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The Impact of ICT on the Growth of the Service Industries

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Abstract

This study examines the contribution of Information and Communication Technology (ICT) to a growth in services. Data at the firm level is employed to investigate how ICT as a key technology, combined with non-technological determinants, can influence firm performance. The study develops an argument that ICT is one of the major success factors at the present time, and this particularly holds true in the case of service firms, primarily due to their fundamental characteristics of interactivity and intensity of information, which are highly compatible with this technology. The results indicate that the presence of ICT explains the higher growth in productivity and profitability experienced by firms in the service industries. Growth in services was also found to be significantly linked to the level of ICT intensity in service firms, especially when this intensity is complemented by organisational change. The impact of ICT on service firms is assessed in detail, while manufacturing firms and other innovation activities serve as benchmarks.

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1. Introduction

The service sector is now a major component of the global economy, particularly in the majority of developed countries. Evidence reveals that, over the last decade, this sector has accounted for around two-thirds of employment and value added in most industrialised economies. In recent years, therefore, increasing attention has been paid to discovering the driving force behind the successful growth of (most) service industries.

Innovation is seen to be the major driver of economic growth, and a number of studies (for example, Barras, 1990; Evangelista, 2000; Gershuny and Miles, 1983; Miles, 2004) appear to confirm the productive relationship between innovation and the growth of the service industries. In particular, ICT (Information and Communication Technology) is regarded to be an extremely important ingredient in innovation in services in the present era (Castellacci, 2006; Hipp and Grupp, 2005; Tidd et al., 2005). Thus, together with non-technological factors like organisational change (Bresnahan et al., 2002; Brynjolfsson and Hitt, 2000, 2003; Tether, 2005), ICT is often used to explain the outstanding upswing of the service industries, and the present study attempts to contribute to innovation literature by providing firm-level evidence to support this claim. In order to do so, this study employs a unique dataset, obtained from an integration of the Norwegian CIS3 (Community Innovation Survey), R&D (Research and Development) survey and financial accounts data**,** to examine how ICT, combined with organisational change, has affected the growth of service firms in Norway.[2] The main objective of the study is specifically to shed light upon: (i) the relationship between ICT and firm-level growth in services; and (ii) the complementarity between ICT and organisational change.

The remainder of this paper is structured as follows. The second section continues with an outline of relevant theories and main hypotheses. This section also provides an explanation of how ICT may be deemed responsible for the high growth in services, with an emphasis on the compatibility of the characteristics of ICT and services. The section ends with a discussion of prior studies of the impact ICT, as well as organisational change, on economic performance. The third section presents the integrated dataset and variables employed in the analysis. The fourth section explores the role played by ICT and other determinants in driving the growth of

[2] The service industries have played a major role in the Norwegian, as well as most of the OECD economies, during recent decades. See Wolfl (2005) for a detailed account of the service economies of these countries.

service firms by means of descriptive statistics and an econometric exercise. The fifth section provides a summary of empirical findings and ends with some concluding remarks.

2. Theoretical Overview and Prior Studies

2.1. A Note on Innovation in Services

It is widely accepted that the manufacturing sector had long been a major contributor to the world's economy, especially since the first industrial revolution (around the 1840s). However, about half a century ago (around the 1960s), the service sector began to play a more important role, and innovation in services increasingly gained the interest of economists and scholars of technical change (for example, Andersen et al., 2000; Barras, 1986; Metcalfe and Miles, 2000). Attention to innovation in services seemingly became significant in the 1990s, when a number of large research projects on service innovation were launched, and some service industries began to be included in R&D and Innovation Surveys. This growing concern hitherto fostered studies of innovation in services, leading to a better understanding of this research topic. The importance of innovation in services is stressed by many prior studies, such as those by Barras (1986, 1990), Evangelista (2000), Miles (2004) Tether et al. (2001) and Tether (2005). Recent evidence suggests that most services have been active in innovation, and many of them have certainly succeeded in achieving an impressive innovative performance. Some studies also regard innovation in services to have been the main thrust of the "service economy" in recent decades (for example, Fuchs, 1968; Gershuny and Miles, 1983; Stanback, 1979).[3]

Gallouj (2002) classifies literature on service innovation into three main categories: (i) Technological approach, which takes into consideration the introduction and diffusion of new technologies into services, which may have improved their productivity and other performance; (ii) Service-orientated approach, which regards innovation in the manufacturing and service industries as being different, and emphasises the "peculiarity" of services related to, for example, non-technological innovation; and (iii) Integrative approach, which investigates the boundary between goods and services, and develops a framework to bridge the gap between them. Despite the different views of innovation in the service industries, one key agreement seems to have been reached, i.e. service innovation is deemed to be a crucial factor of competitiveness and growth of services (Hauknes, 1998). The present study, which

[3] See also Hauknes (1996) for a discussion on analytic approaches related to the service economy.

looks into the question of how ICT and organisational change may jointly contribute to the superior performance of services, follows the technological approach (for example, see Sirilli and Evangelista, 1998; Soete and Miozzo, 1989), while also taking into account the importance of non-technological innovation, as emphasised in the service-orientated approach. Indeed, the heterogeneity of service activities (across industries) may matter in terms of how different services benefit deferentially from innovation. This is why Soete and Miozzo found it necessary to extend Pavitt's (1984) taxonomy of sectoral patterns of technical change by proposing a specific taxonomy for services, which seriously takes into account the heterogeneous characteristics across these industries. Pavitt's taxonomy, which consists of Science-based, Specialised-suppliers, Scale-intensive and Supplied-dominated industries, places all services into one category (namely, Supplier-dominated). Based on trajectories of innovation in services, Soete and Miozzo's taxonomy suggests that only some service industries are supplier-dominated, for example, health, education, public and social services. Two other groups are, in fact, technology-intensive, and these are Scale-intensive physical network industries and Information network industries (for example, wholesale, transport, communication, insurance and financial services), and Science-based and specialised supplier industries (for example, software and business services).[4] Nonetheless, the importance of ICT is common to the service industries in all of these groups. Miozzo and Soete (2001:163) add that these services are "actively engaged in the development and use of data, communication, and storage and transmission of information", which has a pervasive impact on their economic performance. The next section will attempt to explain why ICT may be seen to have been the driving force behind the superior growth of the service industries over recent decades.

2.2. ICT as a Key Technology for Innovation and Growth in Services

The important question is, why did the phenomenal upswing of the service industries come about only recently? The answer to this may lie in the compatibility of the basic characteristics of these industries and their recent key economic driver, and ICT may be taken into account in this respect, since it has been largely instrumental in information/knowledge transfer and interactive learning in the modern economy throughout recent decades. As is argued by Licht et al. (1999) and Hipp and Grupp (2005), ICT is now the major technology for innovation in services. And the outstanding growth of the service industries may relate to

[4] The service industries in these groups are essentially taken into consideration in the present study. See below.

the fact that their fundamental characteristics are highly compatible with this major technical source of "innovation opportunities" (Dosi, 1988). Miles (2004) points out that services are typically interactive, involving a great deal of communication with suppliers and clients in all phases of service activities. Firms in the service industries are naturally "information intensive", organising their businesses with a preponderance of communicative and transactional operations, which establishes an "ICT-friendly" atmosphere. This is an atmosphere which seems crucial to innovation in services, because innovation in these industries essentially focuses on adopting ICT to facilitate and improve the enormous interactions involved in most service operations/activities.

Because of its advantageous capabilities to dramatically accelerate communication speed and increase information channels, ICT saves costs while increasing the output and quality of most service productions. This is particularly the case for services, since service productions mainly consist of "information" components, which constitute the ideal breeding ground for service innovation exploiting ICT (Gershuny and Miles, 1983). As pointed out by Evangelista (2000), due to the compatible characteristics of ICT and services, the use of ICT plays a vital role in service firms' innovation activities, and in boosting their performance. On the basis of ICT, many back-office operations in service firms are able to gain higher efficiency and quality (Miles, 1993). However, the value of ICT to service firms is not only limited to the supply side. Due to a (greater) significance of user-producer interaction (e.g. in service "co-productions") and customisation in service firms, in contrast to that of standardisation in manufacturing firms (Drejer 2004; Gallouj and Weinstein 1997), ICT enables real time and placeless monitoring of customers' demands, replacing the old physical information systems (Castellacci, 2006). For instance, ICT reduces the need for front-office staff to interact on a face-to-face basis with customers (Miozzo and Soete, 2001), as in the case of e-banking, e-auction, e-shopping, e-learning, e-booking (of various kinds), to mention but a few. To explain the mechanisms by which ICT leads to the better innovative performance of service firms in recent times, Barras (1986) emphasises the fact that ICT helps to establish a technological platform for new service innovation, as well as significantly improving existing services. In addition, ICT greatly supports and improves service firms' enormous interactions with suppliers and users, which are, in fact, vital sources of information/knowledge for innovation (von Hippel, 1988; Leonard-Barton, 1995). On the one hand, this line of reasoning attempts to recognise the competitive advantage of an "ICT friendly" atmosphere for service firms, and on the other, points out that ICT plays a major role and is rather indispensible to

the innovation activities of these firms. Thus, innovation based on ICT assists service firms in achieving enormous improvements and a superior economic performance. Despite the heterogeneity of service activities across industries discussed earlier, evidence from OECD (2000) for instance, confirms that most services are active in innovation based on ICT, and that they certainly benefit from being so.

Prior research compares ICT with other great innovations of the past, such as the steam engine (1840s-1890s), electricity (1890s-1940s) and the mass production technique (1940s-1990s), which were more conducive to innovation in manufacturing, and in great part, led to its golden age. Built upon Schumpeter's seminal piece (1939) on the long (Kondratiev) wave of technical change, Freeman and Perez (1988) develop the argument that each wave, which they label a "techno-economic paradigm", has a similar pattern over time and comes with, among other things, an introduction and diffusion of new key technologies, which can facilitate a quantum leap in the productivity of an economic system. Freeman and Louca (2002) extend this argument by proposing that, following the fourth wave of technical change (characterised as the age of mass production), which was beneficial exclusively to firms in the manufacturing industries, the fifth techno-economic paradigm turned up, with ICT as a key driver, by the end of the 1990s. This recent paradigmatic change seems to have allowed the service industries to "leapfrog" in terms of both economic forging-ahead and catching-up (Castellacci, 2006). Put simply, for more than a decade, manufacturing has had to take a back seat to services, which have been on the rise, driven chiefly by ICT-enabled mass service production ("mass servuction"[5]), as well as ICT-enabled service innovation.

In the age of mass servuction, ICT appears to be relatively compatible with the fundamental characteristics of service firms, which are interactive and information-intensive, in comparison with those of manufacturing firms which are much related to the production of goods. Although computers can be seen everywhere, the use of ICT is mainly concentrated in service industries (McGuckin and Stiroh, 2001). Evidence from the US, for example, shows that manufacturing is indeed much less ICT-intensive than services (Pilat and Wolfl, 2004). As discussed above, this is largely due to the nature of services which process and diffuse information in abundance (for example, financial services and telecommunications). Therefore, the advance of ICT, which allows more information to be instantly and effectively

[5] The term 'servuction' was used in prior studies to refer to service production when drawing an analogy with (goods) production in manufacturing. See Gallouj and Weinstein (1997) and Miles (2004).

codified and transferred, together with the increasing move into the knowledge economy, has expanded the scope of ICT usage in firms in many of the service industries (Pilat, 2001).

In addition, Pilat (2001) highlights the growing economic importance of ICT in services, e.g. high ICT consumption in service firms and the mounting demand for ICT-intensive services, which in turn, substantially increases the weight of these industries in the economy. The importance of ICT as a major driver of the service economy has been significant, especially throughout the last decade, since it has led to the service industries catching up with, and even outperforming nowadays, the manufacturing industries (OECD, 1996). In the light of this phenomenon, the present study investigates the role played by ICT in enhancing the growth of firms in Norway's service industries (see below).

2.3. Prior Research on the Effect of ICT on Economic Performance

The (positive) impact of ICT investment was not at all significant in aggregate output statistics for a long time (especially before the 1990s), despite decades of great advancement in terms of this technology. This is usually referred to as the "Solow paradox", in accordance with the famous statement made in 1987 by Robert Solow, the Nobel laureate in economics: "you can see the computer age everywhere except in the productivity statistics". However, it can be argued that the productivity paradox may have been, for example, because of problems with the statistics themselves (measurement problems, analytical deficiencies, etc.), and/or because a certain length of time was required before productive gains from ICT could be realised (Pilat et al., 2002).[6] Brynjolfsson and Hitt (1996, 2000) point out that this productivity paradox seems to have disappeared by the early 1990s, and as evidenced (for both manufacturing and services) over recent years, a number of countries have certainly enjoyed impressive economic growth with the aid of ICT. For instance, the results from the US (Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000) indicate that output growth revived in the 1990s, and significantly accelerated during the period 1995-2000 due to a sharp increase in ICT capital input throughout the decade. The impact of ICT on aggregate growth was also significant in Australia (Parham et al., 2001), Canada (Armstrong et al., 2002), Korea (Kim, 2002), Finland (Jalava and Pohjola, 2001), the UK (Oulton, 2002) and the Netherlands (van der Wiel, 2001). In addition, Pilat and Wolfl (2004) obtained consistent evidence from their study, which applied a distinction between ICT production and ICT use.

[6] The latter is in relation to the claim that other complementary changes in a firm are also needed so as to allow the best-possible exploitation of ICT. See below.

They examined the role of ICT-producing and key ICT-using industries in explaining overall productivity growth in OECD countries, and found that ICT-producing (manufacturing) industries contributed significantly to the growth of Finland, Ireland, and Korea, whereas ICT-using services in some countries, remarkably the US and Australia, experienced an impressive growth in the second half of the 1990s.

Apart from the aggregate evidence, the impact of ICT on growth has been more importantly recognised on the basis of micro-level data from a number of industrialised countries (OECD, 2003). Most of these studies used a variety of econometric techniques and growth accounting methods to examine samples of firms. For example, Lichtenberg (1995) used production function estimates on business firms, and found that the output contribution of computer systems highly exceeds their capital cost. Black and Lynch (2001) analysed both panel and cross-sectional data for firms in the US and found that, in many industries, an increase in productivity growth is due to employees' use of computers. Gretton et al. (2004) analysed firm-level data from the Australian Business Longitudinal Survey, and found positive, significant links between the use of ICT and growth in both the manufacturing and service sectors. Brynjolfsson and Hitt (1996, 2003), based their analyses on US firm-level data, and reported that ICT has a solid impact on productivity. Hempell et al. (2004) analysed comparable panel data of Dutch and German firms in the service industries, and found that ICT capital deepening and innovation have a complementary impact on productivity.

The foregoing prior research supplies evidence which suggests that ICT plays a central role in supporting the growth and economic performance of all industries, including manufacturing and services. However, the firm-level evidence of the influence of ICT, specifically on the growth of service firms is still scarce, especially in terms of Nordic countries, which in fact, extensively rely upon the use of ICT (Sogner, 2009), and are consistently ranked as being highly innovative (Eurostat, 2008). Therefore, this study is devoted to adding to the literature on innovation in services with some empirical findings on the relationship between ICT and the economic performance of service firms in Norway, a country which has gone from being rather poor to occupying a permanent place in the world's richest list. This is not only driven by the country's tremendously growing oil industry, which provides enormous benefits to the national economy, but also the increasing weight of the service sector in Norway.[7] Smith

[7] In a comprehensive study of innovation in Norway, Fagerberg et al. (2009) explain that the impressive growth of the oil industry in Norway has made both direct and indirect contributions to the national economy. The

(2003) demonstrates that, during recent decades, many service industries in Norway have utilised ICT to a considerable extent, but adds that its economic benefits are still unclear. Thus, the present study focuses on an analysis of firm growth in the service industries as a consequence of ICT intensity, while adopting manufacturing firms and other technological innovation activities as benchmarks.[8] Organisational change, considered to be an important non-technological determinant, is also taken into account in explaining the growth of service firms, and this will be discussed in greater detail in the following section.

2.4. ICT and Organisational Change as Complementary Factors driving Firm Performance

Prior research points out that technological and non-technological innovation are complementary, i.e. an attempt at technological innovation would meet only limited success unless it was accompanied by organisational change, since they are immensely interdependent (Chandler, 1962; Nelson 1991). As Bruland and Mowery (2004) argue, technological input alone may not have been able to drive firms and countries to perform well, forge ahead, or catch up with others at different points in time. In fact, organisational innovation has also been an important contributor to the success of firms and countries, from the first industrialisation through different techno-economic paradigms.[9] David (1990) raises the point that factory redesign was a key organisational change which complemented firms' exploitation of electricity more than a century ago. Correspondingly, in the present ICT era, firms may not expect to achieve higher quality products, processes or services by simply plugging in computers (Bresnahan et al., 2002). Although ICT is crucial to firm performance as a "general-purpose technology" (Bresnahan and Trajtenberg, 1995; Carlsson, 2004),[10] a significant contribution of ICT to economic success may only be possible when it is reinforced by complementary organisational change (Brynjolfsson and Hitt, 2003; Milgrom and Roberts, 1990). Therefore, firms should not only focus on the technical dimension of change, but also consider attempting a process of reorganisation (Brynjolfsson and Hitt, 2000;

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indirect ones, for example, include a very significant market expansion, as a result of the growth and development of this industry, for other industries including a number of services.

[8] Pilat and Wolfl (2004) suggest that, due to the high ICT intensity in services in most OECD countries, the impact of ICT on economic performance may be clearer in these industries than in other parts of the economy.

[9] The term 'organisational innovation' is accorded different meanings by different researchers. In line with Pettigrew and Fenton (2000) and Sapprasert (2008, 2009), this term is used here to refer to a non- or less-technological, customary, institutional way of changing how a firm organises its works.

[10] Other examples of general-purpose technologies include the steam engine and electricity. These are regarded as technologies which can be widely applied to, and have pervasive effects on, technical and economic developments.

Davenport and Short, 1990). For example, it would be practical to make use of ICT, which facilitates and improves information processing and transfer, in decentralisation and/or task delegation in firms (Brynjolfsson and Mendelson, 1993). Firms may also exploit ICT when reengineering business processes, such as implementing electronic commerce and adopting just-in-time management (Hempell et al., 2004).

With reference to the sectoral technological taxonomy discussed above, Miozzo and Soete (2001) claim that a combination of ICT and organisational change is of advantage to a number of firms in Scale-intensive physical network services and information network services, as well as Science-based and specialised supplier services. For example, in financial services, most of today's major commercial banks offer Internet banking, which both requires and allows, among other things, the centralisation of an automated payment process and real-time operations/transactions. By employing data networks, which enable marketing, sales and claims processing operations to be transacted online, many insurance firms have managed to open up their market and operate in foreign countries. Brynjolfsson and Hitt (2000) and Brynjolfsson et al. (2002) review some case evidence which also underscores this complementarity of technical and organisational change. For instance, Wal-Mart gained huge economic success over the last decade by improving various operations, especially related to its new purchasing method, based on ICT and organisational change. Large suppliers in the healthcare industry, like Baxter, focused on combining the use of ICT with the redesign of their supply arrangements, and significantly benefited from such a combined change, in terms of performance improvement, cost-cutting and time-saving, etc. This complementarity is important, even to firms within the ICT-producing industries. Examples include Dell and Cisco, which managed to increase work efficiency and productivity by complementing computerisation with changes in system and organisational practice.

A series of quantitative studies also support this line of argument by supplying firm-level evidence of the complementary effects of technological and organisational change on firms' productivity and other performance measures (see Brynjolfsson and Hitt, 2000, for a review). For example, Brynjolfsson et al. (2002), using US firm-level data, found that computer capital and (intangible) organisational assets are complementary factors for higher firm productivity. This productive relationship was also corroborated by other studies from the US such as those by Bresnahan et al. (2002) and Brynjolfsson and Hitt (2003). However, similar firm-level evidence outside the US is still scarce. Therefore, the present study takes into account the

importance of such non-technological changes to service innovation based on ICT in the Norwegian case. One crucial task in the empirical part is to examine to what extent, if at all, ICT and organisational change have jointly led to the better economic performance of service firms in Norway, as presented below.

3. Data and Variables

A unique firm-level dataset employed in the analysis was obtained from an integration of data from the CIS3 (1999 – 2001), R&D survey (1999 – 2001) and annual financial accounts of firms in Norway (1999 – 2003). The two surveys were combined, i.e. a questionnaire which included questions about R&D activities and (European) CIS3 standard questions about innovation activities was created and distributed by Statistics Norway to a large set of firms in Norway with at least 10 employees. There are two main advantages of using this survey data, the first of which is that the response rate was very high (93 %), resulting in a representative sample (of 3,899 firms). Secondly, the questionnaire was structured in the way which allowed both innovative and non-innovative firms (i.e. firms with and without product/process innovation) to answer all of the questions about R&D activities, unlike many other countries where similar surveys were conducted. This helps to avoid having missing values in the R&D part of the dataset used in this study, i.e. no potential sample selection problem relates to this since the information is available for firms in both groups.

Table 1. Descriptive Statistics for ICT Intensity and Economic Performance Indicators

Variables	Valid N	Minimum	Maximum	Mean	SD
Service firms					
Productivity Growth 2001–2003 (exponential) **GPR0103**	963	-2.64	3.18	0.0328	0.78828
Profitability Growth 2001–2003 (exponential) **GPF0103**	861	-5.09	3.43	0.0713	0.99974
ICT Intensity (%) **ICTINTE**	933	0.00	3.99	0.1100	0.13705
Manufacturing firms					
Productivity Growth 2001–2003 (exponential) **GPR0103**	1,474	-3.82	3.44	0.0662	0.69980
Profitability Growth 2001–2003 (exponential) **GPF0103**	1,213	-4.03	3.96	0.1139	0.93599
ICT Intensity (%) **ICTINTE**	1,343	0.00	3.88	0.0116	0.14615

The pooled dataset initially contained 1,464 service and 1,927 manufacturing firms.[11] However, the sample size decreased, since the analysis was restricted to firms with valid information for calculating important variables such as ICT intensity, labour productivity growth and profitability growth. This means that the firms without such information had to be excluded from the analysis (Table 1 provides descriptive statistics for the three variables). Nonetheless, the resulting sample comprised a total of around 1,800 firms (both innovative and non-innovative), in both service and manufacturing industries. Since it conforms to the European standard for the CIS3 (as set by Eurostat), the Norwegian CIS3 essentially provides this study with a range of information about innovation activities at the firm level, and categorical information such as firm size (in terms of employment) and industrial classification (NACE code). However, some of the CIS3 questions referring to firm-level factors which may also matter to a firm's economic performance could not be used for the analysis (i.e. as control variables), such as because of the content of the questions. For example, the (only) question about mergers in the CIS3 asked if a firm had experienced an increase in turnover between 1999 and 2001 as a result of merger with another firm, or part of it. Based on the firms' answer to this question, the study was unable to identify firms which had merged, but had not achieved a turnover increase.[12] Moreover, due to the interest in both innovative and non-innovative firms (and in avoiding the sample selection problem[13]), the study is deprived of some interesting (censored) variables regarding innovation in firms, which exist only in the case of innovative firms, such as sources of information for innovation, cooperation for innovation, and obstacles to innovation.[14] Nonetheless, apart from the CIS information, the financial accounts of Norwegian firms enable the study to obtain two important economic indicators, namely, productivity and profitability growth.[15] The R&D survey supplies the final key information, namely, ICT intensity.

[11] About 500 firms in other industries, such as agriculture, fishing and mining, were set aside.

[12] A merger (or acquisition) can be important to a firm's productivity/profitability because it usually leads to layoff and other savings. However, the only information provided by the CIS in connection with mergers refers to an increase in turnover due to a merger (yes/no), which cannot be used to measure this occurrence for all firms in the sample.

[13] This is a potential problem when only innovative firms are included in an analysis. Nonetheless, the problem may be dealt with by using, for example, matching estimators or a Heckman (1979) model.

[14] The CIS questionnaire structure allows only innovative firms to answer these detailed questions.

[15] Prior studies also used productivity and profitability growth as proxies for economic performance. See, for example, Krugman (1994), Baldwin and Sabourin (2001), Ball and Moffitt (2001), Oulton (2002).

Prior research measured ICT intensity in several ways, for example, as the share of investment devoted to ICT (Doms et al., 2004), as ICT expenditure per employee (Cainelli et al., 2004; Dunne et al., 2001), and as the share of labour equipped with ICT (Maliranta and Rouvinen, 2004). The present study alternatively applies ICT R&D (Research and Development on ICT) expenditure, between 1999 and 2001, over total expenditure (overall expenses in 2001) of a firm as an explanatory variable for ICT intensity (ICTINTE) in the analysis.[16] Consistent with evidence for most OECD countries (Pilat et al., 2002), detailed statistics (not reported here, but available upon request) show that Norwegian firms in different industries are generally ICT-intensive, i.e. that they demonstrate a good level of ICTINTE. These include service firms in both ICT-producing and ICT-using industries,[17] in particular, Business services, Financial services, Computer-related services and Telecommunications. Put another way, not only ICT producers, but also ICT users, conduct R&D on ICT, for example, as the way to learn how best to exploit this technology. This point supports the application/relevance of this variable to the sampled service (and manufacturing) firms taken into account in the analysis.

In addition, the use of information on ICT R&D in the present study is in accordance with a number of previous works which investigated the relationship between innovation and growth using R&D data.[18] The relevance of R&D may be explained by the fact that many firms invest in R&D, even when the majority of fruitful findings have already spilled out into the public domain (Cohen and Levinthal, 1989). This is because, on the one hand, R&D allows the firm conducting it to gain a first-mover advantage in exploiting the new technology found in-house. On the other hand, the same firm can also become a rapid follower by utilising its "absorptive capacity" accumulated through R&D in order to reap the fruits of spillovers from

[16] The combined Norwegian CIS3 R&D survey included a question asking the sampled firms to estimate the share of different R&D activities including R&D on ICT, and the sum of all these activities equals 100 (%). So, when calculating ICTINTE, if the share of ICT R&D of firm X was 20% and the R&D expenditure of firm X was 10,000 NOK, the numerator for firm X is calculated as (20/100) * 10,000. To adjust for this, the numerator is divided by a firm's total expenditure.

[17] For an explanation of this distinction, see Pilat and Wolfl (2004)

[18] Many of these works followed Solow's (1957) well-known decomposition of economic growth, which raises the importance of factors other than typical inputs like labour and capital which underlie productivity residual (that part of output growth not explained by changes in factor inputs). R&D investment is widely seen to be one of these factors, and analyses of the relationship between R&D and firm performance have considerably contributed to literature on economic growth (See Coe and Helpman, 1995; Griliches, 1988; Grossman and Helpman, 1991). The importance of R&D for growth has also been acknowledged in other research camps, including evolutionary economics and innovation studies broadly defined (for example, Cohen and Levinthal, 1989, 1990; Levin et al., 1985, 1987; Rothwell, 1992).

competitors' innovations (Cohen and Levinthal, 1990). This line of reasoning stresses the point that R&D effort is fundamental to the success of innovation and competitiveness, and that the data of R&D expenditure may thus be deemed to be a viable source to be used when constructing a proxy for ICT intensity.

Non-technological innovation like organisational change, which may complement ICT in elevating firm performance, is also taken into account (see above for a discussion on this factor). In this respect, the analysis makes use of the firm-level data, which has a remarkable advantage in measuring intangible organisational investments. As argued by Brynjolfsson and Hitt (2000), non-technological factors cannot be well captured by traditional macroeconomic measurements. The economic contributions of these factors will be examined at the micro level so as to be more appropriate. This analysis employs five non-technological innovation (explanatory) variables constructed based on the following information on organisational change extracted from the firm-level CIS3 data: (i) strategic innovation (STINNO), which refers to the implementation of a new or significantly changed firm's strategy; (ii) managerial innovation (MNINNO), which signifies an attempt to carry out an advanced management technique within a firm; (iii) organisational innovation (OGINNO), which denotes a significant change in a firm's structure; (iv) Marketing innovation (MKINNO), which represents an the introduction of a new or significantly changed marketing concept/strategy of a firm; and (v) Aesthetic innovation (ASINNO), which indicates a significant change in the aesthetic appearance or design of a firm's product. The variable for each type of organisational change equals 1 if a firm is reported to have undertaken the respective type of change between 1999 and 2001, and 0 otherwise.

In addition, information from the CIS3 regarding product and process innovation (PDINNO and PCINNO) was used to create variables to control for the effects of technological innovation. The variables equal 1 if a firm responds that it introduced the respective innovation between 1999 and 2001, and 0 otherwise. Industry and size dummies are also included in the analysis (IND and SIZE). Industrial classification is based on the standard NACE code associated with each firm. Size classes (Size 1, 2, 3 and 4) are classified based on the CIS3 standard breakdown of firm size (in terms of employment), as well as the distribution of firm size in the sample.[19] The value 1 was assigned to each of these control

[19] Sizes 1, 2, 3 and 4 refer to firms with 10-49, 50-99, 100-249 and 250 employees and over, respectively. Dummies for size classes are used as control variables instead of the actual number of employees (or its

variables if a firm belongs to the respective industry and size class, and 0 otherwise. Finally, the analysis includes two measures for a firm's economic performance, namely, labour productivity growth (GPR0103) and profitability growth (GPF0103). These two dependent variables are calculated as (exponential) growth of sales per employee, and of profit per employee, respectively, between 2001 and 2003 (3-year growth rates).

4. Analysis

4.1. Descriptive Evidence

A descriptive analysis of the role played by ICT in explaining firm performance was undertaken by comparing the growth rates (GPR0103 and GPF0103) of ICT-intensive firms (for which ICTINTE > 0) and non-ICT firms (for which ICTINTE = 0) in services, and of firms (both manufacturing and services) the ICT intensity (ICTINTE) of which was above and below the industrial average between 1999 and 2001. Three questions are raised, as follows: (i) whether, and to what extent, ICT-intensive service firms have shown higher growth rates between 2001 and 2003 relative to non-ICT service firms; (ii) whether, and to what extent, service firms with an ICT intensity above the industrial average have shown higher growth rates between 2001 and 2003, compared with those with a lower ICT intensity; and (iii) whether, and to what extent, the differences in these growth rates between 2001 and 2003 between above-average and below-average ICT intensive firms were higher in the manufacturing or service sector. As suggested by Pilat et al. (2002), it may be interesting in an economic sense to compare the performance of ICT-intensive firms with those which have low or no ICT intensity, since this could help to explain the contribution of ICT to growth.

This exercise begins with a comparison of growth rates of ICT-intensive and non-ICT service firms across firms' sizes and industries (see Table 2). The overall results indicate a higher growth of ICT-intensive service firms in terms of both productivity and profitability (the difference is 0.03 and 0.07 %, respectively). However, it seems that these results are driven by the (higher) growth of larger ICT-intensive service firms. In comparison with the growth of non-ICT service firms between 2001 and 2003, ICT-intensive service firms sized 2, 3 and 4 grew higher (0.09, 0.41, 0.72 %, respectively, in terms of productivity, and 0.12, 0.08, 0.46 %, respectively, in terms of profitability), while the opposite is true in the case of Size 1 firms. When attempting to explain the different results for smaller and larger ICT-intensive

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logarithmic value) because the study is also interested in the (possible) relationship between medium-sized firms (i.e. size 2 and 3) and their performance (see below).

Table 2. Mean Productivity Growth (GPR0103) and Mean Profitability Growth (GPF0103) of ICT-Intensive and non-ICT Firms in Services

	GPR0103			GPF0103		
	ICT intensive	Non-ICT	Dif.	ICT intensive	Non-ICT	Dif.
Wholesale trade	0.2208	0.0882	0.1326	0.7158	0.1282	0.5876
Sea Transportation	0.7020	0.2045	0.4975	0.4924	0.2272	0.2652
Transportation and travel services	0.0849	-0.0207	0.1056	-0.1129	-0.1365	0.0236
Business services	0.0553	-0.0219	0.0772	0.1964	-0.1341	0.3305
Financial Services	0.1907	-0.0029	0.1936	0.4104	0.3489	0.0615
Insurance and Pension	1.9400	0.3739	1.5661	2.3100	0.0340	2.2760
Computer-related services	0.1354	-0.0139	0.1493	-0.0239	0.0780	-0.1019
Telecommunications	-0.5668	0.5026	-1.0694	-0.2791	0.3929	-0.6720
Firm size classes (employment)						
Size 1	-0.5823	-0.2415	-0.3408	-0.6449	-0.2401	-0.4048
Size 2	0.0960	0.0041	0.0919	0.0329	-0.0840	0.1169
Size 3	0.5777	0.1707	0.4070	0.3802	0.3010	0.0792
Size 4	1.4155	0.6998	0.7157	1.0181	0.5563	0.4618
Total	0.0566	0.0316	0.0250	0.1568	0.0847	0.0721

service firms, it may be argued that smaller firms typically have a lower scale of business and less members/employees, and hence, less interaction and computerisation. It is thus possible that they benefit less from R&D or innovation based on this technology. When compared across industries, the impact of ICT R&D on growth in services is germane to most cases, except for Telecommunications and Computer-related services.[20] This may relate to the fact that Norwegian ICT producers perform rather poorly, especially compared with those in neighbouring countries like Finland and Sweden, despite enormous R&D efforts being undertaken and governmental support being provided for many decades (Sogner, 2009). However, a number of Norwegian firms in other services (i.e. ICT-using industries) seem to

[20] That is, the sampled firms in Telecommunications/Computer-related services which had invested in ICT R&D (between 1999 and 2001) did not experience higher growth (between 2001 and 2003). Pilat and Wolfl (2004) also show that these ICT-producing services played a rather small role in aggregate productivity growth (between 1996 and 2002) in Norway, as well as in several OECD countries. This may be due to differences in the countries' specialisations, i.e. only a few of the countries are specialised/competent in ICT-producing services. These few countries include Finland, Ireland and Germany.

benefit from developments and applications based on ICT,[21] which are derived, to a large extent, from imports.

Table 3. Mean Productivity Growth (GPR0103) and Mean Profitability Growth (GPF0103) of ICT-Intensive Firms (above and below the industrial average)

	Services			*Manufacturing*		
	ICTINTE > Average	ICTINTE < Average	Dif.	ICTINTE > Average	ICTINTE < Average	Dif.
Productivity Growth						
Size 1	-0.4933	-0.8140	0.3207	-0.3348	-0.3155	-0.0193
Size 2	0.1583	-0.3620	0.5203	0.3176	0.0442	0.2734
Size 3	0.8529	0.1168	0.7361	0.3349	0.1537	0.1812
Size 4	1.9276	0.1084	1.8192	1.5568	0.0305	1.5263
Total	0.2051	-0.2942	0.4993	0.3966	0.0643	0.3323
Profitability Growth						
Size 1	-0.3857	-0.8478	0.4621	-0.1959	0.7819	-0.9778
Size 2	0.2005	-0.6321	0.8326	0.6613	-1.0313	1.6926
Size 3	0.4605	0.3546	0.1059	0.1683	0.3393	-0.1710
Size 4	1.8098	0.0386	1.7712	1.6258	0.1874	1.4384
Total	0.3293	-0.1380	0.4673	0.4361	0.1757	0.2604

Note: The industrial average refers to the median of ICT intensity of firms in each industry (e.g. Wholesale trade, Financial services, Telecommunications). The median was used instead of the mean in computing this average in order to avoid the effect of extreme values of outliers.

The results shown in Table 2 suggest that ICT has helped to improve the economic performance of the majority of Norwegian service firms. The evidence reported in Table 3 appears to corroborate this argument, since it reveals that service firms which invested in ICT above the industrial average between 1999 and 2001 enjoyed higher growth in both productivity and profitability between 2001 and 2003, when compared to service firms which invested less in ICT during the same period. It is worth noting that the differences in growth rates are most apparent in the case of larger firms (Size 3 and 4). This corresponds to the above discussion that more interaction in larger firms possibly increases the benefit of adopting ICT, as well as to one standard justification from the Schumpeterian Hypotheses, which proposes that larger firms have a better capacity to innovate and improve their performance (Schumpeter, 1942).[22] Overall, these results for the service industries respond to

[21] The Norwegian insurance business, for instance, has benefited considerably by its extensive use of ICT since the early twentieth century. For a discussion, see Sogner (2009).

[22] A large body of literature on the so-called "Schumpeterian Hypotheses" embraces two contrasting views of the relationship between the size of firms and innovation. One of the two views emphasises the role of small firms,

the second question above, i.e. there is a sign of a positive relationship between ICT intensity and service firms' growth in productivity and profitability. Nonetheless, this is further tested below in regression models, which include control variables.

With regard to the third question, the results in Table 3 demonstrate that growth rates between above-average and below-average ICT-intensive firms, in terms of both productivity and profitability, differ more in services than in manufacturing. On the whole, these differences are almost double (0.50 versus 0.33 %, respectively, for productivity growth and 0.47 versus 0.26 %, respectively, for profitability growth), and they are also consistent when compared across firms' sizes. Highly ICT-intensive firms in the service industries (devotion to ICT above the industrial average) of almost every size were found to have performed better between 2001 and 2003, compared to those in manufacturing. In summary, the descriptive evidence seems to suggest that there is a productive relationship between ICT and services, i.e. the presence and intensity of ICT drive firm growth in terms of productivity and profitability, and the effects are clearer in the service industries than in manufacturing.

4.2. Econometric Analysis

In this section, the impact of ICT on growth rates is further examined in an OLS (Ordinary Least Squares) regression framework with four model specifications. This econometric exercise is in line with Cainelli et al. (2004), who examined how innovation affects the economic performance of Italian service firms. In their study, three variables were used to measure firm performance, namely growth rates of sales, growth rates of employment, and labour productivity calculated as sales per employee. On the explanatory side, different types of innovation activities were used as regressors to determine their effects.

The present study extends the work of Cainelli et al. (2004) by specifically investigating the impact of ICT R&D and/or organisational change (1999 – 2001) on the growth rates (2001 – 2003) of firms in Norway. In doing so, the data has a lag of two years, which seems appropriate when it comes to estimating the contribution of R&D to productivity (Pakes and

in that entrepreneurs are capable of introducing (radical) innovation to the market, which may devastate the value of incumbent firms ("creative destruction", Schumpeter Mark I, 1911). The other view stresses the relevance of knowledge and other resources accumulated by large firms, for example, through R&D activities, for their innovation process ("creative accumulation", Schumpeter Mark II, 1942). See Scherer (1980), Kamien and Schwartz (1975, 1982), Cohen and Levin (1989) for reviews.

Schankerman, 1984).[23] For the sake of simplicity and clarity, the method used and the results are both discussed below in a step-by-step manner.

$$Y_1 = a_0 + a_1*\text{ICTINTE} + a_2*\text{ORGCHA} + a_3*\text{TECHINNO} + a_4*\text{SIZE} + e_1 \quad (1)$$

$$Y_2 = a_0 + a_1*\text{ICTINTE} + a_2*\text{ORGCHA} + a_3*\text{TECHINNO} + a_4*\text{SIZE} + a_5*\text{IND} + e_2 \quad (2)$$

Both equation (1) and (2) include the following independent variables: ICTINTE (ICT intensity between 1999 and 2001), ORGCHA (dummies for five types of organisational change between 1999 and 2001, STINNO, MNINNO, OGINNO, MKINNO and ASINNO), TECHINNO (dummies for product and process innovation between 1999 and 2001, PDINNO and PCINNO) and SIZE (dummies for four size classes in terms of employment in 2001), where a_i and e_i represent unknown coefficients and error terms, respectively. The differences between these two equations are that the (1), intended as a benchmark estimation, includes both manufacturing and service firms and uses productivity growth (GPR0103) as a dependent variable (Y_1), while the (2), intended for the study's focus on service firms, controls for service heterogeneity by taking in dummies for industrial classification (IND), and employs both productivity growth (GPR0103) and profitability growth (GPF0103) as dependent variables (Y_2) one at a time (see Table 4 & 5). The analysis takes into account all of the service firms in the sample, which, according to Pilat and Wolfl (2004), represent both major ICT-using services (i.e. wholesale trade, business services, financial services, and insurance) and ICT-producing services (i.e. computer-related services and telecommunications).[24]

Table 4 presents the regression results based on the specification in Equation 1. These results corroborate the descriptive evidence and theories outlined above, which point to the importance of ICT to firm growth, particularly in the service industries. In the case of manufacturing firms, the coefficient of ICT intensity (ICTINTE) is positive (0.184), but not statistically significant. This implies that manufacturing firms may also benefit from ICT, but the evidence is unconfirmed in this case. Contrarily, the coefficient of ICT intensity in service firms is positive and highly significant (0.068 at the 1 % level). In both cases, the coefficients

[23] Brynjolfsson and Hitt (2003) also show that, in the case of ICT, a time lag of more than one year enables the effect of computerisation on productivity and output growth to become more apparent.

[24] The CIS3 in most (European) countries, including Norway, does not cover some important industries. A prime example is the retail industry, which is actually an important component of many economies, especially the US (Triplett and Bosworth, 2004; Betancourt, 2004).

of size dummies are also considered to be consistent with the descriptive statistics provided in the previous section. The econometric results indicate a higher growth in larger firms (especially Size 4, i.e. firms with more than 250 employees). Nonetheless, having checked for multicollinearity,[25] the other variables display unclear effects of product and process innovation (PDINNO and PCINNO),[26] as well as organisational change (STINNO, MNINNO, OGINNO, MKINNO and ASINNO), on productivity growth (GPR0103).[27]

Table 4. Impact of ICT and other Innovation Activities on Productivity Growth (GPR0103) of Manufacturing and Service Firms

	Services	Manufacturing
(Constant)	-0.373*** (.048)	-0.380*** (.040)
ICT intensity		
ICTINTE	0.068*** (.025)	0.184 (.115)
Organisational Change		
STINNO	-0.123* (.071)	0.013 (.049)
MNINNO	-0.007 (.076)	-0.014 (.056)
OGINNO	0.039 (.063)	-0.004 (.047)
MKINNO	0.003 (.067)	0.023 (.051)
ASINNO	-0.124 (.080)	0.067 (.051)
Technological Innovation		
PDINNO	-0.003 (.065)	-0.007 (.060)
PCINNO	0.032 (.074)	0.001 (.060)
Firm size classes (employment)		
Size 1	Ref.	Ref.
Size 2	0.306*** (.065)	0.259*** (.051)
Size 3	0.729*** (.062)	0.606*** (.048)
Size 4	1.257*** (.082)	1.085*** (.071)
No. of Observations	674	1119
R^2	0.331 (.320)	0.230 (.223)

*,**,*** denote significance at the 10, 5 and 1 % level, respectively. Standard errors and adjusted R^2 in brackets

[25] Detailed statistics (not documented here, available upon request) indicate that there is no high correlation among these variables.

[26] It may be the case that product/process innovation also is dependent upon ICT intensity. Nonetheless, this causal relationship is difficult to test on the basis of the data used in this study, since these variables refer to the same time period. For example, to examine the influence of ICT intensity on the rates of organisational change, Hollenstein (2004) estimates an equation in which the variable for ICT intensity is lagged by three years.

[27] It should be mentioned that the coefficients of some types of technological innovation and organisational change are negative (for example, product, strategic and managerial innovation), which implies that these attempts may have a negative influence on firm performance. Although these coefficients are not (sufficiently) significant (i.e. unproven findings), it may be explained that, for example, to implement a new strategy or an advanced management technique might not pay off if organisational members are not ready or have strong inertia (Amburgey et al., 1993; Sapprasert, 2008). Also, in terms of manufacturing, focusing on (radical) product innovation can waste money and other resources toward the end of the product lifecycle (Utterback, 1994).

Table 5. Impact of ICT and Other Innovation Activities on Economic Performance of Service Firms (GPR0103 & GPF0103)

	GPR0103	GPF0103
(Constant)	-0.371* (.196)	-0.057 (.248)
ICT intensity		
ICTINTE	0.068*** (.026)	0.053** (.026)
Organisational Change		
STINNO	-0.136* (.072)	-0.193** (.095)
MNINNO	-0.002 (.076)	0.076 (.101)
OGINNO	0.028 (.064)	0.071 (.087)
MKINNO	0.006 (.068)	-0.106 (.092)
ASINNO	-0.135* (.082)	-0.127 (.105)
Technological Innovation		
PDINNO	-0.012 (.068)	-0.027 (.096)
PCINNO	0.036 (.075)	0.077 (.101)
Firm size classes (employment)		
Size 1	Ref.	Ref.
Size 2	0.309*** (.066)	0.300*** (.092)
Size 3	0.727*** (.064)	0.743*** (.086)
Size 4	1.242*** (.086)	1.251*** (.117)
Industry dummy		
Wholesale Trade	0.024 (.198)	-0.254 (.252)
Sea Transportation	0.015 (.210)	-0.427 (.269)
Transportation and Travel Services	-0.097 (.201)	-0.359 (.256)
Business Services	0.001 (.201)	-0.290 (.255)
Financial Services	0.144 (.256)	-0.264 (.260)
Insurance and Pension	0.305 (.259)	0.023 (.321)
Computer-related services	0.045 (.201)	-0.217 (.256)
Telecommunications	-0.029 (.244)	-0.323 (.314)
No. of Observations	674	689
R^2	0.338 (.371)	0.227 (.203)

*,**,*** denote significance at the 10, 5 and 1 % level, respectively. Standard errors and adjusted R^2 in brackets

The effect of ICT on service firms in particular is further explored using both productivity growth (GPR0103) and profitability growth (GPF0103) between 2001 and 2003 as dependent variables, and industry dummies as additional variables to control for industry heterogeneity, as specified in Equation 2. Table 5 illustrates the results of this econometric estimation. Again, regardless of the growth indicators employed, the contribution of ICT as a key success factor of service firms seems evident (Evangelista, 2000; Gershuny and Miles, 1983; Miles, 2000). The coefficients of ICT intensity (ICTINTE) are statistically significant in both model specifications (0.068 at the 1 % level and 0.053 at the 5 % level, with productivity growth and profitability growth employed as dependent variables, respectively), while the results of other explanatory variables are all consistent with those in Table 4. In addition, despite (possible) heterogeneous characteristics across (groups of Norwegian) service industries as pointed out

by Soete and Miozzo (1989),[28] the study found no clear industry-specific effects (IND) on the growths of service firms. This is the case for both producers and users of ICT in Norway.[29] Table 5 does not appear to provide any (significant) evidence to support the point that the sampled Norwegian firms in different service industries may have grown differentially to a considerable extent, for example, due to service heterogeneity.[30]

The results of the estimates so far suggest, among other things, that ICT explains the growth of service firms in Norway. Nevertheless, since no considerable benefit of organisational change has been found as hypothesised, two additional model specifications are taken into account for a further investigation into the joint contribution of ICT and organisational change to growth. As argued above, these aspects of change could be complementary in levering the growth and competitiveness of a firm (Brynjolfsson and Hitt, 2000, 2003). In this respect, a new variable**,** ORG, is constructed to represent (as a proxy for) the five types of organisational change considered in this study (STINNO, MNINNO, OGINNO, MKINNO and ASINNO), and is used to create an interaction term between ICT intensity and organisational change (ICTINTE*ORG). The value of ORG, which refers to the presence of (any attempts at) organisational change, equals 1 if a firm is reported to have undertaken at least one of the five types of organisational change, and 0 otherwise. ICTINTE*ORG, which refers to the joint effort between ICT R&D and organisational change, is the result of multiplying ICTINTE by ORG. Both of these variables are used in Equation 4, following the works of Brynjolfsson et al. (2002) and Hempell et al. (2004),[31] to examine the joint impact between ICT and organisational change on a service firm's growth. Equation 3, where only ORG is added (and replaces the five separate variables for organisational change – ORGCHA,

[28] Castellacci et al. (2009) classify sixty industries in Norway based on their characteristics related to innovation (for example, innovation expenditures, sources and effects). This classification results in three broad groups of industries, which are science-based, resource-based and low-intensity innovators. ICT-producing services (telecommunications and computer-related services) are in the first group, while the last group includes some key ICT-using services, such as wholesale and financial services.

[29] Pilat and Wolfl (2004) also found that, in Norway, the contributions of both ICT-producing and ICT-using services to aggregate productivity growth between 1996 and 2002 were comparable (i.e. quite small). This may relate to the fact that, for decades, the other (resource-based) industries like oil and gas, and fish-farming have been the most important contributors to growth in the Norwegian case (Fagerberg et al., 2009).

[30] Carrying out separate estimates (split-file analyses) per industry may have provided a more detailed view on the effects of service heterogeneity on firm performance. However, this was not possible for many of the industries since the number of sampled firms per industry is too low.

[31] Brynjolfsson et al. (2002) found that ICT and organisational change are complementary inputs which enhance the performance of US firms, whereas the evidence of Hempell et al. (2004) shows some conflict since the joint impact of ICT and organisational change is unclear in the Dutch case.

which was included in Equations 1 and 2 above), is also taken into consideration for the purpose of comparison (of the two sets of results based on Equation 3 versus Equation 4, see Table 6). Both model specifications employ productivity growth (GPR0103) as a dependent variable (Y_3 and Y_4), and ICTINTE as an explanatory variable, and have the same set of remaining control variables with that in Equation 2 (TECHINNO, SIZE and IND; see above for an explanation of these variables), with a_i and e_i also representing unknown coefficients and error terms, respectively. Equations 3 and 4 are formulated as:

$$Y_3 = a_0 + a_1*ICTINTE + a_2*ORG + a_3*TECHINNO + a_4*SIZE + a_5*IND + e_3 \quad (3)$$

$$Y_4 = a_0 + a_1*ICTINTE + a_2*ORG + a_3*(ICTINTE*ORG) + a_4*TECHINNO + a_5*SIZE + a_6*IND + e_4 \quad (4)$$

The results in Table 6 seem to suggest two main points, which are the contribution of a joint effort between ICT and organisational change, and the consistency of the effects of other factors on growth. The estimate based on the specification in Equation 3 yields results comparable to those in Table 5, i.e. productivity growth is influenced by ICT intensity and size, but not industry heterogeneity (IND), technological innovation (TECHINNO),[32] or organisational change (ORG). However, the results change somewhat when the interaction term, ICTINTE*ORG, is added (see Equation 4). The main difference is that the coefficient of ICT intensity (alone) is no longer very significant (ICTINTE), while the new explanatory variable (ICTINTE*ORG) turns out to exert a significant, positive, larger effect on the productivity growth of service firms (the coefficient of 0.134 at the 5 % level). These results imply that investing jointly in ICT and organisational change may be more beneficial, since this could lead to a better performance of the firm than either of them alone. This is in line with Brynjolfsson et al. (2002), who demonstrate that computerisation and reorganisation combined generate a higher value than the simple sum of their separate contributions. Thus, in order to be successful, service firms may need to be reinforced with a combination of ICT and organisational change (Brynjolfsson and Hitt, 2000, 2003).

[32] As discussed above, service innovation is rather non-technological and intangible, and is largely centred on firms' immense interactions with users and suppliers. The unclear effects of technological innovation on the performance of service firms (based on all of the relevant results presented here, see Table 4, 5 and 6) may be due to the fact that it is difficult, and perhaps problematic, to measure their innovation in terms of a traditional typology like product and process innovation, which is more relevant to the production of goods.

Table 6. Joint Impact of ICT and Organisational Change on Productivity Growth (GPR0103)

	GPR0103	GPR0103
(Constant)	-0.394** (.198)	-0.384* (.198)
ICT intensity		
ICTINTE	0.066*** (.026)	0.042 (.028)
Organisational change and its joint contribution with ICT		
ORG	-0.062 (.054)	-0.065 (.054)
ICTINTE*ORG	-	0.134** (.067)
Technological Innovation		
PDINNO	-0.027 (.078)	-0.040 (.069)
PCINNO	0.027 (.074)	0.035 (.074)
Firm size classes (employment)		
Size 1	Ref.	Ref.
Size 2	0.325*** (.067)	0.312*** (.066)
Size 3	0.737*** (.064)	0.733*** (.064)
Size 4	1.244*** (.085)	1.228*** (.086)
Industry Dummy	Yes	Yes
No. of Observations	674	674
R^2	0.330 (.313)	0.334 (.316)

*,**,*** denote significance at the 10, 5 and 1 % level, respectively. Standard errors and adjusted R^2 in brackets

5. Major Findings and Concluding Remarks

This paper explores the links between some innovation activities and the economic performance of firms in Norway. The relationship between ICT and the growth of firms in service industries is of major concern, with manufacturing firms and other types of technological innovation involved in the analysis as benchmarks. Organisational change is also taken into consideration to investigate its joint contribution with ICT to the growth of service firms. Put simply, this study is concerned with two specific research interests, which are the relationship between ICT and firm-level growth in services, and the complementarity between ICT and organisational change.

The study found that most ICT-intensive service firms have outperformed non-ICT service firms in terms of both productivity and profitability growth, and those with ICT intensity which exceeded the industrial average have experienced even higher growth rates. The results also demonstrate a wider performance gap between the more-versus-less ICT-intensive service firms, when compared to the case of manufacturing. This is in line with the argument that ICT is one of the major economic driving forces, particularly for service industries, during the current techno-economic paradigm (Castellacci, 2006; Freeman and Louca, 2002;

Gershuny and Miles, 1983). As Evangelista (2000) points out, this phenomenon is largely due to the information-based fundamental characteristics of services, which give ICT a central role in service innovation and thus, help to promote the superior growth of service firms (OECD, 1996).

The econometric results appear to be along the same lines. It is evident from different estimations that there is a positive relationship between ICT and the growth of service firms, whereas this is not confirmed (not statistically significant) in the case of manufacturing. As is commonly argued, a firm's size has an influence on its economic performance, but other technical innovation activities do not show the same consistent contribution to growth as ICT R&D. This finding seems to be consistent with the view that ICT is the most important technology for innovation in services (Licht et al., 1999), while "other technologies are of relatively minor importance" (Hipp and Grupp, 2005:520). More importantly, the study found a complementary effect of ICT and organisational change on a firm, i.e. a firm's performance can be improved even more if these attempts are undertaken jointly. As Bresnahan et al. (2002) point out, it is possible that a firm which has invested heavily in ICT does not benefit from it as much as expected, and this is because ICT necessitates reorganisation. In many cases, it is not ICT alone, but the joint contribution of ICT and organisational change which is a compulsory recipe for true success (Brynjolfsson and Hitt, 2000, 2003; Brynjolfsson et al. 2002).

However, it is important to note that this study has some limitations, and that it may be extended in many ways. Firstly, the study's lack of information of other types of firms' ICT investment, such as ICT training or the employment of workers equipped with ICT skills, should be mentioned. This is important because, in fact, many service firms do not invest in ICT R&D, but rather undertake a range of other innovation activities related to ICT, and gain competitive advantage from these. To include such information in the analysis would have led to more insights into the issue. Moreover, the analysis may then have been extended to examine in greater detail how the joint effort of different types of ICT investment and different types of organisational change affect firm performance. Also, had the analysis been undertaken with somewhat more observations, it could have obtained sufficient information for separate estimates of each industry, which may have yielded a better understanding of the influence of service heterogeneity on economic performance. To extend the study in this way may lead to more meaningful findings. Finally, since the boundary between manufacturing

and services is increasingly blurring (for example, a vast number of manufacturing firms nowadays also provide services), it would be interesting to study service innovation which may also take place outside the service industries.

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