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Investment in telecommunications infrastructure, growth, and employment - recent research

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Reinhard Wieck · Miguel Vidal

**Investment in telecommunications infrastructure, growth, and
employment – recent research**

Telecommunications investment has been identified as one with a strong potential to spur economic growth and create employment. Investments in telecommunications infrastructure could not only provide a short-term boost to the economy, but also lay the groundwork for long-term improved growth and employment perspectives. Many fiscal stimulus programs adopted by national governments to lessen the impact of the recession and boost economic recovery include substantial stimulus investments related to digital infrastructure.

Indeed research findings indicate that telecom investment has an impact far beyond the scope of the industry itself, promoting growth in adjacent industries and creating new industries. Telecommunications investment explains up to one third of economic growth.

With regard to employment, telecommunications investments have contrary effects: On the one hand, it is widely acknowledged telecom investments lead to significant productivity improvements. Increased efficiency is certainly beneficial for the economy; however, process optimization may lead to job losses. On the other hand, various direct and indirect employment effects can be identified that contribute to create new jobs. Therefore, the question arises whether negative or positive effects prevail.

Our article gives an overview of the most important studies and their key findings, addressing methodology and assessing total contributions of telecom infrastructure investment to GDP growth and employment in important economies in Europe, North America and other parts of the world. We review ICT productivity studies, econometric studies analyzing the relationship between broadband infrastructure and economic development, and “forward looking” studies estimating the multiplier effects of telecom investments.

Most evidence indicates a strong and robust positive relationship between telecom investment and both economic growth and employment. These results confirm that investments in digital infrastructure may significantly contribute to overcome the adverse effects of the economic crisis and improve long-term growth prospects.

JEL codes: O47, L96, K23

Key words Telecommunications, Infrastructure, Broadband, high-speed internet, economic growth

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1. Introduction

As broadband deployment began in the late 1990s and early 2000s, it sparked some interest into the potential economic effects. In light of the economic crisis, interest in the economic impact of broadband deployment has resuscitated, as investment in broadband infrastructure may have the potential to boost economic recovery and help countries to emerge from the crisis. In response to gloomy economic conditions, many countries have implemented fiscal stimulus plans to lessen the impact of the recession and initiate economic recovery. As Andes and Castro (2009) point out, in the past one typical response would be to increase investments in physical infrastructure, such as roads or public buildings. However, while many countries can still benefit from improvements in physical infrastructure, spurring investments in digital infrastructure can have a greater positive impact on job creation and growth. Indeed, many governments have decided to emphasize investments in high speed internet and broadband infrastructure in their stimulus packages (CESifo 2009).

Economists are concerned that growth might stay at permanently lower rates, with investment, employment and productivity growth all feebler than before (Economist 2009). In order to tackle the debt crisis, generating growth is top priority (Economist 2010). Also, unemployment remains a critical issue: In its most recent Employment Outlook report, the OECD points out that OECD countries need to create 17 million jobs to get employment levels back to where they were before the crisis (OECD 2010). Thus, fostering broadband infrastructure investments as a long term engine of growth and employment should remain a priority issue in economic policy.

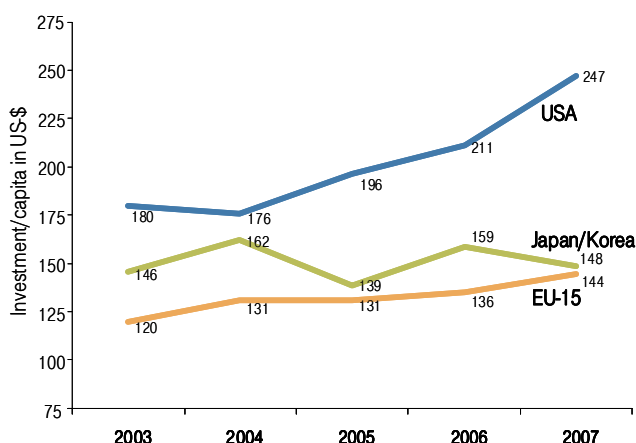
This article is organized as follows: In section 2, we will address telecommunication investment trends worldwide. In section 3, we will discuss major research streams on the economic impact of infrastructure investment and broadband deployment. In particular, we will give a brief summary of ICT productivity studies, econometric studies, and “forward-looking” studies which give specific estimates of future employment and GDP effects resulting from broadband investments. In section 4 we discuss the specific employment effects of telecom investments which have been addressed in the literature.

2. Telecommunication investment trends worldwide

Telecommunication investment as a result of operators upgrading their mobile and broadband networks reached \$185bn in 2007 (OECD 2009b). The United States led in total telecommunication investment with nearly \$75bn in 2007. Looking at investment per capita (see figure 1), investment levels in the U.S. are substantially higher than in Europe and Japan/Korea. Furthermore, in the U.S. investment per capita has been growing at an impressive 12% each year on average since 2004. Industry experts point at broadband deregulation in the U.S. in 2003 and 2004, which has promoted platform competition leading to substantial increases in investment activity (Boam 2008).

OECD experts estimate that 40% of all telecommunication investment was destined for mobile networks. Clearly, with the advent of new fibre technologies, investments in fixed networks need to be substantially increased. This applies in particular to Europe, where the number of FTTH/B subscribers is still at low levels and the deployment of FTTH/B in major European countries in a very infant stage (FTTH Council Europe 2009, 2010). The European Commission quotes a leading consultancy estimating up to €300bn will be necessary to upgrade fixed networks in the European Union (Europa 2008). Clearly, it remains a challenge to remodel the current European regulatory framework in order to provide more incentives for substantial, long term investment in new infrastructure (see e.g. Kopf 2009, Katz 2009).

Figure 1: Public telecommunication investment per capita



Source: OECD (2009b), authors' analysis

3. Telecommunications and the economy: key research streams

LECG (2009) provide a comprehensive taxonomy of the most important research lines which have shaped our current understanding of the impact of broadband, ICT and telecommunications on growth, productivity and employment. Basically, the existing literature can be divided into four categories: (a) older literature on the effect of fixed line telecommunications on economic growth, (b) literature from the late 1990s and 2000s on the impact of ICT on growth and productivity, (c) econometric studies, and (d) “forward-looking” studies focusing on estimating the multiplier effects of broadband investments on GDP and employment.

Table 1: Key Literature and Findings

Type of study & key findings	Key authors/contributions
<i>Study of fixed line telecom impact, 1980s & 90s</i>	
– 1/3 of the per capita GDP growth can be attributed to telecommunications infrastructure investments	Röller, Waverman
– Spill-over benefits allow business to be done over long distances	
<i>ICT productivity studies, 1980s, 1990s&2000s</i>	
– ICT has a significant impact on business productivity in the US	Jorgenson, Stiroh, Van Reenen, Brynjolfsson
– Evidence for European countries and Canada more fragile	
– There is a lag as firms need to invest in complementary capital and work habits need to change	
<i>Econometric studies of broadband</i>	
– Strong evidence that broadband drives employment	Lehr et al. (2005), Crandall et al. (2007), Qiang & Rossotto (2009), LECG (2009), Czernich et al. (2009)
– Strong evidence that there is a positive relationship between broadband deployment and economic growth	
– However, impact varies across countries	
<i>“Forward-looking” broadband studies</i>	
– Major investments in broadband infrastructure will generate substantial employment and GDP growth	Crandall & Jackson (2001), Fornefeld et al. (2008), Atkinson et al. (2009), Katz et al. (2009)
– Positive job effects outweigh negative effects	

Source: LECG (2009), authors' analysis

3.1 Studies of fixed line telecom impact

In their seminal study, Röller and Waverman (2001) looked at growth across 21 OECD countries from 1970 to 1990 and found that about one-third of the per capita GDP growth (0.59 of the 1.96 percent per year growth rate) can be attributed to telecommunications infrastructure investments. They use a simultaneous equation model to integrate demand and supply in the telecommunications sector into the aggregate economy.

Similar results are obtained by Datta and Agarwal (2004), who investigate the long run relationship between telecommunications infrastructure and economic growth, using data from 22 OECD countries for the period 1980-1992. A dynamic panel data method is used for estimation, with corrects for omitted variables bias of single equation cross-section regression. The fixed effects specification accounts for country specific differences. The results show a significant and positive correlation between telecommunications infrastructure and growth, after controlling for a number of other factors.

While Röller and Waverman (as well as Datta and Agarwal) thoroughly address causality issues in their analysis, their period of observation could not yet cover the diffusion of broadband technology.

As Czernich et al. (2009) point out, broadband infrastructure allows the generation and distribution of decentralized information and ideas in markets increasingly relying on information as an input. For businesses high-speed Internet is a tool that allows cutting transaction costs, improving the organization and market fluidity. Broadband should accelerate economic growth by facilitating the development and adoption of innovation processes. In this way, broadband infrastructure may differ not only from other types of public infrastructure such as roads and bridges, but also from more traditional telecommunications infrastructure. Voice telephony has a coordination function and reduces transaction costs for existing businesses. Beyond that, high-speed internet via broadband infrastructure may accelerate the distribution of ideas and information, foster the development of new products and processes, and thereby further facilitating macroeconomic growth.

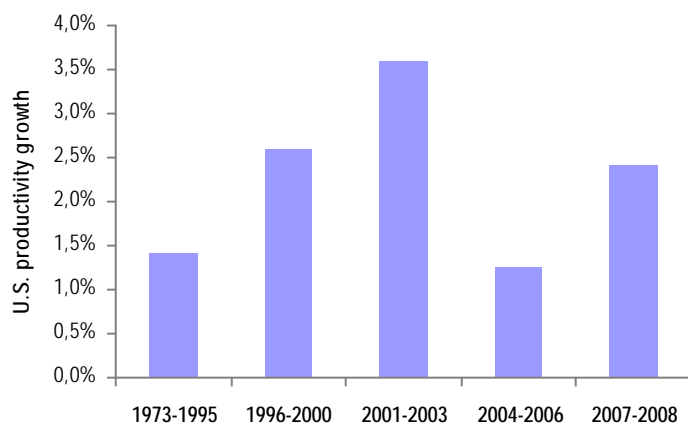
3.2 ICT Productivity Studies

Throughout the 1970s and 1980s, even though firms heavily invested in ICT, productivity growth remained slow. In the 1980s and early 1990s several academics tried to find measurable benefits attributable to ICT; however, they did not find any. This caused many analysts to question the productivity-enhancing impact of ICT. In 1987, Nobel Laureate Robert Solow famously stated that “we see computers everywhere but in the productivity statistics” (Solow 1987).

Crandall, Lehr and Litan (2007) identify mainly three reasons why it is not surprising early analysts did not detect measurable impacts associated with ICT:

- Although investment in ICT represented a significant share of total investment, it still represented only a small share of the total capital stock.
- Measuring ICT inputs is notoriously difficult. One reason is ICT is used most intensively in the service sectors of the economy, for which it is difficult to measure output. Measurement problems make it difficult to assess ICT impacts. Another problem is the rapid pace of innovation and continuously declining prices.
- ICT is considered a *general purpose technology*, i.e. ICT changes the way firms produce goods and services, thereby enhancing the quality of other factor inputs such as labor and non-ICT capital (Bresnahan & Trajtenberg 1995). Sparking quite fundamental techno-

Figure 2: U.S. labor productivity growth¹ (Brynjolfsson and Saunders 2010)



In the late 1990s and early 2000s, with more time and better data available economists were able to overcome the problems that prevented identifying productivity-enhancing effects of ICT. The overall accelerated productivity growth in the second half of the 1990s in the United States (figure 2) was mostly due to ICT. Scholars such as Jorgenson (Jorgenson 2001) were able to identify significant productivity and growth effects attributable to ICT. More recent research suggests that ICT's contribution to growth has slowed down but still remains sizable: Jorgenson, Ho and Stiroh (2008) report that ICT contributed 59 percent of the growth in labor productivity from 1995 to 2000 and 33 percent from 2000 to 2005. From 2000 on, economy-wide productivity growth is driven by innovations in both products and processes in the industries that are the most intensive users of ICT (i.e. ICT as enabler for innovation and productivity growth).

Interestingly, European data failed to show the same positive effect of ICT. As LECG (2009) point out, in the mid 2000s several papers addressed the differences between Europe and the United States. Many of these papers found that the main difference between Europe and the United States appeared to be that the benefits of ICT had not been felt to the same extent in Europe in sectors that were heavy users of ICT, such as retail or finance.

As a more general issue, for many years there has been a productivity gap between Europe and the United States. Over the decade from 1995 to 2005, annual productivity gains averaged 1 percentage point higher in the United States than in the Euro-zone. Productivity rose on average 2.4 percent in the United States during this decade compared to an average 1.4 percent in Europe (Van Ark et al. 2010). Recently, the gap between the United States and Europe widened sharply as U.S. businesses were more aggressive laying off workers: Van Ark et al. estimate that in 2009, labor productivity rose by 2.5 percent in the United States while it fell by 1 percent on average in the Euro area.

In light of the somewhat mixed evidence of the impact of ICT on productivity, the basic findings of the literature can be summarized as follows (Draca et al. 2007, LECG 2009):

- The significance of ICT is that virtually all sectors of the economy are able to use it; the effects of ICT can be felt across the entire economy.

¹ Annual increase in labor productivity in non-farm business sector since 1973.

- However, it takes firms some time to figure out how to best use the ICT available. In some cases, firms, individuals and governments will have to make investments in “complementary capital” (i.e. training, skills, organizational routines) to recognize the full benefits of technology.
- Thus the full effect of ICT is prone to be recognized with a lag, and might be amplified by the flexibility and willingness of the users of ICT to transform their work habits and update their skills; at firm level organizational change might be necessary.

3.3 Econometric Studies of Broadband

Early studies to examine the association between broadband infrastructure and economic development were two policy-oriented reports, namely Crandall, Lehr and Litan (2007) and Lehr, Osorio, Gillett and Sirbu (2005). Both reports find positive associations between broadband penetration and different economic variables such as employment, output, wages and housing prices. In particular, Crandall, Lehr and Litan (2007) find that a one percentage point increase in broadband penetration leads to an increase of 300,000 jobs for the entire U.S. economy.

Table 2: Econometric studies of broadband

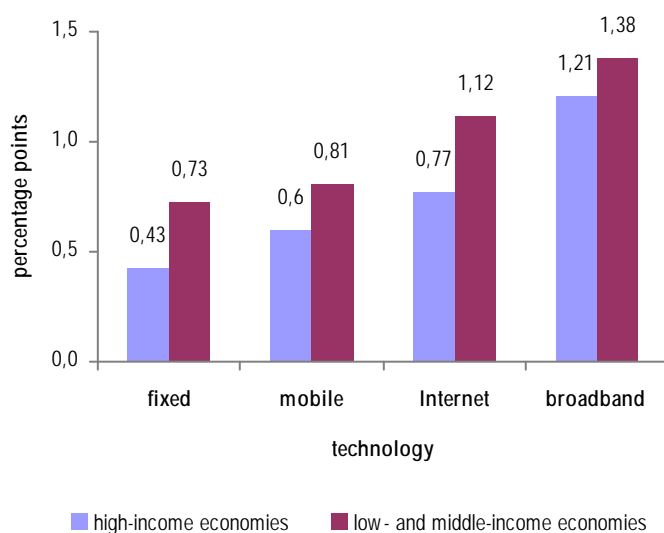
Study	Regional scope	Key findings	Comments
Czernich, Falck, Kretschmer & Wößmann (2009)	OECD	– A 10 percentage point increase in broadband penetration rate raises annual per capita growth by 0.9-1.5 percentage points	Data covers 1996-2007 period; instrumental variable approach to address reverse causality
LECG (2009)	Europe, USA	– In countries with a moderate to good ICT environment, increases in broadband penetration lead to substantial GDP increases – In countries with low propensity for ICT the impact of broadband on productivity and GDP is not apparent	LECG estimate an aggregate productivity model addressing reverse causality / simultaneity issues
Qiang (2009), Qiang & Rosotto (2009)	120 countries	– Fixed line, mobile phone, Internet and broadband have a positive impact on per capita income – Growth effects are larger in developing countries than in developed countries	Cross-sectional endogenous growth model
Koutroumpis (2009)	EU-15	– Broadband deployment has strong and statistically significant growth effects in the European Union	Data covers only the years 2003-2006
Crandall, Lehr & Litan (2007)	USA	– A one percentage point increase in broadband penetration (equal to ~3m lines) means 300,000 more jobs – Statistically significant effect of broadband penetration on output growth, especially in the service industries	Cross-sectional data covers 2003-2005 data (48 states)
Lehr, Osorio, Gillett & Sirbu (2005)	USA	– Broadband added about 1-1.4 percentage points to employment growth rate (1998-2002) – Broadband has positive impact on new business establishments and housing rents (property values)	Cross-sectional panel data set of communities across the U.S. (segmented by zip code); covers 1998-2002 data

Koutroumpis (2009) utilizes the framework developed by Röller and Waverman (2001) and estimates that broadband deployment has had a strong and statistically significant effect on growth in the European Union, although the data covers only the years 2003-2006. He finds that the growth effect of broadband is more pronounced in countries with high existing levels of broadband penetration – that is, the marginal impact of adding broadband lines is higher in countries where there is a “critical mass” of broadband lines already in place.

Qiang (2009) investigates the impact of telecommunications on growth covering 120 economies. An endogenous growth model is used estimate the impact of fixed line, mobile phone, Internet and

broadband on per capita income in a cross-country analysis. The results as summarized in figure 3 indicate significant positive link between each of the telecommunication services and economic growth. The growth effect of telecommunications is larger in developing countries than in developed countries.

Figure 3: Growth effects of ICT (Qiang 2009, Qiang & Rossotto 2009)



Note: The y axis represents the percentage-point increase in economic growth per 10-percentage-point increase in telecommunications penetration. All results are statistically significant at the 1 percent level except for that of broadband in developing countries, which is at the 10 percent level.

LECG (2009) demonstrates increased broadband development can have a significant impact on productivity and economic growth. The study, which is part of the ongoing Connectivity Scorecard research program (Waverman and Dasgupta 2010), focuses on the impact of broadband in 15 OECD countries. The research suggests that with the right skills and infrastructure in place, broadband strategies could increase national productivity and growth by up to 15%. This productivity improvement will increase GDP without increasing resources used in production. For example, the US could increase its GDP by \$100 billion with an increase of 10 additional broadband lines per 100 individuals. The study also underlines the importance of broadband as a stimulant to business growth in the current climate of economic uncertainty.

Czernich et al. (2009) use an instrumental-variable approach in which they model broadband diffusion by an S-shaped diffusion curve. The analysis covers a panel of 25 OECD countries in the period 1996-2007. The authors find robust evidence that the emergence and diffusion of broadband significantly increases economic growth. A 10 percentage point increase in the broadband penetration rate raises annual per-capita growth by 0.9-1.5 percentage points.

Summarizing the econometric studies analyzing the impact of broadband infrastructure on economic growth, it seems the evidence of broadband's positive impact on key economic variables such as GDP growth and employment is robust. It is noteworthy reverse causality or simultaneity issues have been addressed in an adequate manner. This is important as it easily might be argued that a simple association between economic growth and broadband deployment may be driven by reverse causality and omitted variables (Czernich et al. 2009): In particular, individuals in richer countries have a higher ability to pay for broadband services, resulting in more rapid broadband penetration. Furthermore, given rapid technological change in the last decades, broadband diffusion

took place at the same time as the diffusion of other technologies like computers and mobile telephony, making it difficult to isolate the specific effect of broadband. Studies addressing these problems properly (such as Czernich et al. 2009 or LECG 2009) confirm the causal impact of broadband infrastructure on economic growth.

3.4 “Forward looking” Broadband Studies

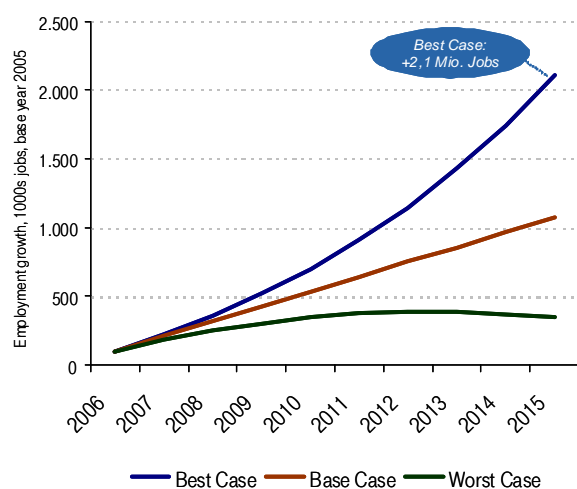
Early studies such as Crandall and Jackson (2001) highlighted the potential economic impact of broadband. Crandall and Jackson estimate (in terms of net present value) the additional economic benefit generated as a result of broadband deployment and its effect on the wider economy in the range of several hundred billion dollars (“The \$500 Billion Opportunity”). Table 3 gives an overview of older and more recent “forward looking” broadband studies.

Table 3: “Forward looking” broadband studies

Study	Regional scope	Key findings	Comments
Katz, Vaterlaus, Zenhäusern, Suter & Mahler (2009)	Germany	<ul style="list-style-type: none"> – Realizing the broadband coverage targets set by the National Broadband Strategy will require investments as of €20.2bn – These investments will generate 407,000 jobs by 2014 – In output terms, the German economy will benefit from an incremental €62.1bn GDP impact (by 2014) 	Katz et al. also contemplate an ‘ultra-broadband scenario’ covering 2015-2020 leading to additional job creation and GDP growth (0.6 percentage points incremental GDP growth)
Atkinson, Castro & Ezell (2009)	USA	<ul style="list-style-type: none"> – \$10bn of investments in one year in broadband networks will support ~498,000 U.S. jobs for a year – Health IT: \$10bn investment in health IT creates 212,000 jobs; Smart power grid: \$10bn investment in the smart grid would create 239,000 jobs 	Study identifies four distinct job creation effects: (i) direct telecom jobs, (ii) direct capital equipment jobs, (iii) indirect and induced jobs, (iv) network effects
Liebenau, Atkinson, Kärrberg, Castro & Ezell (2009)	UK	<ul style="list-style-type: none"> – An additional £5bn investment in broadband networks would create or retain an estimated 280,500 UK jobs for a year 	Study distinguishes three job creation effects: (i) direct, (ii) indirect & induced, (iii) network effect
Fornfeld, Delaunay & Elixmann (2008)	EU-27	<ul style="list-style-type: none"> – More than 2m jobs throughout Europe until 2015 – Cumulated GDP effect: €1,080bn (best case) 	Study identifies / estimates positive and negative job effects: productivity improvements (-), outsourcing (-), innovation/ new economic activity (+)
Crandall & Jackson (2001)	USA	<ul style="list-style-type: none"> – Net present value generated as a result of broadband deployment and its effect on the wider economy estimated at \$500bn 	

In a recent study for the European Commission, Fornfeld et al. (2008) collect evidence of the economic impact of broadband development on labor productivity, employment and growth. According to the model, process improvement, increased specialization in knowledge-intensive activities and broadband-based development of innovative markets resulted in an incremental growth of the European gross value added as of 82.4 billion Euros per year (+0.71%). Employment creation in new activities compensates for job losses due to process optimization and structural displacements. In the best case scenario, broadband could lead to the creation of more than 2 million jobs in Europe in the period until 2015 (figure 3). The scenarios differ in terms of different speeds of adoption of online services, underlining the importance of timing (“speed matters”).

Figure 4: Broadband-related employment growth (EU27) 2006-2015 (cumulative)



Source: Fornfeldt et al. (2008)

However, depending on broadband access and levels of use, impacts are not uniform across European countries, with some seeing more positive broadband-related results than others. In the most advanced European countries, broadband-related growth of gross value added reaches 0.89%, whereas in European countries with less developed broadband related gross value added growth is limited to 0.47%. The study concludes that the key to significant positive impacts are not only access to infrastructure but also the integration of value-added online services in company processes.

Two ITIF studies, Atkinson et al. (2009) and Liebenau et al. (2009), estimate the employment effects of large scale broadband infrastructure investments in the U.S. and UK. For the U.S., Atkinson et al. project a \$10bn investment in broadband infrastructure will create (or retain) 498,000 jobs. For the UK, Liebenau et al. project an additional £5bn investment in broadband networks would create or retain an estimated 280,500 jobs a year.

Katz et al. (2009) calculate the impact of investment in broadband technology on employment and output in the German economy. They analyze two investment scenarios: The first one is based on the government's target to ensure 75% of German households have broadband access of at least 50 Mbps by 2014. The second investment scenario is based on 50% of German households having access to 100 Mbps and another 30% to 50 Mbps by 2020. Katz et al. estimate realizing the first target for 2014 will require an investment of €20.2bn creating 407,000 new jobs. Realizing the more ambitious second target by 2020 would even create 968,000 new jobs in total. In GDP growth terms, over a ten year period (2010-2020) broadband investment following the investment scenarios outlined above leads to an incremental 0.60% annual GDP growth.

4. Investing in broadband infrastructure: examining individual employment effects

Why exactly should investments in broadband infrastructure create employment? In order to better understand the way broadband impacts companies' activities, it is important to look at individual effects on firm and industry level. Table 4 gives an overview of the effects discussed and analyzed in the literature. Basically we distinguish between three literature streams: the technology diffusion

literature, the applied industrial organization literature, and studies based on input/output analysis aiming at quantifying multiplier effects.

Typically, the technology diffusion literature analysis is centered on individual firms adopting new technology (such as broadband) and contemplates the effects emanating from new technology adoption within the adopting firm. The applied industrial organizations literature stream also focuses on firms adopting new technologies, but tries to capture not only intra-firm employment effects but also spill-over effects to other industries and potential intra-industry and inter-industry interdependencies. Studies based on input-output analysis and focusing on multiplier effects are conceptually centered on the telecommunication operators' investment and analyze the effects of that investment on different sectors of the economy.

Table 4: Employment effects

Effect	Direction	Explanation / comments
<i>Technology diffusion literature¹⁾</i>		
Scale effect	-	➤ Capital-skill substitutability: firms substitute physical for human capital
Skill effect	+	➤ Capital-skill complementarity hypothesis: An increase in physical capital of technology-adopting firms increases demand for skilled human capital labor ➤ For <i>general purpose technologies</i> , capital and skills are complements – in industries deploying general purpose technologies, there is a shift in demand for higher-skilled human capital
<i>Applied Industrial Organization, sectoral analysis²⁾</i>		
Direct productivity effect	-	➤ ICT has a positive impact on firms' productivity ➤ Companies adopting broadband-based processes improve productivity between 5% and 10%
Displacement effect (outsourcing)	-	➤ Outsourcing in a near-shoring form: structural displacement of employment from a low-productivity to a high-productivity sector ➤ Broadband facilitates outsourcing to the business sector, typically more productive than outsourcing firms' in-house departments
Off-shoring	+/-	➤ Transfer of activity to another country or region
Competitiveness effect	+	➤ Outsourcing improves competitiveness of the client firm
Innovation effect	+	➤ New services and applications generate growth and employment in adjacent industries / new industries
<i>Input/output analysis, multiplier effects³⁾</i>		
Direct effect telecommunications	+	➤ Additional frontline technicians, new back-office functions within the telecommunications industry
Direct effect capital equipment	+	➤ Jobs are created in companies that manufacture telecommunications, electronic and computer equipment needed to deploy broadband
Direct effect construction	+	➤ Roll-out of fiber infrastructure requires substantial construction work
Indirect and induced effects	+	➤ Direct jobs created in the telecommunications and capital equipment industry and in construction support additional jobs throughout the economy
Network effect (innovation effect)	+	➤ Broadband spurs upstream investment and contributes to the creation of new industries

¹⁾ E.g. Griliches (1969), Bresnahan & Trajtenberg (1995), Majumdar (2008)

²⁾ E.g. Fomefeld et al. (2008), McKinsey (2008)

³⁾ E.g. Atkinson et al. (2009), Katz et al. (2009)

Scale and skill effects have been widely addressed in the technology diffusion literature. The scale effect states firms substitute physical for human capital, i.e. new technology diffusion could lead to downward shifts in labor demand. Griliches (1969) pointed out that new technology increases demand for skilled human capital labor (capital-skill complementarity hypothesis). In particular, in

industries deploying general purpose technologies such as ICT there is a shift in demand for higher-skilled human capital (Majumdar 2008).

The applied industrial organization literature looks at a broader set of employment effects. Two of them, the productivity and the displacement effect, have a negative impact on employment. The adoption of broadband-based processes should lead to process improvements and productivity gains. On firm level, the effect on employment is negative, as more efficient broadband-based processes will allow firms to cut back on labor. According to Fornefeld et al. (2008), companies adopting broadband-based processes improve labor productivity on average by 5% in the manufacturing sector and by 10% in the services sector.

Not unrelated to the direct productivity effect, the displacement effect is also negative. The development of broadband allows the acceleration and automation of information flows between companies, which enables an increased specialization in knowledge-intensive activities. This structural evolution in business environments generates jobs displacement from the traditional sectors of the economy to the services sector. Typically, labor productivity in the business sector is higher than in the rest of the economy. Thus, structural displacement of employment from a low-productivity to a high-productivity sector has a negative effect on employment.

On the other hand, realizing productivity directly or indirectly means increasing competitiveness of client firms and fostering activity in the more dynamic sectors of the economy. Improved competitiveness and new services and applications in technologically more advanced sectors have a positive effect on employment. Broadband creates jobs by enabling the emergence of new businesses developing innovative new services, including electronic commerce, telemedicine, VoIP (Voice over Internet Protocol), video on demand, smart homes, telework, and access to e-government (Atkinson et al. 2009).

In their study, Fornefeld et al. (2008) provide an answer to the key question whether the positive effects outweigh the negative effects: as previously stated, they do. Broadband leads to a positive net employment creation.

While technology diffusion and applied industrial organization literature take technology purchasing firms as a starting point for analyzing employment effects, studies such as Katz et al. (2009) and Atkinson et al. (2009) analyze employment effects based on investments by telecommunication operators, the technology *producing* firms. The multiplier effects identified are all positive: investment creates jobs at the investing firm, at suppliers providing capital equipment required to deploy broadband, and in the construction business. Furthermore, direct jobs (created in the telecom sector, in the capital equipment industry and in construction) support additional jobs throughout the economy (indirect/induced effect). Furthermore, broadband spurs upstream investment and contributes to the creation of new industries (network or innovation effect).

To summarize, multiple effects analyzed on firm and sectoral level underline support and explain how broadband investment contributes to create employment. Job losses due to process innovations leading to productivity gains at technology adopting firms are more than offset by jobs created at technology producing firms and their supplier, by jobs created in adjacent or new industries. Furthermore, there is strong evidence that broadband enhances demand for skilled labor, as industries deploying general purpose technologies typically demand more higher-skilled human capital. Telecom investments stimulate different sectors of the economy, creating jobs throughout the economy.

5. Conclusion and implications

There is substantial evidence that telecommunication investment is a powerful engine of growth and employment. Different literature streams have analyzed the impact of ICT on growth, productivity and employment. Across a broad variety of data sets covering differing regional scopes, time frames and analytical approaches we find robust evidence for a significant economic impact of ICT investment. In particular, elaborate econometric analysis demonstrates that beyond mere correlation there is indeed a *causal* impact of broadband infrastructure on economic growth.

Substantial investments required to roll out fiber infrastructure will have a major impact on the economy, stimulating growth and employment in the short, medium and long term. Clearly, policy makers should encourage telecom investment by creating adequate regulatory incentives for investment and a reliable, predictable legal framework. Whereas it is beyond the scope of our paper to discuss adequate measures, we can affirm that investment levels in Europe are below those in the U.S., indicating the need to foster telecom investment in Europe. A modern high speed broadband infrastructure is essential to reap the benefits of the digital economy in terms of innovations, productivity improvements, growth and employment.

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