Contribution of the digital communications sector to economic growth and productivity in the UK – economic analysis paper

FINAL REPORT PREPARED FOR THE DEPARTMENT FOR CULTURE, MEDIA AND SPORT (DCMS)

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Contents

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1 Introduction

Frontier Economics has been commissioned by the Department for Culture, Media and Sport (DCMS) to investigate the communication sector's contribution to economic growth and productivity in the UK.

The objective of this research is to address the following questions:

i) What are the channels through which the communications sector drives economic growth and productivity?

ii) What is the quantified economic impact of the communications sector on economic growth and productivity in the UK?

iii) What are the insights from historical studies (and where appropriate international examples) for formulating policy interventions in the UK communications sector to maximise the potential for economic growth and productivity?

This economic analysis paper accompanies the report, "Contribution of the digital communications sector to UK economic growth and productivity".

In order to address the three overarching questions, we have:

- Undertaken a review of the published material to identify the channels through which the communications sector contributes to growth;
- Reviewed the available evidence which estimates the quantified contribution of the sector to growth. This has been complemented by new analysis by Frontier which explores the estimated contribution of the sector to growth, using an econometric approach; and,
- Reviewed the available relevant material in order to provides insights around the factors that enable the sector to contribute to growth effectively.

Context

Most of the published studies have traditionally explored the contribution of Information and Communication Technologies (ICT) to economic growth, rather than focusing on communications *per se*.

ICT covers a broad range of factors across information and communications technologies. The communications sector incorporates investment in infrastructure (trenches, cables and ducts, for example); equipment (routers,

transmission equipment, DSLAMs[1], OLTs[2]); along with all the digital content sectors such as video, film, computer games etc.

Although still relatively limited, a greater body of evidence has emerged more recently focusing on communications, in particular mobile communications and broadband.

Within the communications-specific literature, however, there is a greater tendency for the published studies to focus on telecommunications including broadband, as opposed to the 'content' elements of communications (such as for example, television programmes, social networking etc). This should be borne in mind when considering the material reviewed for this project.

This report presents:

- The key channels through which the sector drives growth, drawing on the available evidence;
- Evidence on the estimated quantified impact of the ICT sector and the communications sector specifically on growth;
- Preliminary analysis undertaken by Frontier to explore the relationship between communications and growth, using econometric analysis of past trends; and,
- Some policy insights in terms of the factors that enable the contribution of the sector to growth to be more effective.

[1] **Digital Subscriber Line Access Multiplexer:** allows telephone lines to make faster connections to the internet

[2] **Optical Line Terminal:** service provider endpoint of a passive optical network

2 Channels through which the communications sector contributes to growth and productivity

This section presents the results of a review of published material that has sought to identify the channels through which the sector contributes to growth.

Before presenting the review, it is useful to note that the communications sector can be considered as similar in several ways to other 'network' sectors such as transport. This is briefly explored next, before focusing on the channels through which the sector impacts on growth.

2.1 Shared characteristics with other sectors

The Eddington study of transport's contribution to growth and productivity[3] in the UK found a number of 'micro drivers' through which the transport sector could contribute to economic growth. These were identified as:

- increasing business efficiency,
- enhancing investment and innovation,
- supporting clusters and agglomerations,
- improving the efficient functioning of labour markets,
- increasing competition,
- increasing domestic and international trade and
- attracting globally mobile activity.

In many ways, the transport sector is similar to the communications sector because they each involve reliance on significant fixed infrastructure, and linked with this they have a regulatory framework that regulates how that infrastructure is used and at what price (for some components of their infrastructure at least). In addition, they both allow organisations and individuals to be more connected than otherwise (in person in the case of transport or through visual and/or audio connections in the case of the communications sector). Importantly also, they both play a fundamental role in the day to day activities of businesses, other organisations and individuals. Given these shared characteristics, at least some of

[3] See: http://webarchive.nationalarchives.gov.uk/+/http:/www.dft.gov.uk/adobepdf/187604/206711/executivesummary.pdf

the Eddington 'micro-drivers' are therefore likely to be relevant for the communications sector.

Some studies include the communications sector within a category which is referred to as those providing a 'general purpose technology' as referred to above. In practice, this term is used to describe technologies whose impact spreads widely into a large number of other sectors.[4] The CEBR (2003) report for example highlighted the communications sector in this way and compared broadband with railways and electric power generation. They found that:

- Firstly, **the economic impact of broadband is likely to come through more quickly than those of both railways and electricity**: the analysis undertaken by CEBR (2003) indicated that much of the diffusion of broadband through households would have taken place within 10 years of the first applications. By contrast, after the first investments in railways in the early 1830s, the peak levels of railway investment in the UK did not take place until the late 1840s and significant investment was still taking place as late as the mid-1860s.[5]

  The diffusion of electricity was slower, with only 50 per cent of US manufacturing plants using electricity by 1919, despite electric power generation being invented in the early 1870s;

- Secondly, estimates of the potential impact of broadband on productivity in the CEBR (2003) report are in the range 0.39-2.66 per cent in 2015 and 0.84-5.73 per cent in 2028. These are comparable to those for the electricity sector estimated by previous studies, about 3.3 per cent.[6]

As mentioned earlier, some studies found that the impacts on growth are likely to be greater if a critical mass of penetration is reached. This implies that the more users there are, the greater the benefits – often referred to as 'network externalities'. This characteristic is likely to differ from other infrastructure sectors in which the benefits to one user are not likely to rise with the level of other users. Although congestion and the level of use are relevant for all sectors including communications (all infrastructure has a maximum level of efficient use), this issue appears to have been less explored for the communications sector.

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4 See CEBR (2003): "The Economic Impact of a Competitive Market for Broadband", A CEBR report for The Broadband Industry Group, November 2003.

5 CEBR (2003) refers to B. R. Mitchell, 'The Coming of the Railway and United Kingdom Economic Growth' in Railways in the Victorian Economy, M.C. Reed (ed) 1969.

6 CEBR (2003) refers to the following two studies: David, P.A. and G. Wright: "General Purpose Technologies and Surges in Productivity: Historical Reflections on the Future of the ICT Revolution" paper presented to the International Symposium on Economic Challenges of the 21st Century in Historical Perspective, Oxford University 1999; and Matthews, R.C.O., C.H. Feinstein, and J.C. Odling-Smee (1982) 'British Economic Growth 1856-1873'.

Channels through which the communications sector contributes to growth and productivity

A further issue raised within the literature relates to non-linearity in the effects of investments in infrastructure and growth. The OECD (2009)[7] explored this issue and found that when looking at cross-section analysis and over a period of years, the link between infrastructure and growth demonstrates non-linear characteristics. This means that the strength of the link appears to be related to the initial level of provision. So, for example, for countries which have low initial levels of investment, subsequent investment adds to growth in a way which is often greater than the effect would have been in countries which started from a higher level of initial provision.

The following section discusses the available evidence on the channels through which the communications sector is able to contribute to economic growth and productivity.

2.2 Exploring the evidence on the channels through which the communications sector contributes to growth

Overview

There are several routes through which the communications sector may impact economic growth beyond its direct effect on GDP.

The new opportunities created by the use of communication services by firms and consumers are mainly related to the capacity of communication services to **improve the speed and quality of information flows between the different parties** (within organisations, between organisations, between organisations and customers, etc.). This, in combination with the development of some applications, such as secure payment systems or e-commerce, allows particular channels through which the sector impacts on growth to be identified. These include:

- Enhanced speed and quality of information flows
- Increased business efficiency;
- Improved access to markets;
- Managing people and processes; and
- Enhancing diffusion of innovation.

[7] Balázs Égert*, Tomasz Kozluk, Douglas Sutherland (2009) Infrastructure and Growth, OECD Economics Department Working Paper number 685.

These are the main drivers identified in the literature through which the communications sector impacts economic growth and are discussed in the following.[8]

Enhanced speed and quality of information flows

In many ways, this can be considered to be a general descriptor of the role of communications technologies in everyday life and economic activity. It is therefore fundamental to the role of the sector in facilitating other activities in the economy either to be more effective or productive.

The sector is an example of a general purpose technology (GPT) sector. It develops enabling technology which pervades all sectors of the economy, driving economic growth and productivity. These economic gains become even larger as the benefits of increased investment in capital by the communication sector is reinforced by increased usage across the sectors and is complemented by factors such as skills and organisational change. Essentially, this is because communication costs time and in many cases, money. Therefore, any improvement to the pace and quality of that flow of information would eventually feed its way into GDP.

The value of communications more generally to businesses is demonstrated in the results of a survey for the British Chambers of Commerce (2003) for example, which found that companies of all sizes and sectors considered more effective communication as the biggest benefit of having a broadband connection for their business.

Increased business efficiency

Investment and use of communication services by companies is likely to enhance business efficiency in a number of ways. In particular, the availability of a better communication infrastructure allows companies to reduce transaction costs associated with ordering, gathering information and searching for goods and services. Also, the adoption of standardised electronic contracts for example, can lower the average cost of contracting, especially for business to business transactions.[9] Companies can also improve their performance by adopting more efficient business processes by using certain communications applications which allow the implementation of remote monitoring and logistics management, among others.[10]

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8 See Shanks, S. and P. Barnes (2008): "Econometric Modelling of Infrastructure and Australia's Productivity", Cat. No: 08-01; and, ITU/UNESCO (2011): "Broadband: A Platform for Progress", A Report by the Broadband Commission for Digital Development. June 2011.

9 See Shanks and Barnes (2008).

10 See ITU/UNESCO (2011).

Channels through which the communications sector contributes to growth and productivity

According to a survey by the British Chambers of Commerce (BCC)[11], 46.4 per cent of businesses (among the sample of responders) mentioned an improvement in business productivity associated with broadband; and, 45.3 per cent considered broadband contributed to a cost reduction.

More recently, Ofcom published the results of a survey on the business customer experience with regards to communication services.[12] This found that businesses prioritise communications because they are seen as being ways of achieving cost savings and enabling more effective competition. Examples include: enhanced sales and marketing via web presence, better customer response via smartphones and greater workforce flexibility and efficiency via facilities such as remote access and video conferencing.

Improved access to markets

Another way in which better communications, in combination with an efficient transportation system, may enhance economic growth is by facilitating access to markets:

- Access to customers: businesses can reach customers located far away from their traditional distribution network as sales can be made via the internet. The Ofcom survey referred to above highlights the value business placed on marketing via the internet. In this regard, the diffusion of communication services allows markets to become global in terms of their geographic scope. OECD (2000) found that the internet offers the opportunity to reduce barriers to entry and make markets more contestable. Several studies have investigated the impact of online sales on a number of variables, including retail prices. This evidence is reviewed in more detail below as a case study on e-commerce.
- Access to suppliers: businesses have access to a broader range of suppliers for their inputs, which is likely to lead to cost reductions. A study by Goldman Sachs[13] (2000) found that the efficiency gains associated with e-commerce in business to business transactions ranged between 2 and 40 per cent of total input costs, depending on the industry.
- Access to labour: companies have access to a broader labour market to recruit their employees. With the development of broadband many companies have adopted online recruitment processes, allowing the

11 BCC (2003): "Business Broadband: A BCC Survey: A State of the nation survey into the penetration and impact of broadband on British business", in association with Cisco Systems. September 2003.

12 Ofcom (2010): "The Business Customer Experience", Research document, 7 December 2010.

13 Goldman Sachs (2000): "The shocking economic effect of B2B", *Global Economics Paper*, No. 37

submission of applications from candidates everywhere. Also, the use of videoconferencing provides the possibility of undertaking remote interviews. Overall, this allows companies to select their candidates from a broader pool, hence, increasing the chances of hiring a good match for the company.

An example that has been widely quoted in the literature of how the improvement of communication has affected businesses' access to markets is the case of fishermen in the south of India.[14] This example was reported in an article from the Economist,[15] and was based on the research undertaken by Jensen (2007).[16] It describes how fishermen in the coast of northern Kerala benefited from the use of mobile telephony. Before the availability of mobile telephony fishermen used to keep to their home markets for trading, even if this led to an excess supply and significant waste of fish. The article reports that on average, 5-8 per cent of the total catch was wasted. With the diffusion of mobile telephony, fishermen were able to avoid this inefficiency by selling their fish on markets where demand was high, allowing them to reap higher benefits and reduce the wastage of fish.

Managing people and processes

A key benefit associated with the adoption of communication services by companies and individuals is the improvement in information flows within organisations.

A survey by the BCC (2003) found that companies of all sizes and sectors considered more effective communication as the biggest benefit for their business of having a broadband connection (68 per cent of the firms rated this as beneficial).

Shanks and Barnes (2008) emphasize that better information flows inside a company facilitate better and more timely decision making. Quoting Nadiri and Nandi (2001),[17] they state that the modernisation of the communications network has increased the efficiency of managers' communications, helped the coordination of independent units and increased the transfer of information and knowledge. Similarly, they refer to Madden and Savage (2000, p. 895)[18] who

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14 See Vuong, V. (2008): "Mobile Telecommunication Impact on Developing Countries' Growth", Tilburg University, 30th May 2008.

15 http://www.economist.com/node/9149142?story_id=9149142

16 Jensen, R. (2007): "The Digital Provide: Information (technology), market performance and welfare in the South Indian fisheries sector", *Quarterly Journal of Economics*, 122 (3): 879-924.

17 Nadiri, M.I. and Nandi, B. (2001): "Benefits of communications infrastructure capital in U.S. economy"", *Economics of Innovation and New Technology*, vol. 10, pp. 89–107.

18 Madden, G. and S. Savage (2000): "Telecommunications and economic growth", *International Journal of Social Economics*, vol. 27, no. 7/8/9/10, pp. 893–906.

Channels through which the communications sector contributes to growth and productivity

suggest that "The ability of managers to communicate efficiently over large distances reduces X-inefficiency and expands the stock of entrepreneurial talent".

More broadly, the development of communication systems have enhanced the implementation of "knowledge management" (KM) practices by companies. Clayton (2005) summarises the process of KM into three categories:

- Gathering and storing knowledge,
- Structuring knowledge, and
- Collaboration/sharing of knowledge.

Case study evidence, reviewed by Clayton (2005), shows that on the whole, knowledge management practices have been successful in allowing companies to reap significant savings in terms of time and labour and a better interaction with customers.

In addition to improving information flows inside companies, better communication services have allowed the development of applications such as e-learning, which increases access to education and training (inside and outside companies).

Clayton (2005) analysed case studies which found that an interesting development among some firms has been people development combined with knowledge management to allowing collaborative learning. This has resulted in a higher number of trainees, higher worker productivity and lower costs.

Enhancing diffusion of innovation

From the organisational structure perspective, the availability of efficient communication services in combination with improvements in the transport sector have enabled companies to implement a number of organisational changes. Among others, these include:[19]

- the centralisation of distribution sites;
- industry relocation and concentration,
- the implementation of just in time (JIT) processes.

A clear example of how communication services, and the internet in particular, in combination with a developed transport system, has allowed new models of organisations is the case of Amazon who is able to operate globally delivering a wide range of products. There are many other examples of businesses operating in a similar way.

19 See Shanks and Barnes (2008).

An important organisational change enabled by communication services is the introduction of flexible work patterns and teleworking. According to an Ofcom survey (2010), in 2010 over one third of the companies (36 per cent) worked from a home office. High levels of work mobility were also found, with almost four in five (78 per cent) of those interviewed working out of the office at other fixed locations and/or whilst travelling.

The flexibility facilitated by advanced communication services enables the creation of virtual firms with flat organisational structures and quite often with no fixed teams or branches. Virtual firms use the best people for the job on each project and are characterised by flexible working time, teleworking, knowledge management and flexible office spaces for meetings.[20] Clayton (2005) describes the case of Rauser Advertainment Virtual Office in Germany which specialized in the development of entertainment and advertising products for customers from a variety of countries. This company operated as a virtual organisation, employing six people, using a worldwide network of around 100 freelancers, which allowed it to achieve higher levels of flexibility and lower fixed costs compared to non-virtual companies.

The improvement in ICT has also allowed companies to adopt more decentralised structures as information is easier to transmit inside companies. Lee et al. (2006)[21], quoting Malone (2004),[22] details the process through which ICT allows companies to decentralise their decision making. Firstly, when the costs of sharing information are high, decisions need to be made through independent decentralised channels. As information costs begin to fall, it becomes worthwhile to collect global information together in one central place, where decision makers can work strategically with a more informed view than local decision makers can (the traditional 20th Century Fordist production model is an example of this). As information costs fall a third model emerges and decentralised decision making becomes increasingly important, as information becomes easier to transmit. In this way, Lee et al. (2006) find that ICT allows larger firms to use both the benefits of large organisations (economies of scale and knowledge), and those of smaller ones (freedom, motivation, creativity and flexibility).

From a broader perspective, communications infrastructure and services have been identified by some studies as a determinant for innovation. For example, as stated by Clayton (2005), "Interacting with the end user over the internet is a major innovation (e.g. patients being able to have contact with a virtual medical

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20 See Clayton (2005).

21 Lee, N, P. Schneider and I. Brinkley (2006): "R&D, ICT and Productivity: An evidence paper for the Knowledge Economy Programme", The work foundation.

22 Malone, T.W. (2004): *The Future of Work: How the New Order of Business Will Shape Your Organisation, Your Management Style, and Your Life*, Boston, MA: Harvard Business School Press

team or customers awaiting deliveries being able to track them on their journey).”[23]

In the empirical study undertaken by Martin and Nguyen-Thi (2010)[24], they find that a key feature associated with the communications sector and its digitisation is the capacity to enhance innovations at different levels. They analyse the impact of the use of different communications components (software, intranet, extranet, video conference, electronic forum, group project, online purchases and online sales) on different types of innovations namely, product innovation, process innovation, organisational innovation and innovative performance. They find support for the hypothesis that communications is an “enabler of innovation”. In particular:

- The use of e-commerce increases the probability of product innovation and enhances innovative performance (measured as the percentage of total turnover from product innovations that are new to the firm);
- The use of internal communication tools for facilitating communications, such as electronic groups positively affects the probability of introducing product, process and organizational innovations; and,
- Investment in software is significantly associated with the probability of introducing new organizational methods inside the firm.

The introduction of online marketing has been one of the major innovations enabled by communications services. The Ofcom (2010) survey shows that three quarters of companies with access to the internet had a company website (77 per cent) and 41 per cent were also using the internet for online marketing (41 per cent).

Focusing on broadband, ITU / UNESCO (2011)[25] also emphasize the potential effect on innovation, not only within the communications equipment sector but also in other sectors of the economy that rely on communications. The study specifically mentions several examples of innovative services that have been enabled with broadband, such as telemedicine, online education, video-on-demand, or new forms of commerce and financial transactions.

In addition, by enhancing information diffusion, ITU/UNESCO (2011) stress the role of broadband as an effective means of fostering research and

23 See Clayton (2005), page 33.

24 Martin, L. and T.U. Nguyen-Thin (2010): “Impact of R&D and ICT on Innovation and Productivity: Empirical Evidence from Micro Data”, Paper to be presented at the Summer Conference 2010 on “Opening Up Innovation: Strategy, Organization and Technology”. June 2010.

25 http://www.broadbandcommission.org/report2/full-report.pdf

development activities for industry, as well as the transfer of technical and other types of knowledge.

The consumer perspective

Although most published studies have been undertaken looking at the economy or business impacts of communications, it is important not to lose sight of the potential impacts on consumers.

In addition to the direct benefits that consumers obtain from digital communication services, which are reflected in their willingness to pay for these services, there are also a number of other indirect benefits.

On the one hand, the improvement in companies' performance resulting from the use of communication services through the channels discussed above is expected to lead to higher consumer welfare through the impact on prices, product variety, etc.

On the other, improving the information available and reducing search costs benefits individuals in different ways. These include:

- Individuals can take better and more informed decisions (e.g. the internet is increasingly relied upon to compare prices and services, such as when booking a holiday)
- The development of eGovernment, online banking and related services has allowed individuals to reduce their time spent on government and administrative activities. For example, it is possible to renew Vehicle Excite Duty over the telephone or internet in the UK.

Particular attention has been given to the potential development and impact of e-health (i.e. providing health online). In addition to the cost savings that e-health is expected to have on total healthcare costs[26] it is expected to increase the quality of life by improving the monitoring of patients at home or on the move (e.g. using mobile technology) and reduce the travel costs to the medical centre.

E-education is another development associated with digital communications which is likely to have increased the quality of life. E-learning allows individuals to gain access to educational resources that would not be available otherwise. It also provides higher flexibility in terms of timing, hence, making it easier to invest in education while working.

Further, the introduction of flexible work practices by companies is also likely to exert a positive impact on consumers. For example, teleworking allows individuals to better manage their time and reduce their commuting costs, generating positive external effects on travel. Also, the use of digital

26 ITU/UNESCO (2011) provide a range of 10 - 20 per cent, page 98.

communication services, such as video conference facilities, is likely to reduce the need to travel during business hours.

A recent study carried out by Frontier Economics for Telekom Austria estimated the indirect impact of broadband in terms of the positive external effects of eGovernment (online provision of government services) reduced external costs of transport from tele-working, in a number of countries where the Telekom Austria Group operates. The indirect impact associated with these two effects amounted to almost 12 per cent of the total benefits generated by broadband.

2.3 A case study on e-commerce

There is an increasing body of evidence relating to e-commerce. This illustrates how the channels through which the sector impacts on growth are visible in practice. Box 1 summarises some recent studies that explore e-commerce.

Case –study: e-commerce

E-commerce has been considered in a range of studies. An early study by the OECD on e-commerce[27] considered the potential impact of e-commerce on a number of factors, including prices, competition and economic growth among others. Although the evidence at the time of the survey was rather preliminary, when combined with evidence from other studies, it suggests a range of interesting insights:

- **Prices**: On business to customer transactions, Brynjolfsson and Smith (2000)[28] looked at the prices for books and CDs through both channels (Internet and physical stores) in 1998-1999 found that the prices of these goods were 9-16% lower when sold over the internet. Goldman Sachs (2000)[29] found the efficiency gains associated with e-commerce from business to business transactions ranged between 2 and 40 per cent of total input costs depending on the industry.

- **Competition**: OECD (2000) find that economies of scale become more important among 'digital' and knowledge intensive products as ideas can be shared at close to zero marginal cost; and that the internet offers the ability to reduce barriers to entry and make markets more contestable in other parts of the economy

- **Output**: a study by the Australian Government[30] estimated that e-commerce could exert a net impact on the level of national output of 2.7 per cent. Another early report by Goldman Sachs (2000)[31] suggested a long run increase in the level of GDP of 5 per cent associated with the rise of business to business e-commerce.

- **Productivity**: Franklin et al. (2009)[32] and Clayton (2005)[33] provide some insight on how ICT may affect productivity. Both studies pay particular

27 OECD (2000): "E-commerce: Impacts and Policy Changes", OECD Economic Outlook 67.

28 Brynjolfsson, E. and Smith, D. M. (2000: "Frictionless Commerce? A Comparison of Internet and Conventional Retailers", *Management Science*, 46(4), pp. 563-585.

29 Goldman Sachs (2000): "The shocking economic effect of B2B", *Global Economics Paper*, No. 37.

30 Department of Communications, Information Technology and the Arts (1999): "E-commerce Beyond 2000," Australian Government, Canberra.

31 Goldman Sachs (2000): "The shocking economic effect of B2B", *Global Economics Paper*, No. 37.

32 Franklin, M., P. Stam and T. Clayton (2009): "ICT impact assessment by linking data", *Economic & Labour Market Review*, Vol. 3, No.10, October 2009.

33 Clayton, T. (2005): "IT Investment, ICT Use and UK Firm Productivity", National Statistics.

Channels through which the communications sector contributes to growth and productivity

attention to the role of e-commerce and to the ability of workers to use Internet and computers as a proxy of ICT skills. In **manufacturing**, they find the intensity of e-procurement shows the strongest link to productivity mainly driven by e-links to suppliers and supply chain management; in **distribution services,** the intensity of use of e-commerce for selling which shows the largest impact on productivity; and in other service industries, mainly **business and financial**, the proportion of workers with access to high speed internet is the main ICT variable affecting productivity – owing to the links to customers

- **E-services**: for manufacturing, Criscuolo and Waldron (2003)[34] find e-buying exerts a positive impact on productivity (manufacturing firms using e-procurement are found to have a value added advantage of 4 per cent). However, e-selling seems to reduce productivity (firms using e-selling experience a disadvantage in terms of value added productivity of 3 per cent.), due to pricing effects. In particular, industry sources suggest that at least part of the gain from investment in electronic procurement by firms comes from the ability to use better price transparency to secure more competitive deals, which may come from efficiency gains, but at the expense of suppliers. In retail, e-procurement is found to exert a strongly positive effect on the productivity of small enterprises

The next section explores the available evidence on the estimated quantified impact of the sector on growth.

34 Criscuolo, C. and K. Waldron (2003): "E-commerce and productivity", *Economic Trends 600*, November 2003.

3 Estimated quantified impact of the communications sector on economic growth and productivity

The majority of available evidence explores the impact of ICT on economic growth, rather than focusing on the communications element per se. This is reviewed first before moving on to explore the literature on communications.

3.1 The impact of ICT investment on productivity

Economic growth and productivity are influenced by a broad range of factors. In its technical accounting sense, all capital investments, consumption of communications products and services, employment of labour, overseas trade in communications products and services and R&D spending directly contribute to GDP. Given the prevalence of communications across the economy in terms of broadcasting, publishing, video, film, photography, computer games, music and the transmission of voice and data, the sector's direct impact on growth is significant.

Along with these direct effects, there are also likely to be 'spillovers'. These refer to the wider economic impacts that arise from the use of communications services that may not be reflected in market prices.

Productivity 'spillovers' have been widely analysed and acknowledged in relation to R&D investments (see e.g. Griliches 1992 or Cameron et al. 2005), but the evidence of the impact of ICT on wider economic growth has, at least in the past, been more ambiguous. Results often differ depending on the country, level of disaggregation of the data and period considered.

The following presents the evidence from those studies that have explored the quantified impact of the ICT sector on growth at the industry and firm level, before setting out the evidence on the communications sector impacts on growth.

Industry level studies: impacts of ICT on economic growth and productivity

Results are particularly mixed when the analysis is undertaken at industry level.[35] Using data from France, Germany, the Netherlands and the UK for the period

[35] See Draca, M., R. Sadun and J. Van Reenen (2006): "Productivity and ICT: A Review of the Evidence", CEP Discussion Paper No. 749.

1979-2003, Van Art and Inklaar (2005)[36] find no support for the presence of significant spillovers from ICT investment on productivity[37], either in the U.S. or in European countries.

Using data from the US and the UK for the period 1979-2000, Basu et. al. (2003)[38] test the hypothesis that ICT behaves as a set of technologies that facilitate benefits in a wide range of other sectors (they refer to ICT as a 'general purpose technology' GPT). In particular, they explore whether productivity growth is higher in ICT-using sectors, perhaps with long lags. They find that a large part of the US acceleration of productivity in the late nineties can be attributed to the use of ICT and the role of complementary investments or innovations induced by it. In particular, US industry data suggests that ICT capital is associated with industry productivity growth, with lags of 5 to 15 years. This result finds further support by Basu and Fernald (2006) who extend the analysis for the period 2000-2004. [39]

The evidence for the UK, however, provides weaker support to this theory. In the UK, the growth in productivity did not appear to be correlated with lagged ICT capital growth. Instead, productivity growth in the late 1990s was strongly and positively associated with the growth of ICT capital services (though not precisely defined), while being strongly and negatively associated with the growth of ICT investment more generally.

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36 Van Ark, B. and R. Inklaar (2005): "Catching up or Getting Stuck? Europe's Trouble to Exploit ICT's Productivity Potential", Research Memorandum GD-79.

37 They define productivity to be 'total factor productivity, which captures impacts on growth that are not explained by capital and labour directly.

38 Basu, S., J.G. Fernald, N. Oulton, and S. Srinivasan (2003): "The Case of the Missing Productivity Growth: Or,Does information technology explain why productivity accelerated in the United States but not the United Kingdom?", working paper version forthcoming in the NBER Macroeconomics Annual 2003.

39 Basu, S. and J. Fernald (2006): "Information and Communications Technology as a General-Purpose Technology: Evidence from U.S. Industry Data", Federal Reserve Bank of San Francisco, Working Paper Series.

Figure 1. Summary of industry level studies on the impact of ICT on productivity

Authors	Country	Data	Key results
Basu et al (2003)	US and UK	US: Manufacturing and services, 1977-2000 UK: 34 industries, 1979-2000	Strong correlation between ICT use and industry TFP growth US evidence provides support for GPT stories.*
Basu and Fernald (2006)	US	40-industry data set 1987-2004	
O'Mahomy and Vecchi (2003)	US and UK	US: 31 industries UK: 24 industries Period: 1976-2000	Long run effect of ICT above its factor share (under the growth accounting framework). Hence, long run spillovers.
Van Ark and Inklaar (2005)	US, France, Germany, Netherlands and the UK	60-industry database 1987-2004	No support for significant TFP spillovers from ICT investment. In the 1980s even find that ICT investment and TFP growth are negatively related, with at best normal returns in the 1970s and 1990s.

Source: Based on Draca et al. (2006) and research undertaken by Frontier Economics

Figure 1 above contains some of the key studies at industry level, including the countries considered, the data used and the key findings.

Industry-level analysis is however, by definition, intended to take an aggregate and high level view of the impacts on growth. Firm level analysis is able to provide a more detailed picture by considering investments and impacts on growth at the specific firm level.

Firm level studies: impacts of ICT on economic growth and productivity

In contrast to the mixed evidence found by industry level studies, at the firm level most studies reveal a positive and significant association of ICT with productivity. Consistent with the hypothesis of ICT as a 'general purpose technology', the research shows that the effect of ICT on productivity is likely to be observed with some lag.

Using firm level data for the period 1991-2001, Rincon and Vecchi (2004)[40] analyse the short and long run contribution of ICT on total factor productivity in the US and four European countries, namely, the UK, Germany, France and the Netherlands. Their results provide support for the existence of a positive ICT spillover in the long run both in the US and Europe. In the latter a 1 per cent increase in aggregate ICT capital produces approximately a 0.7 per cent increase in companies' productivity. The long run effect is higher for the US, where a 1 per cent increase in aggregate ICT capital is expected to lead to a 1.5 per cent

40 Rincon, A. and M. Vecchi (2004): "The Dynamic Impact of ICT Spillovers on Companies' Productivity Performance", National Institute of Economic and Social Research.

Estimated quantified impact of the communications sector on economic growth and productivity

increase in companies' productivity. Further, in contrast to the four European countries considered, their results support the presence of a positive spillover in the short run for the US case.

Also using firm level data, Van Leeuwen and Van der Wiel (2003)[41] analyse the extent of ICT spillovers in the Netherlands, looking at the period 1994-1998. Their results suggest the existence of positive and significant spillovers from ICT in firms' productivity.

Figure 2 below presents some of the main references that consider the impact of ICT on productivity at firm level, the countries analysed, the underlying data and the main findings of the analysis.

Figure 2. Summary of firm level studies on the impact of ICT on productivity 2002-2004

Authors	Country	Data	Key results
Hempbell (2002)	Germany	More than 1100 firms from a representative survey in the German business–related and distribution service sector covering the period 1994 to 1999	Significant productivity effects from ICT
Rincon and Vecchi (2004)	US, UK, Germany, France and the Netherlands	Compustat: it includes financial and market data on more than 13,000 international companies Period: 1991-2001	Positive long run spillover in the US and the four European countries analysed Positive short run spillover only in the US
Van Leeuwen and Van der Wiel (2003)	The Netherlands	Constructed linking the detailed accounting data collected in the yearly Production Surveys of Statistics Netherlands over time Period: 1994-1998	Positive and significant spillovers from ICT on firms' productivity

Source: Frontier Economics summary of published material

More recent analysis, such as that by Franklin et al (2009) for the UK ONS[42] looked across 13 counties to explore the impacts of ICT use (over and above IT use) on firm productivity. For the Netherlands and UK they find that the impacts vary by sector of the economy. In manufacturing, productivity is found to be strongly linked to the intensity of e-procurement; in distribution services the intensity of use of e-commerce for selling in other, mainly business and financial demonstrate the strongest link; and, in service industries the proportion of workers with access to high speed internet is found to show a strong link with productivity[43].

41 Van Leeuwen, G. and H. Van der Wiel (2003): "Spillover Effects of ICT", cpb Report 2003/3.

42 Franklin, M., P. Stam and T. Clayton (2009): "ICT impact assessment by linking data", *Economic & Labour Market Review*, Vol. 3, No.10, October 2009.

They also find that in the UK, for manufacturing firms, electronic links to suppliers (associated with supply chain management) are linked with productivity; and for services firms, it is the links to customers that affect productivity.

Given the different nature of the ICT components, ranging from computers to audio and video equipment, it is important to note that it may be that the aggregate estimated impact from ICT may not adequately reflect, the individual contributions of different components. Indeed, many of the studies that have considered ICT appear to focus particularly on the impact of computerisation and IT. Although this is linked with the ability of the communications sector to impact on growth (computers are often needed to access the internet, for example) it is not likely to tell the whole story. Further investigation of material focusing on the communications sector specifically is needed.

There is a growing range of studies that explore the effects of communications infrastructure - and its digitisation - on productivity. These are now explored.

3.2 The impact of digital communications services

As in the case of other network industries such as transport, communications infrastructure is likely to exert an economy wide impact. The sector has experienced significant change in recent decades. Therefore, the type of investment in communications infrastructure in the future is likely to be quite different from the type of investment in communications infrastructure ten years ago.

Early studies focused on the impact on fixed telecommunications infrastructure on growth. Overall, these studies have found that fixed telecommunications facilitates positive spillover benefits on the economy, enhancing output growth and development. Hardy (1980)[44], for example, explored the potential impact of telecommunications on growth using data over 15 developed and 45 developing countries from 1960 to 1973 and found that telephones per capita have a positive impact on GDP. Similarly, Norton (1992)[45], using data from 47 countries for the period 1957-1977, found that telecommunications infrastructure exerts a positive impact on growth. Roller and Waverman (1996)[46] investigate the effect of fixed communications infrastructure on growth, considering a sample of 21 OECD countries during the period 1970s and 1980s. Overall, they find evidence of a

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44 Hardy, A., 1980, "The Role of the Telephone in Economic Development," *Telecommunications Policy*, 4: 278-286.

45 Norton, S. W., 1992, "Transaction Costs, Telecommunications, and the Microeconomics of Macroeconomic Growth," *Economic Development and Cultural Change*, 40: 175-196.

46 Roller, L.H. and L. Wavermand (1996): "Telecommunications Infrastructure and Economic Development: A Simultaneous Approach", Social Science Research Center Berlin, Discussion Papers FS IV 96-16

positive causal link, provided that a critical mass of telecommunications infrastructure is present. The latter point could be inferred as supporting the notion of 'network' effects that are a key characteristic of the communications sector such that the benefits to one user often increase as the overall number of users increases[47].

A more recent study by Shanks and Barnes (2008)[48] considers the impact of communications infrastructure and digitisation (excluding information technologies) on productivity in Australia. Although their results are preliminary, they find a positive impact of communications infrastructure on productivity. In particular, their aggregate estimates result in a communication elasticity of 0.05 suggesting that a 1 per cent increase in investment in communications network infrastructure used by the communication services industry raises productivity by 0.05 per cent. They also find a coefficient for the interaction between digitisation and IT capital of around 0.01, suggesting that they each increase the productivity of the other with an elasticity of 0.01.

The study also finds a positive impact of communications infrastructure on productivity when analysing the impacts across different industries. In this case, their preferred model results in a range of estimates from 0.03 to 0.10, with the largest impact found for Wholesale Trade and Transport & Storage (0.10) and the lowest for Electricity, Gas and Water (0.03)).

In view of the more recent increase in mobile telephony, in particular its significant growth in developing countries, a number of studies have focused on the impact of mobile communications on growth and productivity. Waverman et al (2005)[49] explore this question using data from a large number of developed and developing countries for the period 1980-2003. The authors find that mobile telephony has a positive and significant impact on economic growth, and its impact may be twice as large in developing countries compared to developed ones. In view of these results, the authors consider that mobile phones in less developed countries are playing the same crucial role that fixed telephony played in the richer economies in the 1970s and 1980s.

Gruber and Kouproumtis (2010)[50] explore evidence from 192 countries for the period 1990-2007 to estimate the impact of mobile telecommunications on growth and productivity. As in the case of Waverman et al (2005) they find that

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47 There may be a point at which congestion effects begin to bite, at a very high level of usage of a single piece of infrastructure.

48 Shank, S. and P. Barnes (2008): "Econometric Modelling of Infrastructure and Australia's Productivity", Internal Research Memorandum, Cat No: 08-01.

49 Waverman, L., M. Meschi and M. Fuss (2005): "The Impact of Telecoms on Economic Growth in Developing Countries", The Vodafone Policy Paper Series, No.2, March 2005.

50 Gruber, H. and P. Koutroumpis (2010): "Mobile telecommunications and the impact on economic development", First Draft for Economic Policy.

mobile telecommunications diffusion significantly affects both GDP growth and productivity growth. Their evidence supports the existence of increasing returns from the adoption of mobile telecommunications, i.e. the growth impact increases with the level of diffusion.

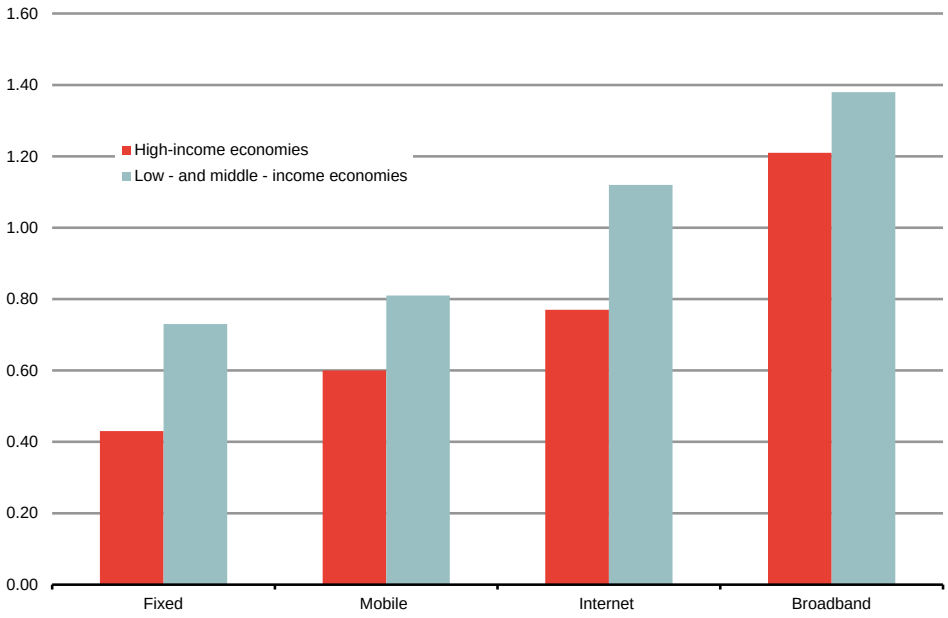
More recently, the focus of published studies has been on broadband. Its prevalence in organisations' and individuals' daily activities has increased the interest in understanding its potential effects in more detail. A recent study published by the ITU/UNESCO (2011)[51] explores the different ways in which broadband infrastructure may impact economic growth, offering an extensive list of references on the topic.[52] As in the case of most of the above mentioned reports on fixed and mobile communications, broadband studies use country level data, looking at the variation in the levels of penetration to infer causal relationships between investment in broadband infrastructure and growth. Overall, broadband has been found to exert a positive and significant impact on output growth. The size of the impact is found to differ depending on a number of factors including, the level of penetration and a country's income. **Figure 3**, which corresponds to Figure 3.1 of the ITU/UNESCO (2011)'s report, shows that the impact of broadband on growth is likely to be relatively higher than the impact associated with other communication technologies. Further, the impact is found to be larger in low and middle income countries than in high-income countries. However, the statistical significance of the impact is higher for the latter.[53]

51 ITU/UNESCO (2011): "Broadband: A Platform for Progress", A Report by the Broadband Commission for Digital Development, June 2011.

52 See Table 3.3. of ITU/UNESCO (2011).

53 See Qiang, C. Z-W. and C. Rossotto (2009): "Economic Impact of Broabband", Information and Communications for Development 2009. The World Bank. http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTINFORMATIONANDCOMMUNICATIONANDTECHNOLOGIES/EXTIC4D/0,,contentMDK:22229759~menuPK:5870649~pagePK:64168445~piPK:64168309~theSitePK:5870636,00.html

Figure 3. Impact of telecommunications on growth



Source: ITU/UNESCO (2011), Figure 3.1

Note: The vertical axis represents the percentage-point increase in economic growth per 10-percentage-point increase in telecommunications penetration.

A similar result is found by Czernich et al. (2011)[54] who, analyse a panel of OECD countries for the period 1996-2007, find that a 10 percentage point increase in broadband penetration raised annual per capita growth by 0.9-1.5 percentage points.

Using data from 15 EU countries for the period 2003-2006, Koutroumpis (2009)[55] finds that there are positive and increasing returns to broadband telecommunications investments, observing a critical mass phenomenon in broadband infrastructure investments. The critical threshold identified is 20 per cent subscriber penetration or 50 per cent household penetration. In other words, the benefits from broadband are observed only once a minimum threshold, in terms of penetration, has been reached.

Overall, existing evidence on the impact of communications infrastructure either as a whole or considering its individual components (fixed telephony, mobile and broadband) provides support for the presence of positive spillovers over the rest

54 Czernich, N., O. Falck, T. Kretschmer and L. Woessmann (2011): "Broadband Infrastructure and Economic Growth", *The Economic Journal*, 121 (May): 5050-532.

55 Koutroumpis, P. (2009): "The economic impact of broadband on growth: A simultaneous approach", *Telecommunications policy* 33(9) 471-485.

of the economy. Arguably, in many studies the evidence for particular communications technologies is less mixed than when considering the ICT sector as a whole.

Figure 4 below summarises the studies which have been reviewed relating to the communication sector's links with productivity.

Estimated quantified impact of the communications sector on economic growth and productivity

Figure 4 Summary of evidence

Author	Country	Year	Summary of findings
Hardy (1980)	15 developed and 45 developing countries	1960-73	Number of phones per capita has a positive impact on growth
Roller and Waverman (1996)	21 OECD countries	1970s and 80s	Positive causal link between fixed communications and growth, provided a critical mass is reached
Shanks and Barnes (2008)	Australia		1 per cent increase in investment in communications network infrastructure used by the communication services industry raises productivity by 0.05 per cent Coefficient of 0.01 between digitisation and IT
Waverman (2005)	Developed and developing countries	1980 - 2003	Mobile telephony has a positive and significant impact on growth. Effect is twice as large in developing countries than in developed
Gruber and Koutroumpis (2010)	192 countries	1990 - 2007	Increasing returns to mobile communications
ITU/UNESCO (2011)			Compared mobile, fixed telecoms, internet and broadband and found the impact of broadband on growth is more significant than the others
Czernich (2011)	OECD	1996 - 2007	10 per cent increase in broadband penetration increases per capita growth by 0.9 – 1.5 per cent
Koutroumpis (2009)	15 EU countries	2003 - 2006	Positive and increasing returns to broadband investment with a critical mass of 20 per cent subscriber and 50 per cent household penetration

To complement this published evidence, Frontier has undertaken some preliminary econometric analysis which explored the relationship between the communications sector and productivity. This is explained next.

Estimated quantified impact of the communications sector on economic growth and productivity

3.3 Frontier's preliminary analysis

Brief introduction to the Frontier analysis

This part of the work was undertaken within a 4-week period to provide quantified evidence to complement that which has already been published.

The purpose of the work is not to provide any definitive answers about the quantified estimates of the communications sector's contribution to growth in the UK. Rather, it is intended to provide some high-level analysis which can be considered alongside other published evidence to help build an understanding of the estimated order of magnitude of the communications sector's relation to growth in the UK.

The analysis has been necessarily constrained in terms of the data sources relied upon and the testing programme undertaken.

Underpinning the approach we have followed the following principles:

- **Robustness of the approach**: we have been working with Professor Ron Smith of Birkbeck University very closely throughout the analysis. All analysis has been discussed and reviewed by him. Frontier is extremely grateful for his expert input to this work
- **Credibility of data sources and understanding of its limitations**: data sources relied upon have fundamental implications for the analysis and subsequent results. A review of available sources was undertaken before selecting one – the EU Commission's published database, EU KLEMS – as a credible and available source of appropriate data. As with all datasets, there are limitations in terms of underlying assumptions and coverage that we have noted and explained below
- **Proportionate testing programme**: the econometrics undertaken relies upon a base equation which is formulated to recognise the data constraints, but also is able to capture the elements we are particularly interested in. The testing programme undertaken has been necessarily constrained by the time available for this work, but has sought to investigate some of the important aspects and relationships within the data to ensure appropriate interpretation.
- **Complementary data interrogation**: in order to interpret results appropriately, throughout the work, other data sources were relied upon (such as Eurostat, Ofcom, OECD) in order to build a picture of the wider trends within the sector so that results can be considered in context.
- **Clarity of limitations**: this econometric analysis does not claim to provide a specific 'answer' to the question of the quantified contribution

Estimated quantified impact of the communications sector on economic growth and productivity

of the sector to growth. There are a number of limitations that must be recognised to ensure appropriate interpretation of the results. These are explained in full below.

The data

Fundamental to the econometric analysis is the availability of credible and robust data that provides coverage of the key variables of interest.

Having reviewed a range of data sources, many were ruled out on the basis of their coverage or robustness. It was important that we were able to rely on data that was:

- **Immediately available for use:** the short time period for this work precluded the possibility of collating new data sources or exploring firm level data (data sets tend not to be available with the required coverage at the firm level)
- **Credible and robust**: for example, the data had undergone peer review of its underlying assumptions and sources
- **An appropriate time series and panel data set**: in order to ensure a sufficient number of observations, a relatively long time-series was required, covering a range of sectors and industries.
- **Suitably disaggregated to highlight the growth variables and communications specific variables required**: given these are the focus of the analysis, these were of course essential.

The dataset used in this project is the EU KLEMS Growth and Productivity Accounts: November 2009 Release, updated March 2011. In particular, the data consists of the UK Basic 0911 file, which provides information on growth accounting variables; and the UK Capital 091 file which provides data on investment, capital stock and capital services. Both files are freely available to download from the EU KLEMS website www.euklems.net.

Variables

The variables included in regression analysis are described in **Table 1**.

Table 1. Data variables

Variable name	Description
TFPva_I	TFP Total Factor Productivity (value added based) 1995=100

K_IT	Information Technology (IT) Computing Equipment Capital Stock
K_CT	Communications Equipment Capital Stock
K_Soft	Software Capital Stock
K_TraEq	Transport Equipment Capital Stock
K-OMac	Other Machinery and Equipment Capital Stock
K-Con	Total Non-Residential Investment Capital Stock
K_Other	Other Capital Stock
K_NICT	Non-Information Communications Technology (ICT) Capital Stock

All capital inputs are defined as levels of real fixed capital stocks, in 1995 prices, measured in millions of pounds. The variables were collected on 30 industries over the period 1970-2007. There were no missing values.

Approach

The approach used has relied on an econometric analysis (ordinary least squares) to explore the extent to which the data is able to show a relationship between a change in communications equipment capital stock and total factor productivity. The specific base equation used is shown in **Figure 5**.

Figure 5. Econometric specification

$$\Delta \ln TFP_{i,t} = \beta_0 + \beta_1 \Delta \ln CT_{i,t} + \beta_2 \Delta \ln IT_{i,t} + \beta_3 \Delta \ln Soft_{i,t} + \beta_4 \Delta \ln NICT_{i,t} + \beta_5 t + \varepsilon_{i,t}$$

The coefficients have a very particular interpretation:

- β_0 is a constant term that estimates the growth in TFP even if there were no investment in capital stock at all

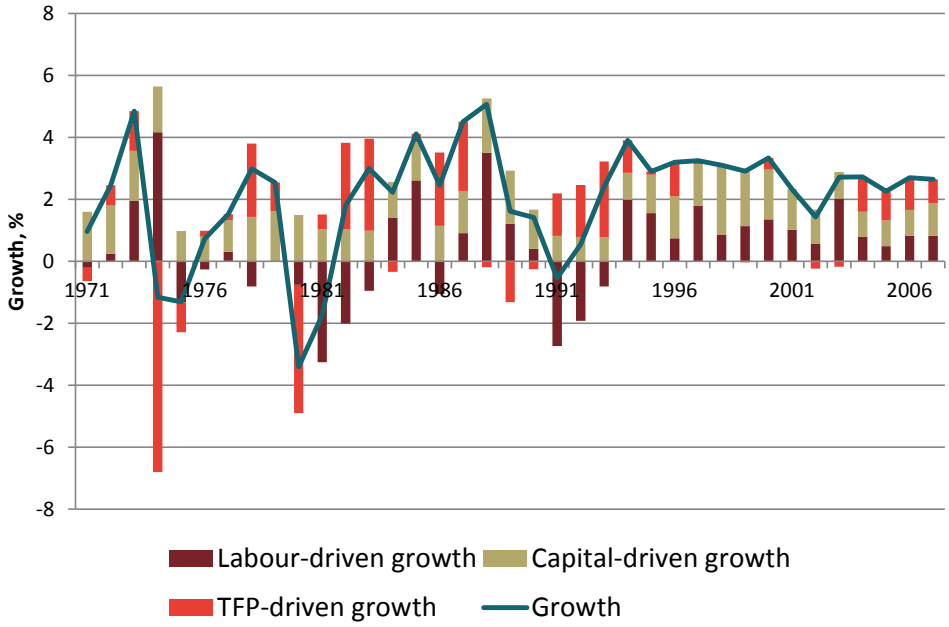
Estimated quantified impact of the communications sector on economic growth and productivity

- $\beta_1$reflects the estimated contribution of the growth in communications equipment capital stock to TFP i.e. a 1 per cent increase in growth of communications equipment capital stock is associated with (on average) a β_1 percentage point increase in the growth of TFP
- β_2, β3 and β4 all reflect the estimated contributions of growth in IT equipment, software and non-ICT investment to TFP, respectively
- t is a time trend hence β_5 reflects the impact of characteristics explained by the fact that it is a particular year
- $\varepsilon_{i,t}$ is an error term, which has different components that we need to be aware of and address if possible
- $CT_{i,t}$ is communications equipment capital stock; $IT_{i,t}$ is information technology capital stock; $Soft_{i,t}$ is software capital stock; and $NICT_{i,t}$ is all other capital stock in the UK

The proxy for productivity used in this equation is total factor productivity, TFP. TFP is a concept used in the established growth accounting framework and essentially captures all of the growth that is not accounted for directly by capital and labour costs (assuming these factors are priced equal to their productivity). Recent trends in economic growth and the contribution to that growth of capital, labour and TFP are shown in **Figure 6**.

It is also important to note the definition of communications equipment (as in Figure 16 in Annexe 1). It covers electronic components, including active, passive and printed circuit boards (PCBs), the manufacture of television cameras, transmission apparatus for radio and television, telephonic switching apparatus (including LANs and modems), telephones and fax machines, the manufacture of audio-visual equipment and related appliances such as loudspeakers, headphones and aerials, as well as other electronic consumer appliances, such as telephone answering machines. It does not therefore cover investment in fixed infrastructure for example, or the communications content sectors.

Figure 6. UK growth and the contributions of capital, labour and TFP



Source: EU KLEMS

TFP captures a wide range of factors. It is therefore driven by the 'spillover' effects and other effects which include intangibles for example. The latter are important because this is an emerging area of literature which demonstrates that as the dynamics of the economy change, other factors drive growth that were not traditionally recognised.

Testing programme undertaken

To explore the relationships of interest, a programme of 5 tests were undertaken:

- A standard OLS approach
- Incorporation of fixed effects i.e. accounting for those industry-specific effects that impact on TFP and persist over time. For example, if an industry's particular geographic location has allowed it to have a different level of growth than might otherwise have been the case
- Whether the impact on TFP has varied across different points in time (we have looked at pre- and post-1995)
- Whether the impact on TFP of communications equipment is more significant for some industries than others. We have looked at service industries as a group and non-services industries

Estimated quantified impact of the communications sector on economic growth and productivity

- Causality i.e. if there is evidence to suggest that communications equipment capital stock growth is able to predict TFP growth, and in turn the extent to which TFP growth is able to predict growth in communications equipment capital stock

Results

The testing programme undertaken provided us with results as follows:

Test 1: OLS

Under OLS, the value of β_1 estimated is 0.047 (with a standard error of 0.017). See Figure 7.

The result is statistically significant and suggests that a 1 per cent increase in communications equipment capital stock is associated with a 0.047 percentage point increase in TFP. It should be noted that causation is not proven, however.

Test 2: fixed effects

Under fixed effects, the value of β_1 estimated is 0.058 (with a standard error of 0.018). See Figure 7 for the detailed results of tests 1 and 2 (OLS and fixed effects).

Figure 7. Results of tests 1 and 2

	OLS	Fixed Effects
Sample information		
Observations	1,110	1,110
No. industries	30	30
Time Period	1980-2007	1980-2007
Coefficients		
$\Delta \ln CT_{i,t}$	**0.047*** (0.017)**	**0.058*** (0.018)**
	0.007	***0.001***
$\Delta \ln IT_{i,t}$	-0.017 (0.012)	-0.019 (0.012)
	0.145	*0.108*
$\Delta \ln Soft_{i,t}$	0.028* (0.016)	0.027* (0.016)
	0.087	*0.095*
$\Delta \ln NICT_{i,t}$	-0.423*** (0.049)	-0.425*** (0.053)
	0.000	*0.000*
t	0.000*** (0.000)	0.000*** (0.000)
	0.007	*0.004*
Test statistics		
R^2	0.0861	0.0846

Robust standard errors in parentheses
****,**,* significant at 1%,5% and 10% respectively. P-values reported in the line below each main result.*

The results are statistically significant for CT investment; low R squared is common in regressions explaining TFP growth. The results suggest that a 1 per cent increase in communications equipment capital stock (CT) is associated with a 0.047 to 0.058 i.e. **a 0.05 to 0.06 percentage point increase in TFP**. **As with OLS, it should be noted that causation is not proven, however.**

As with test 1, this result is both intuitive and informative because it confirms the positive relationship between communications equipment and growth.

The interpretation of these results is illustrated in **Figure 8**.

Estimated quantified impact of the communications sector on economic growth and productivity

Figure 8. Interpretation of results

Illustration

i) GDP growth was 2.64% in 2007 of which TFP is estimated to have contributed 0.77 percentage points, labour 0.82 percentage points and capital 1.05 percentage points

ii) Our analysis suggests that a 1% increase in communications equipment capital stock would 'lead to':

- a direct increase in GDP growth because of the increased investment, and
- An increase in TFP's contribution to growth of 0.05 percentage points (i.e. for example, raising it from say 0.77 % to 0.82% and overall growth would be higher.

Although this may appear a small effect, when compounded can be significant.

Source: Frontier analysis

The results for both of these tests indicate that the association between investment in capital stock not related to information and communications technology (NICT), and TFP is negative. The associated co-efficient is -0.4. This appears counterintuitive but could be for a range of reasons. Underlying problems with the growth accounting framework used to develop the database could at least partly explain this. For example, the shares of economic activity given to capital and labour in deriving economic growth could be an important factor to consider. If the share i.e. weight applied to capital is too great then it would be overestimated in the data and hence would partially explain the negative sign found. However, further work would be needed to explore this in detail.

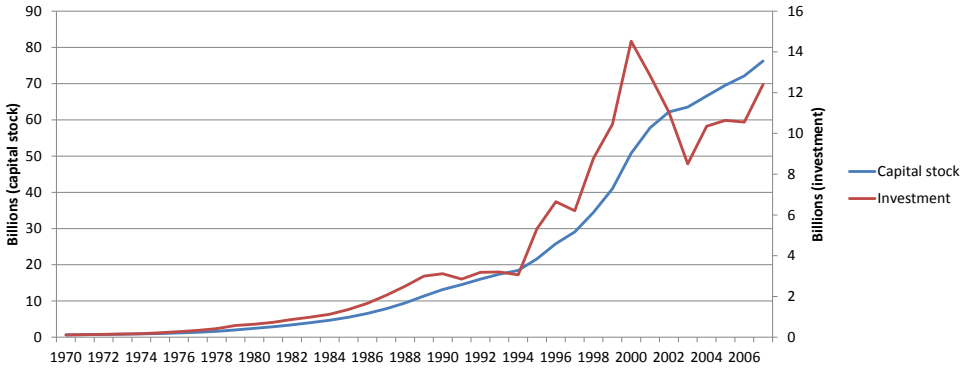
Provisional analysis suggests that when the types of investment are broken down further, as shown in Figure 17, the negative results are driven by the dominance of non-residential structure and other machinery. This would require more work to understand fully why this might be the case as both of these categories capture a wide range of investments.

Overall, our key results of a link between communications investment and growth of a 1 per cent increase in communications capital stock being linked to a 0.05 – 0.06 percentage point increase in economic growth are consistent with the results of another similar study undertaken in Australia. This work by Shanks and Barnes (2008) found that a 1 per cent increase in the network infrastructure of the communications services industry is associated with a 0.05 percentage point increase in productivity (note this is a different variable to that used in the Frontier work).

Test 3: exploring the impact of investment in communications capital stock before and after 1995

It is notable in the data that investment in communications capital stock increased significantly after 1995, as **Figure 9** shows.

Figure 9. Communications equipment capital stock over time



Source: EU KLEMS

Given this trend change, we have explored whether the relationship of communications with growth also changed over time.

The results are shown in **Figure 10**.

Figure 10. Test 3: before and after 1995

	FE (repeated result for test 2)	FE
Sample information		
Observations	1,110	1,110
No. industries	30	30
Time Period	1980-2007	1980-2007
Coefficients		
$\Delta \ln CT_{i,t}$	**0.058*** (0.018)**	
	0.001	
Before 1995	-	**0.064*** (0.022)**
		0.003
After 1995	-	**0.050 (0.030)**
		0.654
$\Delta \ln IT_{i,t}$	-0.019 (0.012)	-0.019 (0.012)
	0.108	*0.110*
$\Delta \ln Soft_{i,t}$	0.027* (0.016)	0.029* (0.017)
	0.095	*0.085*
$\Delta \ln NICT_{i,t}$	-0.425*** (0.053)	-0.422*** (0.053)
	0.000	*0.000*
t	0.000*** (0.000)	0.000*** (0.000)
	0.004	*0.008*
Test statistics		
R^2	0.0846	0.0854

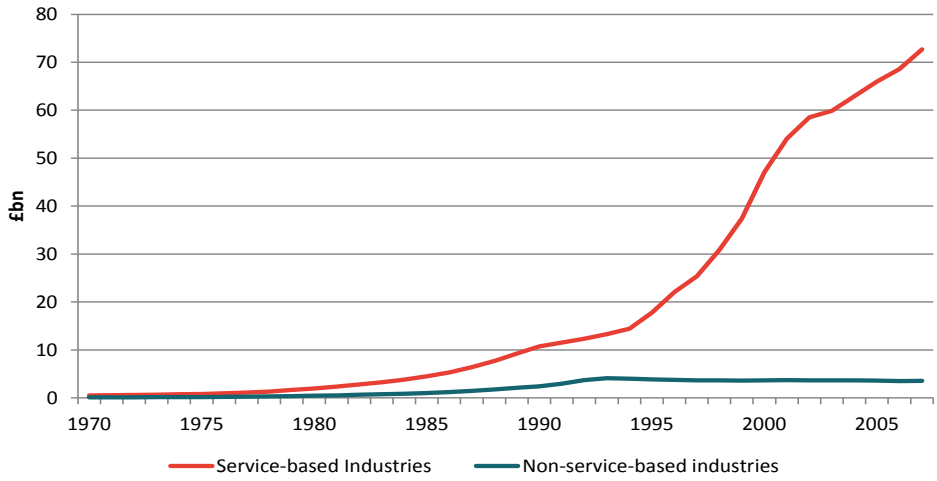
Robust standard errors in parentheses
****,**,* significant at 1%,5% and 10% respectively. P-values reported in the line below each main result.*

The results show that the relationship between communications capital stock investment and productivity are not statistically different before or after 1995. The relevant coefficients are 0.064 before 1995 and 0.050 after 1995.

Test 4: Testing for variation across industries

In order to explore whether the impacts vary across industries, it is interesting to note that communications capital stock in service industries is significantly higher than that in non-service industries, as shown in **Figure 11**.

Figure 11. Capital stock in services and non-services industries



Source: EU KLEMS

In view of this, we explored whether there was a statistical difference in the contribution to growth of communications equipment in both groups. The results are shown in detail in Figure 12.

Figure 12. Test 4: Services and non-services industries

	Service	Non-service
Sample information		
Observations	444	666
No. industries	12	30
Time Period	1980-2007	1980-2007
Coefficients		
$\Delta \ln CT_{i,t}$	**0.025 (0.024)**	**0.084*** (0.028)**
	0.304	***0.003***
$\Delta \ln IT_{i,t}$	0.023 (0.015)	-0.042** (0.017)
	0.140	*0.014*
$\Delta \ln Soft_{i,t}$	-0.034 (0.028)	0.047** (0.022)
	0.221	*0.031*
$\Delta \ln NICT_{i,t}$	-0.448*** (0.077)	-0.413*** (0.071)
	0.000	*0.000*
t	0.001*** (0.000)	0.001** (0.000)
	0.003	*0.030*
Test statistics		
R^2	0.0813	0.0790

Robust standard errors in parentheses

****,**,* significant at 1%,5% and 10% respectively. P-values reported in the line below each main result.*

These show that the association of communications equipment with growth is more significant in non-services industries (coefficient 0.084) than services (coefficient 0.025).

More detailed investigation would be worthwhile to draw out the underlying reasons for this. It could for example, be that the capital stock in non-services industries is lower, therefore a marginal addition to that stock is likely to impact on growth to a more significant extent than if the stock were higher. This cannot be concluded with confidence without further investigation.

Test 5: Causation

An issue widely debated in relevant published material is whether there is evidence of causation in the relationship between investment and growth. In this context, we have sought to explore this relationship using a statistical test of Granger Causality.

If there is 'Granger Causality' then the time series of TFP growth would be able to predict communications equipment capital stock growth, and/or communications equipment capital stock growth would be able to predict TFP growth. TFP would therefore 'Granger-cause' communications equipment capital stock growth if TFP provides statistically significant information about future values of communications equipment capital stock. The specific test is shown in **Figure 13**.

Figure 13. Granger causality test

The first test is CT on TFP:

$$\Delta lnTFP_{i,t} = \beta_{1,i} + \beta_2 \Delta lnTFP_{i,t-1} + \beta_3 \Delta lnCT_{i,t-1} + \beta_4 t + \varepsilon_{i,t}$$

And the second test is TFP on CT:

$$\Delta lnCT_{i,t} = \beta_{1,i} + \beta_2 \Delta lnCT_{i,t-1} + \beta_3 \Delta lnTFP_{i,t-1} + \beta_4 t + \varepsilon_{i,t}$$

Source: Frontier analysis

Here, the equation is estimated with two lags of the potentially causal variable. Having undertaken this test, the results are shown in **Figure 14**.

Figure 14. Granger causality

	FE(1)	FE(2)
Sample information		
Observations	1080	1050
No. industries	30	30
Time Period	1980-2007	1980-2007
Coefficients		
$\Delta \ln TFP_{i,t-1}$	0.111*** (0.031)	0.105*** (0.031)
	0.000	*0.001*
$\Delta \ln CT_{i,t-1}$	0.026 (0.018)	0.024 (0.028)
	0.152	*0.400*
$\Delta \ln CT_{i,t-2}$	-	0.011 (0.028)
		0.703
t	0.001*** (0.000)	0.001*** (0.000)
	0.001	*0.000*
Test statistics		
F	0.0402	0.0379

There appears to be weak evidence to suggest that growth in communications equipment capital stock Granger-causes TFP growth.

	FE(1)	FE(2)
Sample information		
Observations	1080	1050
No. industries	30	30
Time Period	1980-2007	1980-2007
Coefficients		
$\Delta \ln CT_{i,t-1}$	**0.741*** (0.020)**	**0.726*** (0.021)**
	0.000	***0.000***
$\Delta \ln TFP_{i,t-1}$	0.026 (0.033)	0.029 (0.035)
	0.449	*0.402*
$\Delta \ln TFP_{i,t-2}$	-	-0.013 (0.035)
		0.705
t	-0.001*** (0.000)	-0.002*** (0.000)
	0.000	*0.000*
Test statistics		
F	0.7004	0.7011

There appears to be weak evidence to suggest that TFP growth Granger-causes growth in communications equipment capital stock.

Robust standard errors in parantheses
****,**,* significant at 1%, 5% and 10% respectively.*
P-values reported below.

These show that the results are not statistically significant. Therefore, the results do not suggest that we are able to conclude there is causality. That is not to say that it does not exist – the lack of strong results could be explained by other factors. For example:

- There are likely to be technical problems associated with estimating dynamic fixed effect VARs in panels.
- Also, only two variables are present in the VAR model, whereas other variables are likely to influence both TFP and CT

However, further work would be needed in order to drill down into these issues further.

There are a number of limitations associated with this analysis however, as described next.

Limitations

Econometric analysis of the type undertaken for this project must, by necessity, rest on a number of assumptions. It is important to be aware of these so that the analysis can be interpreted appropriately.

Limitations relevant to this analysis are:

- **TFP is a residual term** therefore its value is not in itself estimable. It is the contribution to growth that is not accounted for by capital and labour (i.e. non-remunerated activity). It is derived on some critical assumptions about the share of capital and labour within the economy. If the share attributed to capital were overestimated for example, then the assumed contribution of capital to growth would be estimated as too high, hence other factors that contribute to growth would be underestimated.

- **Growth accounting framework approach has inherent difficulties**: for example, a range of assumptions are made around the rate of depreciation of assets in the economy. Capital assets of a particular type are assumed to have the same rate of depreciation, which may not reflect actual depreciation rates as they would not be quality adjusted. This could lead to mis-measurement issues within the data.

- **Industry level data is very aggregate:** different results might be likely from firm-level data where it is available because although the variations across industries are significant, they are likely to be even greater across firms. It has not been possible within the timeframe of this work to use firm level data.

- Aggregate results such as this **do not necessarily inform what type of investment is more likely to be able to contribute to growth**, nor the associated conditions under which such investment is likely to be effective.

- **Investment in equipment does not say anything about usage** – this is likely to be a key factor in how that investment affects productivity. It has not been possible to incorporate usage (subscriptions to networks or service uptake rates etc) into the econometric analysis because we do not have the detailed data by industry which would be needed, and the time series often does not match that of EU KLEMS as some of the key trends have arisen only over the last 10 years.

- Econometrics is necessarily looking at past relationships. Given the rapid pace of change in the industry, it is likely that **composition of investment in communications in the past is like to be very different to the future** – impacts may therefore be uncertain in the future

Estimated quantified impact of the communications sector on economic growth and productivity

- **The definition of communications equipment is necessarily limited** to its definition in the EU KLEMS data so is not all encompassing of the sector of interest and does not include fixed infrastructure, or some digital communications elements for example.

- **TFP is also likely to capture the effects of investment in intangibles:** although not possible to account for within the framework of the analysis, this implies that attributing TFP to any particular factor is likely to be inaccurate.

4 Policy insights on the factors that influence the communication sector's contribution to growth

The different impacts of ICT on productivity across countries found in many studies (and the contrast between the US and Europe in particular) has led to research focused on the factors that influence the impact of ICT.

Along with ensuring that the underlying infrastructure network is sufficiently expansive, and suitably maintained and functional, there are other factors that are likely to increase the effectiveness of communication's contribution to growth.

A condition identified by the literature that facilitates productivity gains associated with investment on communications and technology is the implementation of organisational changes. This requires a business environment flexible enough to facilitate such changes and a labour force with sufficient skills to adapt and use the new communications equipment and applications.

Lee et al. (2006)[56] stress the importance of organisational factors in understanding the impact of ICT on productivity in the US and Europe. In particular, they distinguish between: (i) organisational level factors (e.g. management capability) and (ii) wider economic factors (e.g. product market regulation).

- The role of **organisational level factors** has also been extensively analysed in the literature. In this regard, Bloom et al. (2005a)[57] found that US owned organisations in the UK showed better IT performance, supporting the hypothesis that US multinationals export their business models to affiliates. Bloom et al. (2005b) [58] went further and explored the importance of management practices for ICT performance drawing on work undertaken by McKinsey looking at the practices of 730 manufacturing firms in France, Germany, the US and the UK. This evidence showed that management practices explained up to 10-15 per cent of the productivity gap between the US and the UK.

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56 Lee, N, P. Schneider and I. Brinkley (2006): "R&D, ICT and Productivity: An evidence paper for the Knowledge Economy Programme", The work foundation.

57 Bloom, N., R. Sadun and J. Van Reenen (2005a) 'It ain't what you do, it's the way that you do I.T. – Testing explanations of productivity growth using US affiliates', Centre for Economic Performance, LSE.

58 Bloom, N. S. Dorgan, J. Downdy, J. Van Reenen and T. Rippin (2005b) 'Management Practices Across Firms and Nations', Centre for Economic Performance, LSE.

The management factors they have explored include shopfloor management (such as lean internal supply chains, documentation of process improvements and the rationale behind introductions of improvements); monitoring (tracking individuals' performance and regular appraisals and job plans); "consequence" management (e.g. making sure that plans are kept and appropriate sanctions and rewards are in place); targets (realistic financial or holistic); and, incentives (promotion criteria, pay/bonuses and fixing/firing bad performers etc).

- **Wider economic factors**. The environment in which firms compete may be an important factor influencing the potential to reap the whole benefits from communications and technology investment. Gust and Marquez (2002),[59] using panel data from 1992 to 1999 for 13 industrial countries, find that burdensome regulatory environments and, in particular, regulations affecting labour market practices have impeded the adoption of information technologies and slowed the productivity growth in a number of industrial countries. Van Reenen et al. (2010)[60] reach a similar conclusion undertaking an exhaustive analysis of the relationship between ICT and productivity in order to explain, among other, the differences observed between the US and Europe. In particular, they find that labour and product market regulations may be significant determinants of cross-country differences in the impact of ICT. Such regulations include employment protection and dismissal law.

  This is further supported by Crafts et al (2005)[61] in referring to a study by Hausman (1997) in which regulation was found to delay the uptake of innovative products such as mobile phones in the US. Crafts et al (2005) also refer to a study by McGuckin (1995) which found that regulations can constrain the ability of firms to exploit the opportunities offered by communications technologies by for example, acting as a constraint on just in time delivery systems. Particular issues referred to include land-use regulations, barriers to entry, restricted shopping hours, trucking regulations and obstacles to cross-border trade.

59 Gust, C. and J. Marquez (2002): "International Comparisons of Productivity Growth: The Role of Information Technology and Regulatory Practices", Board of Governors of the Federal Reserve System.

60 Van Reenen, J., N. Bloom, M. Draca, T. Kretschmer, R.Sadun, H. Overman and M. Schankerman (2010): "The Economic Impact of ICT", Enterprise LSE Ltd.

61 Crafts, N and Leunig, T (2005): "The historical significance of transport for economic growth and productivity". Background paper for the Eddington Report.

A recent report published by McKinsey (2011)[62] emphasizes the role played by the Internet ecosystem (characterised by the human capital, financial capital, infrastructure and business environment) in making a contribution to GDP growth. They develop four indexes denoted by McKinsey i4F (Internet 4 Foundations) and analyse the relationship between these and the performance of Internet supply, estimated through the McKinsey supply index.[63] Consistent with the above evidence, they find that a favourable environment enables a strong performance in Internet supply.[64] The cross country results show a clear advantage of the US in terms of human and financial capital, whereas no big differences are found with regards to infrastructure and business environment between developed countries.

62 McKinsey (2011): "Internet matters: The Net's sweeping impact on growth, jobs, and prosperity", McKinsey & Company.

63 This is a composed index considering several aspects of Internet supply.

64 See McKinsey (2011): Exhibit 14, page 29.

5 Gaps in the evidence

The communications sector is sector is dynamic and rapidly changing. In particular, over the last decade there has been a notable trend towards digital and mobile communications technologies. There is relatively less available evidence on the impacts of these new trends and technologies on economic growth, compared to the impact of more traditional ICT technologies. However, the evidence base is building and will provide increasingly valuable insights over time.

In addition, relatively little attention has been paid to potential congestion/overload or capacity issues that may arise as the use of communication services increases. These are important given the implications for the extent to which equipment is able to operate efficiently. The current net neutrality debate, on the possibility for Internet Service Providers (ISPs) to manage and charge for the prioritisation of traffic, has been mainly motivated by the potential problem of congestion associated with the increasing amount of data traffic demanded by customers. This emerging evidence will also be useful to keep under review.

Annexe 1:Additional data

Figure 15. Industries covered by EU KLEMS

List of industries

- Agriculture
- Automobiles
- Chemicals
- Coke & Fuel
- Community, social & personal services
- Construction
- Education
- Electricty, gas & water supply
- Electrics
- Financial services
- Food & Drink
- Health
- Hotels & Restaurants
- Machinery
- Metals
- Mining
- Other Minerals
- Paper
- Post & Telecomms
- Public Admin & Defence
- Real Estate
- Recycling
- Renting Machinery
- Retail Trade
- Rubber
- Textiles
- Transport
- Transport equipment
- Wholesale trade
- Wood

Figure 16. Definition of communications equipment capital stock

Communications equipment

- Digital MOS integrated circuits (ICs): wafers and chips
- Bare printed circuit boards
- Colour TV tubes
- Linear (analogue) integrated circuits (ICs)
- Telephonic or telegraphic switching apparatus (excl. relays and switching equipment such as selectors for automatic telephone exchangers)
- Radio receivers for motor vehicles
- Colour television projection equipment and videoprojectors
- Colour television receivers with integral tube (excl. television projection equipment, apparatus with a video recorder or player, video monitors)
- Video recorders or player/recorders (incl. laser or digital video disc players/recorders) (excl. those combined with television, for magnetic tape)
- Loudspeakers (incl. speaker drive units, frames or cabinets mainly designed for mounting loudspeakers) (excl. those mounted in their enclosures

Figure 17. Tests 1 and 2 with disaggregated investment categories

	OLS	Fixed Effects
Sample information		
Observations	1,110	1,110
No. industries	30	30
Time Period	1980-2007	1980-2007
Coefficients		
$\Delta \ln CT_{i,t}$	**0.047*** (0.017 s.e.)**	**0.057*** (0.018 s.e.)**
	0.007 (p-value)	***0.002 (p-value)***
$\Delta \ln IT_{i,t}$	-0.015 (0.012)	-0.017 (0.012)
	0.220	*0.168*
$\Delta \ln Soft_{i,t}$	0.027* (0.016)	0.024 (0.017)
	0.097	*0.141*
$\Delta \ln TraEq_{i,t}$	0.006 (0.018)	0.010 (0.019)
	0.746	*0.580*
$\Delta \ln OMac_{i,t}$	-0.182*** (0.028)	-0.181*** (0.030)
	0.000	*0.000*
$\Delta \ln OCon_{i,t}$	-0.146*** (0.040)	-0.136*** (0.043)
	0.000	*0.002*
$\Delta \ln Other_{i,t}$	-0.022 (0.050)	-0.007 (0.055)
	0.654	*0.901*
t	0.000*** (0.000)	0.000*** (0.000)
	0.007	*0.004*
Test statistics		
R^2	0.0912	0.0887

Robust standard errors in upper parentheses against each variable, p-values in lower parentheses
****,**,* significant at 1%,5% and 10% respectively.*

Gaps in the evidence

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