

THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

**Ultra-fast internet:
Demand and supply dimension of broadband policy in the EU**

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Abstract

With the fast pace of technology development in the telecommunications sector, the benefits of fast and ultra-fast internet have been recognised by public sector, private sector and academia in the recent years. The European Union (EU) has acknowledged the importance of fast and ultra-fast internet by including fast and ultra-fast internet as a part of the EU Digital Agenda. To achieve the targets on fast and ultra-fast internet, a number of broadband policies need to be implemented for both broadband access and broadband adoption. Broadband policy which relates to broadband infrastructure or broadband access is called supply side policy while the policy which deals with broadband adoption and the content and applications can be seen as demand side policy.

This thesis has two main purposes. First, it aims to recommend possible broadband policies for the EU to achieve its targets on high speed broadband access (supply side) and broadband adoption (demand side). The second purpose is to suggest the benefits of high speed broadband to the economy. Four appended papers have been conducted to address the first aim while one appended paper has been done to support the second aim. Finally, the cover paper is written to connect all five appended papers and illustrate the whole idea of the topic. This compilation thesis is a cross-disciplinary research based on the disciplines of applied economics, policy as well as social science. Econometrics estimation is the main approach used in three of the five appended papers while economic frameworks and concepts are the basis of the document analysis conducted in the remaining two papers.

The findings of this thesis have shown that, in relation to the first aim, both supply and demand sides of broadband policy are important. They are interrelated and reinforce each other. Thus, policy makers should encourage not only supply side but also demand side of broadband policy because these policies complement rather than substitute each other. In addition, there are 28 member states in the EU which differ in terms of broadband coverage and adoption. One broadband policy tool may fit with one member state but not the others. In addition, the focus of using supply and demand side policy can vary depending on the stage of broadband development. On the findings relating to the second aim, the study has found that there are significant positive impacts of transmission speed on the economy. The findings from the second aim also imply the importance of broadband policy which ultimately affects the economic outputs.

Keywords: broadband policy, supply side policy, demand side policy, the EU Digital Agenda

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List of appended papers in a compilation thesis

The main doctoral thesis (cover paper) is mainly based on these five appended papers which are conducted during the doctoral study

Paper 1:

Kongaut, C. and Bohlin, E. 2015. Understanding market definition, relevant market and significant market power frameworks in EU. In H. Mitomo, H. Fuke and E. Bohlin (Eds.), *The smart revolution towards the sustainable digital society* (pp. 339-369). Cheltenham: Edward Elgar.

Paper 2:

Kongaut, C. and Bohlin, E. 2014. Unbundling and infrastructure competition for broadband adoption: Implications for NGA regulation. *Telecommunications Policy*, 38(8-9), 760-770.

Paper 3:

Kongaut, C. and Bohlin, E. 2015. Towards broadband targets on the EU Digital Agenda 2020: Discussion on the demand side of broadband policy. *Info* 17(3), 1-15.

Paper 4:

Kongaut, C. and Bohlin, E. 2014. Investigating mobile broadband adoption and usage: A case of smartphones in Sweden. *Proceedings of 20th Biennial Conference of the International Telecommunication Society*, Rio de Janeiro, Brazil 2014.

(Currently) submitted to *Telematics and Informatics*

Paper 5:

Kongaut, C. and Bohlin, E. 2014. The impact of broadband speed on economic outputs: An empirical study of OECD countries. *Proceedings of 24th European Regional Conference of the International Telecommunication Society*, Brussels, Belgium 2014.

List of additional papers

These papers are also written during the doctoral study; however, only some parts of these papers are relevant to the main thesis.

Kongaut, C., Bohlin, E. 2014. Impacts of mobile termination rates on retail prices: the implication for regulators. *Info*, 16(2). 80-93.

Kongaut, C. and Bohlin, E. 2013. What makes people adopt ultra-high-speed (100 Mbit/s) broadband? An empirical study of the Swedish broadband market. *Proceedings of the 24rd European Regional Conference of International Telecommunication Society (ITS)*, Florence, 20-23 October 2013.

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I think this is the best part of the thesis, at least to me. The reasons are that there are so many people I would like to express my gratitude and some people I would like to say thank you everyday. It is always awkward for me to vocally say these words; hence, I feel much more comfortable to write them on the paper (or computer these days).

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Chatchai Kongaut, August 2015

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List of abbreviations

4G	Fourth Generation
BEREC	Body of European Regulators of Electronic Communications
DSL	Digital Subscriber Line
EC	European Commission
EU	European Union
GDP	Gross Domestic Product
ICT	Information and Communications Technology
IT	Information Technology
ITU	International Telecommunication Union
KPIs	Key Performance Indicators
LTE	Long-Term Evolution
Mbps	Megabits per second
NGA	Next Generation Access
NGN	Next Generation Network
OECD	Organisation for Economic Co-operation and Development
PPP	Public-Private Partnership
PTS	Post- och Telestyrelsen (The Swedish Post and Telecom Authority)
SMEs	Small and Medium-sized Enterprises
SMP	Significant Market Power
UK	United Kingdom
US	United States
USO	Universal Service Obligation

Ultra-fast internet: Demand and supply dimension of broadband policy in the EU

1. Introduction

1.1 Background

“508 million people, 28 Member States and 1 broadband policy?” Filippo Munisteri, Economic Analyst, DG CONNECT, European Commission (2013)

In recent years, the benefits of fast and ultra-fast broadband services have been broadly recognised by public and private sectors, especially in developed countries. The European Union (EU) is one of the organisations that has realised some of the potential benefits of high-speed broadband. Hence, the European Commission has continuously supported its member states in developing broadband infrastructure as well as broadband policy to provide fast and ultra-fast broadband services to its citizens. The European Commission has initiated and implemented several broadband policies since 1999. Examples of the EU’s broadband policies include several versions of eEurope, i2010 and, recently, the EU Digital Agenda 2020. These policies normally cover both broadband infrastructure and broadband adoption. For example, the EU Digital Agenda 2020 has eight areas of action, including faster internet access and enhancing digital literacy skills and inclusion. The measurement for access is 50% of European households subscribing to a broadband service with a transmission speed of at least 100 Mbps by 2020, while the measurement for adoption is an increase in the percentage of regular internet users from 60% to 75% by 2015 and for 50% of all citizens to use e-government (Munisteri, 2013).

Not only the public sector but also many scholars have recognised the importance of broadband and pointed out the positive impacts of broadband on the economy: that it contributes to the economy through productive use, employment, consumer surplus and firm efficiencies (for more information, see Katz, 2012, and Kelly and Rossotto, 2012). Broadband penetration, in particular, has been emphasised as a driver of the economy of countries and regions in the last decade (see Crandall et al., 2007, Koutroumpis, 2009, and Czernich et al., 2011). It is also important to consider other characteristics, however, in addition to broadband penetration, such as transmission speed, type of connection and quality of service (Middleton, 2013). Transmission speed, in particular, has recently been focused on more by scholars. For instance, Katz et al. (2010) have suggested that if Germany achieves both its broadband penetration and speed targets by 2020, according to its national broadband plan, more than 960,000 jobs will be created as well as additional outputs worth more than 170 billion euro. Fast and ultra-fast broadband infrastructure and services cannot be created automatically overnight however. Efforts and support are needed from both the public and private sectors. On the public side, comprehensive broadband policy is needed to support the implementation of fast and ultra-fast broadband services in a country or region, not only for broadband infrastructure but also for broadband adoption. As in the case of the European Commission, both broadband access and broadband inclusion are presented as the fourth and sixth action areas of the EU Digital Agenda. In practice, however, in the last decade the focus of the public sector and academia has been mainly on the supply side, i.e. broadband infrastructure and access. There has been little focus

on the demand side, i.e. broadband inclusion and adoption; nevertheless, the focus on demand side policy has gradually increased in the last few years.

Whether it is demand side policy or supply side policy, broadband policy is one of the factors of country development. It is therefore important to understand the broadband policy of the past in order to recommend appropriate policy in the future. To be able to suggest future broadband policy on ultra-fast internet, this thesis has therefore chosen interesting examples of empirical evidence of different broadband issues on both the supply and the demand side, mainly in the EU in past years. This thesis also points out the benefits of fast broadband services to the economy. As suggested in Figure 1, this thesis attempts to confirm that broadband policy leads to better broadband services and more broadband infrastructure, and eventually stimulates economic outputs. After the analysis of the supply and demand dimension of broadband policy in the EU, the thesis presents a discussion on policy flexibility and policy implementation in the EU.

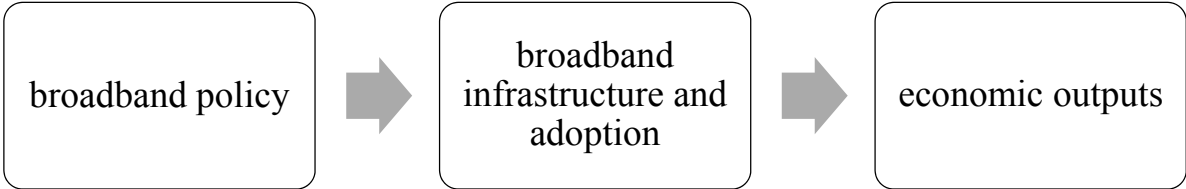


Figure 1: Link from broadband policy to economic outputs

1.2 Aims and research questions

This thesis aims to show the link between broadband policy and economic benefits in the EU through broadband infrastructure and broadband adoption (see Figure 1). The study narrows its focus to fast and ultra-fast internet access and internet adoption, which are part of the action areas of the EU Digital Agenda (for more on the EU Digital Agenda, see Section 2). The purposes of this thesis are to recommend broadband policy in relation to high-speed broadband and to suggest benefits of high-speed broadband to the economy. With its two main purposes, the thesis needs to address two main research questions respectively.

Main research question 1: What are the possible broadband policies for the EU to achieve its targets on high-speed broadband access and adoption?

The first main research question aims to recommend broadband policy for the EU to achieve its targets on high-speed broadband and can be considered from two perspectives: broadband access and broadband adoption. Consequently, the main research question is divided into two sub-research questions: the broadband access perspective (supply side dimension) and the broadband adoption perspective (demand side dimension).

Sub-research question 1: What are the possible supply side policies for the EU to achieve its broadband targets on high-speed broadband access?

A number of broadband policies on the supply side have been focused on in the last decade. To answer sub-research question 1, the thesis investigates some examples of broadband policy tools, such as open access and market definition. The analysis is mainly based on empirical evidence from the past decade and aimed at the implications of future high-speed broadband policy.

Sub-research question 2: What are the possible demand side policies for the EU to achieve its broadband targets on high-speed broadband adoption?

In contrast to the first sub-research question, broadband policy on the demand side has not been emphasised practically by the policymakers in the last decade, which has led to limited empirical data. Hence, the analysis of sub-research question 2 is mainly based on case studies and economic frameworks. Nevertheless, the empirical data on the determinants for broadband adoption are analysed to support greater understanding of demand side policy.

Main research question 2: What is the relationship between high-speed broadband and economic outputs?

The second main research question analyses the relationship between high-speed broadband and economic outputs through the empirical dataset from the OECD countries. Given that broadband policy leads to more broadband infrastructure, services and adoption, this investigation of the relationship between an improved broadband characteristic (faster speed is used as an example for the thesis) and economic outputs aims eventually to link broadband policy to the economy in general.

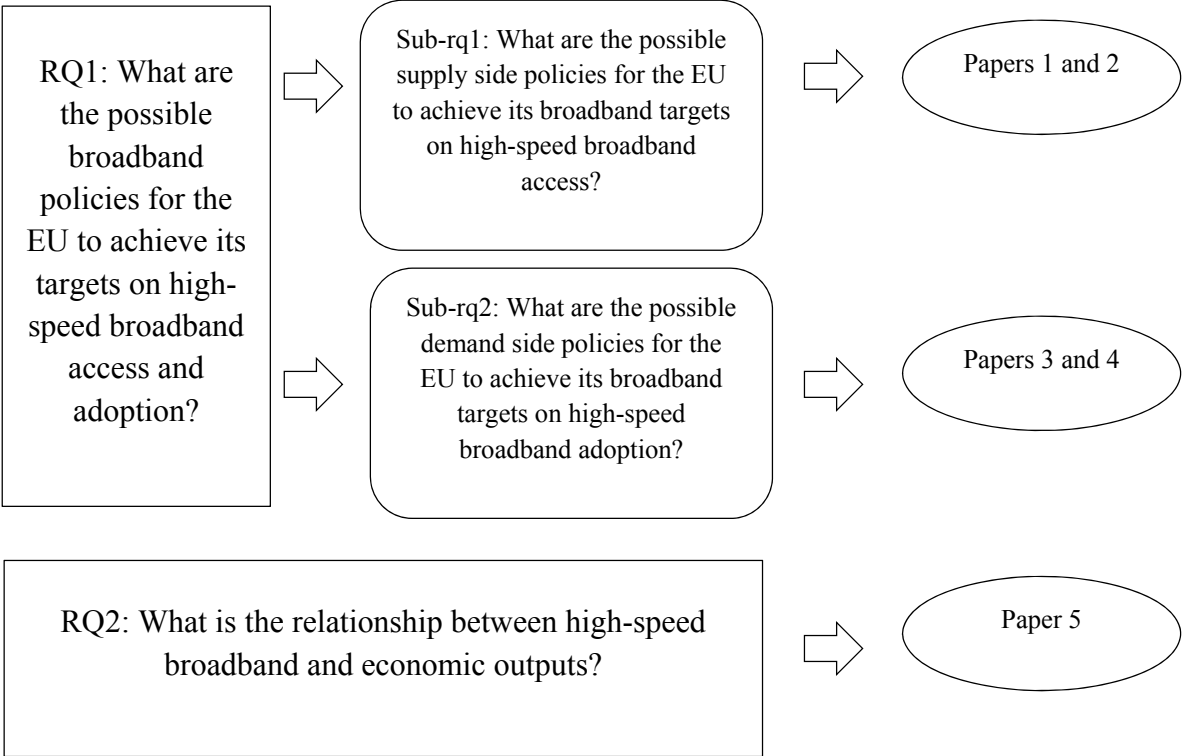


Figure 2: Main research questions, sub-research questions and appended papers

As shown in Figure 2, five appended papers have been written to answer the main as well as the sub-research questions. Nevertheless, the appended papers can only cover certain points of view: they cannot cover everything. Further discussion on this issue can be found in the next section.

1.3 Scope and limitations

While there are many ways to assess and analyse broadband policy in the EU, in the thesis it was decided to analyse broadband adoption and broadband access, which can be considered the demand and supply dimensions respectively. The appended papers to the thesis narrow the scope of broadband policy down to discussing interesting examples. For the supply dimension, the uses of open access policy and market definition are studied in the first and second appended papers. The open access topic was selected because infrastructure sharing has been one of the hotly debated topics of the last decade, from the use of local loop unbundling on digital subscriber line (DSL) technology to the possibility of using infrastructure sharing on fibre technology in the future. Understanding what happened in the last decade can greatly support future implementation of broadband policy. While open access is opted for because of the wide discussion on it, especially in the academic field, market definition is selected for the opposite reason. Market definition is somehow often forgotten in the academic debate, even though identifying the relevant market is the first step before imposing any regulation. By understanding the relevant broadband market, policy and regulatory tools can be used more efficiently. There has generally been less discussion on demand side policy than on supply side policy. One of the appended papers was therefore written to point out the importance of demand side policy by presenting two countries that do very well on demand side policy and their broadband markets. Another appended paper is used to investigate the relationship between socio-economic backgrounds and broadband adoption. That study aims to provide greater understanding of the different determinants that can be used to support demand side policy to increase broadband adoption. Finally, as seen in Figure 2, there is a need for at least one study to bridge the link between broadband policy and economic outputs. The study on the impacts of broadband speed and economic outputs is used as an example to explain that a country's economy can be improved with better characteristics of broadband services.

The thesis nevertheless has some limitations. The first purpose of the thesis is to provide greater understanding of broadband policy in the EU and its economic benefits by analysing it through broadband infrastructure and broadband adoption; however, the thesis cannot cover every broadband policy tool. Thus, not all policies can be investigated in the appended Papers 1-4. Similarly, not all types of economic outputs can be analysed in Paper 5. However, in general, this thesis can make contributions to policymakers by suggesting economic and policy aspects of broadband policy in the EU. Moreover, other regions can benefit from the EU's experiences by learning from its successes as well as its failures. The thesis can also contribute to the academic field of telecommunications policy research. The appended papers have all filled the research gaps by testing, investigating and analysing particular topics.

1.4 Structure of the thesis

This doctoral thesis is a summary of scientific essays in the form of a compilation thesis comprising five appended papers and the cover paper (main thesis). The main thesis consists of seven sections, starting with the introduction in Section 1, which also presents the aims and research questions, scope and limitations, and the structure of the thesis. Next, Section 2 presents the economic reasons for broadband policy and an overview of broadband policy in the EU from 1999 to the current EU Digital Agenda. The purpose of Section 2 is to provide more background to and greater understanding of the topic from an economic perspective of implementing broadband policy and looking through the history and development of broadband policy in the EU up to recent times. Previous studies and relevant frameworks are then discussed in Section 3. The previous studies are divided into three categories: literature on supply side policy, literature on demand side policy and literature on the relationship between broadband services and economic impacts. Network externalities and the ICT ecosystem are also discussed as relevant frameworks. Section 4 presents the methodology of the thesis by providing the research approaches, data collection methods and reflections on the approaches. Section 5 provides a summary and limitations of the appended papers. Section 6 then presents some analysis and discussion based on the appended papers and overall broadband policy in the EU, which has not yet been covered by the appended papers. Finally, Section 7 provides the conclusion by presenting the summary of the thesis, guidelines for future broadband policy and some examples of future research.

1.5 Notes on terminology and definition

There are some words or terms throughout the thesis whose definitions need to be clarified. The purpose of this section is not to identify these words or terms correctly but instead to clarify them for the purpose of mutual understanding.

Broadband policy

In the thesis, broadband policy can be broadly defined as a strategy, initiative or national/regional plan by the authorities. For example, the EU has released several broadband policies, such as eEurope and the Digital Agenda. The main focuses of the broadband policy in the thesis are broadband infrastructure (supply side) and broadband adoption and usage (demand side).

Supply side policy

In the thesis, supply side policy refers to broadband policy that aims to improve the productive capacity on the supply side, such as broadband network/infrastructure or broadband access. Supply side policy covers any market-based strategies, direct public involvement and regulations related to broadband network/infrastructure or broadband access.

Demand side policy

In the thesis, demand side policy refers to broadband policy that aims to stimulate broadband adoption as well as to promote the use of broadband services through the demand side. Demand

side policy covers any market-based strategies, public subsidies and regulations related to consumer adoption and usage.

Fast and ultra-fast/high-speed and ultra-high-speed broadband services

Different organisations have different definitions of fast and ultra-fast/high-speed and ultra-high-speed broadband services based on the speed of transmission. The thesis is mainly based on EU broadband policy; hence, the definition of fast (high-speed) broadband service is one that provides a transmission speed of at least 30 Mbps. Accordingly, the definition of ultra-fast (ultra-high-speed) broadband service is one that provides a transmission speed of at least 100 Mbps.

Broadband ecosystem

Broadband ecosystem is a concept based on the ICT ecosystem by Fransman (2007) and Raja et al. (2010). Broadband ecosystem refers to broadband networks, broadband services, content and applications, users and the six relationships between each pair of market players. The use of the broadband ecosystem in the thesis illustrates greater understanding of the way market players interact with each other and how broadband policy interacts with each market player.

2. Economic justifications for broadband policy and overviews of EU broadband policy

2.1 Economic justifications for public intervention and broadband policy

It is important to first understand the economic perspectives of why there is a need to implement broadband policy. In general, there is a rationale for the public sector to intervene in or enhance the market: in this case, the European Commission and national regulators have used broadband policy and regulations as a tool for public intervention in the EU broadband market based on many justifications. The two main justifications, public goods and broadband benefits, and the political justifications are explained below, adapted from Cremer et al. (2001)¹.

Public goods justification:

Based on Cremer et al. (2001), telecommunications services have one of the two characteristics of public goods: they are non-rivalrous and non-excludable. Non-rivalrous goods means goods that are consumed by many consumers at the same time at no additional cost. Non-excludable goods means goods that are difficult to exclude others from consuming. To a lesser extent, similarly to education and rail services, broadband services can be considered non-rivalrous but excludable. While the private sector can provide broadband services, the public sector can make sure that market failure does not occur due to the characteristics of the public goods of broadband services. To avoid market failure, such as a monopoly or under-provision of broadband services, several broadband policies and regulations have been developed and implemented from before the 2000s. Nevertheless, it is not straightforward to implement broadband policy and regulations. Several economic issues and market players need to be taken into account.

Broadband benefits (positive externalities) justification:

Another reason for the public sector to step in and intervene in the broadband market is that broadband services offer a number of benefits to a country or region. Moreover, different qualities of broadband services are likely to contribute differently to the benefits. Similarly to telephone services, broadband benefits can be generated when more people subscribe to the services. These values of the products when there are more users can be seen as (positive) network externalities (for more details, see Section 3.3). Subscribers in general are not aware of the network externalities when they decide to subscribe to the services; hence, broadband services and the market can be undersubscribed and inefficient. Broadband policy and regulations therefore have a role to solve or reduce this type of market inefficiency.

Political justification:

Besides public goods and broadband benefits, which are economic justifications, there are political justifications that the public sector commonly uses to support its reasons for applying broadband policy and regulations. For example, in many countries, policymakers can use broadband policy and regulations as tools to support their regional policy as well as optimise

¹ Cremer et al. (2001) mentioned these justifications for the use of the universal service obligation (USO); however, these perspectives can also be applied to the use of broadband policy and regulations in general.

welfare. However, the political justifications are very subjective and differ from country to country. As a guideline, the priority for justifications to implement broadband policy and regulations should be based on the economic perspectives.

While these justifications support the ideas of broadband policy and regulations, there is criticism of broadband policy and regulations that they can backfire and instead distort the market, which is discussed later in Section 2.4. To be able to recommend future broadband policy and regulations, it is important to understand the history of the success and failure of European broadband policies in the past.

2.2 History of broadband policy in the EU (1999-2010)

Internet services and, later on, broadband services have been recognised by the EU since the 1987 Green Paper on the development of the common market for telecommunications service; however, the first broadband policy that aimed to stimulate broadband development was introduced in 1999 in ‘eEurope – An information society for all’ (Teppayayon, 2012). This section provides an overview of the history of broadband policy from 1999 until the current EU Digital Agenda 2020. The success and failure of broadband policies in the EU so far are also discussed through the demand and supply dimension at the end of this section.

eEurope – An information society for all (1999):

The first broadband policy, eEurope, aimed to bring the EU citizens into the digital age, bring about digital literacy and strengthen social cohesion. In the first version of eEurope, there were ten priorities: 1) bringing young Europeans into the digital age, 2) cheaper internet access, 3) stimulating the growth of e-commerce, 4) fast internet for all education and research communities, 5) implementing smart cards for secure electronic access, 6) making risk capital available to high-tech SMEs, 7) developing e-participation for the disabled, 8) providing access to health care online, 9) enhancing intelligent transport and 10) ensuring two-way electronic access for government online (EC, 1999). While the policy consisted of ten areas, the most emphasised area was ‘cheaper internet access’. The reasons were that, at that time, most internet providers were in a dominant position. The European Commission therefore attempted to provide more choices and cheaper internet services. As a result, to encourage competition in the local network, the regulation on unbundled access to the local loop was enforced at the end of 2000 for use with operators that had significant market power (EC, 2000).

eEurope 2002 – Impact and priorities:

eEurope 2002 aimed to encourage greater internet connectivity in the EU, increase network competition and stimulate internet use focusing on training and consumer protection. In addition, three key objectives were categorised for the action plans: 1) cheaper, faster and secure internet services; 2) investing in people and skills and 3) encouraging internet use (EC, 2001). Similarly to the first eEurope, cheaper internet services were emphasised by the European Commission. While unbundled access to the local loop was still the main focus, several regulatory frameworks were introduced after the issuing of eEurope 2002, such as the 2002 regulatory framework, access and interconnection, authorisation and licences, universal service

and data protection. Interestingly, in this broadband policy, faster internet services had already been emphasised along with cheaper ones. This focus on faster internet implied that the European Commission had started to recognise the importance of broadband speed and launched a policy accordingly to ensure faster services.

In addition, one of the regulatory frameworks that was issued in 2002 was a guideline for market analysis, including the assessment of significant market power under the Community regulatory framework for electronic communications networks and services. The launch of this framework implied that the focus of the EU policy at that time was on addressing the supply side to create more competition in the market as well as increase infrastructure for broadband access (in the case of broadband-related markets).

eEurope 2005 – An information society for all:

eEurope 2005 was an action plan that succeeded eEurope 2002. The main aim of eEurope 2005 was to encourage the development of secure internet services, content and applications. Furthermore, eEurope 2005 attempted to transfer digital connectivity into economic productivity. An increase in online public services, such as e-government, e-learning and e-health, was therefore the main goal at that time (EC, 2002). According to eEurope 2005, the new regulatory framework for the radio spectrum was the focused action plan. In addition, digital inclusion and increased online services were emphasised more in this action plan.

i2010 – A European information society for growth and employment:

As productivity growth and the number of jobs became more related to the information and communications technology (ICT) industry, the European Commission created a new initiative, i2010, to support economic growth as well as employment through the ICT industry. Three priorities were broadly proposed through i2010. These priorities included a single European information space, strengthening ICT innovation and investment, and promoting an inclusive European information society (EC, 2005). The first priority, a single European information space, addressed faster broadband services, richer content, a higher level of interoperability and better security. The second priority aimed to increase state funding to ICT-related projects and research. The third priority, an inclusive European information society, emphasised fostering ICT services to be more accessible, particularly through the use of public services. After the launch of i2010, some regulatory frameworks were revised to better suit the new technologies and dynamics of the telecommunications market. For example, in 2007, the European Commission revised the Recommendation on relevant product and service markets susceptible to ex ante regulation. Moreover, in 2009, there was an amendment to the 2002 regulatory frameworks, access and interconnection frameworks and authorisation and licences frameworks.

From 1999 to 2010, while broadband access and broadband adoption had both been addressed in several ways through broadband policy in the EU, the policymakers seemed to emphasise the infrastructure and access side more strongly. While there was still no clear conclusion on whether the EU was on the right track, broadband technologies and the market had been changed continuously and dramatically since the previous decade. New broadband policy and

new targets had therefore been proposed. In 2010, the European Commission launched a new initiative named ‘The EU Digital Agenda 2020’ that included eight action areas to develop the ICT industry in the EU.

2.3 The EU Digital Agenda 2020 and the Digital Single Market Strategy (2010-present)

In March 2010, the EU launched the Europe 2020 strategy to set a number of targets for the EU in the next decade. The goals for the Europe 2020 strategy include, for example, achieving high levels of employment, a low carbon economy and social cohesion (EC, 2010). The Digital Agenda 2020 is also one of the key strategies to encourage better quality of life for European citizens through the use of ICT. The EU Digital Agenda consists of eight action areas with several key performance indicators (KPIs) to measure them (see Table 1).

Table 1: The eight action areas of the EU Digital Agenda and examples of its measurements

Areas of action	Examples of measurements in some of the areas of action
1. Creating a vibrant digital single market 2. Improving interoperability and standards 3. Ensuring internet trust and security 4. Expanding fast and ultra-fast internet access 5. Higher investment in research and innovation 6. Strengthening digital literacy skills and inclusion 7. Applying information and communications technologies (ICT) to provide benefits for the EU society 8. Making international aspects of the Digital Agenda	1. Online buying and selling: by 2015, 50% of citizens should buy products/services online, 33% of SMEs should sell or buy online and 20% of citizens should buy cross-border online 2. Roaming difference: by 2015, the difference between national tariffs and roaming tariff should be closer to zero 3. Broadband and fast broadband access: by 2020, all European households should have access to broadband of at least 30 Mbps, and no fewer than 50% should be able to access broadband of 100 Mbps or more 4. Internet usage: by 2015, regular internet users should increase to 75% of citizens 5. Research and innovation: increase public investment to 11 billion euros 6. E-government: 50% of citizens should use e-government

Source: EC (2010) and Munisteri (2013)

According to Table 1, several of the action areas are related to broadband services in different ways. In relation to the study of this thesis, the focus is on the fourth (*fast and ultra-fast internet access*) and sixth (*digital literacy skills and inclusion*) action areas. As shown in Table 1, several KPIs also attempt to measure the availability and usage of broadband services. For example, all European households should have access to broadband with a connection speed of at least 30 Mbps, and no fewer than 50% should be able to access broadband with a connection speed of 100 Mbps or more by 2020. On the broadband usage side, regular internet users should increase to 75% of citizens by 2015 and 50% of the EU citizens should use e-government. To achieve these ambitious targets, the European Commission has launched more broadband policies and recommendations (or updated versions) since 2010. Examples of these policies are the Next Generation Access Networks (NGA) Recommendation in 2010, the State Aid Broadband Guidelines in 2012, the Proposal for a Regulation on measures to reduce the cost of deploying high-speed electronic communications networks in 2013, and the Recommendation

on relevant product and service markets within the electronic communications sector susceptible to ex ante regulation in 2014.

Since autumn 2014, a new President of the European Commission, Jean-Claude Juncker, has been elected as well as a new team of commissioners. One of the new team's priorities for the telecommunications sector is the 'Digital Single Market Strategy'. According to the European Commission (2015), three main areas have preliminarily been set to be the main focus. These areas are 1) facilitating better access to digital goods and services, 2) building the environment for digital networks and services and 3) Creating long-term growth potential for a European Digital economy and society (Industry 4.0). However, these strategies are still at an early stage. A more comprehensive Digital Single Market Strategy will be shown later in 2015. Thus, there has not yet been any clear evidence of the new strategy for evaluation in the thesis. The scope of this thesis, analysis, evaluation and recommendation of broadband policy are therefore mainly based on previous broadband policies in the EU and the EU Digital Agenda 2020. However, the analysis and discussion of the EU Digital Single Market are beyond the scope of the thesis, and the analysis and discussion are based on the EU still being fragmented as of now.

2.4 The critics of broadband policy in the EU

The EU has recently been criticised by a number of scholars as a laggard of high-speed broadband development, particularly compared with the US and Japan (see, for example, Briglauer and Gugler, 2013, and Yoo, 2014). Furthermore, there have been several criticisms of the broadband policy and regulation in the EU; for example, the effects of access regulation on the next generation network (NGN) investment and criticism that the EU seems to prefer service competition over infrastructure competition. Furthermore, while broadband policies in the EU, including the EU Digital Agenda, cover both broadband infrastructure and adoption, the emphasis of broadband policy is practically mainly on the supply side. Batura (2014) has mentioned that the measures for the EU Digital Agenda are still heavily focused on the supply side.

To understand all these issues and be able to evaluate EU broadband policy, reviews of previous literature are needed to facilitate greater understanding of the broadband policy in the EU as well as to recommend future broadband policy to fit with the new dynamics of the broadband market. Broadband services are also considered crucial factors for the economy and development of society. The reviews of broadband benefits therefore not only provide a wider understanding of the issue but also imply and address that it is important to have appropriate broadband policy that can lead to greater broadband penetration and adoption and ultimately a better economy and society in a region.

3. Relevant frameworks and previous literature

As the thesis divides broadband into a supply and a demand dimension, Section 3 first introduces what supply and demand side policies are and then provides previous studies based on them. Later, the section points out the interrelation between the supply side policy and the demand side policy based on the frameworks of network externalities and the ICT ecosystem. Lastly, the section presents how broadband ultimately contributes to the economy by reviewing the literature of broadband impacts on the economy.

3.1 Supply side policy

In this thesis, supply side policy refers to broadband policy that aims to improve the productive capacity of broadband services, particularly broadband infrastructure, network and access. There are several ways for policymakers to implement supply side policy. Policies can be in the form of a subsidy, tax, direct/partial investment or regulation. In the last decade, as seen in Section 2, the EU emphasised the use of supply side policy through regulation. Examples are the regulation on unbundled access to the local loop, the assessment of significant market power under the community regulatory framework, the 2002 regulatory frameworks, and access and interconnection frameworks. Since the thesis cannot cover previous studies for all supply side policies, only studies on market definition and access regulation are discussed extensively. Nevertheless, other supply side policies are briefly summarised first.

General summary of supply side policies:

Based on the report by FSR (2011), supply side policies are categorised into three groups based on their objectives: 1) reducing operators' costs, 2) supporting operators' entrance into the market and 3) direct development by the public sector. FSR (2011) and Belloc et al. (2012) have summarised the supply side policy tools. Overviews of supply side policy adapted from both studies are presented in Table 2.

Table 2: Different types of supply side policy

Objective(s) of supply side policy	Example(s)
Reducing operators' costs	<ul style="list-style-type: none">- Fiscal incentives; for example, supply side subsidy and tax credit- Policy on infrastructure sharing- Low interest and long-term loan programme- Policy on administrative simplification
Facilitating operators' entrance into the market	<ul style="list-style-type: none">- Spectrum policy; for example, efficient use of digital dividend and encouraging spectrum sharing/trading- Territorial mapping programme- Policy on infrastructure competition
Direct development by the public sector	<ul style="list-style-type: none">- Direct investment in the networks- Public-Private Partnerships with either public or private ownership of the infrastructure network- Increase public information points; for example, in schools, libraries and metropolitan areas- Providing broadband services through municipal utilities

Based on FSR (2011) and Belloc et al. (2012)

While there are a number of policy tools on the supply side, direct investment from the government seems to be the most effective since it guarantees broadband infrastructure in the

long run as well as solving the problem of barriers from incumbents. However, there are some disadvantages of using direct public funding. It is somewhat unclear whether a large amount of money should be spent only on broadband projects, especially considering the current economic situation in the EU. Moreover, the use of public funding cannot raise incentives for telecommunications operators to invest in broadband infrastructure. To stimulate more investment from the private sector, direct development of broadband infrastructure can also be implemented by involving the private sector. This relationship between investment from the public and private sectors is called public-private partnership (PPP). The strong advantage of PPP is that while it aims to solve market failure with support from the public sector, it also improves public policy by attracting investment from the private side (Falch and Henten, 2009).

Another important supply side policy tool from Table 2 is spectrum policy. Wireless technology, such as 4G/LTE, is currently one of the most important factors for the growth of mobile broadband. The purpose of spectrum policy is to manage and allocate spectrum efficiently. Examples of spectrum policy are encouraging a market-based approach to spectrum assignment, allowing the assignment of shared spectrum access and re-farming of spectrum² (EC, 2010). There are also other supply side policies that encourage operators to invest in broadband infrastructure, such as fiscal incentives, loan programmes, territorial mapping programmes and administrative simplification. In general, these types of broadband policies can be implemented along with other broadband policies.

Literature on market definition:

The concepts of market definition and significant market power (SMP) analysis were introduced in 1998; nevertheless, the current version of market definition and SMP analysis is largely based on the 2002 guidelines on market analysis and the assessment of significant market power under the Community regulatory framework for electronic communications networks and services. According to BEREC (2012), SMP analysis in the EU can be generalised into three steps: 1) identifying the relevant market, 2) SMP assessment and 3) imposing ex ante regulation³. Market definition and SMP analysis lead to several ex ante regulations; for example, local loop and bitstream unbundling regulation for the broadband market.

Even though identifying the relevant market and SMP assessment are the first and second steps before imposing any ex ante regulation, the literature on market definition and SMP assessment is somehow surprisingly limited, especially compared with the last step of using the ex ante regulation. So far, studies on market definition mostly point out that the current SMP analysis framework has less flexibility and relies too much on competition law (De streef, 2008a, 2008b). One of the important issues for SMP analysis, which some scholars (see Never, H. and Preissl, B., 2008, and Hou, 2008) have also analysed, is the concept of the three cumulative criteria test. The three cumulative criteria test is used to test whether there is a need for regulation on a particular market. The three criteria include: 1) the existence of non-transitory or high barrier to entry, 2) ineffective competition in the market and 3) the ex post regulation

² Spectrum policy is a very important and big topic. This thesis only mentions spectrum policy as part of supply side policy. The details of the various spectrum policies are beyond the scope of the thesis.

³ More details on the process of SMP analysis are explained in appended Paper 1.

by competition law is not sufficient to solve the problem. However, with the three cumulative criteria test, if adopted properly, the current approaches may lead to excessive regulation (Never, H. and Preissl, B. 2008). Hou (2008) has also criticised that the third criterion (competition law is not sufficient) should not have been applied while identifying relevant markets but instead at the later stage when imposing regulation.

With regard to broadband services, the substitution of retail for broadband markets can also determine broadband markets at wholesale level; therefore, the European Commission should take this substitution into account for relevant broadband markets (Schwarz, 2007). In addition, according to the public consultation in 2013 on the revision of the Recommendation on relevant markets, comments from BEREC, TDC⁴ and KPN⁵ were in line with Schwarz (2007) that the relevant broadband market should be technologically neutral and include all technologies. Furthermore, the substitution between fixed broadband and mobile broadband may also need to be taken into account since mobile broadband currently has a significant effect on the whole broadband market because of the explosive growth of smartphone usage. Nevertheless, in practice, many countries in the EU member states still do not believe that fixed broadband and mobile broadband can be completely substituted yet.

Literature on access regulation:

Access regulation has been widely debated since the early 2000s when the European Commission decided to implement the regulation on unbundled access to the local loop. Most studies on access regulation were empirical studies based on econometric approaches. From the early to mid-2000s, many scholars analysed the impacts of access regulation on broadband penetration (for example, Bauer et al., 2003, and Garcia-Murillo, 2005). Later, the discussion moved to the impacts of access regulation on investment as well as the debate on the use of access regulation (service competition) or infrastructure competition (see, for example, Distaso et al., 2006, Höffler, 2007, and Bouckaert et al., 2010). Findings from previous studies vary, however, as scholars have suggested positive, neutral and negative effects. The affiliations of the scholars therefore need to be considered and previous literature carefully interpreted. As there is a large amount of literature on access regulation, selected studies have been chosen and summarised as follows.

Bauer et al. (2003) were among the early studies that analysed the impacts of access regulation on broadband penetration using data from the OECD countries in 2001. The authors found that access regulation (unbundling) had a positive, though not statistically significant, impact on broadband penetration. Nevertheless, Garcia-Murillo (2005), who also used a dataset from 2001 but with more observations (about 100 countries), has suggested that access regulation has significant positive impacts on broadband penetration, particularly in a group of mid-income countries. Since then, the dataset has become more available; hence, more studies with more sophisticated methods have been conducted. The results, however, have become more varied. While some scholars (Grosso, 2006, and De Ridder, 2007) have suggested positive impacts of access regulation on broadband penetration, some (Boyle et al., 2008, and Bouckaert et al.,

⁴ Danish telecommunications operators (incumbent)

⁵ Dutch telecommunications operators (leading in the mobile market)

2010) have found that the impacts are not significant and policymakers should rather encourage infrastructure competition. As infrastructure competition becomes another alternative, many scholars have analysed the impacts of infrastructure competition compared with access regulation (in a form of service competition). Distaso et al. (2006), Höffler (2007), Nardotto et al., (2012) and Gruber and Koutroumpis (2013) are among those scholars. Distaso et al. (2006) applied econometric estimation to support their theoretical models. The authors have found that infrastructure competition can significantly increase broadband penetration. However, service competition has insignificant impacts. Similarly to Distaso et al. (2006), Nardotto et al. (2012) have suggested that access regulation does not affect broadband penetration while infrastructure competition has positive impacts. In addition, Höffler (2007) has suggested a positive impact of infrastructure competition on broadband penetration; however, the author was concerned that the cost of infrastructure duplication may be too high and service competition may be preferred in this case. Gruber and Koutroumpis (2013) are also in line with Höffler (2007). They found that the duplication cost from infrastructure competition may ultimately raise the cost for end-users. Recently, the debate on access regulation has moved to several discussions to foster investment in NGN, such as fibre technology. Examples of these studies are Nitsche and Wiethaus (2011), Bourreau et al. (2012) and Cambini and Silvestri (2013).

3.2 Demand side policy

In this thesis, demand side policy refers to broadband policy that aims to improve broadband products or services through the consumer side as well as to promote the use of broadband. In contrast to the literature on supply side policy, there were far fewer studies on the demand side in the last decade. Hence, the thesis opts to categorise the demand side study by first briefly summarising demand side policies. Previous literature that emphasises different programmes of demand side policy and literature on broadband adoption and usage then follow.

General summary of demand side policies:

As excellently summarised by FSR (2011), demand side policy tools are categorised into two groups: increasing the value of broadband services and reducing the costs of adopting broadband services. Overviews of demand side policy are shown in Table 3. It is also possible that some of the supply side policies can benefit the demand side and vice versa.

Table 3: Different types of demand side policy

Objective(s) of supply side policy	Example(s)
Increasing value of broadband services	<ul style="list-style-type: none"> - Increasing broadband demand by providing greater availability of public services, such as e-government, e-education and e-health - Increasing quality of broadband services, such as quality standard and internet security - Raising awareness of the benefits of broadband services by both households and businesses; for example, by supporting IT education and e-commerce - Policy on digital literacy
Reducing costs of adopting broadband services	<ul style="list-style-type: none"> - Demand subsidies or tax reductions for broadband services (and complementary products) for consumers or target groups - Policy on demand aggregation

Based on FSR (2011) and Belloc et al. (2012)

As shown in Table 3, demand side policy in general is used to increase the demand for broadband adoption by consumers. In addition, the use of demand side policy can be combined with supply side policy to help the EU achieve both access and adoption targets. Raising broadband demand through public online services is among the common approaches, along with increasing broadband quality and consumer awareness. IT education and the skill of citizens are important factors that lead to higher usage of broadband. Demand subsidies and tax reductions for broadband services are also commonly used for the targeted groups that the policymakers aim to encourage to use more broadband services by reducing the price of them. This price reduction approach can also be applied to other products that are complementary to broadband services, such as computers and laptops.

Policy on demand aggregation is an example of a policy tool that benefits both the demand and the supply side. The demand aggregation programme combines potential consumers' demand for broadband services to improve resource allocation. While this policy can raise the bargaining power on the demand side, it can be used to guarantee that there will also be enough profits on the supply side (FSR, 2011, and Belloc et al., 2012).

Literature on different programmes of demand side policy:

Not only is the focus of broadband policy in practice on the supply side, but the academic literature on the importance of demand side policy is also limited. Most studies either heavily focus on the evaluation of supply side policy or refer to both supply and demand side policies equally. For example, FSR (2011) and Belloc et al. (2012) have summarised and evaluated demand side policies. However, these studies have evaluated supply and demand side policies equally. On the demand side, most studies have instead investigated the determinants of broadband adoption and usage. Nevertheless, there are a few studies that focus on demand side policy. Hauge and Preiger (2010) is one of the few examples. First, the authors divided demand side policy to solve four issues: high price of broadband, lack of computers, lack of digital literacy and lack of value of broadband. Then, the authors discussed and evaluated several types of demand side programmes to support broadband policy. Another example is Trkman and Turk (2009). These authors aimed to evaluate one of the demand side policies, i.e. the e-government programme. Trkman and Turk (2009) applied a conceptual model to evaluate the relationship between broadband adoption and e-government. The authors suggested that the success of e-government depends on how policymakers encourage citizens to use online public services⁶.

Literature on broadband adoption and usage:

While the literature on the importance of demand side policy is quite limited, the literature on broadband demand (adoption and usage) was conducted before the 2000s. Nevertheless, broadband technologies have continued changing. Therefore, the study has gradually moved from internet services to standard broadband, high-speed broadband, mobile internet and mobile broadband accordingly. Madden and Simpson (1997) were among the early scholars who applied econometric analysis to investigate the determinants of broadband adoption in

⁶ In fact, there is literature related to e-government; nevertheless, most does not directly discuss the relation to demand side policy or broadband adoption.

Australian households. The authors found that household income has positive impacts, while installation fee has negative impacts on broadband adoption. Building up from Madden and Simpson (1997), more studies on broadband demand have been investigated through several econometric techniques in several countries during the last decade. Examples are Savage and Waldman (2005) for broadband adoption in the US and Cerno and Pérez Amaral (2006) for Spain. Other approaches were also applied by scholars, such as data mapping analysis and actor analysis to determine broadband adoption. LaRose et al. (2007) and Yamagawa et al. (2012) were among them. The findings of each study, however, varied depending on the focus and the area used for the analysis. It is not only broadband adoption that has been analysed; there has also been a wide range of literature on broadband usage in the last decade. Examples are Goldfarb and Prince (2008), Orviska and Hudson (2009) and Srinuan and Bohlin (2013). Goldfarb and Prince (2008) used the US survey and found that in the adoption group, those groups with lower income and lower education are likely to spend more time online because of the differences in the opportunity cost of leisure time. In the EU case, Orviska and Hudson (2009) have analysed internet usage in the EU countries. The authors suggested that the younger generation tends to use the internet for chats, leisure and job searches while the older generation (about 50-60 years) use it for health and information searches. In the developing country case, Srinuan and Bohlin (2013) analysed broadband usage in Thailand. Their findings were also in line with those of Goldfarb and Prince (2008) that the lower income group tends to use broadband for social networking, video streaming and online games more than the higher income group.

In a similar way to voice telephone services, the impacts of mobile broadband are becoming more relevant; however, it is still at the early stage compared with fixed broadband. Mobile broadband adoption has increased significantly in the last few years, however, due to the explosive growth in smartphones and the implementation of LTE technology and 4G networks. More data have therefore become available, which has led to more research on mobile internet and mobile broadband having been conducted. Previous studies on mobile internet and broadband usage were mostly conducted in Japan as it is a country with early adoption of mobile internet (see, for example, Funk, 2005, and Okazaki, 2006). The investigation into mobile internet adoption and usage was later also conducted in other countries. The findings so far have been similar to those for fixed broadband in that the results usually depend on the differences in social demographic characteristics in different areas of analysis. Nevertheless, with mobile broadband becoming more relevant, it is important to continue to develop the studies on mobile broadband adoption and usage.

3.3 Bridging the supply side and the demand side

It is important to realise that both supply and demand side policies are important and should be used to complement each other. The reason is that broadband demand from consumers depends on the availability of broadband access and infrastructure (Falch et al., 2006). From the policy point of view, some scholars have also suggested that broadband policy can be effective in a different way. FSR (2011) has mentioned that demand side policy can have little impact if there is low availability of broadband infrastructure, while Belloc et al. (2012) have suggested that demand side policy can have greater effect than supply side policy if there is enough broadband

coverage. To further illustrate the relationship between broadband supply and demand and their policies, two frameworks, network externalities and the ICT ecosystem are discussed.

Network externalities:

According to Shapiro and Varian (1999), the values of many of the services in the telecommunications sector, such as telephone, e-mail and internet access, depend on the number of users or subscribers. The increasing value from a greater number of users can be considered *network externalities* or *network effects*. Similarly, broadband services are a type of internet access. Network externalities are an important framework to help understand the impact of broadband policy to expand the use of broadband services. Atkinson (2007) has explained that there are both direct and indirect network externalities from broadband services. The direct ones are similar to Shapiro and Varian (1999)'s definition in which the values of adopting broadband are higher when there are more broadband adopters. The indirect effects are the values in relation to the content and applications. Atkinson (2007) has further pointed out that these indirect effects of broadband and its applications are like the chicken and egg relationship. It can be explained that more sophisticated applications can generally be provided with higher speed connections to broadband services. At the same time, broadband services are likely to be developed with higher speeds if users are willing to use contents and applications that require higher speed connections. This content and these applications can thus be considered complementary services to broadband. Video streaming applications are among the examples of applications that can ultimately affect the supply side. Users in general may not realise these direct and indirect network externalities of broadband services when they decide to subscribe. It is therefore important for the policymakers to ensure there are broadband policies that help consumers to realise the value of the broadband service, such as the use of public online services and the campaign to use online applications in other sectors (for example, e-education, e-health, e-banking and e-commerce).

ICT ecosystem:

The concept of the ICT ecosystem is proposed by Fransman (2007). The ICT ecosystem consists of four layers: network element providers, network operators, content and application providers, and final consumers. There is also a relationship between each pair of two layers; hence, there are six relationships in total. Fransman (2007) further explained that four influences can affect the outcome of the ICT ecosystem through these six relationships: competition, regulation and law, financial institutions and other institutions. Similarly to Fransman's (2007) concept, a study from the World Bank by Raja et al. (2010) has proposed that broadband should be considered a *broadband ecosystem*. According to Raja et al. (2010), the broadband ecosystem consists of broadband networks, broadband services, applications and users. Nevertheless, Raja et al. (2010) have only introduced four relationships rather than six between each layer (there is no mention of the relation between networks and application, or between broadband services and consumers). In Raja et al. (2010), the authors have suggested that different types of broadband policies can be implemented through the four relationships.

In this thesis, the use of the broadband ecosystem is based on the model from Raja et al. (2010) and the six relationships from Fransman's (2007) models. With regard to Fransman's four

influences (2007), broadband policy can be considered a tool to support competition, regulation and law as well as finance. The broadband ecosystem in this study is used to explain how both supply and demand side policies generate the impacts from one layer to other layers. Supply side policy is implemented through broadband networks/infrastructure and broadband services while demand side policy is generated through content and applications as well as end-users (consumers). In addition, the effects of policies go to other layers through six relationships. The use of the broadband ecosystem and implemented policy in this study can be illustrated as in Figure 3.

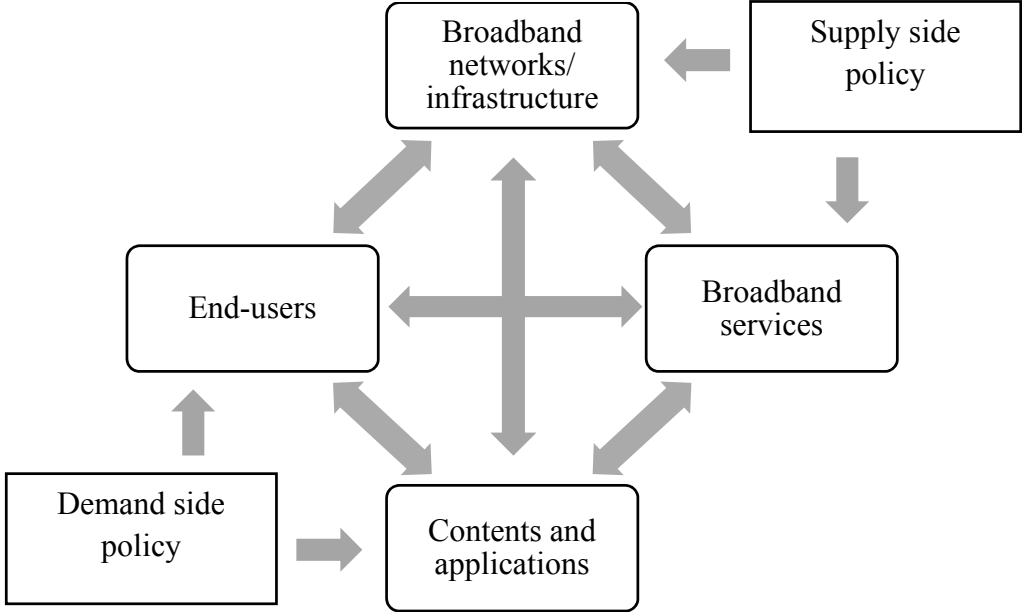


Figure 3: Broadband ecosystem and broadband policy

Source: Based on Fransman (2007) and Raja et al. (2010)/taken from appended Paper 3

Furthermore, the effects of broadband policy on the broadband ecosystem can be multiplied when considering the effects of network externalities through the broadband ecosystem. It is also implied that both supply and demand side policies can be implemented to develop the broadband ecosystem and are equally important.

3.4 Broadband contributions to the economy

All the broadband policies mentioned previously aim to generate either greater broadband infrastructure or higher broadband adoption. Unsurprisingly, most organisations, providers and scholars have already recognised that broadband contributes a number of benefits to the economy and society. For example, broadband can contribute benefits through several sectors, such as entertainment, education, health care, banking and public services. It can also help firms to improve productivity and indirectly increase household income through externalities (ITU, 2012). In addition, many studies have pointed out that greater broadband penetration has better economic impacts. From about the mid-2000s, there have been a number of studies that attempt to investigate this kind of relationship. Lehr et al. (2005) have investigated broadband penetration in the US and suggested that while it is still a preliminary analysis, greater broadband access stimulates economic growth. Using US data, Crandall et al. (2007) have also

investigated the broadband impacts on employment and output growth in various sectors. The authors found that the impacts of broadband penetration on employment growth, especially in the education, finance and health care sectors, were significant. Koutroumpis (2009), who used the OECD countries for his analysis, found that the impacts of broadband adoption on the economic outputs of 22 OECD countries were positively significant, particularly for the Scandinavian countries, which have higher broadband penetration than the other OECD members. Czernich et al. (2011) also obtained the data from the OECD countries and concluded that a 10% increase of broadband penetration leads to a 0.9-1.5% increase in annual growth in GDP per capita. Thompson Jr. and Garbacz (2011) used a number of countries from the ITU database and suggested that mobile broadband penetration has significant direct impacts on GDP; however, the impacts of fixed broadband penetration are insignificant. To sum up this group of literature, it can be seen that all the studies point in the same direction that greater broadband availability leads to greater economic impacts; however, the details and methods of these studies differ.

As seen in the EU Digital Agenda 2020, while the focus is still on broadband penetration, the European Commission has started to recognise the importance of broadband speed. For example, one of the key performance indices is that at least 50% of people should be able to access broadband with a minimum connection speed of 100 Mbps (ultra-fast broadband) by 2020. Similarly, some scholars have now also started to investigate the impact of broadband speed. According to Atkinson et al. (2009), the benefits of faster broadband services compared with standard broadband are remarkably faster file transfer, allowing video streaming content and applications, enabling real time and high quality communication, and allowing users to use several applications at the same time. Furthermore, there have recently been some studies on broadband speed or faster broadband services; however, these types of studies are still limited. Examples are Katz et al. (2010), Forzati and Mattsson (2012) and Rohman and Bohlin (2012 and 2013). Katz et al. (2010) have investigated broadband targets in regards to both penetration and speed in Germany and concluded that over 960,000 additional jobs and productivity worth more than 170 billion euro will be added if Germany is successful in its broadband target. Forzati and Mattsson (2012) applied fibre deployment data in Sweden from 2007 to 2010. The authors found small but significant results that in areas with fibre access, there are positive benefits on job employment for the populations. Rohman and Bohlin (2012) applied the data from OECD countries and found that, on average for the OECD countries, doubling broadband speed contributed 0.3% to GDP growth. Later, the same authors suggested that in the OECD countries, the households could benefit from broadband services when the speed of transmission was at least about 2-4 Mbps (Rohman and Bohlin, 2013). Recently, Mack (2014) applied a spatial lag model to evaluate the relationship between broadband speed and economic impact in each sector. The author has found that broadband speed has significant impacts on agricultural and rural establishments but insignificant impacts on health care and public administration. Nevertheless, the author only used the data from the state of Ohio in the US.

The trend of broadband contribution studies has gradually moved from the impacts of broadband penetration on the economy to the impacts of other characteristics. Currently, broadband quality differs across countries and regions. It is therefore not only broadband access

that matters but other broadband characteristics such as transmission speed, type of connection and quality of service are also important (Middleton, 2013).

4. Methodology and its reflections

4.1 Research approaches and data collection

This thesis is a study on broadband policy based on a study on telecommunications regulation. A study on telecommunications regulation is generally based on economics, policy and law; in a similar way, this thesis is a study on cross-disciplinary research based on applied economics, policy and social science. Nevertheless, the main discipline of this thesis is economics, with three of the five appended papers having applied econometrics estimation as the main approach while the other two papers' analysis are through economic frameworks and concepts. Each paper applies different approaches to suit different topics for analysis and different natures of the dataset and can be explained as follow.

The approach of the first paper, *Understanding market definition, relevant market and significant market power (SMP) frameworks in the EU*, is document analysis of various economic issues from several reports and relevant studies. The main dataset used for the analysis is the public consultation in 2013 on the revision of the Recommendation on relevant markets. About 66 contributions from different stakeholders, for example broadcast and telecommunications regulators, telecommunications operators, telecommunications operator associations and consumer associations, commented on the revision of the Recommendation on relevant markets. In addition, reports from several reliable organisations such as BEREC, the European Commission, ITU and OECD are used as supporting documents. The second paper, *Unbundling and infrastructure competition for broadband adoption: Implications for NGA regulation*, applies panel data technique (econometric estimations) to the panel dataset. The panel data technique is used because the study aims to analyse the empirical evidence of the causality relationship between infrastructure policy and broadband penetration. The main dataset is a secondary one based on OECD reports and working papers. In addition, the World Bank statistics, the ITU database and previous studies from De Ridder (2007) and Boyle et al. (2008) are used as supporting datasets. Paper 3, *Towards broadband targets on the EU Digital Agenda 2020: Discussion on the demand side of broadband policy*, uses two frameworks, network externalities and the ICT ecosystem to explain the relationship between broadband policy on the supply and the demand side. Furthermore, a comparative case study analysis of Korea and Sweden is used as an example. Various reports from Ovum, ITU and the Korean government, and other relevant literature are compiled for the case of Korea while reports from the Swedish Post and Telecom Authority (PTS) and Swedish government reports are mainly used for the Swedish case. In addition, reports from OECD and the European Commission, and other relevant studies are used as supporting documents. Paper 4, *Investigating mobile broadband adoption and usage: A case of smartphone in Sweden*, applies a cross-section regression analysis (econometric estimations) on the questionnaire conducted by PTS. The regression analysis is applied as the study attempts to investigate the causality between socio-economic background and usage characteristics of Swedish households and smartphone adoption. The main dataset is based on an annual nationwide survey of the usage of telecommunications services by Swedish households. Similarly to Paper 1, Paper 5, *Impact of broadband speed on economic outputs: An empirical study of OECD countries*, uses panel data technique (econometric estimations) on the panel dataset. This study attempts to investigate the

empirical evidence of the relationship between variables. However, in Paper 5, the analysis is the causality relationship between broadband speed and economic outputs. The details of the econometric estimation also differ from Paper 1 because of the different datasets and statistical issues, for example the endogeneity problem. The main data source for Paper 5 is a broadband speed dataset from the Ookla website. Moreover, the secondary dataset is mainly from OECD reports. World Bank statistics are also used. Lastly, this cover paper, which is the main thesis itself, applies a document analysis approach through relevant literature on the EU broadband policy, and it includes five appended papers.

Table 4: Summary of the main and supporting data sources and main research approach in the appended papers

Paper	Data sources		Main research approach(es)
	Main data sources	Supporting data sources	
Paper 1	Contributions from the public consultation in 2013 on the revision of the Recommendation on relevant markets	Reports from BEREC, the European Commission, ITU and OECD	Document analysis
Paper 2	Dataset based on OECD reports and working papers	ITU database, De Ridder (2007) and Boyle et al. (2008)	Panel data regression analysis
Paper 3	Reports from Ovum, ITU, the Korean government, PTS, the Swedish government	Reports from OECD, the European Commission and other relevant studies	Comparison case studies, framework analysis
Paper 4	Swedish annual nationwide questionnaire conducted by PTS	Reports from PTS	Cross-section regression analysis
Paper 5	Dataset retrieved from the Ookla website	OECD reports, World Bank statistics and dataset from http://www.heritage.org ,	Panel data regression analysis
Main thesis	Relevant literature, appended papers and various reports mainly from the European Commission		Document analysis

4.2 Reflections on research approaches

As seen in the previous section, the choice of approach of each appended paper is different. This is because of the differences in the objectives of the studies in each appended paper as well as the characteristics of the dataset. Papers 2, 4 and 5 mainly aim to investigate the causality of various variables. The datasets were therefore collected in a numeric form, and various multiple regressions were selected to fit with each dataset and the statistical issues respectively (for example, heterogeneity, endogeneity and multicollinearity). On the other hand, Papers 1 and 3 aim to understand previous frameworks and whether they can be fitted to new scenarios. More qualitative approaches are therefore chosen. Paper 1 applies document analysis based on the empirical data from the public consultation while Paper 3 opts to use the cases from two countries to understand the frameworks and events. As a result, the thesis combines both quantitative and qualitative approaches to fit with the issue focused on in the appended papers.

Even though the thesis mainly applies economic approaches, as this is cross-disciplinary research, the philosophy of science of this thesis should still be discussed. According to Caldwell (1980), knowledge of the philosophy of science can help economic methodologists explain various methodological positions as well as offering new areas of research. Thus, the research process, ontology and epistemology of the thesis are reflected here. The thesis is largely based on previous theories, frameworks and literature. The study adapts the previous knowledge to new circumstances. For example, this study adapts and develops the previous studies on basic broadband and applies them to high-speed broadband contexts. After the research questions are specified in each appended paper, the data are obtained and research approaches chosen to confirm or reject previous knowledge. The results are then discussed, interpreted and presented and, lastly, the conclusion is provided together with policy recommendations. It could be said that this type of research process, which is mainly based on confirmation (or rejection) of the previous knowledge, is based on a deductive approach. Nevertheless, after the confirmation or rejection of the results, the knowledge is built on previous knowledge and applied to a new context. Lastly, the application in the new context is used to suggest policy recommendations.

The main parts of this study aim to explain and predict society through a causal relationship between different factors, for example, the relationship between socio-economic background and broadband adoption, and the relationship between broadband speed and economic outputs. Hence, it could be said that the epistemology of this study is based on positivism orientation. Lastly, the phenomenon of this study is analysed by considering social phenomena independent; therefore, it could also be said that the ontology of this study is in line with objectivism orientation.

4.3 Reflections on the choices of multiple regressions (econometric estimations)

Three out of the five appended papers applied econometric approaches for the choice of multiple regressions. As mentioned in the previous section, a multiple regression method suits Papers 2, 4 and 5 because the main aim of these papers is to investigate causality, and the nature of their datasets is normally in numeric forms. Different econometric estimations are chosen since they can cope with or at least reduce some statistical problems such as heterogeneity, endogeneity and multicollinearity. Nevertheless, the thesis is a cross-disciplinary study that involves economics, policy and social science. The econometric regressions in the thesis were therefore not directly derived as in typical economic research papers. Instead, the choice of regression in each appended paper was adapted from previous studies that analysed similar types of services. Nevertheless, the selected methods have been widely used and are reliable enough among scholars in the field. For example, Paper 4 adapted the investigation on broadband adoption and usage, which has been widely used in the last decade, to the investigation into smartphone adoption and usage. In a similar way, Paper 5 adapted the analysis of broadband penetration to the analysis of broadband speed.

For the regression techniques, the choice of regressions is based on the characteristics of the dataset. Papers 2 and 5 analyse the data across the OECD countries with periods of time; the panel data regression techniques are therefore used. Paper 4, on the other hand, applied

questionnaire data for only one year in one country; hence, the cross-sectional data analysis is used. In addition, various techniques of regression analysis are used to deal with statistical problems. With the emphasis on policy implication and cross-discipline research, the econometric models are generally explained briefly (compared with economic papers in which the models are derived from a more theoretical perspective) and based on the adaptation of the models from previous studies. Nevertheless, the details of the different models, interpretation of statistical results and limitations of each model used in Papers 2, 4 and 5 are further explained in the appended papers.

5. Summary and limitation of the appended papers

This doctoral thesis is built and based on the findings from five appended papers summarised as follows.

5.1 Summary of each appended paper

Paper 1: Understanding market definition, relevant market and significant market power (SMP) frameworks in the EU

In the European telecommunications sectors, identifying the relevant market and testing the SMP are important processes before imposing any supply side regulation. While most studies in the last decade have focused on the part imposing the regulation, this paper tries to fill the gap by adding greater understanding of the market definition, relevant market and SMP frameworks in the EU. Using various reports, including empirical evidence from the public consultation results, this paper carefully explains various economic issues particularly related to the broadband market. The paper discusses, for example, the impacts of competition in different platforms in the fixed broadband market on market definition, the impacts of the substitution between fixed and mobile broadband on market definition and the trade-off between the dynamic and static regulation. In addition, the public consultation results of the revision of the Recommendation on relevant markets are summarised to show that these economic issues lead to diverse opinions from different stakeholders on market definition and identification for the relevant market. Furthermore, several stakeholders believe that Markets 4, 5 and 6, which are related to the broadband market, are in need of revision because of the unclear boundaries between each market and the move towards technological neutrality.

To sum up, with broadband technologies having greatly evolved in the last decade, the criteria for analysing the market definition and the 2007 Recommendation need to be more flexible to support the new EU Digital Agenda and fit the new dynamic of technologies, especially in the broadband market⁷.

Paper 2: Unbundling and infrastructure competition for broadband adoption: Implications for NGA regulation

This paper focuses on two important regulatory tools for supply side policy on the broadband market: infrastructure sharing and infrastructure competition. In the last decade, there have been many scholarly debates regarding these two regulatory tools (see, for example, Distaso et al., 2006, Bouckaert et al., 2010, and Gruber and Koutroumpis, 2013⁸). Hence, this paper uses the empirical data of local loop unbundling (representing infrastructure sharing) from 2002-2008 in OECD countries to expand the debate in this research field and to suggest future recommendations in regard to fibre technology for high-speed broadband. The contributions

⁷ Note that there is now an update on the current situation of the market definition. According to the European Commission (2014), the relevant markets have been reduced from seven to four, and the markets related to the broadband market have been redefined to fit better with current broadband technologies. The results of Paper 1 are therefore in line with the new changes to the recommendation.

⁸ A more extensive review on the debates can be found in Cambini and Jiang (2009), although the authors' main focus is on the relationship between broadband investment and regulation.

from the empirical evidence of this paper are that infrastructure sharing can be used to increase broadband penetration, especially in areas where there is a dominant technology. Infrastructure competition, on the other hand, is useful in areas where there is already enough infrastructure, such as capitals and cities that are densely populated. The choice of regulatory tool therefore depends on the existing infrastructure in the area.

This paper also discusses the use of infrastructure sharing on the fibre network: even though local loop unbundling may not be applied fully to fibre networks, it can indicate benefits and drawbacks of the infrastructure sharing concept in the past decade. Understanding these benefits and drawbacks can be useful in the implementation of fibre technology for high-speed broadband.

Paper 3: Towards broadband targets on the EU Digital Agenda 2020: Discussion on the demand side of broadband policy

Over the past years, when it has come to broadband policy, policymakers and academic scholars have mostly emphasised the supply side. Even though the EU stated the demand side targets in its Digital Agenda (the 6th action area of the EU Digital Agenda), the policy from the EU itself, in practice, has still been closely related to broadband access. It is not enough for the EU to only have access to ultra-fast broadband. To achieve its broadband targets, it is equally important that the EU enhances digital literacy, skills and inclusion. This paper therefore aims to point out the importance of demand side policy to overall broadband policy. Unlike the other appended papers, which are based on empirical evidence, this paper therefore opts to use the framework analysis of network externalities and the ICT ecosystem along with two case studies, of Korea and Sweden, to understand the relationship between supply side and demand side policies. The reason is that while there has been limited literature on demand side policies, a few scholars have conducted good studies by evaluating empirical evidence of demand side policy (see FSR, 2011, and Belloc et al., 2012). This paper therefore conducts analysis using network externalities and the ICT ecosystem frameworks to explain the interrelation between supply side and demand side policies. Furthermore, the examples of the two case studies of Korea and Sweden show that both countries have implemented supply side and demand side policies. With regard to the demand side, the focus on content and applications is what has made them successful.

In short, the findings of this paper support the contributions that in the national broadband plan, the supply and demand side policies are interrelated and reinforce each other. It is also important for policymakers to consider that demand side policy should complement the implementation of supply side policy, not substitute it.

Paper 4: Investigating mobile broadband adoption and usage: A case of smartphone in Sweden

With the introduction of 4G network/LTE technology in the last few years, mobile broadband can now support significantly faster transmission speeds for broadband services. In addition, mobile broadband can be used instead of fixed broadband in areas where (fixed) broadband access and infrastructure are limited or not available. This paper selects Swedish smartphone adoption and usage as a case study since Sweden is one of the countries with early adoption of

4G/LTE technology. The dataset then becomes available for empirical study. Even though this paper does not examine demand side policy directly, the study investigates the determinants of smartphone (representing mobile broadband) adoption and usage in Sweden. Understanding the determinants and relevant factors can be useful for future recommendations of broadband policy on enhancing digital inclusion. For instance, policymakers can stimulate the use of broadband services through public online content and applications, especially to those who are still non-adopters. The paper applies cross-country analysis using bivariate probit with a sample selection approach. The empirical results suggest that a group of respondents who are older, have a lower income, lower level of education and live outside the capital are less likely to adopt a smartphone than those who are younger, have a higher income, higher level of education and live in the capital. On the usage side, the empirical evidence shows different results depending on the application. The result that is of interest is that a group of respondents with a lower income are more likely to use applications that can save costs, such as online shopping or Skype calls, compared with using an offline service.

With the growth of smartphones and mobile broadband services, which are currently becoming more important to users, mobile broadband can be used as a regulatory tool in broadband policy, particularly on the demand side, to reduce the gap of the digital divide in a country (Srinuan, C. et al., 2012, and Prieger, 2013).

Paper 5: Impact of broadband speed on economic outputs: An empirical study of OECD countries

Ultra-fast broadband services can provide a number of benefits such as significantly improving the speed of sending/receiving files, facilitating high quality video content and applications, enabling high quality real time audio and video communications, and allowing users to use several applications at the same time (Atkinson et al., 2009). Accordingly, ultra-fast broadband services are likely to stimulate greater economic benefits than standard broadband services. In practice, the importance of ultra-fast broadband services has been recognised by policymakers; for example, the European Commission has already included fast internet access in the EU Digital Agenda. Nevertheless, in the academic field, there have only been a few studies investigating the speed issue, especially with the empirical dataset. This study therefore applies the knowledge from previous literature on the impact of broadband penetration on the economy to the impact of broadband speed on economic outputs. The results from this paper imply that there are positive impacts of faster transmission speeds of broadband services on economic outputs. This study also suggests that the effects are greater in countries with a lower income.

Furthermore, as suggested in the first section on connections from broadband policy leading to better broadband services and greater broadband infrastructure and eventually stimulating economic outputs, this study supports the second part of these connections and implies that implementing high-speed broadband infrastructure and encouraging broadband adoption in national broadband policy will ultimately lead to economic development.

Table 5: Summary of the findings from the five appended papers and support literature, and relevancy to the thesis

Title of appended paper(s)	Main finding(s)	Supporting literature and implication for the main thesis
Understanding market definition, relevant market and significant market power (SMP) frameworks in the EU	Broadband technologies have developed significantly in the last decade. The old market definition, SMP framework and market recommendation may not be able to keep up with the fast pace of technological changes and several of the economic issues. The criteria for analysing the market definition and the market recommendation therefore need to be more flexible and adapted to support the new EU Digital Agenda and fit with the new dynamic of the technologies, especially in the broadband market	Larouche and De Visser (2006) and Schwarz (2007) Implication: Identifying the relevant market and testing the SMP are the first important step before imposing any supply side regulation. Most of the Markets in the latest (2014) recommendation are closely related to broadband markets. Understanding the market definition, relevant market and significant market power (SMP) frameworks in the EU leads to appropriate regulation to ultimately achieve the broadband targets
Unbundling and infrastructure competition for broadband adoption: Implications for NGA regulation	While infrastructure sharing can be used to increase broadband penetration, especially in areas where there is only one dominant technology, infrastructure competition can provide more benefits in areas where there is already enough infrastructure, such as capitals or cities that are densely populated. Hence, the choice of regulatory broadband tools depends on the characteristics of and existing infrastructure in the area.	Picot and Wernick (2007) and Gruber and Koutroumpis (2013) Implication: While local loop unbundling may not fully apply to fibre networks, in relation to broadband policy (on the supply side), the decision to apply either infrastructure sharing or infrastructure competition can vary between member states depending on the characteristics and existing infrastructure of the member states
Towards broadband targets on the EU Digital Agenda 2020: Discussion on the demand side of broadband policy	To support the EU Digital Agenda 2020, broadband policy needs to be implemented through all market players, (high-speed) broadband infrastructure, (high-speed) broadband services, content and applications, and users. In addition, the findings support the fact that supply and demand side policies are interrelated and reinforce each other. Hence, supply side policy on its own may not be enough for the EU to achieve its broadband targets	FSR (2011), Izsak and Edler (2011) and Belloc et al. (2012) Implication: It is crucial to recognise the importance of demand side policy because demand side policy complements the implementation of supply side policy; it does not substitute it. The timing of using demand side policy can also be crucial because while broadband diffusion is still low, demand side policy may only have small impacts. Nevertheless, demand side policy has significant impact (even more than supply side policy) when broadband diffusion has been developed to a particular point.

Title of appended paper(s)	Main finding(s)	Supporting literature and implication for the main thesis
Investigating mobile broadband adoption and usage: A case of smartphone in Sweden	On smartphone adoption: There is less probability of a group of respondents who are older, have a lower income, lower level of education and live outside Stockholm to adopt a smartphone than those who are younger, have a higher income, higher level of education and live in Stockholm. A policy to encourage non-adopters in order to reduce the digital divide is therefore needed. On smartphone usage: The findings differ depending on the applications. Some interesting results are that lower income respondents tend to use more online shopping and internet telephone than those who have a higher income. The reasons may be that these applications can save costs; hence, policymakers can facilitate the lower income non-adopters to consider adopting mobile broadband if they realise the benefits of using mobile broadband.	Goldfarb and Prince (2008), Orviska and Hudson (2009), Vergara and Grazzi (2011) and Srinuan and Bohlin (2013) Implication: Understanding the determinants and relevant factors of mobile broadband adoption and usage is useful for recommending broadband policy (on the demand side) to encourage greater adoption and usage of mobile broadband as well as to reduce the digital exclusion of the EU citizen. With the significant growth of smartphones, mobile broadband becomes more important as a regulatory tool in broadband policy to reduce the gap of the digital divide in a country.
Impact of broadband speed on economic outputs: An empirical study of OECD countries	The significance of regression level results of at least 10% in all models supports the idea that there are positive effects of faster broadband services on economic outputs. The findings also suggest that the impacts are greater in OECD countries with lower incomes. This therefore implies the importance of broadband policy that aims to develop high-speed broadband infrastructure and adoption.	Katz et al., (2010), Thompson Jr. and Garbacz (2011) and Rohman and Bohlin (2012) Implication: The overall benefits of high-speed broadband to the economy are only one example of how broadband affect the economy. The benefits of broadband can also point out a connection from broadband policy that leads to better broadband services and infrastructure that eventually stimulate economic outputs.

5.2 Limitation and clarification of each appended paper

Besides the findings in Section 5.1, there are limitations in each appended paper that need to be acknowledged. Paper 1, Understanding market definition, relevant market and significant market power (SMP) frameworks in the EU, was written before the new 2014 Recommendation was released; hence, it is not possible to include this latest information in the study. For example, a discussion on the new release of the 2014 Recommendation is missing. There has also been more recent literature on fixed-mobile substitution (see, for example, Briglauer et al., 2011, Gryzbowski et al., 2014, and Hoernig et al., 2015) that can improve understanding of the market definition analysis. For Paper 2, Unbundling and infrastructure competition for broadband adoption: Implications for NGA regulation, it is important to emphasise that it only presents the static circumstance of broadband policy impacts even though the dynamic models

can better explain the dataset. In addition, Paper 2 aims to simplify and generalise the impact of local loop unbundling as infrastructure sharing to provide some contrast between infrastructure sharing and infrastructure competition. However, the transition to NGA regulation is more complex and more variables need to be considered. Paper 3, Towards broadband targets on the EU Digital Agenda 2020: Discussion on the demand side of broadband policy, is next. It is a policy-oriented paper; hence, there is a need for further empirical studies to support its findings. Paper 4, Investigating mobile broadband adoption and usage: A case of smartphone in Sweden, analysed smartphone adoption in Sweden in 2013. The study is only based on the questionnaire in 2013. Hence, future studies with datasets of more than one year could provide a broader perspective for future analysis. Lastly, Paper 5, Impact of broadband speed on economic outputs: An empirical study of OECD countries, has simply adapted the analysis of broadband penetration to broadband speed. As mentioned in the study, this is an early study of a broadband speed analysis to generalise the causality of broadband speed and economic outputs. Future studies on specific sectors in specific countries could provide the analysis in more detail.

6. Analysis and discussion

6.1 Analysis of the appended papers

This section provides a deeper analysis of how each appended paper contributes to the main thesis and the two main research questions, which are 1) *What are the possible broadband policies for the EU to achieve its target on high-speed broadband access and adoption?*, and 2) *What is the relationship between high-speed broadband and economic outputs?* The implications of the five appended papers vary depending on the main purpose of each paper. Papers 1, 2, 3 and 4 aim to answer the first research question and present different points of view on broadband policy and regulation. Paper 5 aims to answer the second research question by showing that higher connection speeds of broadband services can generate positive benefits for the economy. At the same time, the findings from Paper 5 imply that appropriate broadband policy will ultimately lead to a greater economy. To smoothen the analysis, this section starts by analysing Paper 5, then Papers 1, 2, 3 and 4.

As higher broadband transmission speeds lead to greater economic outputs, there is a need for appropriate broadband policy and regulation to improve high-speed broadband infrastructure as well as encourage further high-speed broadband adoption. (Paper 5)

High-speed broadband infrastructure requires a lot of investment from either the public or private sector. These great amounts of investment have sometimes raised a question for both the public and private sectors of whether it is worth investing in the infrastructure for high-speed broadband. To answer this question, firstly, much content and many applications currently require higher broadband speeds to work efficiently; for example, the use of video conferencing, online education, tele-health and many entertainment applications. With the use of these content and applications, Pellegrino and Klemann (2012) have suggested that, compared with normal broadband, high-speed broadband can increase economic growth, job creation and public welfare. Previous studies including Paper 5 have recently also supported the fact that higher broadband speeds have a positive overall effect on economic outputs and particular sectors (see Katz et al., 2010, Forzati and Mattsson, 2012, Rohman and Bohlin, 2012, and Mack, 2014). Secondly, the EU Digital Agenda and the national broadband plans to provide 100% of broadband services and a certain percentage of high-speed broadband in several countries (see Table 6) have implied that policymakers have considered that broadband can bring a number of benefits to countries. Lastly, compared with Japan and Korea, the average broadband speed in EU member states still lags behind (as of Q4 2012⁹). To improve its competitiveness in the global market, the EU needs to improve its high-speed broadband infrastructure to catch up with other developed countries in other regions.

⁹ Based on the data from the Ookla website

Table 6: Broadband targets (speed and penetration) in the EU and selected member states

Country	Date of policy	Target			Comment
		Speed	Penetration	Date	
EU	May 2010	100% for 30 Mbps and 50% for 100 Mbps		By 2020	Source ¹⁰
UK	February 2013	100% for 2 Mbps and 90% for 24 Mbps		By 2015	Source ¹¹
Sweden	November 2009	100 Mbps	40% in 2015 and 90% in 2020		Source ¹²
France	November 2011	High-speed broadband	70% by 2020 and 100% by 2025		Source ¹³
Italy	Late 2008 (integrated with the EU plan in 2010)	At least 50% for 100 Mbps		By 2020	Source ¹⁴
Spain	July 2010	80% for 10 Mbps and 50% for 100 Mbps		By 2015	Source ¹⁵
Germany	February 2009	50 Mbps	75% by 2014 and 100% as soon as possible		Source ¹⁶

Source: Taken from Paper 5/Compiled by the authors from various sources

These reasons suggest that there is a need to invest in high-speed broadband either through the public sector or the private sector. Further analyses are therefore presented to explain which policy tools would be useful to support the development of high-speed broadband infrastructure and encourage the use of high-speed broadband in the EU. The analyses from Papers 1, 2, 3 and 4 emphasise some important aspects to facilitate the development of high-speed broadband. The analyses covers both the supply and the demand sides, which are market definition, infrastructure sharing and infrastructure competition, the lack of focus on demand side policy and the determinants of broadband adoption and usage. The next section aims to analyse this with other aspects not covered by Papers 1, 2, 3 and 4.

Market definition is the first step before imposing any regulation, including broadband regulation; market definition should therefore take the new market dynamic into consideration and be technology neutral. (Paper 1)

A regulatory framework for defining the relevant market covers not only the broadband market but also the telecommunications sector in general. The European Commission has recently released the latest version of its Recommendation on relevant product and service markets

¹⁰ The European Commission, 2010

<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0245:FIN :EN:PDF>

¹¹ Department for Culture, Media and Sport, 2013

<https://www.gov.uk/government/policies/transforming-uk-broadband>

¹² Ministry of Enterprise, Energy and Communications,

2009 <http://www.government.se/content/1/c6/13/49/80/112394be.pdf>

¹³ Ministry of Economy and Finance., 2011

<http://www.ladocumentationfrancaise.fr/var/storage/rapports-publics/114000700/0000.pdf>

¹⁴ Ministry of Economic Development

http://www.sviluppoeconomico.gov.it/images/stories/pdf_upload/DIGITAL-ITALY.pdf

¹⁵ Ministry of Industry, Tourism and

Trade. https://www.planavanza.es/InformacionGeneral/Estrategia2011/Documents/Estrategia_2011-2015_PA2.pdf

¹⁶ Ministry of Economics and Technology, 2009

<http://www.zukunft-breitband.de/DE/breitbandstrategie,did=523872.html>

within the electronic communications sector susceptible to ex ante regulation (see EC, 2014). According to the new Recommendation, the markets have been reduced from seven in the 2007 version to only four in the latest version in 2014. According to the Annex of the EC (2014) Recommendation on relevant product and service markets within the electronic communications sector susceptible to ex ante regulation, the four markets are Market 1: Wholesale call termination on individual public telephone networks provided at a fixed location, Market 2: Wholesale voice call termination on individual mobile networks, Market 3: a) Wholesale local access provided at a fixed location, b) Wholesale central access provided at a fixed location for mass-market products and Market 4: Wholesale high-quality access provided at a fixed location. In this recommendation, according to the 2014 version, two of the four markets are related to the broadband market and the other two to call termination. The change to this Recommendation is also in line with the results from Paper 1, which was written before the release of the new Recommendation. The findings of the appended paper, concluded from several stakeholders in the public consultation in 2013, suggested that Markets 4, 5 and 6 from the 2007 Recommendations, which are related to the broadband market, need revision due to the unclear boundaries between them. Several contributions have also suggested the Recommendation be more technologically neutral. In relation to policy for high-speed broadband, history has shown that the broadband market and new technologies have developed continuously. A regulatory framework should continue to be updated and be flexible enough to fit with the changing broadband market and technologies. Defining the relevant market is very important for broadband policy because it is the first step of imposing the regulation on the supply side, particularly now when half of the markets in the 2014 Recommendation are related to broadband and high-speed broadband markets.

Infrastructure sharing or infrastructure competition can be used as a broadband policy tool, especially on the supply side. However, the decision to use infrastructure sharing or infrastructure competition should be based on the number of existing broadband infrastructures and the population in the area/region/country. (Paper 2)

Market competition is one of the important strategies of broadband policy on the supply side. In general, policymakers can encourage competition in the broadband market in two ways: competition within the same type of infrastructure (infrastructure sharing) and competition between different infrastructures (infrastructure competition). Which competition is better for broadband penetration has been hotly debated in the last decade (see Distaso et al., 2006, Höffler, 2007, Nardotto et al., 2012, and Gruber and Koutroumpis, 2013). With the development of NGN infrastructure, the decision on which types of policy tools to apply is crucial to the development of infrastructure for high-speed broadband. The findings from Paper 2 support the use of both infrastructure sharing and infrastructure competition as broadband policy tools. Nevertheless, the decision to choose one policy tool over another should be based on the number of existing broadband infrastructures and the population in the area/region/country. If the area is densely populated, for example, in the capital, where several technologies are already implemented, infrastructure competition should be used as the main strategy to expand high-speed broadband infrastructure. On the other hand, if the area is rural with no infrastructure or only one dominant technology, infrastructure sharing should be used

as the main strategy. In the case of a lack of investment in the rural area, public funding should be considered in combination with infrastructure sharing.

The supply and the demand side of broadband policy are important and interrelated and reinforce each other. Policymakers should encourage not only the supply side but also the demand side of broadband policy because the policies complement, not substitute, each other. (Paper 3)

According to the European Commission (2013), the percentage of fixed broadband adoption is still much lower than the percentage of fixed broadband coverage. In 2011, fixed broadband coverage was already as high as 95.7% in the EU; however, only 70% of those who could access it actually subscribed to broadband services. The main reasons for non-subscribers are either lack of interest in broadband service or lack of digital literacy. This situation implies that demand side policy is also important and should be addressed by policymakers who should implement demand side policy along with supply side policy. Findings from Paper 3 also support this argument. Based on the ICT ecosystem framework by Fransman (2007) in Section 3, while supply side policy can be applied through broadband infrastructure and services, demand side policy can facilitate broadband adoption through content and applications as well as end-users' incentives. With network externalities, the effects can be multiplied through re-enforcement between broadband supply and demand.

The timing of addressing the supply and demand side is also important. According to FSR (2011) and Belloc et al. (2012), demand side policy tends to have less effect or even insignificant impacts when there is low broadband diffusion. On the other hand, demand side policy has greater impact than supply side policy if the stage of broadband diffusion has reached a certain point. To support demand side policy, case studies in Korea and Sweden in Paper 3 showed that content and applications are crucial for these two countries to drive broadband demand. Online public services and new content and application development suited to the EU citizens' everyday lives should therefore be emphasised. In addition, the digital inclusion programme should be implemented to reduce the number of non-adopters.

Mobile broadband has great potential to bring a number of benefits in the future; hence, understanding what determines mobile broadband adoption and usage can be very useful for broadband policy, especially on the demand side. (Paper 4)

With the development of LTE technology in recent years, mobile broadband is able to generate much faster broadband services. In addition, the recent explosive growth of the smartphone has led to a significant increase in mobile broadband adoption. Hence, mobile broadband has great potential to bring a number of benefits and can be used in broadband policy, for example, to contribute to the economy or reduce digital divide gaps in a region. Mobile broadband can also facilitate the EU achieving its broadband targets. Furthermore, mobile networks are usually easier to roll out and require less investment than fixed broadband networks. With these benefits of mobile broadband, understanding what determines mobile broadband adoption and usage can be very useful for the demand side of broadband policy. For example, understanding the determinants can support policymakers in choosing the tools for demand side policy as well as specifying their target groups. For example, according to the findings in Paper 4 on adoption,

frequent use of internet significantly increases mobile broadband adoption. Hence, the demand side policy that should be implemented should be that which supports frequent use of the internet. The support can be through everyday activities, such as online public services, online shopping and e-banking. On the usage side, one of the findings from Paper 4 shows that citizens with a low income tend to use applications that can reduce their costs compared with using an offline service. Policymakers could therefore persuade this low income group by pointing out the benefits of using mobile broadband, which could save them expenditure on many services. Alternatively, policymakers could have subsidy programmes to support those who are less likely to adopt mobile broadband, such as older citizens and those on a low income.

All five of the appended papers have shown some applications to develop broadband policy in the EU. However, broadband policy is a broad topic and there are several policies to support the EU broadband targets. The next section will describe aspects that have not been covered by the appended papers.

6.2 Analysis of other broadband policies in the EU

The findings from the appended paper cover a number of issues of broadband policy in the EU, such as market definition, infrastructure sharing and infrastructure competition, the need to emphasise demand side policy, and the benefits of high-speed broadband. However, there are still more concerns regarding EU broadband policy, such as the inclusion of broadband in the universal service obligation, the lack of investment in high-speed infrastructure networks and the fragmentation of the EU. The purpose of this section is to analyse other topics that have not been covered by the appended papers. Table 6 in Section 6.1 shows that the targets of the EU's broadband policy and of the member states are mostly to have 100% coverage for standard broadband and high numbers for ultra-fast broadband. According to the appended papers, policies analysed in Section 6.1 can facilitate both standard and ultra-fast broadband coverage and broadband adoption. However, more policies need to be considered in order to guarantee the broadband targets or at least come as close to the targets as possible. Universal service obligation (USO) is one policy tool to ensure broadband access for the citizens of a country or region. However, there are limitations on using universal service concepts with broadband services.

Is USO the right direction to achieve broadband targets in the EU?

USO is generally used in network utilities sectors and in the telecommunications sector. The definition of USO is '*a defined minimum set of services of specified quality which is available to all users independent of their geographical location and, in the light of specific national conditions, at an affordable price*' (EC, 1998). Cross-subsidisation is traditionally used as a funding mechanism for the USO programme. In the EU, USO has been applied to some telecommunications services, such as public pay phones and access at fixed location and provision of telephone service. There are several benefits of supporting the use of USO to help the EU achieve its broadband targets. For example, USO can be a good policy tool to reduce the digital divide and facilitate the information society, and broadband may be necessary to use particular services. However, the use of USO on broadband services has been discussed and debated in the EU from the mid-2000s until now. The reasons for the European Commission

not including broadband in USO is not to distort the market while there are still alternative market mechanisms, financial instruments and other public intervention tools (EC, 2011). The market distortion from using USO is likely to slow down broadband development, particularly for fast and ultra-fast broadband. Nevertheless, each member state can choose to apply USO to broadband services with its own justification, country by country. According to the OECD (2012), Finland, Malta and Spain have decided to include broadband services in the scope of USO. With the possibility of market distortion, there are other available policy tools to achieve broadband targets than USO. Direct public funding and public-private partnership are among those alternatives.

Direct public funding and public-private partnership

Direct public funding and public-private partnership mechanisms can be implemented at many levels, depending on the involvement between the public and private sectors. If there is no involvement from the private sectors, then it is only direct public investment. If there is some involvement from the private sectors, the interaction between the public and private sectors is considered a public-private partnership (PPP). In the EU, many member states have already used both direct public investment and PPP as their policy tools. According to FSR (2011), Sweden and France are the obvious examples regarding direct public investment. The investment in both countries was to build a backbone infrastructure. In Sweden, the main approach of rolling out a fibre network for high-speed broadband was publicly funded through municipalities. In addition, the national regulator needs to ensure that the wholesale services leased to telecommunications operators are non-discrimination. In France, more than 1 billion euros have been provided by local authorities to build the backbone infrastructure since 2003. For PPP, there are several types of interaction between the public and private sectors. Nevertheless, in the EU, the common concept is that the public sector participates in the planning and co-financing process while the private sectors are responsible for building and operating the networks as well as selling the services. Examples of PPP in the EU are the CityNet project in the Netherlands, FibreSpeed and Connected Community in the UK and many cases in France (FSR, 2011, and Belloc et al., 2012). Furthermore, public utility companies, such as electricity companies, can also play an important role in providing fast and ultra-fast broadband infrastructure. According to Falch and Henten (2009), in Denmark, Iceland and Sweden, their electricity companies have provided infrastructure for service providers, such as broadband, television broadcast and IP telephony.

The benefits of direct public investment and PPP are that it is likely that high-speed broadband development will be guaranteed in the long run; however, it is questionable whether the funding should be spent on high-speed broadband infrastructure rather than other projects. Nevertheless, the decision to implement direct public investment and PPP should depend on the current situation of each member state and whether there is already enough supply and demand for broadband services in the areas or countries (Kongaut, 2014). So far, USO, direct public funding and PPP are among the supply side policy tools. There are also a number of demand side policy tools that can facilitate the EU achieving its broadband targets.

What about demand side policy tools?

As mentioned in Section 3.2, there are a number of demand side policy tools, such as encouraging public online services, IT education programmes, and demand subsidies or tax reductions for broadband or its complementary services. Normally, demand side policies can be implemented along with supply side policies regardless of the scenario of broadband infrastructure. Nevertheless, the impacts of the demand side may vary depending on the scenario of broadband infrastructure in some specific cases. For example, in rural areas, if there is no broadband infrastructure at all, the effect of using the demand side policy may be insignificant. While most demand side policy tools can be used with citizens in general, these demand side policy tools can also be implemented for specific target groups, for example, providing IT education programmes to citizens in particular sectors or of a particular age, and demand subsidies to those on a low income. The target groups for demand side policy can also differ in each member state.

6.3 Discussion

According to the reviews of the literature in Section 3 and the analysis in Sections 6.1 and 6.2, the research questions of this thesis can be answered and discussed as follows.

1) What are the possible broadband policies for the EU to achieve its target on high-speed broadband access and adoption?

First, as suggested by an analysis in the appended papers in Section 6.1, broadband policy should emphasise both (high-speed) broadband access and adoption. This implies that supply side policy and demand side policy should both be enhanced. Nevertheless, the decision to choose which policy tools to use depends on the stage of broadband development in the country. There are 28 member states in the EU with different broadband coverage and adoption rates. The focus on using supply and demand side policy varies between member states because of the different stages of broadband development. One broadband policy may therefore fit one member state but not others. Accordingly, three scenarios are proposed to discuss how to implement different broadband policy tools: a lack of high-speed broadband infrastructures, only one dominating high-speed broadband infrastructure and moderate to several broadband infrastructures.

According to Table 7, in the first scenario there is a lack of high-speed broadband infrastructure. This situation can be seen in rural areas where broadband infrastructure is difficult to reach. In this scenario, broadband infrastructure needs to be implemented as soon as possible. It is crucial for the policymakers in this scenario to guarantee broadband infrastructure in the areas. On the supply side, direct public investment or public-private partnerships may need to be considered to provide sufficient broadband infrastructure. Wireless technology can also be used to support areas through which fixed broadband cannot pass. If a country has many areas like this as in this scenario, USO should be considered as an alternative approach. Later on, the use of infrastructure sharing can facilitate competition between the services. Nevertheless, if there is a need for investment from the private sectors, infrastructure sharing should be used with care. On the demand side, in this situation, the supply of broadband infrastructure is likely to later

turn into a monopoly; policymakers should therefore ensure that the price of the services is affordable. Demand side subsidies or tax reductions for the target groups can be implemented if necessary. Digital literacy and internet security can also encourage the demand side in general, including in this scenario.

Table 7: Three scenarios of broadband infrastructure

Scenario(s) of broadband development	Example(s) of scenario	Recommended broadband policy
Lack of high-speed broadband infrastructures	Mostly rural area of a country, area with low population density	<i>Supply side:</i> Direct public investment or public-private partnership, broadband-USO and infrastructure sharing <i>Demand side:</i> Demand side subsidies, tax reduction, digital literacy campaign and internet security programme
One dominating high-speed broadband infrastructure	Depending on the existing infrastructure in a(n) area/country	<i>Supply side:</i> Infrastructure sharing and the support of mobile broadband coverage <i>Demand side:</i> IT skill programmes and campaigns to support online usage (e-banking and e-commerce)
Moderate to several broadband infrastructures	Most capital cities, urban areas that are densely populated	<i>Supply side:</i> Market-related mechanism policy tools such as infrastructure competition <i>Demand side:</i> Policy to increase public online service and increase public online area

Source: Compiled by author

In the second scenario, there is only one dominating high-speed broadband infrastructure. This scenario can occur differently depending on the existing infrastructure in the countries. On the supply side, infrastructure sharing can be used to facilitate competition between the services. On the other hand, infrastructure competition may not fit in this scenario as implementing another high-speed broadband infrastructure directly by the public sector may lead to high cost duplication. Nevertheless, adaptation of other public utilities such as the electricity utility is possible. Alternatively, mobile broadband can be used as another technology for the consumer. It is therefore crucial for the policymakers to ensure wireless coverage in the dominant area. With the supply and demand sides of the broadband market being closely related, the use of demand side policy can also support competition on the supply side. There are a number of policy tools that can increase the demand for broadband, for example, IT skill programmes and campaigns to support online usage, such as e-banking and e-commerce.

The last scenario has moderate to several broadband infrastructures. This scenario can be seen in capital cities and urban areas that are densely populated. Assuming that there is already sufficient infrastructure and competition in the area, the goal of policymakers is to maintain this situation and ensure demand from the citizens. Moreover, in this scenario, broadband policy can be used to support the information society and a better quality of life for people in the area. On the supply side, market mechanism tools should mostly be implemented not to distort the market and maintain the healthy supply situation. Infrastructure competition can be used as a

policy guideline in this scenario. With the competition from different technologies, such as cable, fibre and wireless, the prices of high-speed broadband services are likely to go down. At the same time, with the competition from different technologies, new innovations and services can also be developed. On the demand side, policy has a great effect when there is enough broadband diffusion (Belloc et al., 2012). In addition, high demand can drive the development of new content and applications that ultimately affect broadband services and infrastructure. In this scenario, demand side policy can be made by increasing public online services (e-government, e-education and e-health), increasing public online areas, such as parks and libraries, as well as reducing the non-adopter groups.

Furthermore, there are a number of policy tools that should be implemented regardless of the scenario. On the supply side, for example, market definition and relevant market, which is the first step of market intervention, should be carefully defined and implemented regardless of the scenario. In addition, the policy tools related to spectrum management are important for the development of mobile broadband. On the demand side, policies for digital literacy and internet security can benefit consumers regardless of the scenario; these policy tools should therefore be implemented along with other policy tools in each scenario (Kongaut, 2014).

As suggested by Table 7, broadband policy should be implemented differently based on the stage of broadband development in a country. As broadband development varies among member states in the EU, flexibility of the broadband policy from the European Commission is very important. While the European Commission should allow some flexibility for each member state, at the same time, it should provide some guidelines for member states to be able to choose the right policy tools. Furthermore, many studies compare the EU policy model with those of other countries, especially the US and leading Asian countries such as Japan and Korea. The question is raised on which policy tools the EU should follow other countries and what the differences are between the EU and those leading countries. It is crucial to point out the main difference between the EU and other countries. While countries like the US, Korea and Japan have a small number of telecommunications operators, there are 28 member states, more than 20 national regulators and a number of telecommunications operators in the EU. Back to the first quote from the start of this thesis, “508 million people, 28 Member States and 1 broadband policy?” *Filippo Munisteri, Economic Analyst, DG CONNECT, European Commission (2013)*. The key to the answer to this quote is the flexibility of the broadband policy because, unlike the US, Japan and Korea, the EU is still fragmented¹⁷ and consists of several member states that have their own interests. It is therefore almost impossible for the EU to follow the models of the US, Japan or Korea. It is very important for the European Commission to set policy and regulation that allow some flexibility for each of the member states. Nevertheless, some of the policy tools from these countries may be useful or adapted as best practices, such as a number of demand side policy programmes in Korea.

¹⁷ Even though the European Commission is trying to create an EU single market that aims to solve this fragmentation, the EU single market may take a long time and is outside of the scope of this thesis. The recommendation from this thesis is therefore based on the EU still being as fragmented as it is currently.

2) *What is the relationship between high-speed broadband and economic outputs?*

While the second research question seems to be more straightforward than the first, it is important to address this research question to justify the investment for overall benefits to the countries and regions. The reviews of the literature on broadband contributions to the economy in Section 3 point in the same direction that higher broadband penetration leads to greater economic outputs (Lehr et al., 2005, Crandall et al., 2007, Koutroumpis, 2009, Czernich et al., 2011, and Thompson Jr. and Garbacz, 2011). However, broadband penetration on its own cannot fully explain the impacts on economic outputs. Transmission speed and quality of broadband currently differ across countries. For example, if two countries have the same amount of broadband penetration but one country has an average speed of broadband below 1 Mbps and another has an average speed of broadband higher than 30 Mbps, will the impacts of broadband on the economy be the same in these two countries? If not, which countries have greater benefits? Middleton (2013) has mentioned that there are a number of characteristics to consider for broadband services, such as transmission speed, type of connection, quality of service and service provider. Broadband penetration has recently also become more stable and mature in many developed countries. The interests of broadband contributions to the economy have therefore moved from broadband penetration to transmission speed. Paper 5, along with studies from Katz et al. (2010), Forzati and Mattsson (2012), Rohman and Bohlin (2012) and Mack (2014), has shown that there are indeed *significant positive impacts* of transmission speed on the economy. In addition to other studies, Paper 5 has suggested that the effects of broadband speed are stronger in lower income than in higher income countries among the OECD members. With the evidence from this thesis along with previous studies, it is crucial for the policymakers to ensure high-speed broadband infrastructure and encourage broadband adoption for the citizens to ultimately develop their economies and societies.

7. Conclusion

7.1 Summary

The thesis has so far analysed several aspects of broadband policy in the EU as well as investigated the impacts of faster broadband services on the economy. First, two main research questions have been proposed: “*What are the possible broadband policies for the EU to achieve its target on high-speed broadband access and adoption?*” and “*What is the relationship between high-speed broadband and economic outputs?*”. Quantitative and qualitative approaches have then been applied in an attempt to answer these two research questions. The overall findings of this thesis have suggested that, for the first research question, both the supply and the demand side of broadband policy are important. They are interrelated and reinforce each other. Policymakers should therefore encourage not only the supply side but also the demand side of broadband policy because these policies complement rather than substitute each other. There are also 28 member states in the EU that differ in terms of broadband coverage and adoption. One broadband policy tool may fit one member state but not the others. In addition, the focus on using supply and demand side policies can vary depending on the stage of broadband development. On the findings relating to the second research question, the study has found that there are significant positive impacts of greater broadband speed on the economy. The connections from broadband policy, broadband infrastructure and service and economic outputs were suggested earlier in Section 1. Thus, the findings from the second aim also imply the importance of broadband policy, which ultimately affects the economic outputs. The findings regarding the first research question are mainly supported by FSR (2011) and Belloc et al. (2012) while the results relating to the second research question are consistent with those of Katz et al., (2010), Thompson Jr. and Garbacz (2011) and Rohman and Bohlin (2012). Lastly, the contributions of this thesis are mainly suggestions of broadband policy for the EU to be able to achieve its Digital Agenda targets, particularly on broadband access and broadband adoption areas. From the academic point of view, this thesis not only adds more empirical evidence on the hotly debated topic, such as service and platform competition, but also fills the gap of the other parts of broadband policy research that are still limited, such as the concept of SMP, the relevant market and the importance of demand side policy. Furthermore, the thesis also adapts previous studies, for example, the study of broadband penetration and broadband adoption and usage, to fit with new types of technologies, the study of broadband speed and determinants of smartphone adoption as in the thesis.

7.2 Policy recommendation and future research

In terms of policy recommendations, in relation to the first research question, the European Commission should address both the supply and the demand side and have a broadband policy that is flexible. The flexibility will leave room for the national regulators of the member states to provide a broadband policy that suits the stage of broadband development in each member state. In addition, the European Commission can provide a guideline on how to implement broadband policies under different conditions to support also the member states. For the policy recommendation, according to the findings from the second research question, policymakers at both country and regional levels should emphasise the importance of greater quality of

broadband services, including faster speed. Hence, broadband policies that aim to support high-speed broadband infrastructure and content and applications that require a high-speed connection are very important.

For future research, there are a number of possibilities to extend the knowledge from the thesis. On the supply side of broadband policy, most studies have investigated at macro level how the policy tools affect broadband infrastructure, services or investment in the whole region or a group of countries. A case study of a specific country, however, could better analyse it on a case by case basis. In addition, there have recently been great improvements in the development of wireless technology. Hence, the analysis of wireless infrastructure and the substitution between fixed and mobile broadband is also interesting. On the demand side of broadband policy, while there are a number of studies on broadband determinants, the analysis of how particular policy tools affect broadband adoption is still limited. With countries adopting more tools on the demand side, the availability of data can support this type of research in the future. Lastly, on the study of the relationship between broadband speed and economy, this thesis has only covered the impacts in a generalised way through all the countries in the OECD. The effect, however, can vary in different countries and different sectors. Thus, future research on the micro level data of broadband speed and a case study analysis of the impacts in a particular area are needed.

References

- Atkinson, R., Castro, D., Ezell, S. and Ou, G. 2009. The need for speed: The importance of next-generation broadband networks. The Information Technology and Innovation Foundation (ITIF). Washington, D.C.
- Batura, O. 2014. Universal service in the EU information society policy. *Info* 16(6), 24-34.
- Bauer, J. M., Kim, J. and Wildman, S. S. 2003. Broadband uptake in OECD countries: Policy lessons and unexplained patterns. *Paper presented at the 14th European Regional Conference of the International Telecommunication Society, August 23-24, Helsinki.*
- Belloc, F., Nicita, A. and Rossi, M. A. 2012. Whither policy design for broadband penetration? Evidence from 30 OECD countries. *Telecommunications Policy* 36(5), 382-398.
- BEREC 2012. Draft BEREC Report on co-investment and SMP in NGA networks BEREC. BoR(11)69.
- Bouckert, J., Van Dijk, T. and Verboven, F. 2010. Access regulation, competition, and broadband penetration: An international study. *Telecommunications Policy* 34(11), 661-671.
- Bourreau, M., Cambini, C. and Doğan, P. 2012. Access pricing, competition, and incentives to migrate from “Old” to “New” technology. *International Journal of Industrial Organization* 30(6), 713-723.
- Boyle, G., Howell, B. and Zhang, W. 2008. Catching up in broadband regressions: Does local loop unbundling really lead to material increases in OECD broadband uptake? *Paper presented at the 19th European Regional Conference of the International Telecommunication Society, September 18-20, Rome.*
- Briglauer, W. and Gugler, K. 2013. The deployment and penetration of high-speed fiber networks and services: Why are EU member states lagging behind? *Telecommunications Policy* 37(10), 819-835.
- Briglauer, W., Schwarz, A. and Zulehner, C. 2011. Is fixed-mobile substitution strong enough to de-regulate fixed voice telephony? Evidence from the Austrian markets. *Journal of Regulatory Economics* 39(1), 50-67.
- Cambini, C. and Jiang, Y. 2009. Broadband investment and regulation: A literature review. *Telecommunications Policy* 33(10-11), 559-574.
- Cambini, C. and Silvestri, V. 2013. Investment sharing in broadband networks. *Telecommunications Policy* 37(10), 861-878.
- Caldwell, B. 1980. Positivist philosophy of science and the methodology of economics. *Journal of Economic Issues* 14(1), 53-76.

Cerno, L. and Pérez Amaral, T. 2006. Demand for internet access and use in Spain. In: Preissl, B. and Müller, J. (Eds.), *Governance of Communication Networks: Contributions to Economics*, Physica-Verlag: Springer, 333-353.

Crandall, R., Lehr, W. H. and Litan, R. 2007. The effects of broadband deployment on output and employment: A cross-sectional analysis of U.S. data. *Brookings Institution working paper*. Washington, D.C.

Cremer, H., Gasmi, F., Grimaud, A. and Laffont, J. J. 2001. Universal service: An economic perspective. *Annals of Public and Cooperative Economics* 72(1), 5-43.

Czernich, N., Falck, O., Kretschmer, T. and Woessman, L. 2011. Broadband infrastructure and economic growth. *The Economic Journal* 121(May), 505-532.

De Ridder, J. 2007. Catching-up in broadband – What will it take? OECD, Paris.

De Streel, A. 2008a. Current and future European regulation of electronic communications: A critical assessment. *Telecommunications Policy* 32(11), 722-734.

De Streel, A. 2008b. The relationship between competition law and sector specific regulation: The case of electronic communications. *Reflets et perspectives de la vie économique* 47(1), 55-72.

Distaso, W., Lupi, P. and Manenti, F. M. 2006. Platform competition and broadband uptake: Theory and empirical evidence from the European Union. *Information Economics and Policy* 18(1), 87-106.

European Commission (EC) 1998. Directive 98/10/EC of the European Parliament and of the Council of 26 February 1998 on the application of open network provision (ONP) to voice telephony and on universal service for telecommunications in a competitive environment. L101/24. April 1998.

European Commission (EC) 1999. eEurope – An information society for all. Communication on a Commission Initiative for the special European Council of Lisbon. COM(1999) 687 final, December 1999.

European Commission (EC) 2000. Regulation (EC) 2887/2000 of the European Parliament and of the Council on unbundled access to the local loop. Regulation (EC) 2887/2000, December 2000.

European Commission (EC) 2001. eEurope 2002 – Impact and priorities. Communication from the Commission to the Council and the European Parliament. COM(2001) 140 final, March 2001.

European Commission (EC) 2002. eEurope 2005 – An information society for all. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2002) 263 Final. May 2002.

European Commission (EC) 2005. i2010 – A European information society for growth and employment. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. COM(2005) 229 Final. June 2005.

European Commission (EC) 2010. A digital agenda for Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2010) 245 final/2, August 2010.

European Commission (EC) 2011. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Universal service in e-communications: report on the outcome of the public consultation and the third periodic review of the scope in accordance with Article 15 of Directive 2002/22/EC. COM(2011) 795 final. November 2011.

European Commission (EC) 2013. Broadband lines in the EU: situation at 1 July 2012. Communications Committee Working Document. DG CNECT/F4, February 2013.

European Commission (EC) 2014. Commission recommendation on relevant product and service markets within the electronic communications sector susceptible to ex ante regulation in accordance with Directive 2002/21/EC of the European Parliament and of the Council on a common regulatory framework for electronic communications networks and services. C(2014) 7174 final, October 2014.

European Commission (EC) 2015. Digital Single Market Strategy: European Commission agrees areas for action. European Commission – Press release. IP/15/4653. Retrieved on 24 April 2015 from http://europa.eu/rapid/press-release_IP-15-4653_en.htm

Falch, M., Saugstrup, D. and Schneider, M. 2006. 'How to achieve the goal of broadband for all'. In: Preissl, B. and Müller, J. (Eds.), *Governance of Communication Networks, Connecting Societies and Markets with IT*, Heidelberg, Physica-Verlag. pp. 203-226.

Falch, M., and Henten, A. 2009. Achieving universal access to broadband. *Informatica Economica* 13(2), 66-174.

Forzati, M. and Mattsson, C. 2012. Socio-economic effects of FTTH/FTTX in Sweden. *Proceedings of the 14th International Conference on Transparent Optical Networks (ICTON 20s12)*, 2-5 July 2012, Coventry.

Fransman, M. 2007. Innovation in the new ICT ecosystem. *Communication & Strategies* 68, 89-110.

FSR (Florence School of Regulation). 2011. Study on Broadband Diffusion: Drivers and Policies. IRG: Independent Regulators Group, following the terms of reference within IRG(11)11 issued on 31 May 2011.

Funk, J. L. 2005. The future of the mobile phone internet: An analysis of technological trajectories and lead users in the Japanese market. *Technology in Society* 27(1), 69-83.

- Garcia-Murillo, M. 2005. International broadband deployment: The impact of unbundling. *Communications & Strategies* 57, 83-105.
- Goldfarb, A. and Prince, J. 2008. Internet adoption and usage patterns are different: Implication for the digital divide. *Information Economics and Policy*, 20(1), 2-15.
- Grosso, M. 2006. Determinants of broadband penetration in OECD nations. *Paper presented at the Australian Communications Policy and Research Forum*, Sydney.
- Gruber, H. and Koutroumpis, P. 2013. Competition enhancing regulation and diffusion of innovation: The case of broadband networks. *Journal of Regulatory Economics* 43, 168-195.
- Grzybowski, L., Nitsche, R., Verboven, F. and Wiethaus, L. 2014. Market definition for broadband internet in Slovakia – Are fixed and mobile technologies in the same market? *Information Economics and Policy* 28, 39-56.
- Hauge, J. A. and Prieger, J. E. 2010. Demand-side programs to stimulate adoption of broadband: What works? *Review of Network Economics* 9(3), Article 4.
- Hoernig, S., Bourreau, M. and Cambini, C. 2015. Fixed-mobile substitution and termination rates. *Telecommunications Policy* 39(1), 65-76.
- Hou, L. 2008. The Assessment of Collective SMP: Lessons Learned from the First Round of Market Review. *Proceedings of the First Annual Conference on Competition and Regulation in Network Industries (CRNI)*, 28 November 2008, Brussels.
- Höfler, F. 2007. Cost and benefits from infrastructure competition. Estimating welfare effects from broadband access competition. *Telecommunications Policy* 31(6-7), 401-418.
- ITU. 2012. Impact of broadband on the economy. Broadband series. Telecommunication Development Sector. ITU, Geneva.
- Izsak, K. and Edler, J. 2011. ‘Trends and challenges in demand-side innovation policies in Europe’. Thematic report 2011 under specific contract for the integration of INNO policy TrendChart with ERAWATCH (2011-2012). Technopolis-group. Brussels.
- Katz, R. L. 2012. *The impact of broadband on the economy: research to date and policy issues*, Geneva: International Telecommunication Union, April 2012.
- Katz, R. L., Vaterlaus, S., Zenhäusern, P. and Suter, S. 2010. The impact of broadband on jobs and the German economy. *Intereconomics: Review of European Economic Policy* 45(1), 26-34.
- Kelly, T. and Rossotto, C. M. (Eds.). 2012. *Broadband strategies handbook*. Washington DC: The World Bank.
- Kongaut, C. 2014. Broadband Policy and the EU Digital Agenda: Demand and Supply Dimensions of Ultra-fast Internet. *Thesis for the degree of licentiate of philosophy*. Chalmers University of Technology, Gothenburg.

- Koutroumpis, P. 2009. The economic impact of broadband on growth: A simultaneous approach. *Telecommunications Policy* 33(9), 471-485.
- LaRose, R., Gregg, J., Strover, S., Straubhaar, J. and Carpenter, S. 2007. Closing the rural broadband gap: Promoting adoption of the Internet in rural America. *Telecommunications Policy* 31(6-7), 359-373.
- Lehr, W. H., Osorio, C. A., Gillett, S. E. and Sirbu, M. A. 2005. Measuring broadband's economic impact. *Proceedings of the 33rd Research Conference on Communication, Information, and Internet Policy (TPRC)*, September 23-25, Arlington, VA.
- Mack, E. A. 2014. Businesses and the need for speed: The impact of broadband speed on business presence. *Telematics and Informatics* 31(4), 617-627.
- Madden, G. and Simpson, M. 1997. Residential broadband subscription demand: An econometric analysis of Australian choice experiment data. *Applied Economics*, 29(8), 1073-1078.
- Munisteri, F. 2013. Broadband policy development and implementation in the EU, Presentation for ITU Asia Pacific Centre of Excellence Training, October 2013.
- Middleton, C. 2013. Beyond broadband access: What do we need to measure and how do we measure it? In: R. D. Taylor and A. M. Schejter (Eds.), *Beyond broadband access: Developing data based information policy strategies* (pp. 9-22). New York: Fordham University Press.
- Never, H. and Preissl, B. 2008. The three-criteria test and SMP: How to get it right. *International Journal of Management and Network Economics* 1(1), 100-127.
- Nitsche, R. and Wiethaus, L. 2011. Access regulation and investment in next generation networks – A ranking of regulatory regimes. *International Journal of Industrial Organization* 29(2), 263-272.
- OECD. 2012. Working Party on Communication Infrastructure and Services Policy: Universal Service Policies in the Context of National Broadband Plans. DSTI/ICCP/CISP(2011)10/Final. OECD.
- Okazaki, S. 2006. What do we know about mobile internet adopters? A cluster analysis. *Information and Management* 43(2), 127-141.
- Orviska, M. and Hudson, J. 2009. Dividing or uniting Europe? Internet usage in the EU. *Information Economics and Policy* 21(4), 279-290.
- Pellegrino, G. and Klemann, R. 2012. Get up to speed: How developed countries can benefit from deploying ultrafast broadband infrastructures. *White Paper February 2012*, Cisco Internet Business Solutions Group (IBSG).
- Prieger, J. E. 2013. The broadband digital divide and the economic benefits of mobile broadband for rural areas. *Telecommunications Policy*, 37(6-7), 483-502.

- Raja, S., Kim, Y. and Kelly, T. 2010. Building broadband: Strategies and policies for the developing world. Global Information and Communication Technologies Department of World Bank, Washington D.C.
- Rohman, I. K. and Bohlin, E. 2012. Does broadband speed really matter as a driver of economic growth? Investigating OECD countries. *International Journal of Management and Network Economics* 2(4), 336-356.
- Rohman, I. K. and Bohlin, E. 2013. Impact of broadband speed on household income: Comparing OECD and BIC. *Proceedings of the 24th European Regional Conference of the International Telecommunication Society (ITS)*, October 20-23, Florence.
- Savage, S. J. and Waldman, D. M. 2005. Broadband internet access, awareness, and the use: Analysis of United States household data. *Telecommunications Policy* 29(8), 615-633.
- Srinuan, C., Srinuan, P. and Bohlin, E. 2012. An analysis of mobile Internet access in Thailand: Implications for bridging the digital divide. *Telematics and Informatics* 29(3), 254-262.
- Srinuan, C and Bohlin, E. 2013. Analysis of fixed broadband access and use in Thailand: Drivers and barriers. *Telecommunications Policy* 37(8), 615-625.
- Schwarz, A. 2007. Wholesale market definition in telecommunications: The issue of wholesale broadband access. *Telecommunications Policy* 31(5), 251-264.
- Teppayayon, O. 2012. *A comprehensive framework for future broadband policy: Assessing the EU initiatives*. Thesis for the degree of doctor of philosophy. Chalmers University of Technology.
- Thompson Jr., H. G. and Garbacz, C. 2011. Economic impacts of mobile versus fixed broadband. *Telecommunications Policy* 35(11), 999-1009.
- Vergara, S. and Grazzi, M. 2011. ICT access in Latin America: Evidence from household level. *MPRA Paper No. 33266*, Munich. Available online at <http://mpra.ub.uni-muenchen.de/33266/>
- Yamagawa, P., Cadillo, G. and Tornero, R. 2012. Critical factors for the expansion of broadband in developing countries: The case of Peru. *Telecommunications Policy* 36(7), 560-570.
- Yoo, C. S. 2014. U.S. vs. European Broadband Deployment: What Do the Data Say? University of Pennsylvania Law School, Institute for Law and Economics Research Paper No. 14-35.

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