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## Conference Paper

# An empirical study of unbundling regulation on broadband adoption in OECD countries: What can we learn for future regulation?

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# **The 19th ITS Biennial Conference 2012**

## **“Moving Forward with Future Technologies: Opening a Platform for All”**

18 - 21 November 2012, Thailand

**An Empirical Study of Unbundling Regulation on Broadband Adoption in OECD  
Countries: What Can We Learn for Future Regulation?**

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# **An Empirical Study of Unbundling Regulation on Broadband Adoption in OECD Countries: What Can We Learn for Future Regulation?**

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## **Abstract**

Broadband adoption is considered one of the drivers of both economic and social development. Local loop unbundling (LLU) regulation is one of the main strategies to open access to an incumbent's bottleneck network in order to soften its monopoly power and encourage competition in the digital subscriber line (DSL) broadband market. Many studies, however, suggest that LLU regulation can slow down new infrastructure investment. Fibre optic technology is also increasingly becoming an option for the next generation network (NGN). This development is turning out to be the new challenge for regulators, incumbents and new entrants. With the similarities to DSL broadband and the move towards technology neutrality, regulators may also be able to adjust their future next generation access (NGA) regulation by learning from the strengths and weaknesses of LLU regulation. This paper therefore aims to analyse the impacts of unbundling policy on various aspects of broadband adoption that can be presented as consumer welfare. The possible adaptation to NGA regulation is also discussed in this paper.

The empirical results of this study show that LLU regulation is one of the strategies to increase broadband adoption, particularly in the countries that have difficulty encouraging infrastructure competition. Nevertheless, several studies suggest that unbundling regulation reduces the incumbent's incentive to invest. With the dramatic growth in technologies, the main policy to increase broadband penetration should be competition between them, while unbundling regulation can be implemented carefully and differently in each country that has inefficiency that is harmful to consumers in its market from a monopoly incumbent. The decision to apply access regulation from DSL to fibre technology is therefore crucial to whether the regulator regulates the NGN market from the early stage of investment or waits for the NGN market to become more mature. Alternatively, the regulator can opt not to intervene in the market for a certain period of time, as access regulation can delay the growth in infrastructure investment.

**Keywords:** Local loop unbundling, broadband adoption, access regulation

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## 1. Introduction

In the past few decades, there has been a broad and mutual understanding that information and communications technology (ICT) is a crucial factor for economic growth. Broadband, in particular, is currently considered a massive driver of both economic and social development. According to the OECD (2009a), broadband networks not only directly support communication and transaction platforms for all sectors but also indirectly improve and generate new ideas for several sectors, such as construction, transportation, education and medical systems. The significant economic contribution by broadband penetration has also recently been studied by several previous researchers. For example, Fornefeld, Delaunay and Elixmann (2008) explained the significant impacts of broadband on productivity, growth and the economy. For empirical studies using an econometric approach, Koutrompis (2009) found that a 1% increase in broadband penetration had a positive effect of 0.025% on economic growth in the OECD countries. Katz and Avila's (2010) estimations yielded similar results with a coefficient of 0.018 for the positive impacts of broadband penetration on economic growth in the Latin America countries. These positive results of broadband penetration are also found in most other studies from the past decade.

As broadband penetration is crucial to the economic and social aspects in countries, an appropriate broadband policy needs to be implemented. National regulatory authorities (NRAs) in several countries have applied various broadband regulations to promote competition in the market. Local loop unbundling (LLU) regulation is one of the main strategies, especially in the European Union (EU), to open access to an incumbent's bottleneck<sup>2</sup> network in order to soften its monopoly power and encourage competition in the digital subscriber line (DSL) broadband market. Nevertheless, many studies, such as Bourreau and Dogan (2004), and Friederiszick, Grajek and Roller (2008), have recently suggested that LLU regulation can have the opposite effect, slowing down new infrastructure investment, and that it can usually be seen as a trade-off between a short-run framework (service-based competition) and a long-run framework (facility-based competition). However, unregulating network access may have a negative effect on consumer benefit as the problem of incumbents having full monopoly power may arise instead.

The fibre optic technology for the next generation network (NGN) is also starting to be developed and is becoming an alternative. This development is turning out to be the new challenge for regulators, incumbents and new entrants. With the similarity to DSL broadband and the move towards technology neutrality, the regulators may also adjust their future regulation of fibre technology by learning from the strengths and weaknesses of LLU regulation. The main aim of this paper is therefore to analyse several aspects of unbundling policy to provide a better understanding of how the policy affects not only broadband

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<sup>2</sup> In the telecom sector, a *bottleneck* is a situation in which a telecom operator has natural monopolistic power over its own services that are necessary for other operators to access and that cannot be economically duplicated.

penetration, which can be presented as consumer welfare, but also possible future adaptation to the next generation access (NGA) regulations. Furthermore, some countries have not implemented the LLU regulation; hence, they can also benefit from the analysis in this study.

The analysis of unbundling regulation follows previous literature; however, more details on policy are considered. Several previous studies have also focused on the trade-off between competition and investment. This study aims to stress consumer welfare in a static setting and discussions on future applications of NGA regulation. This paper is divided into eight sections, starting with this introduction. Section 2 provides a background to broadband, and Sections 3, 4 and 5 present the methodology, relevant theories and previous studies respectively. A model for econometric estimation is suggested in Section 6 while the result of the empirical evidence is presented in Section 7, including a discussion. Lastly, Section 8 presents a discussion on the possibility of unbundling policy for future NGA regulation and the conclusion.

## **2. Broadband Overview**

The term *broadband* generally refers to a service that provides high-speed internet access. Definitions have been provided by several institutions and, consequently, different definitions have been given by different organisations. For instance, according to its Recommendation I.113 for the ITU standardisation sector, the International Telecommunications Union (ITU) has provided the definition of broadband as “a transmission capacity that is faster than primary rate Integrated Services Digital Network (ISDN) at 1.5 or 2.0 Megabits per second (Mbps)” (ITU, 2003). The OECD, on the other hand, suggests that broadband is a service that provides Internet access with speeds above 256 Kbps (OECD, 2009b). Furthermore, several regulators and government bodies define broadband differently by country. Nevertheless, the main data used in this paper are mostly based on the OECD database. The definition of broadband used in this paper is therefore the one given by the OECD.

Broadband service can be implemented by various technologies; however, the dominant platform is DSL along with the growth of the cable modem platform. The OECD (2009b) also describes several technologies for broadband service as follows.

**Digital Subscriber Line (DSL):** DSL is the most widely available technology for broadband service. DSL technology has been adapted from the use of copper lines, which have been in place since the installation of fixed telephone. Currently, more than half of broadband connections are based on DSL technology.

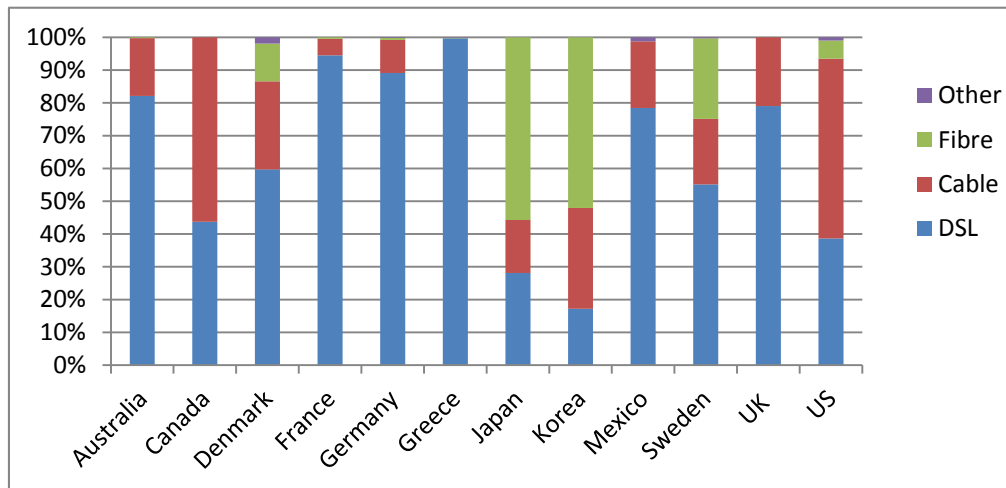
**Cable modem:** Cable modem is another technology for broadband service. Cable broadband has been developed from the cable infrastructure for the cable TV service. Cable technology has increased recently; however, its growth is still related to the existing cable TV infrastructure. Nevertheless, it has become the second most widely available technology in several countries after DSL.

Fibre to the home/node: Fibre to the home/node (FTTH/N) technology, which is referred to in this paper as NGN, is the technology deployed by fibre infrastructure. The coverage is still low compared with DSL and Cable technology; however, it currently plays a significant role in broadband service in Japan and South Korea and it has started to increase in countries like Denmark and Sweden. The interest in fibre networks lies in the high-speed data connection rate, which is believed to be an important social and economic driver for the future. The growth in fibre and its importance will create a new challenge for both operators and regulators to overcome in the near future.

Other technologies: Besides DSL, Cable modem and FTTH/N technologies, there are others that can provide fixed broadband services. These technologies include satellite broadband and fixed wireless broadband (WiMAX). These technologies only play a small part in general adoption by the population; however, they tend to be used more in rural area.

Mobile broadband: Mobile broadband technology is undergoing massive growth and has been very important to social and economic growth in recent years. Mobile broadband can be considered a complementary or substitute service, though not completely, to fixed broadband depending on the situation (OECD 2009b). Even though the access policy for mobile broadband, including fixed wireless, can be seen differently to that of fixed wired broadband, ultimately, substitution between mobile and fixed broadband is needed in order to set an optimal policy.

**Figure 1: Total broadband subscription by access technology<sup>3</sup> (June 2010)**



Source OECD (2011)

Figure 1 presents percentages of broadband subscriptions by technology in selected OECD countries. In 2010, most broadband subscriptions in the OECD countries, especially the EU, are still dominated by DSL technology. The exceptions are two countries from Asia, Japan

<sup>3</sup> This figure excludes wireless and mobile broadband subscriptions

and Korea, in which fibre technology dominates. Broadband subscriptions in two countries from North America, Canada and the US, are covered by DSL and Cable technologies with cable technology prevailing slightly. Interestingly, even though Sweden and Denmark are still dominated by DSL technology, the growth of fibre technology has increased significantly compared with other European countries. With the future transition of technology from DSL to fibre, learning the benefits and drawbacks of unbundling regulation on DSL could provide a better understanding of the regulation of NGN.

### **3. Methodology**

The methodology applied in this study is combined with discussions on theory and previous studies, and an empirical analysis. First, relevant theory and hypothesis are discussed and analysed along with previous literature. Next, the econometric estimations on panel data are applied to support the argument as empirical evidence. Finally, the conclusion and recommendation are suggested according to an analysis from theory, previous literature and empirical evidence.

### **4. Related Theory and Hypothesis**

As seen in Section 2, as the majority of broadband connections still rely on DSL technology, the advantages and disadvantages of unbundling regulation have been discussed for many years. There are two main concepts related to unbundling regulations. Both are part of the reasons regulators decide to regulate the DSL broadband market. An understanding of the relevant theory and hypotheses can provide greater insight into previous studies and the discussion in this study. This theory and hypothesis can even be adapted slightly and applied to the NGA regulation.

#### **4.1 One-Way Access Pricing Theory**

The OECD (2004) described the one-way access model as a situation in which a monopoly operator has an infrastructure that other operators need as input to provide their services. The one-way access pricing problem arises as a new entrant needs to compete in the retail market while purchasing incumbent wholesale services. In the DSL broadband market, even with the liberalisation of the telecom market, an incumbent still has a monopoly advantage by owning the standard fixed telephone line. On the other hand, small operators have to compete in broadband service in the retail market with an incumbent while buying access from an incumbent. Without intervention at the access level by the regulator, the incumbent is not only able to set the price as high as in the monopoly market but an incumbent also has no incentive to lease its network to rivals. The regulator then needs to regulate at the retail level, which is not desirable for regulators or operators. For these reasons, unbundling regulation intends to solve a problem of incumbent natural monopoly and support greater competition in the market.

However, many scholars have suggested that even though unbundling regulation encourages competition in the DSL broadband market, it can slow down future investment in other platforms (technologies/ infrastructures), especially fibre, which can provide higher speeds. This situation concerns a trade-off between competition within the same technology (service-based competition) and competition between different technologies (facility-based competition). It is therefore important for the regulator to set priorities depending on the situation in each country.

## **4.2 Ladder of Investment**

The Ladder of Investment hypothesis is proposed by Cave and Vogelsang (2003) and has been developed since 2001. The purpose of the Ladder of Investment is to solve the trade-off dilemma between service-based competition in the short run and facility-based competition in the long run. More precisely, the Ladder of Investment approach is a compromise between service-based competition and facility-based competition that supports access by new entrants to the incumbent network at a reasonable price while, at the same time, encouraging the new entrants to invest further in their own network without a big investment at one time, especially the first investment in access. Later on, NRAs will need to set the regulations to encourage and provide incentives to invest for both the incumbent and new entrants using access pricing and the limited period of time for new entrants to use the incumbent's access networks. Ultimately, according to the Ladder of Investment hypothesis, new entrants will be able to compete with the incumbents and invest in their own infrastructure as they become known in the market and have their own customers. However, many studies including Cave (2010) have mentioned that the last step for new entrants, which is having their own local loop, is not economically feasible.

Even though unbundling regulation can potentially delay investment and the Ladder of Investment hypothesis may not completely solve the service-based and facility-based trade-off problem, it can create more services in each ladder while leaving the incumbent to exploit its monopoly power is not an appropriate option. Moreover, if the replacement effect<sup>4</sup> to invest in the new infrastructure is too high for the incumbent, the incumbent will still prefer to gain its benefit from the existing infrastructure rather than investing in the new ones.

## **5. Previous Literature**

Due to the lack of literature on NGA regulation, it is important to learn about this type of access regulation from LLU regulation. During the last decade, studies on the effects of LLU regulation have been conducted several times with different methodologies, including a theoretical modelling approach, econometric analysis approach and qualitative case study approach. The discussions on the impacts of LLU regulation are usually either on broadband

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<sup>4</sup> Replacement effect in telecom can be defined as the effect of operators not investing in new infrastructure to replace old ones. For example, the more profit the incumbents make from the old infrastructure, the higher the replacement effect.



penetration or broadband investment. As this paper aims to focus on the static setting, this section discusses mainly the studies on the impacts on broadband penetration.

As many countries started to adopt LLU regulation from the early 2000s, the data did not become widely available until the mid-2000s. However, there is some early literature explaining the LLU regulation at the early stage. Bauer, Kim and Wildman (2003), and Garcia-Murillo (2005) obtained the cross-country data from 2001 and applied the various econometrics approaches to point out the determinants for broadband penetration. While Bauer, Kim and Wildman (2003) found that policy, including unbundling regulation, has a positive coefficient but insignificant effect on broadband penetration, Garcia-Murillo (2005) pointed out that LLU regulation is highly significant to broadband penetration, especially in middle income countries. Later on, more studies were conducted due to the greater availability of datasets. For example, Grosso (2006), De Ridder (2007), Boyle, Howell and Zhang (2008), and Bouckaert, Van Dijk and Verboven (2010) have obtained data from OECD countries to empirically analyse the impacts of LLU regulation. However, previous studies provide their results differently. While Grosso (2006) and De Ridder (2007) found that LLU regulation has a positive effect on broadband penetration, Boyle, Howell and Zhang (2008), and Bouckaert, Van Dijk and Verboven (2010) argue that the impacts of LLU regulation are insignificant and it is better for the regulator to encourage competition between different technologies. Nevertheless, the studies have different approaches to specifying the LLU regulation in their models.

Distaso, Lupi and Manenti (2006), and Höffler (2007) provided more neutral opinions with interesting theories to support their findings. They also applied the LLU prices as one of the factors to explain the impact of LLU regulation on broadband penetration. For Höffler (2007), the author suggested that inter-platform competition between DSL and cable technology has positive effects on broadband adoption; however, the author also pointed out, by estimating social welfare, that the benefit from inter-platform competition could be lost due to the cost of duplicating an existing infrastructure is higher. The author suggested that although the magnitude of intra-platform competition is less than that of inter-platform competition, it can prevent unnecessary infrastructure duplication costs. Interestingly, Distaso, Lupi and Manenti (2006) applied a theoretical model of oligopoly competition between different products to analyse how intra-platform competition and inter-platform competition affect broadband adoption. The authors supported their theoretical model with testing using empirical evidence. The econometric evidence also supports the theoretical model that inter-platform competition is a main factor for increasing broadband adoption while intra-platform competition is insignificant. Moreover, they found that a decreasing LLU price can increase broadband penetration, pointing out that it can indirectly encourage intra-platform competition.

Further discussion on the LLU price can be found in Madden, Bohlin and Ahmad (2011). The authors applied a benchmark approach and data envelopment analysis (DEA) of the LLU

price during the same period of time as this study, from 2002 to 2008, suggesting that the (cost-based) wholesale access price set by regulators is, on average, becoming more effective.

Along with empirical studies, qualitative studies, especially country case studies, have also been conducted during the last decade. For instance, De Bijl and Peitz (2008) commented that for countries with high inter-platform competition, access regulation can distort the broadband market and have a negative effect on the incentive for operators to invest in new infrastructure. Contrastingly, Picot and Wernick (2007) suggested that along with inter-platform competition, LLU regulation supports broadband penetration in Europe, especially in areas that lack other technologies. The authors also mentioned that although LLU regulation has an insignificant effect in Korea, there is open access regulation for cable modem technology instead. With the advantages and limitations of both quantitative and qualitative approaches, this study does not ignore the country-case study concept even though this paper is mainly based on empirical cross-country evidence. Selected studies from the past decade are summarised in Table 1. For more comprehensive reviews, see Cambini and Jiang (2009), or Berkman (2010).

**Table 1 Previous studies on the impacts of unbundling regulation on broadband penetration**

<b>Author(s)</b>	<b>Methodology/data</b>	<b>Main finding on unbundling regulation</b>
Bauer, Kim and Wildman (2003)	OLS regression/ OECD 2001	The authors found that population density and preparedness are the main significant determinants affecting broadband uptake. However, the result of unbundling policy on broadband uptake provided a positive coefficient though it was insignificant.
Garcia-Murillo (2005)	Logit and OLS regression/ OECD, ITU, WDI 2001	The author found that unbundling policy has a positive effect on broadband availability. Unbundling policy significantly increases the probability of broadband being provided, especially in middle income countries.
De Ridder (2007)	OLS regression/ OECD, ITU 2005 and 2002	The author suggested that the number of years of unbundling is positively significant to broadband penetration.
Distaso, Lupi and Manenti (2006)	Fixed effect, random effect and instrumental variable (IV) regression/EC annual report 2000-2004	The authors found that platform competition <sup>5</sup> is one of the main factors for increasing broadband penetration, while lowering the unbundling price can also encourage broadband adoption.
Picot and Wernick (2007)	Qualitative discussion on broadband deployment in the US, Korea and Europe	The authors pointed out that while platform competition has a greater impact on broadband adoption, unbundling policy nevertheless encourages broadband uptake in countries where infrastructure is lacking.
Boyle, Howell and Zhang (2008)	OLS regression/ OECD, ITU 2005 and 2002	The authors criticised the De Ridder (2007) study and argued that the increase in broadband adoption is mainly due to the length of time that broadband has been available, while the unbundling policy is statistically insignificant.

<sup>5</sup> In this paper, platform competition is a short term for inter-platform competition (competition between technologies/infrastructure)

To sum up, the previous studies in the early 2000s mostly pointed out that unbundling policy can encourage broadband penetration; however, previous studies from the mid-2000s focused more on infrastructure investment in which unbundling policy can be seen as a trade-off for competition and investment. Even though most studies believed that the platform competition is the main driver for increasing broadband adoption in the long run, there were mixed results on how unbundling policy affects broadband adoption. According to these studies, this situation may imply that unbundling policy is useful at the early stage when there is one dominated platform to increase the number of services, but when there are more choices of technology, the unbundling policy can have different impacts depending on the country and policies. The question of NGN now is whether fibre technology will completely dominate other technologies in the future.

## 6. Data and Model Specification

The data sources for the empirical evidence are secondary data from 2002 to 2008 that are based mainly on the reports and working paper from the OECD. The World Bank's online database, the ITU database and additional data collected by previous studies have been obtained as supporting data. The panel data technique is applied for econometric estimations. The model specification followed the approach by Bauer, Kim and Wildman (2003) that captures demand and supply at an aggregate level from demand and supply at a local broadband access market level. The demand and supply function can be adapted as follows.

$$\text{Demand: } q_{demand} = f(\text{price, income, substitute product}) \quad (1)$$

$$\text{Supply: } q_{supply} = g(\text{price, competition, regulation, country demographic}) \quad (2)$$

Applying this at country aggregate level at equilibrium where (1) is equal to (2), the aggregate equations can be derived as in (3) and (4).

$$\sum_i f(\text{price, income, substitute product}) = \sum_i g(\text{price, competition, regulation, country demographic}) \quad (3)$$

$$\text{Aggregate demand: } Q_{demand} = \text{Aggregate supply: } Q_{supply} \quad (4)$$

Using equation (4), broadband penetration can finally be derived as a reduced aggregate function form of all the variables and can be presented by  $Q$  as in (5).

$$Q = h(\text{price, income, substitute products, competition, regulation, country demographic}) \quad (5)$$

According to the given approach, the dependent variable in the models is broadband penetration while the independent variables in the models are broadband price, market concentration, unbundling policy, GDP per capita and population density. Broadband price

presents the price while market concentration can be considered the competition factor in the equation. Different variables of unbundling policy are chosen to determine regulation. GDP per capita presents income and, finally, the population density variable is given as a country demographic. Unfortunately, the mobile broadband retail prices are not available for this paper while the narrow band retail prices are not appropriate substitute products for this study. The substitute product prices are therefore omitted from this study.

The model specifications are presented in two parts. The first model aims to capture the effect of unbundling regulation on broadband penetration using a dummy variable when countries apply LLU policy. The second model mainly captures the effects of access price when countries have already considered applying LLU regulation. Both models can be derived as follows.

$$\text{Model 1: } \ln pen_{it} = \beta_0 + \beta_1 \ln price_{it} + \beta_2 LLUdummy_{it} + \beta_3 platform_{it} + \beta_4 GDP_{it} + \beta_5 density_{it} + \varepsilon_{it}$$

$$\text{Model 2: } \ln pen_{it} = \beta_0 + \beta_1 \ln price_{it} + \beta_2 LLUprice_{it} + \beta_3 platform_{it} + \beta_4 GDP_{it} + \beta_5 density_{it} + \varepsilon_{it}$$

An explanation of each variable is given in Table 2

**Table 2: Description of variables**

Variables	Description
<b>Dependent variable</b>	
$\ln pen_{it}$	the natural logarithm function of broadband penetration per 100 subscriptions for country i at time t
<b>Independent variables</b>	
$\ln price_{it}$	the natural logarithm function of the broadband retail price (euro) for country i at time t
$LLUdummy_{it}$	the dummy variable of LLU regulation for country i at time t, which equals 1 if the country applies LLU regulation and 0 otherwise
$LLUprice_{it}$	the natural logarithm function of the wholesale unbundling price (euro) for country i at time t
$platform_{it}$	the platform variable is presented as the concentration index of the broadband market for measuring platform competition for country i at time t, obtained using the sum of the square values of the broadband subscriptions in each technology and dividing this by the square values of the overall broadband subscriptions; the lower the concentration index, the greater the competition in the broadband market
$GDP_{it}$	GDP per capita (euro) for country i at time t
$density_{it}$	population density (person/km <sup>2</sup> ) for country i at time t

Broadband penetration and broadband retail price data<sup>6</sup> from 2002 to 2008 are taken from OECD reports. For the LLUdummy variable, the data provided by De Ridder (2007), and Boyle, Howell and Zhang (2008) are used as a reference. The LLUprice data are obtained

<sup>6</sup> The average of the broadband retail price data for 2006 and 2008 is used for the broadband retail price in 2007 due to unavailability of data.

from the project between Chalmers University of Technology and the National Telecommunications Commission (Thailand) in 2010. GDP per capita is taken from the World Bank's online database while population density is obtained from the ITU database. Lastly, the platform (concentration index) variable is also taken from the broadband subscription by technology from the OECD reports with the concentration index calculated by the formula as follows (as in Koutrompis, 2009). The values of the platform variable are within the range  $0.25 \leq Platform_{it} \leq 1.00$ .

$$Platform_{it} = \sum_{m=1}^n \frac{(\text{subscription by technology})_m^2}{(\text{total broadband penetration})^2}$$

The descriptive statistic of each variable is presented in Table 3. For the variables in the natural logarithm function, the descriptive statistics of the variables before transform are shown instead.

**Table 3: Description statistics of variables**

Variable	Observation	Mean	Std. Dev.	Min	Max
$pen_{it}$	210	14.24	10.07	0.01	36.81
$price_{it}$	210	70.69	200.47	0.58	2132.58
$LLUdummy_{it}$	210	0.88	0.33	0	1
$LLUprice_{it}$	170	10.81	2.58	4.70	20.10
$platform_{it}$	210	0.62	0.18	0.33	1
$GDP_{it}$	210	26439.42	14215.92	3768.38	80767.06
$density_{it}$	210	132.24	120.63	2.55	478.88

To avoid multicollinearity problems between the independent variables, the Pearson's correlation coefficient is performed, with a correlation of more than 0.70 considered a benchmark for high correlation. There is no surprise that the broadband retail price seems to be slightly correlated with many variables; however, the Pearson's correlation is not high and even below 0.50 to all variables. The summary of the Pearson's correlation coefficient matrix for Models 1 and 2 is presented in Tables 4 and 5.

**Table 4: The Pearson's correlation coefficients of independent variables from Model 1**

Variable	$lnprice_{it}$	$LLUdummy_{it}$	$GDP_{it}$	$density_{it}$	$platform_{it}$
$lnprice_{it}$	1.0000				
$LLUdummy_{it}$	-0.3677 (0.0000)	1.0000			
$GDP_{it}$	-0.4673 (0.0000)	0.3561 (0.0000)	1.0000		
$density_{it}$	-0.2952 (0.0000)	0.1438 (0.0373)	0.0070 (0.9200)	1.0000	
$platform_{it}$	0.0412 (0.5526)	-0.0093 (0.8939)	0.0824 (0.2342)	-0.1984 (0.0039)	1.0000

The figures in parentheses are the p-values, providing the significant level of the Pearson's correlation coefficients

**Table 5: The Pearson's correlation coefficients of independent variables from Model 2**

Variable	$Inprice_{it}$	$LLUprice_{it}$	$GDP_{it}$	$density_{it}$	$platform_{it}$
$Inprice_{it}$	1.0000				
$LLUprice_{it}$	0.3425 (0.0000)	1.0000			
$GDP_{it}$	-0.4673 (0.0000)	0.2410 (0.0051)	1.0000		
$density_{it}$	-0.2952 (0.0000)	-0.3535 (0.0000)	0.0070 (0.9200)	1.0000	
$platform_{it}$	0.0412 (0.5526)	0.1275 (0.0976)	0.0824 (0.2342)	-0.1984 (0.0039)	1.0000

The figures in parentheses are the p-values, providing the significant level of the Pearson's correlation coefficients

## 7. Result and Discussion

Of all the independent variables, this paper focuses on the competition between technologies and the unbundling policy. Figure 2 presents the relationship between broadband penetration and platform competition, the average during 2002-2008, while Figure 3 depicts the relationship between broadband penetration and unbundling price, the average during 2002-2008.

**Figure 2: broadband penetration and platform competition by country, average during 2002-2008**

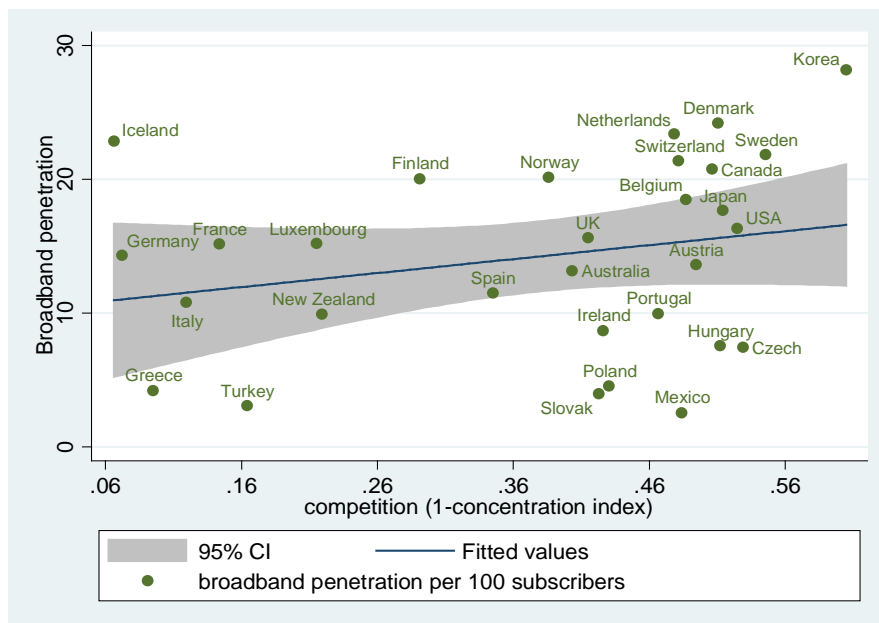


Figure 2 shows that the countries with greater competition (applying by 1-concentration index) between technologies during 2002-2008, such as the US, Korea, Japan, Sweden and Denmark, are likely to have more broadband penetration than others. The expected sign of the  $platform_{it}$  (concentration index) coefficient in econometric regressions should therefore be negative. However, some countries in Figure 2 with a high competition index, such as the Czech Republic, still have a low level of broadband adoption. This result indicates that there are also other important determinants that can affect broadband adoption.

**Figure 3: broadband penetration and local loop unbundling price by country, average during 2002-2008**

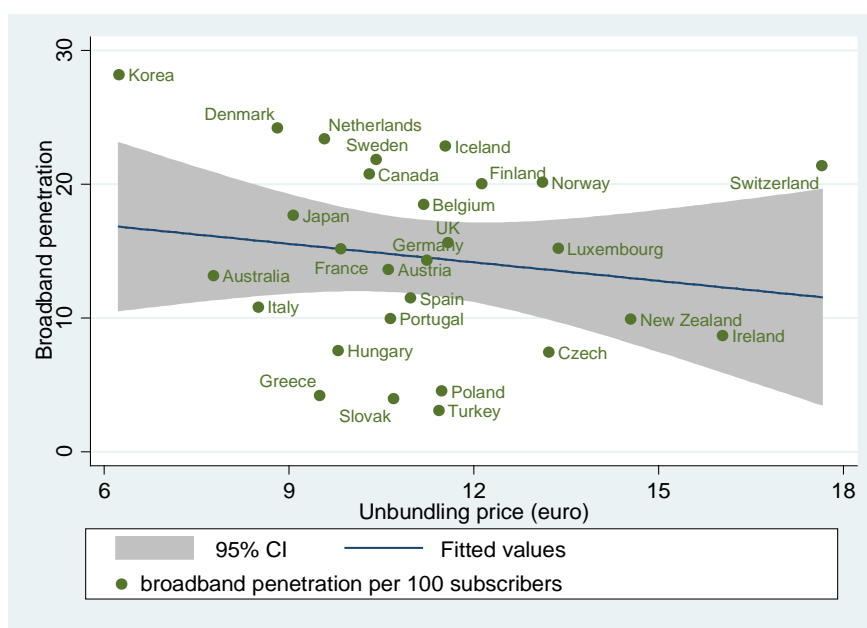


Figure 3 presents the relationship between broadband penetration and unbundling price. This figure indicates that on average, countries with a lower unbundling price are likely to have a higher ratio of broadband adoption per 100 subscribers. Similarly to Figure 2, other factors should be included to determine broadband adoption, for example, Switzerland with the highest average unbundling price still has a very high portion of broadband penetration. Nevertheless, the expected sign of the unbundling price should be negative.

The econometric estimations applied in Models 1 and 2 from Section 6 consist of OLS<sup>7</sup>, 2SLS<sup>8</sup>, GLS<sup>9</sup> and G2SLS<sup>10</sup>. The first estimation, pooled OLS, is used as a reference for other approaches. The GLS approach is also applied as the random effect estimation on panel data since the Hausman test suggests that the random effect is preferred compared with the fixed effect estimation. There is also concern over an endogeneity problem of the platform variable. Since it is unclear if the platform variable is exogenous enough, the instrumental variable approach is applied to OLS and GLS by using the first lag value of the platform variable as an instrument. The instrumental variable estimations of OLS and GLS are called 2SLS and G2SLS respectively. The estimation results from four approaches to Models 1 and 2 from Section 6 are presented in Tables 6 and 7 accordingly.

<sup>7</sup> OLS: Ordinary least squares

<sup>8</sup> 2SLS: Two stages least squares

<sup>9</sup> GLS: Generalised least squares

<sup>10</sup> G2SLS: Generalised two stages least squares

**Table 6: Regression results for Model 1**

<b>Dependent Variable:</b>				
<i>Inpen<sub>it</sub></i>	<b>OLS</b>	<b>2SLS</b>	<b>GLS</b>	<b>G2SLS</b>
<b>Independent Variable</b>				
<i>Inprice<sub>it</sub></i>	-0.5793 (0.0639)***	-0.4690 (0.0540)***	-0.5540 (0.0479)***	-0.4363 (0.0404)***
<i>LLUdummy<sub>it</sub></i>	0.6728 (0.2306)***	0.4842 (0.1748)***	0.7932 (0.1918)***	0.5749 (0.1537)***
<i>GDP<sub>it</sub></i>	0.6278 (0.0987)***	0.6303 (0.0814)***	0.8404 (0.1696)***	0.8179 (0.1392)***
<i>density<sub>it</sub></i>	-0.0004 (0.0005)	-0.0001 (0.0003)	-0.0003 (0.0009)	0.00003 (0.0007)
<i>platform<sub>it</sub></i>	-1.1795 (0.4108)***	-1.0428 (0.3877)***	-1.0460 (0.4287)**	-0.8183 (0.6072)
<i>constant</i>	-2.0528 (1.0121)**	-2.2458 (0.8312)***	-4.4629 (1.7728)**	-4.4658 (1.4414)***
No. of observation	210	180	210	180
R-square	0.6801	0.7110	0.6742	0.7067
F-test/Wald chi-square	58.60***	84.45***	355.67***	325.14***

The standard errors are present in parentheses. The significant level is reported using \*\*\*, \*\* and \*.

\*\*\* significant at 1%, \*\* significant at 5% and \* significant at 10%.

**Table 7: Regression results for Model 2**

<b>Dependent Variable:</b>				
<i>Inpen<sub>it</sub></i>	<b>OLS</b>	<b>2SLS</b>	<b>GLS</b>	<b>G2SLS</b>
<b>Independent Variable</b>				
<i>Inprice<sub>it</sub></i>	-0.4906 (0.0768)***	-0.4003 (0.0686)***	-0.4078 (0.0500)***	-0.3396 (0.0442)***
<i>LLUprice<sub>it</sub></i>	-0.7562 (0.2952)**	-0.5240 (0.2691)*	-1.1833 (0.3354)***	-0.7820 (0.2957)***
<i>GDP<sub>it</sub></i>	0.5269 (0.1053)***	0.5588 (0.0814)***	0.7547 (0.1989)***	0.7201 (0.1588)***
<i>density<sub>it</sub></i>	-0.0006 (0.0004)	-0.0003 (0.0003)	-0.0002 (0.0009)	0.00008 (0.0008)
<i>platform<sub>it</sub></i>	-0.8623 (0.3931)**	-0.7532 (0.3719)**	0.5255 (0.5224)	0.4307 (0.5479)
<i>constant</i>	0.9990 (1.1295)	-0.1493 (0.9176)*	-1.4335 (2.1092)	-2.1258 (1.6951)
No. of observation	170	149	170	149
R-square	0.5196	0.5559	0.4499	0.4760
F-test/Wald chi-square	16.62***	21.02***	198.29***	170.00***

The standard errors are present in parentheses. The significant level is reported using \*\*\*, \*\* and \*.

\*\*\* significant at 1%, \*\* significant at 5% and \* significant at 10%.

According to the results, for both models, GDP per capita has a positive effect on broadband adoption in all regressions with at least a 1% significant level while the retail price of broadband has a negative effect on broadband adoption in all estimations with at least a 1% significant level, as expected. Conversely, the results of both tables provide insignificant coefficients for the population density variable. For unbundling policy, the results from Table 6 indicate that during 2002-2008, the countries with LLU regulation generally have greater broadband penetration compared with countries without LLU regulation, with a significant



level of at least 1% in all regressions. For the wholesale unbundling price, results from Table 7 suggest that lowering the wholesale unbundling price leads to higher broadband adoption during the period 2002-2008. These results on LLU from Tables 6 and 7 imply that unbundling policy can be considered one of the strategies to increase broadband adoption. Interestingly, the platform variable (the concentration index) that implies competition between each technology does not have the expected signs in all regressions. From Table 6, the signs of the coefficients are as expected that a lower concentration (greater competition between technologies) can increase broadband adoption; however, the regression in G2SLS does not provide a significant result at the 10% level. From Table 7, the results show that greater competition between technologies can improve broadband adoption only in pooled OLS and 2SLS regressions while the results of GLS and G2SLS provide the opposite sign but insignificant results. According to previous studies, platform competition is considered one of the main drivers of broadband adoption. These insignificant results in some regressions, according to Tables 6 and 7, for the platform variable can be explained by unbundling policy having greater impact on broadband adoption than platform competition at the early stage when DSL technology is dominant. The focus on competition in one technology, DSL in this situation, is therefore more relevant. Later on, when other technologies are growing, the platform competition becomes one of the main strategies to increase overall broadband adoption. To further investigate the above explanations, the same dataset is estimated by G2SLS regression but during two different periods of time: 2003-2006 and 2006-2008.<sup>11</sup> The results are presented in Table 8.

**Table 8: G2SLS regression results for two different periods of time**

<b>Dependent Variable:</b> <i>Inpen<sub>it</sub></i>	<b>Model 1</b> <b>2003-2006</b>	<b>Model 2</b> <b>2003-2006</b>	<b>Model 1</b> <b>2006-2008</b>	<b>Model 2</b> <b>2006-2008</b>
<b>Independent Variable</b>				
<i>Inprice<sub>it</sub></i>	-0.4022 (0.0615)***	-0.2543 (0.0600)***	-0.2385 (0.0324)***	-0.2115 (0.0295)***
<i>LLUdummy<sub>it</sub></i>	0.5225 (0.2103)**	-	0.1933 (0.2336)	-
<i>LLUprice<sub>it</sub></i>	-	-1.6643 (0.4292)***	-	-0.1147 (0.1540)
<i>GDP<sub>it</sub></i>	0.9535 (0.1925)***	0.7684 (0.2077)***	0.5916 (0.0695)***	0.5813 (0.0735)***
<i>density<sub>it</sub></i>	0.0005 (0.0010)	0.0003 (0.0010)	-0.00002 (0.0004)	-0.0002 (0.0004)
<i>platform<sub>it</sub></i>	-1.5942 (1.0655)	0.2137 (0.8154)	-0.5855 (0.2291)**	-0.6147 (0.2291)***
<i>constant</i>	-5.5259 (1.9437)***	-0.8008 (2.2413)	-2.2973 (0.7790)***	-1.7430 (0.7897)**
No. of observations	120	94	90	81
R-square	0.6677	0.4095	0.7961	0.7631
Wald chi-square	145.79***	85.37***	212.95***	187.54***

The standard errors are present in parentheses. The significant level is reported using \*\*\*, \*\* and \*.

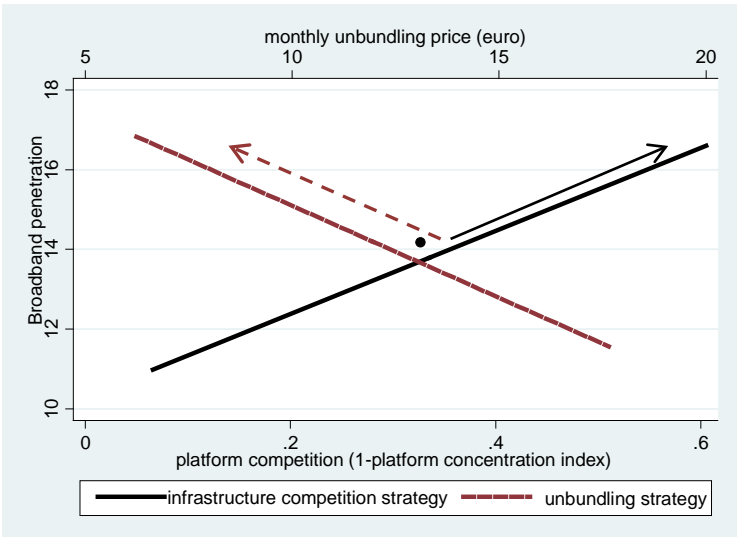
\*\*\* significant at 1%, \*\* significant at 5% and \* significant at 10%.

<sup>11</sup> The 2002 data are excluded as they are used as an instrument variable for the 2003 data while the 2006 data are included in both periods to maintain a sufficient number of observations for significant results.

Not surprisingly, the signs and significant level of coefficients of broadband price, GDP per capita and the density variables from Table 8 are similar to those of Tables 6 and 7. Interestingly, the results on unbundling policy were significant, at least at the 5% level, during the 2003-2006 period but not the 2006-2008 period, while platform competition had significant results, at least at the 5% level, during 2006-2008 but not during 2003-2006. With platform competition were averagely increasing over time during 2002-2008, these results support the earlier explanation that at the early stage when one technology is dominant, the unbundling policy is one of the main strategies while at the later stage, platform competition becomes one of the main drivers of broadband adoption. All the results from Tables 6, 7 and 8 imply that unbundling policy can be useful for increasing broadband penetration, especially when one technology is dominant. This raises an interesting question: Will fibre technology dominate other technologies in the future broadband market?

Along with the econometric results, it is interesting to consider a multi-country comparison between countries with high fibre infrastructures, such as Japan, Korea and Sweden. These countries apply the unbundling regulation to other technologies. For example, Japan and Sweden have unbundling requirements for the fibre network while Korea has at least open access obligations for cable owners. Interestingly, the fibre network in the US is growing without unbundling regulation. This growth is mostly due to the special characteristics in the US where there are two incumbents' networks, telecommunications and cable modem incumbents, competing for most households. As most countries do not have this specific characteristic network as in the US, the unbundling regulation on NGN can be seen as another strategy to support platform competition for NRAs.

**Figure 4: broadband penetration and platform competition/LLU price by country, average from 2002 to 2008**



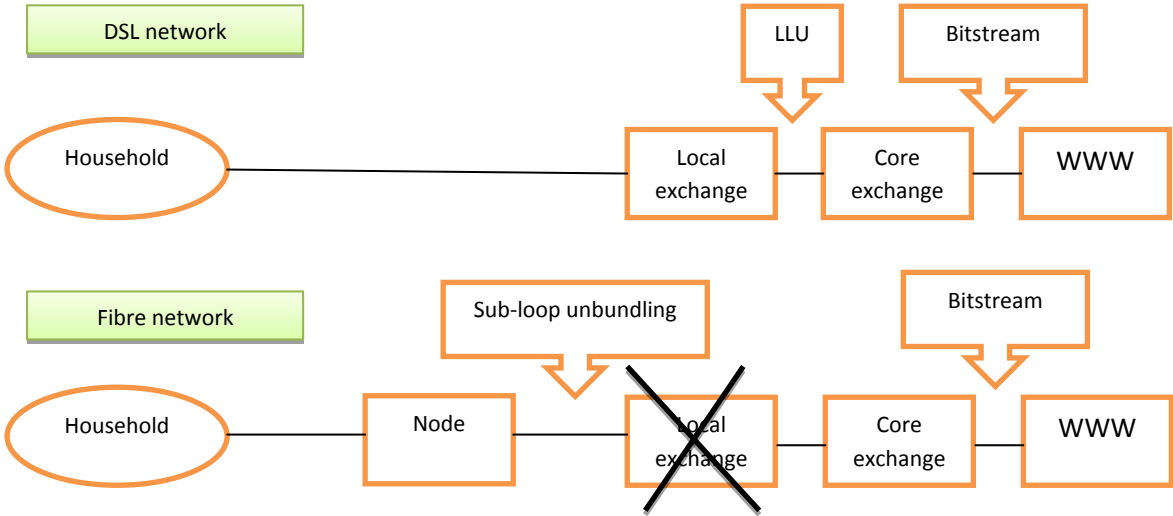
The discussion is simplified in Figure 4: NRAs have two strategies, platform competition and unbundling policy, as instruments for increasing broadband penetration. Where the platform competition passes through the right side of the point at which the solid line crosses the dashed line, the figure suggests that a country has sufficient level of platform competition.

The regulator then should focus on infrastructure competition as a main strategy to achieve greater broadband penetration. In this situation, unbundling policy become less significant when there are adequate competitions between different technologies. Conversely, the left side of the point at which the solid line crosses the dashed line presents the situation where platform competition level in a country is too low and a regulator has difficulty encouraging platform competition due to a lack of infrastructure or for other limitations. Unbundling policy (by lowering the unbundling price) should be preferably encouraged as a main strategy for greater broadband adoption. Figure 4 therefore captures a break-even point between these two strategies.

**8. Possible Adaptation of NGA Regulation**

The transition of unbundling regulation from DSL technology to fibre technology should be considered carefully. Currently, NGN is beginning to be built in many countries. The development of NGN therefore raises the question of NRA in each country and whether to apply access regulation as in the DSL market. The similarities and differences between the DSL and fibre networks should be considered rigorously.

**Figure 5: Similarities between the DSL network and NGN**



Source: Cave (2010)

Even though the access products from NGN are moderately similar to those of the DSL network (see Figure 5, adapted from Cave, 2010). The NGN situation differs from that of DSL technology. For example, the cost of NGN is not sunk as in the DSL network, and the operators’ incentive for NGN investment is critical (Cave 2010). Importantly, the broadband market currently consists of various technologies. The market is more competitive and differs from the last decade when DSL technology was dominant. Geographical, political and technological differences between countries also need to be considered. The theory and hypothesis, and previous studies, along with the empirical evidence from this study, all need

to be taken into account to summarise the possible adaptation of unbundling policy in NGN. Table 9 presents the summary of the discussion and analysis of the theory, previous literature and empirical evidence from this study.

**Table 9: Comparison of discussions and analysis from theory, previous literature and the empirical evidence**

Summary based on theory and hypotheses	Summary based on previous literature	Summary based on empirical evidence from this study
<p>Due to one-way access pricing, there is still a need for intervention at the wholesale level in NGN, such as unbundling policy to encourage more competition in the market and to soften monopoly power. Even the Ladder of Investment hypothesis cannot completely solve the trade-off dilemma, encourage more competition in the market and generate greater variety of services in each ladder for the final consumers. Nevertheless, this theory and hypothesis were countered by the argument of a lower incentive for investment.</p>	<p>Early literature seems to suggest that unbundling policy has a positive effect on broadband penetration. Nevertheless, the literature at the later stage considers the disadvantage that unbundling may reduce the incentive of investment and be seen as a trade-off. Platform competition is also preferred in the long run. Interestingly, some literature suggests that unbundling can be used coupled with platform competition while some scholars disagree and believe that the damage of unbundling will be greater than the benefits.</p>	<p>The evidence of this study focuses on broadband adoption. The results show that overall, unbundling regulation supports the growth of broadband adoption, especially when one technology is dominant. On the other hand, when many technologies compete with each other, platform competition should be the main strategy while unbundling policy becomes less significant.</p>

According to the discussion, along with encouraging platform (technology) competition, when properly regulated, unbundling policy is likely to provide more benefits than drawbacks, especially in countries in which there are not many options for other technologies, as leaving the NGA unregulated can indirectly lead to low competition in the market and monopolistic retail price, which can ultimately harm consumers. With regard to the investment issue, unbundling policy is only one of many factors for determining the incentive of infrastructure investment while the main factor of investment should come from an overall economic environment in each period. Alternatively, if investment from the incumbent is urgently needed, regulators may choose to compromise by stating clearly to the operators that they will not regulate access in the case of fibre during certain periods of time to let the incumbent operators gain some benefit back from their investment. As promoting competition can significantly improve consumer benefit, the regulators can, however, set the access regulation later when the fibre market becomes more mature and move towards a technology neutrality concept. Importantly, the regulator needs to state clearly all the conditions, such as the period of time, access price method or unbundling part of the network, to both the incumbent and smaller operators, whether it regulates the NGA market from the early stage of investment or waits for the NGA market to become more mature. Ultimately, it is also important for the regulator to consider the social benefit, especially consumers, as the first priority.

Lastly and importantly, mobile broadband technology and capacity are also developing dramatically. Considering the history of mobile and fixed telephony, mobile broadband may be able to dominate fixed broadband in the future even though fibre technology is currently considered the major infrastructure for high-speed broadband. It is interesting to see how the broadband technology, market and policy will pan out in the future.

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