, if ICT adoption requires complementary

investments to generate productivity gains, positive effects of ICT adoption on productivity should be more likely to occur in innovative firms.

In addition, the economic growth literature discussed above leads to another hypothesis relating to ICT usage and productivity. Evidence shows that ICT-related productivity increases are primarily observed in those sectors that have invested heavily in the usage of ICT, including trade, financial services, business services, and the ICT manufacturing sectors themselves (van Ark 2002, van Ark et al. 2003, Nordhaus 2002).

There are various possible reasons for this empirical observation. For example, it could be that ICT generates more substantial possibilities for product, process, and service improvements in some sectors than in others. Thus, the technological opportunities could vary among sectors. This would justify why some sectors are more intensive users of ICT than others are, and it would rationalise why productivity growth is more likely to be observed in those sectors that have heavily invested. In addition, sectors that have already made substantial investments in ICT usually consist of many firms that were among the early users of new ICT solutions. Thus, these sectors started to use particular ICT before other sectors did. Since productivity gains due to ICT usually fully materialise with some significant time lag after the initial investment (Brynjolfsson and Hitt 2003), it could be that the positive productivity effects of ICT are particularly noticeable in sectors that are already advanced users of ICT because these early movers had more time to realise the positive effects of ICT-related investments. Thus, due to differences in technological opportunities across sectors and/or due to earlier investments and time gaps between investments and productivity increase, it is plausible to expect that ICT-related productivity gains are more likely to occur among advanced users of ICT. Thus, the following hypothesis can also be formulated:

> **Hypothesis 3**
>
> *Positive effects of ICT on productivity are more likely to occur in firms that are advanced users of ICT.*

These two hypotheses are jointly examined in Exhibit 2, which shows evidence on the relationship between ICT usage, innovation and productivity development, based on 2006 *e-Business Watch* survey data. The telephone interviews contained a question asking respondents if the productivity of their firm increased, decreased or stayed roughly the same, comparing the last financial year with the year before. The respondents had to give ad-hoc answers, so most likely this variable is only a very crude and potentially biased measure of productivity development. Nevertheless, it provides first results that could be investigated with more methodical rigor in follow-up studies.

The x-axis of Exhibit 2 shows how many out of 7 e-business technologies a firm is currently using. This serves as a proxy for the ICT development level of firms, with the simple intuition that the more advanced a firm is the more e-business technologies it uses, everything else equal. Relating this to the percent of firms reporting productivity increases (y-axis) shows that more advanced users of ICT are more likely to experience a positive trend in productivity, represented by the upward slope of the curves in Exhibit 2. This supports hypothesis 3.

Exhibit 2 – Productivity increase, ICT usage and innovative activity
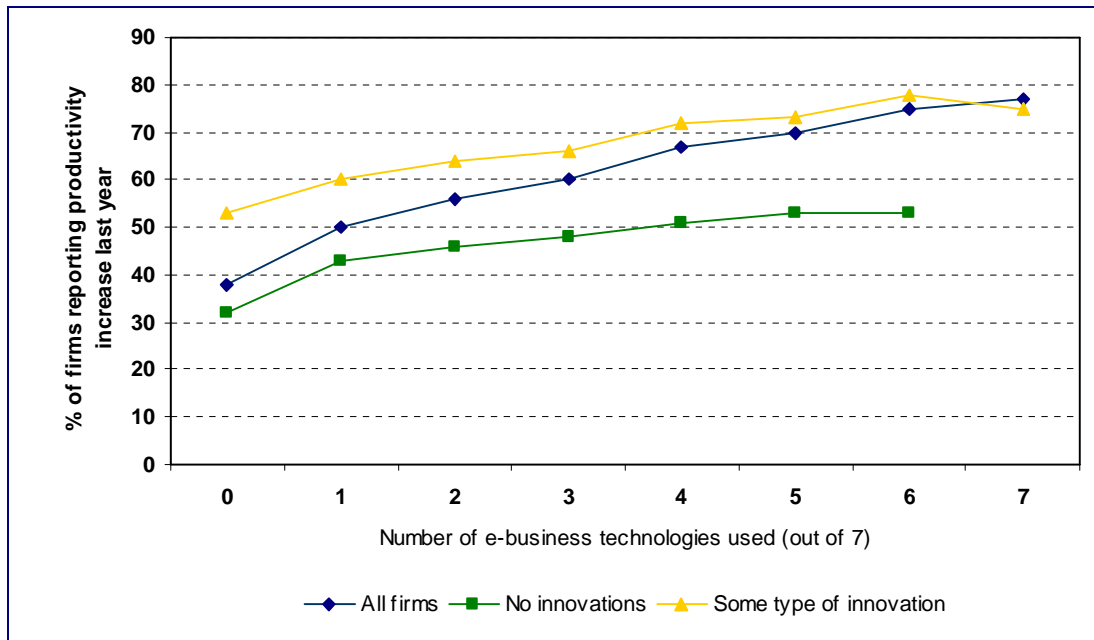
Base (100%): All companies. N = 10,392
Questionnaire reference: I1-4, U16, D1b, D1d, D1f, B5, E1, F2, F4
Technologies counted are: E-Learning, ERP, SCM, Knowledge Management, CRM, Online Sales and Online Purchasing

Source: *e-Business W@tch* (Survey 2006)

Exhibit 2 also suggests that innovative firms (yellow line at the top) are more likely to exhibit productivity increases than non-innovative firms (green line at the bottom) at all stages of ICT development. This supports hypothesis 2. Both the positive correlation between ICT development level and productivity increase as well the difference in productivity development between innovative and non-innovative firms at all stages of ICT development are statistically significant at above the 99% confidence level. Thus, there is empirical support for the claim that positive effects of ICT on productivity are more likely to occur in firms that conduct innovations and firms that are already advanced users of ICT. The lowest share of firms that reported productivity improvements is among non-innovating firms with low degrees of ICT usage.

4   Employment dynamics

Other highly relevant and much debated issues are the employment effects of innovation and technical change in general, and the impacts of ICT on employment dynamics in particular. The central question is if technological change and an increasing use of ICT creates or destroys jobs. There is no unambiguous answer to it, and recent research has emphasised that employment effects vary with the level of analysis (firm, sector, national economy) and the type of innovation (product vs. process).

A common simplified argument is the following: Because innovation and an increasing use of ICT are related to growth, it is believed that innovation and intense usage of ICT will solve the unemployment problem in Europe. However, innovations and ICT investments might lead to productivity growth without leading to GDP growth. The employment effects can be very different for productivity and GDP growth (Edquist et. al. 2001). In addition, growth effects vary for miscellaneous types of innovation (Kuznets 1972). A common conceptual framework is to differentiate between product and process innovations. This conceptual framework can also be applied to study the impacts of ICT because ICT investments can result in product or process innovations at the firm level. Product innovations can occur in goods or in services, while process innovations can be either technological or organisational, with varying implications for employment effects.

A product innovation corresponds to the creation of a new production function. Given a sufficient demand for the new product, it will usually create additional demand for both capital and labour production factors by the innovating firm. This is often called the *compensation effect* (Pasinetti 1981). However, if the new product does not satisfy a completely new kind of demand or does not serve an entirely new function, i.e. if it only functionally replaces an old one, there will also be a *substitution effect*. The net employment effect of such an innovation could be either negative or positive, depending on (1) whether the new demand for satisfying the function changes when the new product replaces the old one and (2) the labour intensity of the production technology of the new product compared to the old one. However, in most cases product innovations are employment creating even if substitution effects are taken into account (Katsoulacos 1986, Kuznets 1972, Edquist et. al. 2001, p. 97).

Process innovations usually also have both a compensation and a substitution effect, however, their net effect is less clear than for product innovations. Process innovations usually reduce the costs of production for a given unit of output; hence, they increase productivity per unit of input. In micro-economic models, this corresponds to an outward shift of an existing supply function. Depending on the price elasticity of demand, this outward shift of the supply function will lead to growth and lower equilibrium prices.

This compensation effect is stronger for competitive industries and high price elasticity's of demand. However, an increase in productivity implies that a given level of output can be produced by less amount of input. Thus, if demand and output remain constant, a process innovation will lead to a reduction of labour, ceteris paribus. While the compensation effect can mitigate job losses, they can only promote net employment gains when growth in production and demand outstrips productivity growth. This only

happens when the price elasticity of demand is greater than zero, which is only rarely the case (Edquist et. al. 2001, p. 119).

Also, the effects depend on the specific kind of process innovation. Technological process innovations that replace labour by capital will have a stronger employment reducing effect than process innovations that lead to organisational changes. In fact, organisational process innovations might be either labour saving or capital saving, while technological process innovations are primarily labour-saving (Edquist et. al. 2001, p. 35-37). Organisational innovations are also special in the sense that they can be viewed as investments into human capital by the provision of new knowledge through education, training and learning-by-doing (Becker 1975). This constitutes a special kind of investment because it is durable, generates continuing returns and is embodied in "knowledge carriers" (Machlup 1980). Thus, if an employment reducing effect of organisational process innovations exists at all, it is likely to be much smaller than the employment reducing effect of technological process innovations.

In addition to this static firm-level view on different kinds of innovation, a dynamic macro-level view emphasises that there are likely to be secondary effects of innovation because whether something is a process or a product innovation is essentially a matter of perspective. Some product innovations in one sector can turn out to be process innovations in another sector leading to secondary employment effects. Edquist et. al. (2001, p. 100) differentiate the net-employment effect of product innovations according to three product categories consumer products, investment products and intermediate products. Only investment products can play the double role of employment generation in one sector and labour displacement in another. The net-employment effect of an investment product innovation hence depends both on the effect in the technology producing sector and the effects in the using sectors. ICT are an example of such an investment product, which makes the net employment effects of ICT more ambiguous. For consumer and intermediate goods innovation, there is usually only the primary (typically employment increasing) effect.

A double role of product innovation can also occur in the service sector if the new product is an organisational innovation that is commoditised and sold as a consulting service. The net employment effect of such an organisational innovation depends also on the size of the compensation and the substitution effect in the sectors adopting the innovation and in the sector that supplies the consulting service. An example of such an innovation are ICT outsourcing services. Again, the net employment effect is hard to determine and it cannot be simply assumed that it will be necessarily positive.

Thus, it is clear that the employment effects of innovations depend on the specific type of innovation. They can also vary significantly between aggregation levels (firm, industry, national economy). An employment increase in one (successfully innovating) firm might lead to employment losses at the industry level or at the national level, depending on whether output growth offsets productivity growth. Thus, the net impact of an innovation on employment remains essentially an empirical issue that cannot be unambiguously predicted ex ante.

Empirical evidence suggests that overall employment effects of innovation at the firm level tend to be positive. Firms that innovate in products, but often also in processes, grow faster in their respective markets and are more likely to expand their employment

than non-innovative firms, regardless of industry, size, or other characteristics (for an overview see Pianta 2004).

From a more aggregate perspective, empirical studies on the industry level show that the employment impact is positive in industries characterised by high demand growth and orientation towards product (or service) innovations, while process innovation tends to lead to job losses. Recent sectoral evidence for Europe suggests a prevalence of labour-saving process innovations. Slow growth on the demand side and increasing international competition has pushed many firms towards restructuring and process innovations. This leads to the well-known phenomenon of jobless productivity growth, which is currently being witnessed in many European countries. However, product innovation has confirmed its positive effects on output and jobs (Pianta 2000, 2001, Antonucci and Pianta 2002, Evangelista and Savona 2002, 2003).

The overall effect depends on the country and period being studied. The higher economic growth (total output and demand), the higher is the positive impact of innovation, while technical change in stagnating or closed economies tends to be associated with serious employment losses. According to Pianta (2004), the empirical evidence suggests that institutional factors and macroeconomic conditions play an important role for the nature and the effect of technical change on employment at the macro level. The employment impact is generally more positive the higher is the ability to generate new products and to invest in new economic activities, and the stronger is the effect of price reduction, leading to increased demand. Aggregate studies generally point out the possibility of technological unemployment, which emerges when industries or countries see the prevalence of process innovations in contexts of weak demand. Firms innovating in both products and processes may be successful in expanding output and jobs regardless of economic context, but often at the expense of non-innovating firms. Yet, the long run trend has been towards simultaneous growth in per capita income, productivity and employment growth (van Ark et al. 2004)

The *e-Business W@tch* survey provides data that allow the analysis of the patterns of innovative activity and employment development at the firm level. Studying the employment effects of ICT at the sector or country level is not possible with the *e-Business W@tch* data since they lack both the required dynamic perspective and a comprehensive coverage of all sectors of the economy. Thus, the empirical analysis in this report only looks at the firm-level effects of ICT, innovation and employment.

In particular, the above discussed finding that product innovations are often associated with employment growth at the firm level should hold both for ICT-related and "traditional," non-ICT-related product innovations. Yet, it is unclear ex ante if this positive effect will also hold for ICT-enabled process innovations. Thus, the following hypothesis can be stated:

> **Hypothesis 4**
>
> *Firms that conduct product innovations, whether they are ICT-related or non-ICT-related, are more likely to increase employment.*

Hypothesis 4 reflects the findings from previous research on the relationship between product innovation and employment development (Katsoulacos 1986, Kuznets 1972, Edquist et. al. 2001, p. 97) and extends them to ICT-related product innovations. The hypothesis is not trivial because, from a theoretical perspective, a negative impact of product innovation on employment at the firm level could occur if the new product substitutes an old product the same firm produces, and if the old product was more labour intensive. However, the existing empirical evidence suggests that is rarely the case. Thus, according to existing empirical literature, Hypothesis 4 claims that positive effects of *both* ICT-related- and non-ICT-related product innovations on firm-level employment growth can be expected.

Exhibit 3 provides support for hypothesis 4. 22% of non-innovative firms report an increase in employment, compared to 34% of firms that carried out non-ICT-enabled product innovations and 43% of firms that had ICT-enabled product innovations. The share of employment increasing firms is significantly higher among firms with product innovations than among non-innovative firms at above the 99% confidence level.[4]

Although not explicitly hypothesised, the data suggest a similarly positive pattern for process innovations. Thirty-seven percent of firms that conducted non-ICT-enabled processes, and 43% of firms that reported ICT-enabled process innovations increased employment in 2005. Again, these are significantly higher shares of firms that increased employment than in the reference group of non-innovative firms.[5] Thus, at least for the firms included in this sample, there is no evidence for an employment decreasing effect of process innovations. Also, firms that used ICT to innovate were more likely to increase employment than firms that innovated in non-ICT-related ways. This finding corresponds to econometric results with data from the *e-Business W@tch* 2003 survey (Koellinger 2005). Together, these empirical results suggest that the immediate effect of ICT usage and innovation on employment at the firm level is positive. However, as outlined above, this cannot be generalised to the sector or country level as their might be substitution effects that are not captured at the micro level of analysis.

---

[4]   According to Chi-2 Tests (Sheskin 2003).

[5]   According to Chi-2-Tests (Sheskin 2003).

Exhibit 3 - Employment development of firms and innovative activity
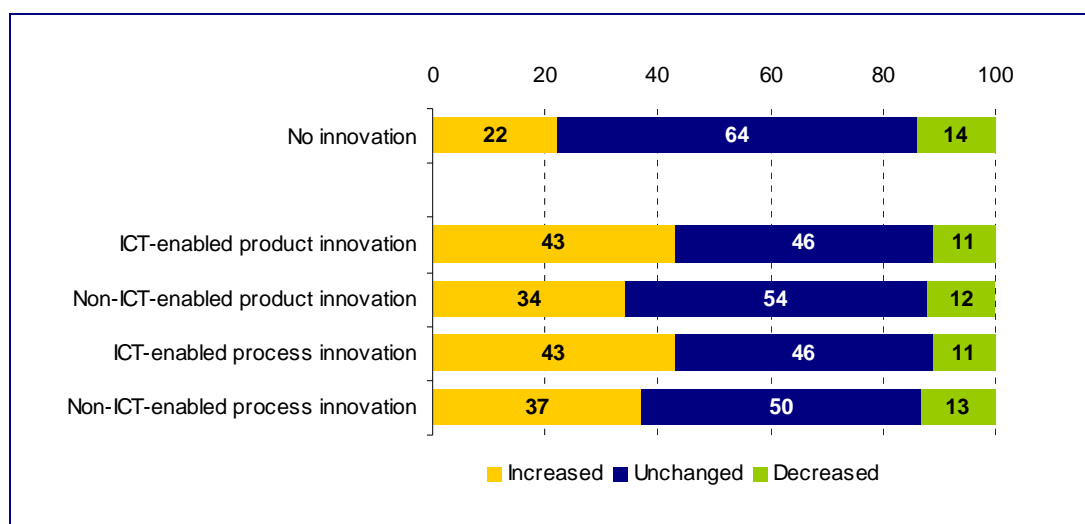
Base (100%): All companies. N = from 13,516 to 13,610 depending on missing values
Questionnaire reference: I1-4, U4

Source: *e-Business W@tch* (Survey 2006)

In addition to the quantity impact of innovation on employment, there also exists a quality aspect. The question is "*what kind of jobs are created or destroyed by innovation?*" A large literature on skill-based technical change (Acemuglu 2002) finds that technical change is biased towards skilled workers as it replaces unskilled labour and increases wage inequality and polarisation. Un-skilled jobs have long been declining in absolute terms in Europe and growing only slowly in the US, while skilled jobs for educated workers are created at a faster pace in most countries (Pianta 2004).

Existing empirical studies emphasised that ICT tends to be a skill-biased technology (Berman et al. 1994, Autor et al. 1998). ICT is implemented and facilitated largely by a substantial supply of skilled labour (e.g. IT specialists and consultants) and it substitutes certain types of low skill functions because the computer takes over tasks that were previously executed manually (e.g. aggregating orders for office material from various employees in an online procurement system). Hence, the application of ICT may increase the relative wage gap between skilled and unskilled labour because it decreases the demand for unskilled workers and simultaneously increase the demand for skilled employees. Yet, ICT can also be used to facilitate new products and services in markets that use abundant and cheap unskilled and semi-skilled labour, so the net-effect of ICT on different types of labour can vary among industries.

Nevertheless, the implementation and productive usage of ICT usually requires the presence of educated and skilled personnel. Due to this complementary between skilled labour and ICT usage, firms that have a higher share of well-educated employees should have advantages in adopting ICT and hence higher levels of ICT usage than otherwise comparable firms.

Empirical evidence on the relationship between employee qualification and ICT usage at the firm level is presented in Exhibit 4, which shows a non-parametric spline estimation[6] of the average percent of employees with a college degree, depending on the ICT development of firms. Again, the ICT development level of firms is approximated by counting the number of e-business technologies, out of seven, that each individual firm uses. Exhibit 4 clearly shows that the share of highly educated employees is higher among more advanced users of ICT.

However, Exhibit 4 also shows that the relation between ICT usage and personnel skills is non-linear. In particular, the most advanced users of ICT with a development index value of 7 exhibit a lower average level of employees with a college degree (37%) than the second most advanced group of ICT users with an index value of 6 (43%).

Exhibit 4 – Spline estimation on education level of employees by ICT development firms
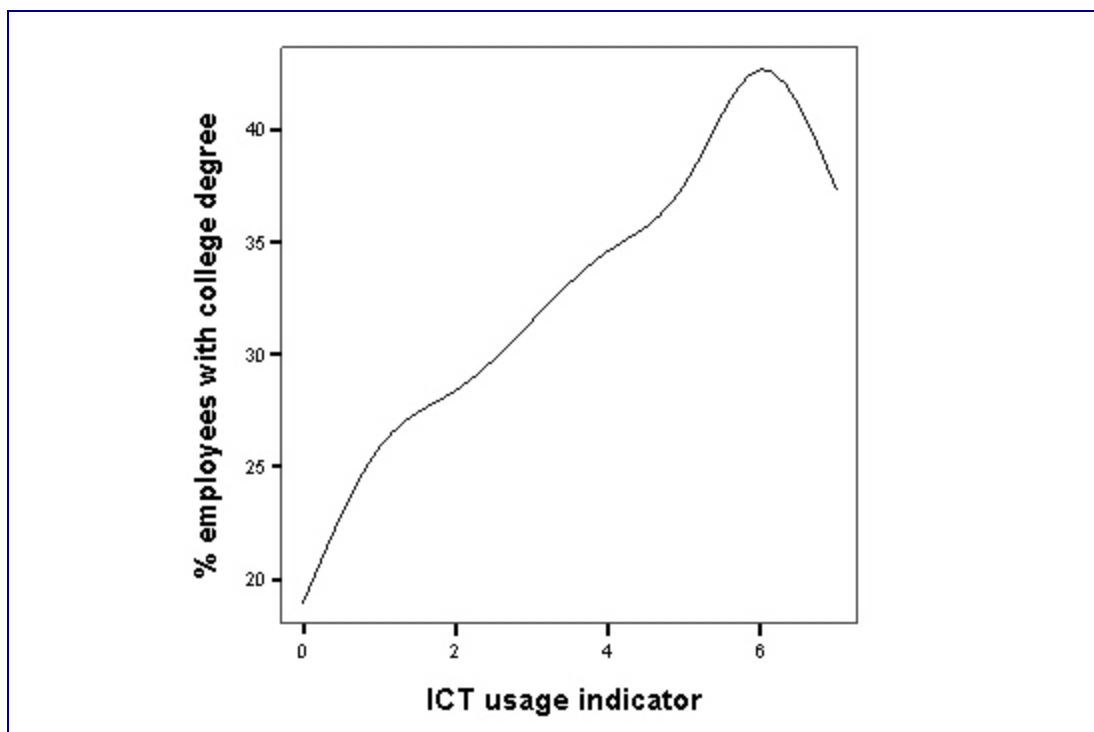
Base (100%): All companies. N = 10,813. Questionnaire reference: U5, D1b, D1d, D1f, B5, E1, F2, F4
Technologies counted are: E-Learning, ERP, SCM, Knowledge Management, CRM, Online Sales and Online Purchasing

Source: *e-Business W @tch* (Survey 2006)

One possible interpretation of this non-linear effect is that there could be some sufficient level of college-educated employees that is necessary to operate a very ICT-intensive firm. After this sufficient level is reached, a further increase in staff with tertiary education does not necessarily further increase the ICT and innovative capacity of a firm. This sufficient level might vary strongly among firms and industries. In the sample analysed, the sufficient level seems to be between 35 and 40% on average. Nevertheless, in the

---

6   Splines are non-parametric piecewise polynomial functions that can have a locally very simple form, yet at the same time be globally flexible and smooth. Splines are very useful to empirically test relationships between variables with unknown functional form, e.g. if assuming a linear relationship is not necessarily warranted.

sample analysed, there is only a very small number of firms that exhibit the highest possible ICT development index (65 firms or 0.6% of the sample). Thus, a positive relationship between ICT development level and the share of highly educated employees can be found for the vast majority of the sample.

Finally, another important question is whether more intense usage of ICT is associated with increasing or decreasing employment at the firm level. Most investments in ICT promise efficiency gains because they enable automation of a variety of routine tasks. It is unclear ex ante what the long run effects of such ICT investments are. If these efficiency gains mainly automate routine tasks and therefore substitute low-skilled labour, the employment effects of a superior endowment with ICT at the firm level are likely to be negative. However, if ICT-induced process improvements are combined with organisational change and investments in human capital and favourable demand conditions, the employment effects of a superior endowment with ICT at the firm level could also be positive. Similarly, this could also occur if ICT is primarily used to create new products and services.

Addressing this issue, Exhibit 5 shows the relation between the ICT development index and employment dynamics at the firm level. The data clearly show that more advanced users of ICT are more likely to exhibit increases in employment. Consistent with the evidence presented in Exhibit 3, this suggests that the compensation and growth effect of intense ICT usage and innovation dominate possible labour substitution effects at the firm level, at least in the sample of firms analysed here. Although this result can and should not be generalised to the macro level, these results show that intensive use of ICT does not necessarily lead to negative consequences for employment.

Exhibit 5 - Employment development and ICT development level of firms 2005
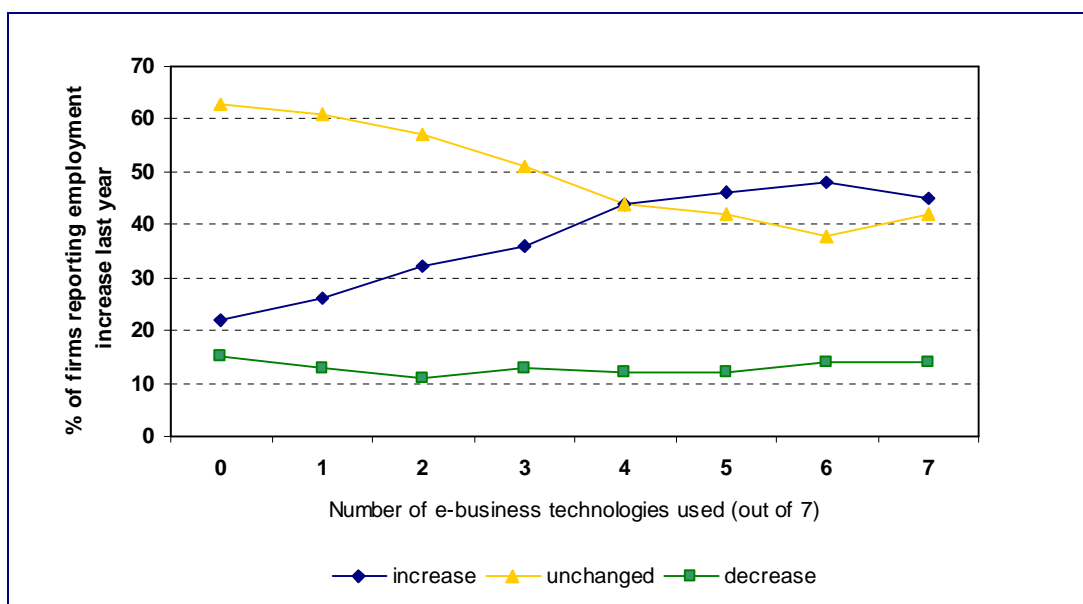
Base (100%): All companies. N = 11,530. Questionnaire reference: U4, D1b, D1d, D1f, B5, E1, F2, F4
Technologies counted are: E-Learning, ERP, SCM, Knowledge Management, CRM, Online Sales and Online Purchasing

Source: *e-Business W @tch* (Survey 2006)

5 Conclusions

5.1 General conclusions

The evidence discussed above suggests that ICT and e-business are currently triggering important structural changes in the economy. These new technologies have implications for the competitiveness of individual enterprises, the competitive dynamics in markets, the creation of new markets, the demand for labour, the price of products and production factors, the type of products and services that are produced, and ultimately the structure and performance of entire national economies.

The empirical evidence presented in this study, based on firm-level data from the e-Business Survey 2006, corresponds with the theoretical predictions that suggest that ICT and innovation are positively associated with turnover and productivity growth at the firm level. Table 1 summarises the hypotheses and the empirical evidence discussed above.

Table 1 – Overview of hypothesis and empirical results

Hypothesis	Empirical evidence
1) Innovative firms, whether their innovations are ICT-related or non-ICT-related, are more likely to exhibit increasing turnover.	**yes**
2) Positive effects of ICT on productivity are more likely to occur in firms that conduct innovations.	**yes**
3) Positive effects of ICT on productivity are more likely to occur in firms that are advanced users of ICT.	**yes**
4) Firms that conduct product innovations, whether they are ICT-related or non-ICT-related, are more likely to increase employment.	**yes**

In addition to these hypothesised relationships, evidence from the new *e-Business Market W@tch* data suggests that ICT usage and high levels of employee's skills complement each other, leading to skill-biased technological change and an advantage of firms with highly skilled employees in adopting and using ICT. Moreover, the empirical evidence presented above suggests a positive relationship between ICT-development and employment growth at the firm level. Data also suggest that firms conducting ICT-related process innovations are more likely to increase employment than non-innovative firms. These are good news because they suggest that intense usage of ICT and a continuous strive of firms towards productivity increases can go together with employment growth, at least at the micro-level of analysis.

However, these empirical results should also not be overstated. The theoretical literature suggests that the effects of ICT are likely to vary significantly among firms, sectors and nations. For example, it is more likely to find positive effects of ICT on productivity and employment in ICT-producing sectors and sectors that are already advanced users of ICT. In addition, the employment effects of ICT are likely to vary among sectors that produce ICT and those that only use ICT. Furthermore, the employment effects among the users of ICT depend on the specific circumstances of ICT usage. Thus, the empirical results reported above are contingent upon the specific choice of countries and sectors included in the survey and should not be generalised.

The causal relationships are complex and the actual impacts of ICT on corporate performance, productivity and employment depend on many firm- and sector-specific factors. As a result, more ICT usage does not necessarily imply superior performance and productivity growth. Instead, these positive impacts are contingent upon auxiliary factors such as the competitive dynamics in individual markets, the ability of firms to transfer ICT investments into innovative activity, and the speed of innovation and technology diffusion.

Nevertheless, the evidence presented above emphasises that ICT remains an important variable both for strategic management and for policy aiming at improving business performance and economic progress. In many sectors and firms, the innovative potential of ICT has not yet been fully exploited. This implies that ICT-related innovations can still result in competitive advantages, if the innovating firm is able to protect its innovation from imitation by rivals. In addition, investments in ICT and e-business combined with complementary investments in human capital and organisational change are still likely to result in further increases in labour- and total-factor-productivity.

5.2   Policy implications

From a policy perspective, there are several things worth discussing from the above discussion and evidence:

1. There is **no direct link between ICT and economic variables** such as profitability, productivity and employment dynamics. Instead, ICT has only indirect effects that occur via innovations that are carried out and triggered by the adoption of new ICT. Although ICT remains an important source of innovation in Europe at the moment, it is not necessarily true that ICT-enabled innovation must be superior to non-ICT-enabled innovation. Also, "lagging behind" in terms of ICT development does also not automatically lead to competitive disadvantages because continuous technological improvements and falling prices of ICT can make it attractive for firms to delay adoption. In addition, not all ICT are necessarily beneficially in all firms and sectors.

    Thus, instead of promoting ICT in general or specific ICT solutions, **policy should focus on improving the framework conditions for innovation in general**. This includes improvements and higher investments in education in many EU countries, more public engagement in R&D, a further deregulation of markets to stimulate competition via innovation, and improved conditions for firms to finance risky and innovative projects. These generic and technology-neutral policies will also benefit the diffusion and impact of ICT.

2. Investments into innovation and new technologies might be subject to market failure, which can result in either too much or too little investment in technology compared to the social optimum. However, it is **not clear a-priori or even after empirical observations which scenario occurs** and what the social optimum would actually be. Thus, policies that aim at speeding up the diffusion of particular technologies are trying to hit an invisible target, which might result in

severe windfall gains. As a rule of thumb, **policy should not interfere directly if there is no clear sign of a market failure**.

3. Even if there is public benefit to speeding up the diffusion of a particular technology, it should be realised that the leverage of public policy is quite limited and the positive impacts of such policies are often more a matter of belief than of empirical facts. Academic studies on this issue concluded that governmental intervention rarely speeds up the diffusion process and government-controlled firms do not move faster than privately owned companies (Hannan and McDowell 1984, Oster and Quigley 1977, Rose and Joskow 1990). This also suggests that public funds are likely to be **better spent in areas where positive returns are beyond doubt** as, for example, investments in education and R&D.

4. ICT and e-business are current examples of technological change and economic development. Most likely, ICT will remain an important enabler for further economic development in the future: the ICT producing industry is still very innovative in developing new software and other services (e.g. communication services) for business; hardware is continuously becoming cheaper and more powerful (Moore's law still applies). Thus, it can be expected that new ICT and other technologies with potentially important economic impact will be developed in the future.

Public organisations will, therefore, need to **continue monitoring and analysing the impact of these developments**. If such market surveys are entirely left to the private sector, there is a risk that results are biased towards the commercial interest of the market research firms rather than providing "the big picture" from different perspectives. An initiative such as *e-Business W@tch* with a broad coverage of topics and sectors would not be feasible without public funding. Such initiatives generate new knowledge that can help resolving information asymmetries and enable policy makers and firm owners to take informed decisions.

Consequently, **ongoing action** of public policy is mainly needed in two areas:

- Improving the **framework conditions for innovation** in general; this includes education, R&D and market regulation.

- **Monitoring and analysing recent technological developments**, with the aim to inform governmental institutions, industry and the interested public about implications of these developments.

References

Acemoglu, D. 2002. Technical change, inequality and the labor market. *Journal of Economic Literature* 40(1), 7-72.

Antonucci, T. and Pianta, M. 2002. The employment effects of product and process innovations in Europe. *International Review of Applied Economics* 16(3), 295-308.

Autor, D.H., Katz, L.F., and Krueger, A.B. 1998. Computing inequality: Have computers changed the labour market? *Quarterly Journal of Economics* 133(4), 1169-1210.

Bailey, E.E. and Lawrence, R.Z. 2001. Do we have a new economy? *NBER Working Paper* W8243, Cambridge, Massachusetts.

Beath, J., Katsoulacos, Y. and Ulph, D. 1987. Sequential product innovation and industry evolution. *Economic Journal* (Supplement) 97, 32-43.

Beath, J., Katsoulacos, Y. and Ulph, D. 1995. Game-theoretic approaches to the modeling of technological change, in: Stoneman, P. (Ed.), *Handbook of the Economics of Innovation and Technological Change*. Blackwell, Oxford and Cambridge, pp. 132-181.

Becker, G. 1975. *Human Capital*. NBER, New York.

Berman, E., Bound, J., and Griliches, Z. 1994. Changes in the demand for skilled labour within U.S. manufacturing: Evidence from the annual survey of manufacturers. *Quarterly Journal of Economics* 109(2), 367-398.

Bertschek, I. and Kaiser, U. 2004. Productivity effects of organizational change: Microeconometric evidence. *Management Science* 50(3), 394-404.

Breshnahan, T.F. and Trajtenberg, M. 1995. General purpose technologies: 'Engines of growth'? *Journal of Econometrics* 65, 83-108.

Brynjolfsson, E. and Hitt, L., 1996. Paradox lost? Firm-level evidence on the returns to information systems spending. *Management Science* 42(4), 541-558.

Brynjolfsson, E. and Hitt, L.M. 2000. Beyond computation: Information technology, organizational transformation and business performance. *Journal of Economic Perspectives* 14(4), 23-48.

Brynjolfsson, E. and Hitt, L.M. 2002. Information technology, workplace organization and the demand for skilled labor: Firm-level evidence. *Quarterly Journal of Economics* 117, 339-376.

Brynjolfsson, E. and Hitt, L.M. 2003. Computing productivity: Firm level evidence. *Review of Economics and Statistics* LXXXV(4), 793-808.

Chan, Y., 2000. IT value: The great divide between qualitative and quantitative and individual and organizational measures. *Journal of Management Information Systems* 16(4), 225-261.

Dasgupta, P. and Stiglitz, J. 1980. Industrial structure and the nature of innovative activity. *Economic Journal* 90, 266-293.

David, P.A. 1990. The dynamo and the computer: A historical perspective on the modern productivity paradox. *American Economic Review Papers and Proceedings* 1(2), 355-361.

Denis, C., McMorrow, K. and Röger, W. 2004. An analysis of EU and US productivity developments. *European Commission Economic Papers* 208, Brussels.

Devaraj, S. and Kohli, R. 2000. Information technology payoff in the healthcare industry: A longitudinal study. *Journal of Management Information Systems* 16(4), 41-67.

Devaraj, S. and Kohli, R. 2003. Performance impacts of information technology: Is actual usage the missing link? *Management Science* 49(3), 273-289.

Edquist, C., Hommen, L. and McKelvey, M. 2001. *Innovation and Employment*. Edward Elgar, Cheltenham and Northampton.

Evangelista, R. and Savona, M. 2002. The impact of innovation on employment and skill in services – evidence from Italy. *International Review of Applied Economics* 16(3), 309-318.

Evangelista, R. and Savona, M. 2003. Innovation, employment and skills in services – firm and sectoral evidence. *Structural Change and Economic Dynamics* 14(4), 449-474.

Fudenberg, D. and Tirole, J. 1985. Pre-emption and rent equalization in the adoption of new technology. *Review of Economic Studies* 52, 383-401.

Geroski, P. 1995. Markets of technology: Knowledge, innovation and appropriability, in: Stoneman, P. (Ed.), *Handbook of the Economics of Innovation and Technological Change*. Oxford and Cambridge, pp. 90-131.

Götz, G. 1999. Monopolistic competition and the diffusion of new technology. *Rand Journal of Economics* 30(4), 679-693.

Gordon, R.J. 2000. Does the 'new economy' measure up with the great inventions of the past? *Journal of Economic Perspectives* 14(4), 49-77.

Gordon, R.J. 2002. Comments to 'Productivity growth and the new economy' by Nordhaus (2002). *Brookings Papers on Economic Activity* 2002:2, 245-253.

Greenwood, J. and Jovanovic, B. 1998. Accounting for growth. *NBER Working Paper* 6647, Cambridge, Massachusetts.

Hannan, T.H. and McDowell, J.M. 1984. The determinants of technology adoption: The case of the banking firm. *Rand Journal of Economics* 15, 328-335.

Hannan, T.H. and McDowell, J.M. 1990. The impact of technology adoption on market structure. *Review of Economics and Statistics* 72, 164-168.

Harris, S.E. and Katz, J.L. 1991. Organizational performance and information technology investment intensity in the insurance industry. *Organization Science* 2(3), 263-295.

Helpman, E. 1998. *General Purpose Technologies and Economic Growth*. MIT Press, Massachusetts.

Jorgenson, D.W. 2001. Information technology and the U.S. economy. *American Economic Review* 91(1), 1-32.

Jorgenson, D.W. and Stiroh, K.J. 2000. U.S. economic growth and the industry level. *American Economic Review* 90(2), 161-167.

Hempell, T. 2002. Does experience matter? Productivity effects of ICT in the German service sector. *ZEW Discussion Paper* 02-43, Mannheim.

Ittner, C.D., Larcker, D.F. and Rajan, M.V. 1997. The choice of performance measures in annual bonus contracts. *Accounting Review* 72(2), 231-255.

Kamien, M.I. and Schwartz, N.L. 1982. *Market structure and innovation*. Cambridge University Press, Cambridge et. al.

Katsoulacos, Y.S. 1986. *The Employment Effect of Technical Change*. Wheatsheaf, Brighton.

Koellinger, P. 2005. Why IT matters - An empirical study of e-business usage, innovation, and firm performance. *DIW Berlin Discussion Paper* 495.

Koellinger, P. 2006. *Technological Change - An Analysis of the Diffusion and Implications of e-Business Technologies.* Humboldt-Universität zu Berlin, http://edoc.hu-berlin.de/docviews/abstract.php?lang=ger&id=26708.

Kohli, R. and Devaraj, S. 2003. Measuring information technology payoff: A meta-analysis of structural variables in firm-level empirical research. *Information Systems Research* 14(2), 127-145.

Kuznets, S. 1972. Innovations and adjustments in economic growth. *Swedish Journal of Economics* 74, 431-451.

Machlup, F. 1980. *Knowledge: Its Creation, Distribution and Economic Significance – Vol. 1: Knowledge and Knowledge-Reproduction.* Princeton University Press, Princeton.

Malone, T. and Rockart, J. 1991. Computers, networks and the corporation. *Scientific American* 265(3), 128-136.

March, J.G. and Sutton, R.I. 1997. Organizational performance as a dependent variable. *Organization Science* 8(6), 698-706.

Moore, G.E. 1965. Cramming more components onto integrated circuits. *Electronics* 38(8), 114-117.

Nordhaus, W.D. 2002. Productivity growth and the new economy. *Brookings Papers on Economic Activity* 2:2002, 211-244.

Oliner, S. and Sichel, D. 2000. The resurgence of growth in the late 1990s: Is information technology the story? *Journal of Economic Perspectives* 14(4), 3-22.

O'Mahony, M. and Van Ark, B. 2003. *EU Productivity and Competitiveness: An Industry Perspective – Can Europe Resume the Catching Up Process?* European Community, Paris.

Oster, S. and Quigley, J. 1977. Regulation and the diffusion of innovation: Some evidence from building codes. *Bell Journal of Economics* 8, 361-377.

Pasinetti, L. 1981. *Structural Change and Economic Growth*. Cambridge University Press, Cambridge.

Pianta, M. 2000. The employment impact of product and process innovation. in: Vivarelli, M. and Pianta, M. (eds). *The Employment Impact of Innovation: Evidence and Policy*. Routledge, London.

Pianta, M. 2001. Innovation, demand and employment. in: Petit, P. and Soete, L. (eds). *Technology and the Future of European Employment*. Edward Elgar, Cheltenham.

Pianta, M. 2004. Innovation and employment. In: Fagerberg, J., Mowery, D. and Nelson, R. (eds.). *The Oxford Handbook of Innovation*. Oxford University Press, Oxford.

Pilat, D. 2005. The economic impacts of ICT – Lessons learned and new challenges. Paper prepared for Eurostat Conference "Knowledge Economy – Challenges for Measurement".

Prasad, B. and Harker, P.T. 1997. Examining the contribution of information technology toward productivity and profitability in U.S. retail banking. *Wharton School Working Paper* 97-07, University of Pennsylvania, Philadelphia.

Reinganum, J. 1981. Market structure and the diffusion of new technology. *Bell Journal of Economics* 12, 618-624.

Rose, N. and Joskow, P. 1990. The diffusion of new technologies: Evidence from the electric utility industry. *Rand Journal of Economics* 21, 354-373.

Ruttan, V.W. 2001. The computer and semiconductor industries. *Technology, Growth, and Development*. Oxford University Press, New York.

Shaked, A. and Sutton, J. 1986. Relaxing product competition through product differentiation. *Review of Economic Studies* 49, 3-13.

Sheskin, D. 2003. *Handbook of Parametric and Nonparametric Statistical Procedures.* 3rd edition. Chapman & Hall/CRC, Boca Raton.

Stoneman, P. and Kwon, M.J. 1996. Technology adoption and firm profitability. *Economic Journal* 106(437), 952-962.

Sutton, J. 1991. *Sunk Costs and Market Structure: Theory and History*. MIT Press, Cambridge, USA.

van Ark, B. 2002. Measuring the new economy: An international comparative perspective. *Review of Income and Wealth* 48(1), 1-14.

van Ark, B., Inklaar, R. and McGuckin, R.H. 2003. ICT and productivity in Europe and the United States: Where do the differences come from? *CESifo Economic Studies* 49, 3/2003, 295-318.

van Ark, B., Frankeman, E. and Duteweerd, H. 2004. Productivity and employment growth: An empirical review of long and medium run evidence. *Research Memorandum* GD-71, University of Groningen.

van Ark, B. and Inklaar, R. 2005. Catching up or getting stuck? Europe's trouble to exploit ICT's productivity potential. *Research Memorandum* GD-79, University Groningen.

van Ark, B. and Piatkowski, M. 2004. Productivity, innovation and ICT in old and new Europe. *Research Memorandum* GD-69, University of Groningen.

Vickers, J. 1986. The evolution of industry structure when there is a sequence of innovations. *Journal of Industrial Economics* 33, 515-529.

Weill, P. 1992. The relationship between investment in information technology and firm performance: A study of the valve manufacturing sector. *Information Systems Research* 3(4), 307-333.

Annex I: The e-Business Survey 2006 – Methodological Notes

Background and scope

e-Business W@tch collects data relating to the use of ICT and e-business in European enterprises by means of representative surveys. The e-Business Survey 2006, which was the fourth survey after those of 2002, 2003 and 2005, had a scope of 14,081 telephone interviews with decision-makers in enterprises from 29 countries, including the 25 EU Member States, EEA and Acceding / Candidate Countries.[7] Interviews were carried out in March and April 2006, using computer-aided telephone interview (CATI) technology.

Questionnaire

The questionnaire is similar to those used in the previous surveys from 2002 to 2005 in order to ensure a basic continuity of the research approach. The module on ICT impact was substantially extended compared to 2005, in response to current policy interest, in exchange for some questions from other modules.

Some questions which were also used in previous surveys were slightly modified. The most important change in this context concerns questions on e-commerce: up to 2005, companies were asked whether they "purchase / sell online"; in 2006, companies were asked whether they "place / accept orders online". This is a more precise question, since the terms "purchasing" and "selling" leave it open whether ordered goods also have to be paid online in order to qualify for "online purchasing / selling".

Some specific topics were added or expanded in the questionnaire in order to reflect the latest e-business developments; examples are the new questions on the use of RFID and Voice-over-IP.

The questionnaires of all four surveys (2002, 2003, 2005, 2006) can be downloaded from the *e-Business W@tch* website (www.ebusiness-watch.org/about/methodology.htm).

Population

As in 2005, the survey considered only **companies that used computers**. Thus, the highest level of the population was the set of all computer-using enterprises which were active within the national territory of one of the 29 countries covered, and which had their primary business activity in one of the 10 sectors specified on the basis of NACE Rev. 1.1.

Evidence from previous surveys shows that computer use can be expected to be 99% or more in all sectors among medium-sized and large firms. Differences are more relevant, however, for micro and small enterprises, in particular in the food and beverages industry, the textile and footwear industries, construction and tourism. In these four sectors, 10-30% of micro enterprises and 4-15% of small firms (depending on the country and sector) do not use a computer.[8] This should be considered when comparing figures over the years, as figures either represent a percentage of "all companies" (as in 2002 and 2003)

---

[7] The EEA (European Economic Area) includes, in addition to EU Member States, Iceland, Liechtenstein and Norway. Acceding Countries with whom an Accession Treaty has been signed are Bulgaria and Romania; Candidate Countries, which are candidates for accession into the EU, are (as of September 2006) Croatia, the former Yugoslav Republic of Macedonia, and Turkey. In most of these countries, interviews and/or case studies were conducted.

[8] Non-computer users include typically small craft firms (textile, construction), bars, restaurants or pensions (in tourism), and small food producing companies.

or a percentage of "companies using computers" (as in 2005 and 2006). Differences are minimal, though, when figures have been weighted by employment.

The 10 sectors which were selected for the 2006 survey are extremely heterogeneous in terms of their size. Construction and tourism are by far the largest with about 1.5 million enterprises in each of the EU-25.[9] At the other end of the range is the consumer electronics industry with about 5,400 enterprises; this is a factor of about 280 between the largest and smallest sector. This imbalance has inevitably a substantial impact on weighting and thus on aggregate results, which are dominated by figures from construction and tourism.

Table 1: Population coverage of the e-Business Survey 2006

No.	NACE Rev. 1.1	Sector name	No. of enterprises in EU-25 *	No. of interviews conducted
1	DA 15 (most groups)	Food and beverages	282,000	1,709
2	DC 19.3	Footwear	13,700	980
3	DE 21	Pulp, paper and paper products	18,400	1,158
4	DL 30, 32.1+2	ICT manufacturing	31,800	1,687
5	DL 32.3	Consumer electronics	5,400	665
6	DM 35.11	Shipbuilding and repair	7,200	150
7	F 45.2+3 (selected classes)	Construction	1,546,000	2,655
8	H 55.1/3, I 63.3, O 92.33/52	Tourism	1,500,000	2,663
9	I 64.2	Telecommunication services	12,900	1,580
10	N 85.11	Hospital activities	(e) 13,000	834

* mostly based on Eurostat SBS, latest available figures

(e) = estimated on the basis of figures for the former EU-15 (no figures available for EU-25)

Sampling frame and method

No cut-off was made in terms of minimum size of firms. The sample drawn was a random sample of companies from the respective sector population in each of the seven countries, with the objective of fulfilling minimum strata with respect to company size class per country-sector cell. Strata were to include a 10% share of large companies (250+ employees), 30% of medium sized enterprises (50-249 employees), 25% of small enterprises (10-49 employees) and up to 35% of micro enterprises with less than 10 employees.

Samples were drawn locally by fieldwork organisations based on official statistical records and widely recognised business directories such as Dun & Bradstreet or Heins und Partner Business Pool (both used in several countries).

The survey was carried out as an enterprise survey: data collection and reporting focus on the enterprise, defined as a business organisation (legal unit) with one or more establishments.

Due to the rather small population of enterprises in some of the sectors, target quota, particularly in the larger enterprise size-bands, could not be accomplished in each of the countries. In these cases, interviews were shifted to the next largest size-band (from large to medium-sized, from medium-sized to small), or to other sectors.

---

[9] Construction (NACE Rev. 1.1 F 45) in total has about 2.3 million enterprises. The sub-sectors covered in 2006 (see Table 1) account for about 1.5 million out of these.

Fieldwork

Fieldwork was coordinated by the German branch of Ipsos GmbH (www.ipsos.de) and conducted in cooperation with its local partner organisations (see Table 2) on behalf of *e-Business W@tch*.[10]

The survey had a scope of 14,081 interviews, spread across the 29 countries and 10 industries covered. In 10 countries ("EU-10"), all 10 sectors were covered; in the other countries, selected industries were surveyed. In most countries, between 400 and 750 interviews were conducted. Pilot interviews prior to the regular fieldwork were conducted with 23 companies in Germany in February 2006, in order to test the questionnaire (structure, comprehensibility of questions).

Table 2: Institutes that conducted the fieldwork of the e-Business Survey 2006 and no. of interviews per country (#)

	Institute	# Int.		Institute	# Int.
BE	Ipsos Belgium, 1050 Brussels	400	MT	Misco International Ltd., Valetta VLT 04	101
CZ	Ipsos Czech Republic, Skolska 32/694, 110 00 Praha 1	750	NL	Ipsos Belgium, 1050 Brussels	400
DK	Vilstrup Research AS, 1360 Copenhagen	403	AT	Spectra Marktforschungs-gesellschaft m.b.H., 4020 Linz	400
DE	Ipsos GmbH, 23879 Mölln	800	PL	Ipsos Poland, 02-508 Warszawa	752
EE	Marketing and Public Opinion Research Centre SKDS, Riga LV-1010	314	PT	Ipsos Portugal, 1070-15 Lisbon	400
EL	Synovate Hellas, 15451 Athens	407	SI	GfK Gral-Iteo trazne raziskave d.o.o., 1000 Ljubljana	400
ES	Ipsos Eco Consulting, 28036 Madrid	754	SK	GfK Slovakia Ltd., 813 41 Bratislava 1	400
FR	Ipsos France, 75739 Paris	751	FI	Taloustutkimus Oy, 00510 Helsinki	752
IE	Landsdowne Market Research, Dublin 1	400	SE	GfK Sverige AB, 22100 Lund	400
IT	Demoskopea S.p.A., 00199 Roma	756	UK	Continental Research, London EC1V 7DY	750
CY	Synovate Cyprus, 2107 Nicosia	209		EEA and Acceding/Candidate countries	
LV	Marketing and Public Opinion Research Centre SKDS, Riga LV-1010	432	NO	Norstat Norway, 0159 Oslo	401
LT		404	BG	TNS BBSS Gallup Interbational, 1164 Sofia	400
LU	Ipsos GmbH, 23879 Mölln/20097 Hamburg	117	RO	Field Insights, Bucharest 2	440
HU	Szonda Ipsos, 1096 Budapest	772	TR	Bilesim International Research & Consultancy Inc. Turkey, 34676 Istanbul	400

---

[10] The survey was carried out under two different contracts. The survey in the six largest EU countries (DE, ES, FR, IT, PL, UK) was carried out as part of the e-Business W@tch contract between the European Commission and empirica GmbH; the survey in the other countries was carried out in parallel, but under a different contract (following an open call for tender for the "extended e-Business W@tch survey", issued in 2005).

Non response: In a voluntary telephone survey, in order to achieve the targeted interview totals, it is always necessary to contact more companies than just the number equal to the target. In addition to refusals, or eligible respondents being unavailable, any sample contains a proportion of "wrong" businesses (e.g., from another sector), and wrong and/or unobtainable telephone numbers. Table 3 shows the completion rate by country (completed interviews as percentage of contacts made) and reasons for non-completion of interviews. Higher refusal rates in some countries, sectors or size bands (especially among large businesses) inevitably raises questions about a possible refusal bias. That is, the possibility that respondents differ in their characteristics from those that refuse to participate. However, this effect cannot be avoided in any voluntary survey (be it telephone- or paper-based).

Table 3: Interview contact protocols: completion rates and non-response reasons (2006, examples)

			CZ	DE	ES	FR	HU	IT	NL	PL	FI	UK
1		**Sample (gross)**	5595	7763	7730	8686	21540	8533	4576	11054	3016	11821
	1.1	Telephone number does not exist	283	1055	0	186	5545	717	349	2282	139	2663
	1.2	Not a company (e.g. private household)	79	80	356	66	2076	89	219	681	34	324
	1.3	Fax machine / modem	56	48	0	79	1120	61	28	53	4	130
	1.4	Quota completed -> address not used	43	124	660	1939	1665	2154	1002	877	66	158
	1.5	No target person in company	17	359	730	142	9	178	232	959	319	736
	1.6	Language problems	9	18	0	25	0	1	36	0	41	20
	1.7	No answer on no. of employees	2	1	10	13	6	8	1	19	1	0
	1.8	Company does not use computers	48	47	158	250	279	314	235	460	28	51
	1.9	Company does not qualify	134	330	103	156	0	113	47	813	49	215
		Sum 1.1 – 1.9	671	2062	2017	2856	10700	3635	2149	6144	681	4297
2		**Sample (net)**	4924	5701	5713	5830	10840	4898	2427	4910	2335	7524
	2.1	Nobody picks up phone	1071	582	1645	6	1023	647	82	513	22	1898
	2.2	Line busy, engaged	83	122	57	46	89	0	3	73	1	1
	2.3	Answering machine	143	145	121	1315	1200	0	9	127	1	145
	2.4	Contact person refuses	2080	1125	2553	131	2011	729	1653	2009	578	2523
	2.5	Target person refuses	450	1865	202	1475	2776	642	113	280	405	1618
	2.6	No appointment during fieldwork period	3	11	70	182	2571	384	112	150	50	376
	2.7	Open appointment	295	953	35	1896	258	1041	21	763	459	51
	2.8	Target person is ill / unavailable	2	31	0	0	0	13	0	29	2	32
	2.9	Interview abandoned	43	67	271	29	108	686	34	176	15	130
	2.10	Interview error, cannot be used	4	0	5	5	32	0	0	38	50	0
		Sum 2.1 – 2.10	4174	4901	4959	5085	10068	4142	2027	4158	1583	6774
3		**Successful interviews**	750	800	754	751	772	756	400	752	752	750
		Completion rate (= [3] / [2])	15%	14%	13%	13%	7,12%	15%	16,48%	15%	32%	10%
		Average interview time (min:sec)	19:19	18:46	17:29	19:39	17:14	16:43	19:00	23:44	20:19	20:16

The use of filter questions in interviews

In the interviews, not all questions were asked to all companies. The use of filter questions is a common method in standardised questionnaire surveys to make the interview more efficient. For example, questions on the type of internet access used were only asked to those companies that had replied to have internet access. Thus, the question whether a company has Internet access or not serves as a filter for follow-up questions.

The results for filtered questions can be computed on the base of only those enterprises that were actually asked the question (e.g. "in % of enterprises with internet access"), but can also be computed on the base of "all companies". In this report, both methods are used, depending on the indicator. The base (as specified in footnotes of tables and charts) is therefore not necessarily identical to the set of companies that were actually asked the underlying question.