

Gruber, H.; Hätönen, J.; Koutroumpis, P.

Conference Paper

Broadband access in the EU: An assessment of future economic benefits

24th European Regional Conference of the International Telecommunications Society (ITS): "Technology, Investment and Uncertainty", Florence, Italy, 20th-23rd October, 2013

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Gruber, H.; Hätönen, J.; Koutroumpis, P. (2013) : Broadband access in the EU: An assessment of future economic benefits, 24th European Regional Conference of the International Telecommunications Society (ITS): "Technology, Investment and Uncertainty", Florence, Italy, 20th-23rd October, 2013, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/88492>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Broadband access in the EU:

An assessment of future economic benefits

H. Gruber¹ J.Hätönen² P. Koutroumpis^{3,4}

This paper evaluates the net benefits of the implementation of the broadband infrastructure deployment targets by 2020 as entailed by the Digital Agenda for Europe Initiative set forth by the European Commission. We estimate the returns from broadband infrastructure for the period 2005-2011, differentiating the impact of broadband by levels of adoption and speed while accounting for reverse causality and extensive heterogeneity. We find that in the base case scenario the overall benefits outweigh the costs by 32% for the entire European Union. We further extrapolate the returns by country under different scenarios of implementation. In most cases the benefits are substantially well above the costs. The findings lead to policy recommendations related to the role of public support for the generalized build out of broadband infrastructure.

Keywords: broadband networks, economic impact, Digital Agenda

JEL: O33, O38, O52

Paper for ITS Conference at EIU Florence October 2013

Draft September 2013

¹ European Investment Bank (gruber@eib.org)

² European Investment Bank

³ Imperial College Business School (p.koutroumpis@imperial.ac.uk)

⁴ The views expressed are of the authors and do not commit the affiliating institutions.

1. Introduction

The contribution of broadband networks to national economic output and productivity growth is well documented (Koutroumpis 2009; Czernich et al, 2011) and they are now considered an essential enabling infrastructure in most modern knowledge based economies. The policy debate in Europe and the relatively poor macroeconomic growth performance have led the Union missing out on growth opportunities comparatively to its global counterparts. The ‘wait-and-see approach’ for investments in broadband infrastructure and the lack of clear policy formulations favouring next generation access (NGA) have played a pivotal role in this outcome. At the same time innovation-driven technologies and the surrounding ecosystem of applications have shifted the political and regulatory status quo into forms of indirect national and EU-level interventions (including the Connecting Europe Facility proposed by the European Commission and several national Broadband Plans backed with support schemes) to supplement the cases where the market players will simply not invest.

General-purpose infrastructures, such as broadband, are also the enablers for measureable spillovers on adopting sectors including Health, Manufacturing, Financial Services, Electricity, Education and ICT. Consequently there is a risk in delaying high speed broadband build out as the EU will fall behind on two fronts: (i) on the supply side of infrastructure, because telecommunications operators may not be able to develop and deploy advanced services while equipment providers may not develop appropriate standards and technologies; (ii) on the demand side as the adopting sectors may not be able to benefit from the productivity enhancing features of ICT, with the perspective of declining social welfare and diminished ability to cope with demographic changes.

Telecommunication services are nowadays provided mostly on competitive market terms and therefore investment in broadband infrastructure has to accommodate relatively short financial return horizons. But the market forces guided by such incentives are not necessarily providing the socially optimum broadband coverage for a country and may justify compensatory policy action. This market failure argument leading to a wedge between financial and economic return applies in particular in areas of low population density, where the network deployment unit costs are high and therefore do not cater for sufficient financial returns. On the other hand scarce public funds should only be used when there is a sufficiently large economic return to society and when market forces are not able to provide it.

The policy response from the European Commission is the “Digital Agenda for Europe”, one of the seven flagship initiatives within the “Europe 2020 Strategy” aiming to foster smart, sustainable and inclusive growth in the EU. The Digital Agenda, presented in May 2010,

entails a set of objectives in terms of broadband roll out, such as the target to bring broadband access for all Europeans by 2013, access for all Europeans to much higher internet speeds (30 Mbps or above) by 2020, and 50% or more of European households subscribing to internet connections above 100 Mbps.

To reach these targets, the existing network infrastructure needs to be extended by a mix of wireless and wireline technologies. Substantial investments are required in order to roll-out efficiently these new networks, while at the same time trying to make use of existing infrastructures for cost reductions. However, due to the generally very long payback periods and low financial return a major part is not available from pure market sources. The European Commission therefore claims the need for entirely new finance instruments and mechanisms, including direct public intervention to ensure meeting of the targets set in the Digital Agenda. A major question in the policy debate is whether such additional resources constitute a good use of public funds at times of economic austerity induced by the protracted economic and financial crisis in Europe. The novelty of this paper is to show that the investment in broadband infrastructure has relatively high economic returns but across an array of uncertainties and therefore subsidies to broadband infrastructure for meeting the Digital Agenda objective constitute an efficient use of public funds.

Section 2 presents a survey of the relevant economic literature and illustrates the way broadband infrastructure has a bearing on economic growth. Section 3 describes a set of scenarios for broadband infrastructure build out to meet the coverage targets entailed by the Digital Agenda along with an estimate of the cost. In Section 4 the econometric model is presented to estimate the parameters for the economic return of broadband infrastructure. Section 5 proceeds to the evaluation of the economic benefits against the cost of broadband infrastructure build-out, and the conditions under which the use of public subsidies is efficient. Section 6 concludes.

2. The economic effects of broadband infrastructure

There is ample empirical evidence that the diffusion of broadband infrastructure and services provides substantial economic benefits and represents an important driver of economic growth. The economic benefits manifest themselves directly and indirectly for consumers and businesses and vary substantially across sectors. Moreover the local culture, managerial attitudes and indigenous regulatory frameworks have been found to affect the impact of these infrastructures.

The World Bank produced one of the earliest studies on the impact of broadband on national economic growth (Qiang and Rossotto 2009). This work looks at a sample of 66 high-income economies for the period 1980-2002 (when in fact broadband was quite scarce and only the Republic of Korea, Canada and Hong Kong had achieved adoption levels beyond 10%). It

found that – other things being equal – an additional 10 broadband lines per 100 people in high income economies increased the national Gross Domestic Product (GDP) per capita by 1.21% during that period. Studies that looked into the same effects for more recent periods have generally found more conservative figures. For example, in his study on an OECD sample of 22 countries for the period 2002 to 2007 Koutroumpis (2009) finds a strongly positive and significant link for the impact of broadband adoption on GDP expansion. He suggests that the annual GDP of the ‘average’ country in the dataset benefited by 0.24% from broadband adoption: this was equivalent to about 10% of annual GDP growth for these countries during the period 2002-2007. Czernich et al (2011) performed a similar exercise looking at a broader OECD sample between 1996 and 2007. They confirm that broadband adoption has a significant and positive impact on national GDP per capita, and estimate this to increase by 0.9% to 1.5% for every additional 10 broadband lines per 100 people. These last two studies control for reverse causality in explicit ways; they introduce structural models that disentangle the effects and perform several robustness checks.

There is evidence that the impacts of growth in broadband are greater in countries with relatively high levels of take-up. Koutroumpis (2009) identified a threshold of 30 lines per 100 people (50% of households), at which broadband yielded returns double those achieved at lower levels of penetration. He found that the average impact of broadband on annual GDP growth in the period 2002-2007 increased from 0.15% in low penetration countries (such as Greece and Italy), to 0.23% in medium penetration countries (such as Germany and the UK), to 0.39% in high penetration countries (such as Norway and the Netherlands) – see the chart below. Furthermore, the marginal impacts associated with *growth* in broadband penetration were greater for higher-penetration countries: an additional 10 lines per 100 people led to 0.7% additional annual GDP growth in low penetration countries, 0.8% in medium penetration countries, and 1.0% in high penetration countries.

Measuring consumer surplus is an analytic process that heavily depends on the quality of the end product vis a vis the final price. During - and soon after - the ‘dot com’ era the estimates for the returns of ubiquitous broadband access on the US economy were estimated to some 284\$-427\$ billion per year (see Crandall and Jackson, 2001). More recently these estimates were substantially undercut albeit the rapid drop in equipment costs and the experience gained over a decade of continuous network expansion. Dutz et al (2009) estimated the consumer surplus from household use of broadband in the US in the order of \$32 billion per year, up from an estimated \$20 billion in 2005. This increased consumer benefit corresponds to a gradually changing attitude with explaining the service transformation from a luxury to a necessity and hence reducing its perceived elasticity of demand. This study estimated that with even higher speeds, broadband would provide consumers even greater benefits – at minimum an additional \$6 billion per year. On the same front Greenstein and McDevitt (2012) confirm these findings for a sample of OECD countries. They explain that many

countries have experienced increased consumer surplus because they simultaneously experience large improvements in broadband quality and declining real prices. The quality-adjusted new consumer surplus from broadband (over dial-up counterfactual) for the UK increased from \$14 billion in 2006 to \$45 billion in 2010. These studies illustrate the very wide variation in the estimates of consumer surplus – e.g. for the US in 2009, Greenstein and McDevitt estimated a quality-adjusted consumer surplus of \$95 billion, whereas Dutz et al (2009) put the consumer surplus for that year at \$32 billion. Such variation compared to other mature products and services is perhaps understood as a result of the dynamism of this market with rapid changes in quality improvements (i.e. speed) and substantial price reductions.

Empirical evidence has also emerged of broadband having a material impact on business innovation. For example, Bertschek et al. (2011) find a causal impact of broadband internet on firm performance using a sample of German manufacturing and services firms. Their study looks at the early stages of broadband in the country (2001-2003), using detailed firm-level information on a sample of over 900 firms. Their findings suggest that broadband access had no significant effect on labour productivity, at that stage of its development in Germany, but that it had a substantial impact on their innovation activity. Broadband use (of this sample of German firms in 2002) had a positive and significant impact on the probabilities of both process innovation and product innovation in 2001-2003: i.e. firms that used broadband in that early phase of the market's development were more likely to reshape their business processes and to bring new or improved products and services to the market. Regarding the finding of no significant impact on labour productivity, the authors suggest that *“this process of reorganisation was accompanied by a phase of experimenting and learning, which is typical for the introduction of a general purpose technology. Broadband effects on labour productivity might arise in the long run”*.

The changes in business operations enabled by broadband, and associated ICT, do not happen immediately, however. In practice, it takes time for a business to realise the full benefits of new broadband connectivity. One of the most widely cited pieces of research on the lag effect associated with ICT investments is a study looking at the effects of ‘computerization’ on productivity using data from 527 large US firms over the period 1987-1994 (Brynjolfsson and Hitt, 2003). The authors find that the long term impacts are substantially more important than the short term impacts: *“computerization makes a contribution to measured productivity and output growth in the short term (using 1-year differences) that is consistent with normal returns to computer investments. However, the productivity and output contributions associated with computerization are up to 5 times greater over long periods (using 5- to 7-year differences). The results suggest that the observed contribution of computerization is accompanied by relatively large and time-consuming investments in complementary inputs, such as organizational capital, that may be omitted in conventional calculations of productivity.”*

In realising the benefits of broadband, and associated ICT investments, much appears to be dependent on the culture and skills of companies' management. A particularly clear illustration of this is provided by Bloom et al, who performed an analysis of multinationals operating in Europe over the period 1999-2006 (Bloom, Sadun, and Van Reenen, 2012). They showed that US-owned multinational firms achieved significantly greater productivity gains through IT than non-US multinationals, and that establishments taken over by US firms achieved significantly greater productivity gains through IT than statistically similar establishments taken over by non-US multinationals. They also found that US-owned firms had higher levels of people management than their non-US counterparts, and that this accounted for their greater success in achieving benefits through the use of IT. The authors suggest that *“part of the IT-related productivity gains underlying the post-1995 period is related to the management practices of US firms rather than simple natural advantage (geographical, institutional, or otherwise) of being located in the US environment. US firms appear to have transplanted these management practices abroad, so that their overseas subsidiaries also enjoyed a productivity miracle.”* They estimate that this superior use of IT accounts for about half of the US-Europe difference in productivity growth in the ten years from 1995.

The differences between US and European firms in their exploitation of ICT may also be reflected in differences in their skills profiles. A study by O'Mahony et al analysed the impact of ICT on the demand for skilled labour in the US, the UK and France in the period 1979 to 2000 (O'Mahony, Robinson and Vecchi, 2008). In the European countries they found a stronger impact of the level of ICT intensity (measured by ICT capital divided by total capital) on the demand for IT workers than on the demand for highly skilled workers not in IT occupations. In contrast, in the US the impact of ICT intensity was much larger on the demand for non-IT workers with a degree than on the demand for IT workers. The authors suggest that this may reflect different phases of ICT adoption over that period, with European firms being at an earlier stage of adoption, requiring more ICT-specific human capital, whereas in the US the diffusion of technology had reached a point at which more general skills were required to undertake the necessary organisational changes in order to reap the full productivity benefits.

Previous research has established the complementarity between IT and skills, and between IT and organisational change. For example, Bresnahan et al analysed several indicators of IT use, workplace organisation and the demand for skilled labour using firm-level data over the period 1987-1994 (Bresnahan, Brynjolfsson and Hitt, 2002). They found that the interactions between IT use, workplace organisation, and human capital (but not always levels of these variables individually) positively predicted firm productivity. Information technology created increased demand for skilled labour; but *organisational* changes induced by IT may have a much larger effect on skills than the technical change itself.

Regulation can also have an impact on the extent to which benefits are realised from ICT. Using data from 13 countries from 1992 to 1999, Gust and Marquez (2004) found that burdensome regulatory environments in industrial countries impede adoption of ICT practices and the resulting productivity gains. They suggested that restrictive labour market regulation may protect workers from the process of job creation and job destruction (and protect existing firms from the entry of new firms), but that this also appears to have slowed the adoption of ICT in some countries, and this in turn played a role in explaining differences in productivity across countries in the 1990s. Van Reenen et al (2010) came to a similar conclusion when analysing the link between ICT and productivity between the US and Europe, in a report for the European Commission. They suggest that labour market regulations and product market regulations may be “*significant determinants of cross-country differences in the impact of ICT. High levels of labour and product market regulation are associated with a lower productivity impact of ICT. This effect seems to be most severe with respect to labour market regulation (LMR). The LMR effect offsets the main effect of ICT by approximately -45% while product market regulation (PMR) has a more limited offsetting impact of -16.2%.*”

While many developed countries have had over a decade of broadband availability, the introduction of mass market ‘superfast’ or ‘ultrafast’ services – i.e. faster broadband, normally delivered through fibre-based access infrastructure – has been relatively recent in most countries. We are still therefore at an early stage in terms of gathering evidence of faster broadband’s incremental impacts – over and above the impacts of broadband in general. Rohman and Bohlin (2012) undertook one of the first attempts to measure the impact on broadband speed on economic growth, utilising a combination of OECD data for 33 countries over the period 2008-2010 and a proprietary speed testing dataset. Their regression analysis found that the coefficient of average achieved downstream broadband speed was not statistically significant, but that the coefficient of broadband speed squared was significant and positive – suggesting a non-linear relationship between broadband speeds and GDP per capita growth. They interpreted their findings as suggesting that doubling the connection speed would contribute an additional 0.3 percentage points to annual GDP growth (the mean speed in the sample was 8.3Mbps⁵). Another study, in a European country which introduced faster broadband services relatively early (Sweden), examined the socio-economic effects from FTTH deployments (Forzati and Mattsson, 2011). Using a sample of 290 Swedish municipalities for the period 2007-2010, they found that a 10% increase in the proportion of the population with access to FTTH was associated with a positive change in municipality-level employment after 2.5 years of between 0% and 0.2%.

⁵ Megabits per second

3. The European broadband infrastructure and the cost of meeting Digital Agenda targets

The average EU household penetration of broadband connections is lagging behind other developed countries including the US (70.3% household penetration), Japan (65.1%) and Australia (70.7%)⁶. Moreover, the EU is well behind the leading countries in broadband such as South Korea with a household penetration of 96.7% and in next generation broadband adoption.

There is no official definition of speed classes, but there is agreement that what is generally referred to as “basic broadband” is not enough to benefit from many of the important services that can be provided. Likewise, Next Generation Access (NGA) typically involves access speeds higher than 30 Mbps that can be provided by fiber or cable TV lines⁷. Most of the EU broadband lines are based on xDSL technologies and average speeds are usually lower than in other developed countries with high broadband penetration rates. Lines based on fibre to the home (FTTH) solutions and fibre + LAN only represent between 1.8 and 5% of all broadband lines, while this share is much higher in countries such as Japan (51.4%) or Korea (46%). In the US, FTTH lines represent 6% of all broadband lines. Although FTTH deployment has accelerated in 2009, differences are still striking. Figure 1 shows an international comparison of the evolution of the number of NGA broadband line, illustrating how Europe is falling behind other countries, including China.

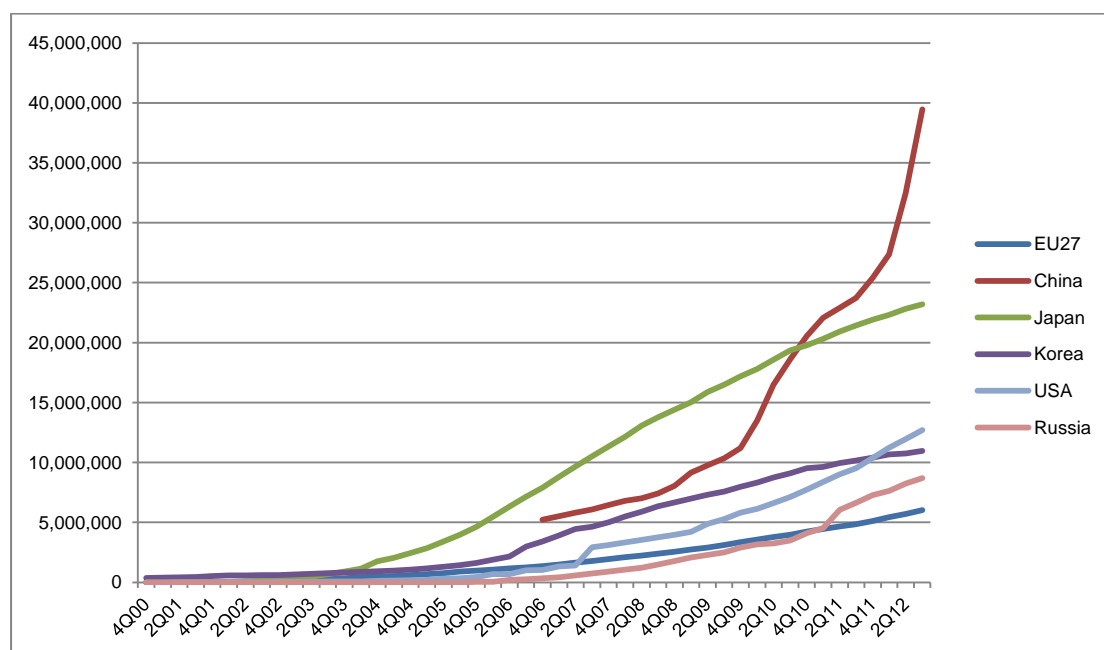


Figure 1: NGA lines in the EU are trailing behind all global competitors (Source: Informa Telecoms and Media)

⁶ Source of data is OECD

⁷ Strictly speaking, xDSL may achieve also similar speeds in particular when amenable to « vectoring » technologies. But this is crucially dependent on the quality and length of copper local loops and thus not feasible in all cases.

Another striking feature for Europe is the fact that Europe is well covered with broadband infrastructure, only that users fail to pick up the service. The low penetration of the service is contrasted with a high degree of availability. The average reported xDSL household coverage in the EU is 94%, relatively high in comparison to other OECD countries (average 88.0%) and above the US (82%) and Australia (91%).

On the other hand, there is also low availability of NGA networks. The cable household coverage of 48% for the EU is below the OECD average of 59% and well below the 96% in the US. Also the coverage of fibre to the home or building (FTTH/B) is with 4.5% of households well below the OECD average of 17.0% and the 13.1% of the US, and significantly below the 86.5% in Japan and the 67% in South Korea. We therefore see low broadband take up by users and low degree of infrastructure competition among networks. This has induced European policy makers to act by launching the Digital Agenda for Europe as a policy initiative to provide Europe with widespread coverage of NGA to broadband with the targets indicated above: full broadband coverage by 2013, 30 Mbps or above by 2020 and more than 50% of European households using services requiring connections above 100 Mbps.

These Digital Agenda targets leave room for interpretation in the implementation. For instance how the access levels (e.g. homes connected) and the speed targets introduced in the DAE are interpreted in terms of their symmetry (i.e. download or symmetric download-upload) and whether they refer to actual or theoretical speeds carry great implications to the available technology options and thereby to the cost of deployment.

Hätönen (2011) reports on calculations on the total cost to reach all the DAE targets, taking into account the different possible technology scenarios which are indicated as follows:

- Minimum: Theoretical speed, with internet centers in rural areas
- Base: Theoretical speed, coverage to the household
- Advanced: Actual Speed, coverage to the household
- Maximum: Actual symmetric speed, coverage to the household

The underlying base assumptions for each scenario include the following: Coverage is the benchmark infrastructure variable; niche technologies like Satellite and WiMAX are excluded; the focus is on residential broadband access; competition and regulatory parameters are not considered and a single platform is only modelled Hätönen (2011). Countries were split into three types of areas: urban (more than 500 inhabitants per km²), suburban (between 100 and 500 inhabitants per km²) and rural (less than 100 inhabitants per km²). Population density is the most important parameter affecting deployment unit costs.

The total cost of the Digital Agenda ranges substantially depending on the outlined requirements. This can be as low as approximately EUR 73 billion for the whole EU in the

Minimum scenario and could reach EUR 221 billion in the Maximum scenario. The Base scenario will require approximately EUR 84 billion and the Advanced EUR 143 billion. However, this is very sensitive on the use of legacy infrastructure. Including cable upgrades the total cost of the Digital Agenda decreases substantially. This can be as low as approximately EUR 47 billion for the Minimum scenario and could reach EUR 221 billion for the Maximum scenario. The Base scenario will require approximately EUR 56 billion and the Advanced EUR 104 billion. (Hätönen (2011))

The largest cost item of the Digital Agenda is the second target, covering total population with high-speed (> 30Mbps) access. As we move towards more advanced scenarios, calling for actual and eventually symmetric speeds in the Maximum Scenario, the costs for the first and second target increase both in absolute terms and as percentage of the total.

The methodology used to examine the financing gap consists in finding so-called capital expenditure (capex) thresholds for market operators to provide a business case for fibre deployment, as this along with cable is the technology required for providing NGN services. The capex threshold is defined as the maximum capital expenditure that can be matched by expected revenues, that is, the investment volume up to which FTTH deployment is financially viable. Finding the capex thresholds first requires developing a cost curve as a function of population density, which can be represented in a cumulative manner, going from high-density (i.e. low-cost) areas to low-density (high-cost) areas. This representation allows stating that, for instance, 40 percent of EU households live in areas where FTTH deployment costs less than EUR 500 per household. Next, hypothetical business cases are built using multiple scenarios, variables, and sensitivities, from which the capex thresholds are derived. These capex thresholds can then be translated into population densities, and further to the share of total required cost based on the results of the cost study. The difference between the capex threshold and the total cost of deploying an EU-wide FTTH network gives an indication of the financing gap. The reported costs for a household passed with fibre (FTTH) vary greatly with population density. The cost is of course dependent on several other variables such as availability of ducts, type of terrain and local labour costs. Industry benchmarks were used to identify the cost distribution curve in different population density areas. The identified cost points were further connected by applying a relatively simple methodology⁸ given limited data availability. By applying this approach, we arrive at cost levels between EUR 150 and EUR 540 per home passed in urban areas, between EUR 540

⁸ A benchmark value for deployment cost of EUR 112,500 per km² is derived based on various sources of industry benchmarks and EIB experience on costs per household covered in different areas with varying population density. This translates into an average cost per household passed at different population densities (assuming 2.4 inhabitants per household on average based on Eurostat). For the purpose of this analysis it is assumed that the household size is the same in different density areas. While this is a simplification, it gives a sufficient base for assessing the finance gap. Also, due to the fact that the deployment cost is dependent on a number of cost variables, with no data available for several of them, an accurate computation would be impossible to achieve anyway.

and EUR 2700 in suburban areas, and over EUR 2,700 in rural areas.

4. Assessment of economic return for broadband infrastructure

This section estimates the parameters of an endogenous growth model that links the returns of technological improvements with capital and labour contributions to the total economic output. These parameters will be used to estimate the economic benefits of increased broadband access infrastructure availability taking into account the findings for the total cost established earlier. Using a simultaneous equations model we therefore first estimate the return parameters of broadband infrastructure for the period 2005-2011, differentiating the impact of broadband by levels of adoption and speed while taking into account the effects of reverse causality and extensive heterogeneity. Then we extrapolate the individualized returns by country using different scenarios of implementation. In doing so, we utilize the most detailed sample on the total infrastructure cost requirements depending on demography, technology choice and network reuse. Effectively we monetize the conceptual policy goals, acknowledging the degrees of uncertainty within this attempt. We finally estimate the required investment and subsidies by country and the cumulative and net gains by different implementation approach.

4.1. The model

The simultaneous equation model, based on Roller and Waverman (2001), Koutroumpis (2009) and Gruber and Koutroumpis (2011), is set up as follows:

Aggregate production function

$$GDP_{it} = f(K_{it}, L_{it}, BB_Lines_{it}) \quad (1)$$

This links real GDP_{it} in country i at time t to a set of production factors. In particular the stock of capital (K), labour (L) and the stock of broadband and fixed telecommunications infrastructure. The stock of broadband infrastructure is needed rather than the broadband investment because consumers demand infrastructure and not investment *per se*. There is an explicit acknowledgement of telecommunications capital, approximated by the broadband infrastructure in terms of broadband lines (BB_Lines). Real GDP thus is a function of labour force, capital stock and broadband and fixed line infrastructure. While the coefficients for labour (L) and capital (K) should be typical for production functions, the coefficient of broadband penetration in equation (1) estimates the one-way causal relationship flowing from the stock of broadband telecommunications infrastructure to aggregate GDP. This may lead to misleading results because of possible reverse causality. In order to disentangle the possible effects of broadband telecommunications infrastructure on GDP and the inverse we specify a

model consisting of three equations for demand and supply of broadband infrastructure, as well as an infrastructure output function.

Demand for broadband infrastructure:

$$BB_Pen_{it} = g(GDPC_{it}, BBPr_{it}, HHI_{it}) \quad (2)$$

The demand equation (2) states that broadband penetration is a function of GDP per capita (GDPC), the price of a standard service for the connection to the network (BBPr) and the market segmentation as a proxy for competition (HHI). This demand equation is expected to display negative price elasticity and positive income elasticity. Competition is expected to exert a positive effect on demand.

Supply of broadband infrastructure:

$$BB_Rev_{it} = h(BBPr_{it}, GDPC_{it}, HHI_{it}, HHT_{it}, URB_{it}) \quad (3)$$

Modeling the supply of fixed telecommunications infrastructure is not always straightforward. Coverage decisions depend on operators' strategic decisions as well as the socio-economic and geographic parameters. Equation (3) can thus be seen as a stylized representation of the supply side. It links the aggregate broadband revenue in a country by the service operators to broadband price levels for that period, urbanization and income levels. Competition across firms (HHI) and technologies (HHT), as indicated by the Herfindahl indices, can also affect the supply of these services. All these parameters affect potential and existing operators as well as the dynamics of the supply side of the market. Under normal conditions, price should have a positive sign, reflecting a positively sloped supply curve. Likewise the level of per capita income should also have a positive effect on the supply side. Urbanization (URB) should also have a positive effect on supply as it is less costly for firms to supply broadband services in relatively densely populated urban areas compared to rural areas.

Broadband infrastructure production function:

$$\Delta BB_Pen_{it} = k(BB_Rev_{it}) \quad (4)$$

The infrastructure equation (4) states that the annual change in broadband penetration is a function of the broadband revenues, taken as a proxy of the capital invested in a country during one year. The sign is expected to be positive.

Broadband infrastructure production equation:

$$\Delta BB_Pen_{it} = k(BB_Rev_{it}) \quad (5)$$

The infrastructure increase is modeled as a function of revenues, as this should be the main source of funding of infrastructure growth by broadband firms.

Equations (3), (4) and (5) endogenize broadband telecommunications infrastructure because they involve the supply and demand of broadband telecommunications services. The econometric specification of the model uses a linear version of the equation to which an error term is added.

The dataset used in this study consists of annual observations from the 27 EU member countries for the six year period between 2005 and 2011. The countries included in the analysis used are listed in the appendix. The data used have been collected by various sources depending on their nature and availability (see table 1) as well as the summary statistics. The Hirschman-Herfindahl (HHI_{it}) market and technology concentration index for each country i is calculated as the sum of the squares of market shares of all firms in the market at time t .

Variable	Obs	Std. Dev	Min	Max	Source
GDP (\$ billions, constant 2000)	132	887	5.92	3,630	World Bank
GDPC (\$, constant 2000)	132	20,842	3,733	117,954	World Bank
Labour (millions population)	135	11.1	0.165	42.4	World Bank
Fixed stock of capital (\$ billions, constant 2000)	157	108.0	0.869	421.0	World Bank
Broadband Lines (millions)	162	5.68	0.032	26.7	Informa
Broadband penetration (% of population)	135	8.54	1.40	38.71	Informa
HHI	162	0.309	0.130	1	Informa
Broadband price (\$, constant 2000)	162	34	4.846	328.5	ITU
Urbanization (%)	132	15.92	12.5	97.41	World Bank
Broadband Revenue (\$ millions, constant 2000)	132	7.51	0.120	31.9	ITU

Table 1. Data, sources and summary statistics

4.2 Results

We run 3SLS regressions. Across all specification we include country and year fixed effects to account for location specific or temporal effects not yet taken into account. We develop different frameworks to test for the significance of broadband adoption and speed or quality at the national level. Given the lack of adequate within country observations we are restricted to use more aggregate national statistics that often blur the actual image for leading cities (like London or Paris) and the periphery in a country. We try to account for this with the use of country level controls in all specifications.

The first set of estimates referring to model (1) in table 2, shows that labor and capital have the expected signs, significance and ratios for the set of observations we used. At the same time broadband adoption enters the regression with a positive and highly significant coefficient. Given the average broadband penetration levels at the period (~16.5%) we infer that the use of the networks contributed annually 1.36% GDP for the countries in the sample⁹. This estimate is in line with previous findings by Koutroumpis (2009), Quiang and Rossoto (2009) and Czernich et al (2011). Besides the demand and supply functions also have the expected results with income as a major contributor to adoption and supply of broadband services. Additionally the reported results of the local operators are clearly affecting their propensity to invest.

In model (2) we divide countries into two clusters according to performance criteria: those that had an average speed offering above 2Mbps (that is 2 Megabytes per second in the downstream throughput of connections) and the rest of the countries below this threshold. While this division is somehow arbitrary it cuts our sample in two almost equal parts. From a usage perspective the 2Mbps are a relatively low barrier for quality of services. Nevertheless it is clear that users with better connections can often take advantage of basic video, file sharing and voice over IP services. The specification with this clustering suggests that countries with better connections have a marginally higher but statistically significant impact from broadband on their national accounts. Running the same tests as before we find that the additional benefits amount to 0.2% for the period and 0.032% an annual basis. This is certainly a minor change compared to the impact of the infrastructure per se but still significant and measurable. In real terms this is an additional 2.4 billion Euros each year for the EU27 economy.

Further scrutinizing our sample we break it into another division for a lower speed threshold in model (3). We now choose the 1Mbps (again for the downloading throughput), which is clearly a bare minimum for any broadband service to perform. The results are similar as before with an additional 0.1% for the countries in the higher cluster and a 0.016% annually. The EU level impact now drops to 1.2 billion Euros per year for the more advanced group of countries. The difference between the two thresholds is no considered trivial but these speeds were dominant averages at the time (2005-2010). For example the average broadband speed in the UK for 2012 rose to almost 10Mbps (Ofcom, 2012) indicating the push to a wider range of services.

As noted in most previous studies, the level of adoption is the key determinant of GDP contribution. If high quality networks are in place but are not used there is no impact to capture at the national or regional level. There is an increasing returns to scale hypothesis confirmed in Koutroumpis (2009) that seems to hold for wider ICT metrics like the Web

⁹ We use the formula from Roller and Waverman (2001), Koutroumpis (2009) and Gruber and Koutroumpis (2011):

$$\{[(BBpen_{2011}-BBpen_{2005})/BBpen_{2005}] * BBcoef + 1\}^{(1/years-1)}$$

Index (2012) and the degree of Digitization (Katz and Koutroumpis, 2012). Breaking our sample in its mean we run our models again for countries with higher than 15% broadband adoption. The results are shown for model (4) show the high adoption cluster enters the regression with a significantly higher coefficient than before. The GDP differential for this change is now much larger. There is almost 0.2% of GDP added each year in countries with more than 15% broadband subscribers (or approximately 35% of households) and a 1.22% for the period. The increasing returns to scale hypothesis also holds here.

Table 2. Econometric results broadband impact, by quality of connections and penetration rate

Variables	3SLS estimates (1)	3SLS estimates (2)	3SLS estimates (3)	3SLS estimates (4)
Growth (GDP_{it})				
Labour (L_{it})	0.801* [0.438]	0.788* [0.440]	0.800* [0.438]	0.743* [0.070]
Fixed stock of capital (K_{it})	0.416*** [0.044]	0.414*** [0.044]	0.415*** [0.044]	0.416*** [0.043]
Broadband Lines (BB_Lines_{it})	0.083*** [0.015]	-	-	-
High Speed (>2Mbps)	-	0.085*** [0.016]	-	-
Low Speed (<=2Mbps)	-	0.083*** [0.015]	-	-
High Speed (>1Mbps)	-	-	0.084*** [0.016]	-
Low Speed (<=1Mbps)	-	-	0.083*** [0.016]	-
High Penetration (>15%)	-	-	-	0.090*** [0.015]
Low Penetration (<=15%)	-	-	-	0.078*** [0.015]
Demand (PEN_{it})				
GDPC ($GDPC_{it}$)	0.906*** [0.041]	0.906*** [0.041]	0.906*** [0.041]	0.906*** [0.041]
BB. Price (BB_Pr_{it})	-0.528*** [0.070]	-0.528*** [0.070]	-0.528*** [0.070]	-0.530*** [0.070]
HHI (HHI_{it})	-1.163*** [0.182]	-1.163*** [0.182]	-1.163*** [0.182]	-1.150*** [0.181]
Supply (BB_Rev_{it})				
BB Price (BB_Pr_{it})	0.318*** [0.116]	-0.318** [0.116]	-0.318** [0.116]	-0.312** [0.116]
GDPC ($GDPC_{it}$)	0.585*** [0.070]	0.585*** [0.069]	0.585*** [0.069]	0.585*** [0.070]
HHT (HHT_{it})	0.397 [0.330]	0.397 [0.330]	0.397 [0.330]	0.397 [0.330]
HHI (HHI_{it})	-0.502 [0.375]	-0.502 [0.375]	-0.502 [0.375]	-0.502 [0.375]
Urbanization (URB_{it})	1.218*** [0.205]	1.218*** [0.205]	1.218*** [0.205]	1.218*** [0.205]
Output ($APen_{it}$)				
BB Revenue (BB_Rev_{it})	0.280*** [0.058]	0.280*** [0.058]	0.280*** [0.058]	0.280*** [0.058]
Observations	131	131	131	131

Notes:

All estimates contain calendar fixed effects and country fixed effects.

High and Low penetration cluster represent 50% of observations of the sample (65 and 66 observations per cluster).

High Speed/Low Speed: Countries with a majority of High Speed Lines/Low Speed Lines

Standard errors in squared brackets.

***, **, * denote statistical significance at the 1%,5% and 10% level, respectively.

5. The cost benefit analysis of the Digital Agenda

The economic effects of broadband investments can only be realized after they have been deployed, adopted and used hence the returns realized today essentially reflect the investments made years or even decades ago. From that standpoint the assessment of a EU wide broadband policy framework like the Digital Agenda for Europe can only assess its impact with a non-trivial degree of uncertainty. In doing so an array of calculated and hard to estimate risks have to be taken into account ranging from technological changes and financing conditions to the level political stability and social cohesion across the union. Using the estimates just derived we build a forecasting framework with several assumptions purposely trying to take due account of the broader economic impact broadband infrastructure. The key assumptions are that we take the cost of the infrastructure related to the broadest use of FTTH technology (Maximum scenario with 222 billion Euro) and assume that the entire amount is invested upfront. These assumptions reflect a cautionary approach as both the total cost could be reduced with similar performance levels (Advanced scenario) and the financing could be stretched over a longer period. Moreover we parameterize the model on three basic variables: the fixed capital investment, the labor participation and the net additional broadband subscribers until the targets of the Digital Agenda are reached. These are the main inputs of the model used to estimate the impact of broadband infrastructure and its outputs.

Our base scenario assumes that the intervention to implement the Digital Agenda for all countries in the EU would yield a 2% increase on year to year broadband adoption. This reflects a marginally higher pace of adoption compared to the *ceteris paribus* state and is almost equivalent to one fifth of the actual growth rate experience in previous years. The rationale for higher broadband adoption rates is based on the assumption of demand stimulation strategies also foreseen by the Digital Agenda, a higher net benefit from broadband use and the wider use of the cloud. Once the adoption targets of the Digital Agenda have been achieved (50% of the population subscribing to high speed broadband) the broadband adoption rate falls back to zero for the rest of the period resulting in no added effects from increased adoption rates. As different countries have different levels of adoption and quality across regions this change is modelled for each area separately. The fixed stock of capital change in this scenario is also assumed to grow at a steady rate of 2% annually representing the lowest figure across the EU for the last decade (2000-2010). The labor participation is assumed to follow the same pattern as the rest of the economy and coming back gradually to the 2008 levels in 2020 with a steady marginal growth of 0.02% annually. The implementation of the agenda yields a higher growth rate sooner and then gradually dissipates, as saturation levels will be reached.

The net benefit from the implementation of the agenda is estimated to have a wider EU economic impact of slightly more than 222 billion Euro. This value is the overall effect of broadband use on the economy and suggests that the entire project (132% of the total) will be indirectly paid back within the agenda implementation horizon. So the payback period is considerably shorter than the useful economic life of the infrastructure, which can be easily in excess of 15 years. This finding would suggest that the direct macroeconomic advantage for the EU is significantly higher than its cost.

Table 3 Base Case results.

	Infrastructure Cost (EUR bn)	Net Cumulative Gains EUR bn	Returns/Costs
Austria	5.6	5.24	0.94
Belgium	3.3	2.96	0.90
Bulgaria	4.5	-2.37	-0.53
Cyprus	0.2	0.19	0.96
Czech Republic	5.7	3.41	0.60
Denmark	3.7	3.41	0.92
Estonia	0.5	0.32	0.63
Finland	3.6	3.23	0.90
France	31.5	24.50	0.78
Germany	43.3	65.67	1.52
Greece	4.5	7.41	1.65
Hungary	4.7	2.57	0.55
Ireland*			
Italy	24.6	53.41	2.17
Latvia	0.8	0.50	0.62
Lithuania	1.5	0.16	0.11
Luxembourg	0.2	0.30	1.52
Malta*			
Netherlands*			
Poland	9.5	10.49	1.10
Portugal	4.3	6.14	1.43
Romania	10	-1.85	-0.18
Slovak Republic	2	2.02	1.01
Slovenia	1	0.79	0.79
Spain	17.6	40.43	2.30
Sweden	4.7	6.90	1.47
United Kingdom	26.3	45.98	1.75
EU27	213.60	281.83	1.32
*Insufficient observations			

At member state level, there is a substantial variance across this average, but for almost all countries the result is nevertheless positive. Rudimentary infrastructures in some cases coupled with a lack of adequate synchronization with e-services can delay the pay-off of this investment (Bulgaria, Romania). A very large rural population in other cases (more than 45% of total population in Hungary, Lithuania, Slovenia, Slovak Republic, Romania) results in high initial cost of implementation for fiber access. This is particularly relevant in our simulation as there are three more cost effective technology variants we can utilize to suitably cover those areas and get a high pay-off quickly.

We have also elaborated other scenarios, reflecting the economic crisis that has affected most European economies resulting in prolonged stagnant or negative growth rates and increasing unemployment. The constrained scenario assumes a EU wide continuation of current performance both relatively to fixed capital investment and labor participation. Effectively we assume no change in both values from their historic lows for the entire period until 2020. Broadband adoption is still modestly growing as a result of the intervention. The GDP rates are presented below and compared with the ECD forecasts. In this setting the returns of the project are still promising but a longer payback period has to be modelled compared to the base case. The project returns 89% of its cost by the end of 2020 in terms of indirect spillovers over the EU economy¹⁰.

Three more specifications including a high unemployment, a pull out of investment and an adoption boom have been modelled. All these cases can act as sensitivity tests for the returns from the Digital Agenda. The estimated returns are still positive with longer payback periods for the high unemployment and pulling out of investment scenarios and much shorted for the adoption boom. Nevertheless across all specifications the investment indirectly returns at least 70% by the end of the implementation period. Looking within countries these adverse scenarios exhibit significant payback period variation depending on the local conditions. For example in the high unemployment Spain and Greece still achieve a remarkable return on investment – primarily due to existing conditions – whereas Hungary quickly turns negative. Pulling out investment aggressively cuts French, German and British return on investment by roughly 40% and seems to hit countries with the highest nominal FDIs in the EU.¹¹

Additional macroeconomic and telecommunications specific models

A number of additional scenarios have been tested. The results for EU27 are listed in table 4. The detailed country-level results are available on request. Below is a description of the characteristics of the scenarios.

¹⁰ Country level tables are included in the appendix

¹¹ A closer analysis of the country specific conditions that extends beyond the scope of this paper is available upon request.

Recessionary Scenario (high unemployment): A significant negative effect on labor participation is assumed (based on the average annual change per country for the study period 2005-2011) on average equal to -1 percentage point annually and -10 percentage points less participation until 2020 (a rather extreme scenario). A marginal effect on fixed capital formation (equal to the total broadband deployment and existing capital formation at 2%) and a 2% increment of annual broadband adoption to meet the Agenda targets (required)

Recessionary Scenario (pulling out investment): A significant negative effect on fixed capital formation is assumed on average equal to -3 percentage point annually (a rather extreme scenario too). A stagnating level of labor participation is assumed and a 2% increment of annual broadband adoption to meet the Agenda targets (required)

‘Adoption boom’ Scenario: A significant effect on adoption is assumed with an increment of 4% over traditional rollout (instead of 2% which is the required target for the Digital Agenda goals). A marginal effect on labor participation is assumed (based on the average annual change per country for the study period 2005-2011) on average equal to 0.02 percentage points and a marginal effect on fixed capital formation (equal to the total broadband deployment and existing capital formation at 2%).

Table 4. EU27 results for additional scenarios

	Maximum Agenda Cost (bn EUR)	Net Cumulative Minimum Gains bn EUR	Returns/Costs
Recessionary Scenario (high unemployment)	213.60	236.89	1.11
Recessionary Scenario (pulling out investment)	213.60	220.88	1.03
‘Adoption boom’ Scenario	213.60	595.54	2.79

6. Conclusion

This paper has provided econometric estimates that show broadband diffusion is conducive to furthering economic growth. Moreover by calibrating model on the country specific investment needs to fulfill the broadband deployment goals as indicated by the Digital Agenda and the benefits that derive from the infrastructure. It emerges that for the EU as a whole the benefits of broadband investment outweigh their cost. In the base case the return from broadband deployment is 32% above the cost. At member state level, there is a substantial variance across this average, but for almost all countries the result is nevertheless

positive.. This result is held up also in a variety of scenarios with much more adverse conditions than is in the base case.

The findings of this paper provide support to the idea that there is a public interest in rolling out broadband infrastructure along the lines indicated by the Digital Agenda. It is clear that the market would not provide the speed and extent of coverage entailed by these estimates. It therefore calls for extended public subsidies to ensure the widespread roll out of broadband infrastructure.

References

- Bertschek, Irene, Daniel Cerquera, and Gordon Klein. 2011. "More Bits – More Bucks? Measuring the Impact of Broadband Internet on Firm Performance." *SSRN Electronic Journal*. doi:10.2139/ssrn.1852365.
- Bloom, Nicholas, Raffaella Sadun, and John Van Reenen. 2012. "Americans Do IT Better: US Multinationals and the Productivity Miracle." *American Economic Review* 102 (1) (February): 167–201.
- Bresnahan, T. F., E. Brynjolfsson, and L. M. Hitt. 2002. "Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-Level Evidence." *The Quarterly Journal of Economics* 117 (1) (February 1): 339–376.
- Brynjolfsson, Erik, and Lorin M. Hitt. 2003. "Computing Productivity: Firm-Level Evidence." *Review of Economics and Statistics* 85 (4) (November 13): 793–808.
- Crandall, Robert, and Charles L Jackson. 2001. "The \$ 500 Billion Opportunity: The Potential Economic Benefit of Widespread Diffusion of Broadband Internet Access."
- Czernich, Nina, Oliver Falck, Tobias Kretschmer, and Ludger Woessmann. 2011. "Broadband Infrastructure and Economic Growth." *The Economic Journal* 121 (552) (May 12): 505–532.
- Dutz, Mark, Jonathan Orszag, and Robert Willig. 2009. "The Substantial Consumer Benefits of Broadband Connectivity for US Households." Internet Innovation Alliance.
- Forzati, Marco, and Crister Mattsson. 2011. "Socio-economic Return of FTTH Investment in Sweden , a Prestudy."
- Hätönen, Jussi. 2011. "The economic impact of fixed and mobile high-speed networks." *EIB Papers* 16.2 (2011): 30-59.
- Greenstein, Shane, and Ryan McDevitt. 2012. "Measuring the Broadband Bonus in Thirty OECD Countries."
- Gruber, Harald, and Pantelis Koutroumpis. 2013. "Mobile telecommunications and the impact on economic development." *Economic Policy*, July, 387-426.
- Gust, Christopher, and Jaime Marquez. 2004. "International Comparisons of Productivity Growth: The Role of Information Technology and Regulatory Practices." *Labour Economics* 11 (1) (February): 33–58.
- Koutroumpis, Pantelis. 2009. "The Economic Impact of Broadband on Growth: A Simultaneous Approach." *Telecommunications Policy* 33 (9) (October): 471–485.
- O'Mahony, Mary, Catherine Robinson, and Michela Vecchi. 2008. "The Impact of ICT on the Demand for Skilled Labour: A Cross-country Comparison." *Labour Economics* 15 (6) (December): 1435–1450.
- Qiang, Christine Zhen-wei, and Carlo M Rossotto. 2009. "Economic Impacts of Broadband." In *Information and Communications for Development 2009: Extending Reach and Increasing Impact*, 35–50. World Bank.
- Röller, Lars-Hendrik, and Leonard Waverman. 2001. "Telecommunications infrastructure and economic development: A simultaneous approach." *American Economic Review*, (2001): 909-923.

Rohman, Ibrahim Kholilul, and Erik Bohlin. 2012. "Does Broadband Speed Really Matter for Driving Economic Growth? Investigating OECD Countries." *SSRN Electronic Journal*. doi:10.2139/ssrn.2034284.

Van Reenen, John, Nicholas Bloom, Tobias Kretschmer, Raffaella Sadun, Henry Overman, and Mark Schankerman. 2010. "The Economic Impact of ICT." Final report.