GO MOBILE GO EVERYWHERE?! THE ROLES AND EFFECTS OF MOBILE BROADBAND POLICIES

By

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ABSTRACT

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Significant differences in mobile broadband penetration rates exist among countries. This dissertation studies whether public policies influence these differences. It does so by examining the factors that are related to mobile broadband penetration. Within this framework, it aims to understand what kind of policies/regulations, if any, are necessary and/or sufficient conditions for higher mobile broadband (high speed mobile Internet) penetration rates. Although many studies have probed the factors influencing fixed broadband penetration, few studies have focused on mobile broadband. Because policy, supply, and demand factors interact with each other, it is difficult to examine the complexity of multiple interactions among these factors by only using economic approaches or case studies. In order to capture the complicated interactions among these factors, Qualitative Comparative Analysis (QCA) was utilized in addition to econometric approaches to analyze the policy and economic factors that affect mobile broadband penetration. This allows a detailed examination of how broadband-related regulations/policies and other economic factors (both on the supply and demand side of broadband markets) affect mobile broadband penetration in OECD (Organisation for Economic Co-operation and Development) countries.

Using QCA, the dissertation found six necessary conditions for higher mobile broadband penetration: 1) technology neutrality, 2) higher quality of regulation, 3) higher fixed broadband penetration rates, 4) higher mobile competitive intensity, 5) higher urban population, and 6) higher education. Analyzing sufficient conditions showed several paths for a country to have higher mobile broadband penetration, all of which were combinations of factors. This indicates the complexity of the interaction of various conditions for mobile broadband penetration. According to the sufficient solutions, high education, high income, higher fixed broadband penetration, a competitive mobile market, and higher urban population were the most important factors for a country to have higher mobile broadband penetration rates. The results of econometric analyses were largely consistent with these findings and also found income, education, and competition to be important determinants of mobile broadband penetration.

Overall, the dissertation shows that policy makers may be able to contribute to increased mobile broadband penetration if they can improve the six conditions necessary for such an outcome. However, it is more difficult to find conditions that are sufficient. The analysis suggests that the sufficient conditions to improve mobile broadband penetration vary depending on the specific circumstances. For example, if a country does not have high income, it is important for the government to include mobile broadband into the universal service objective. Although some factors can be affected by policy makers in the short run or long run, some factors such as education are outside of the remit of broadband regulators and therefore require broader policy coordination.

Keywords: mobile Internet, mobile broadband, regulation, public policy, Qualitative Comparative Analysis, panel data

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Chapter 1

Introduction: Mobile Broadband

The importance of broadband[1] (high speed Internet access, both fixed and mobile) for economic and social developments has been pointed out in many studies and reports (CISCO, 2013; Crandall, Jackson, & Singer, 2003; Czernich, Falck, Kretschmer, & Woessmann, 2011; Esiobu, 2015; Greenstein & McDevitt, 2009; ITU, 2003; Raul L Katz & Koutroumpis, 2012; Koutroumpis, 2009; Kretschmer, 2012; W. H. Lehr, Osorio, Gillett, & Sirbu, 2005; NTIA, 2010, 2011; Qiang, Rossotto, & Kimura, 2009; Sutherland, 2014; Van der Wee, Verbrugge, Sadowski, Driesse, & Pickavet, 2014; Warman, 2015). Although recent contributions also have pointed to risks and downsides of digital technologies and increased connectivity (for example, the decrease of job opportunities due to the productivity gains from using digital technologies, see Rotman, 2013, 2014; The Economist, 2015.1.3, and low income in the mobile sharing economy), many countries believe that the disadvantages of poor broadband access would be significant and have adopted measures to improve broadband adoption (e.g., the National Broadband Plan in the U.S., the National Broadband Network in Australia, the National Broadband Network in Australia, the Ultra-Fast Broadband (UFB) Network in New Zealand, the Indonesia Broadband Plan (IBP) in Indonesia, the High Speed Broadband Network (HSBB) in Malaysia, and the National Optical Fiber Network in India) (Beltrán, 2014; Calvo, 2012; ITU, 2012; Gunaratne, 2014). According to the Broadband Commission, by 2014, 140 out of 196 countries had

[1] The definition of broadband varies among institutions. According to ITU (International Telecommunication Union), broadband is “transmission capacity that is faster than primary rate Integrated Services Digital Network (ISDN) at 1.5 or 2.0 Megabits per second (Mbits)” (ITU website: http://www.itu.int/osg/spu/publications/birthofbroadband/faq.html). In this study, following OECD (Organisation for Economic Co-operation and Development) conventions, broadband is defined as “services enabling at least a 256 Kbps advertised downlink Internet access”(Development), 2009, p. 8).

developed national broadband policies and 13 countries were planning to introduce such policies (Broadband Commission, 2014). In the Digital Agenda, the European Union established the objective to ensure all people in EU countries have access to the Internet (at speeds of a least 30 Mbit/s) and that half of the population subscribe to Internet access over 100 Mbit/s by 2020 (Cawley, 2014; EC, 2010; Lemstra & Melody, 2014a). Recognizing the increasing importance of mobile access, some countries have included mobile broadband into their broadband universal service plans (e.g., the U.S.).

Having mobile access to the Internet allows users to access the Internet wherever they are. Being able to access the Internet anywhere has many advantages for users. Mobile broadband allows users to enjoy most of the advantages that fixed broadband have, for examples, job search, e-government, e-learning, and emergency help (Schadelbauer, 2014), without the constraints of location. Mobile broadband also provides more flexibility for customization and personalization, and made "personal broadband" possible (Lehr & Oliver, 2014). This capability made mobile broadband a possible solution for narrowing the digital divide between urban and rural areas, especially in areas where fixed broadband is not available (Prieger, 2013; Srinuan, Srinuan, & Bohlin, 2012). When the quality of fixed broadband is not satisfying, mobile broadband could provide an alternative for Internet access (Deshpande, 2014). Because of these advantages, increasing the penetration rates of mobile broadband has been included in government policy goals of many countries.

However, the factors that can help a country improve mobile broadband penetration are not fully understood. Many studies have examined the drivers of fixed broadband penetration, but systematic knowledge on the determinants of mobile broadband penetration is much more scattered and incomplete. In addition, the diffusion of mobile broadband cannot be understood as a stand-alone fashion. Most countries with mobile broadband started with fixed broadband. However, it is not clear how fixed and mobile broadband evolve and "converge" together (Lehr & Oliver, 2014). Seeking to narrow these knowledge gaps, this dissertation aims to understand what kind of policies/regulations and economic factors are necessary and/or sufficient for having higher mobile broadband penetration rates. Looking at mobile broadband penetration rates in the world reveals huge gaps among countries. For example, in OECD (the Organisation for Economic Co-operation and Development) countries, the gap between the highest (South Korea, with 104.25% subscriptions) and the lowest (Mexico, with 9.82% subscriptions) mobile broadband subscriptions[2] is 94.4%. What are the main factors that explain these huge differences in penetration rates of penetration rates among different countries? Do policies play an important role in addition to country-specific characteristics, such as income and education?

Examining Factors Influencing Mobile Broadband Adoption: An Overview

The main purpose of this dissertation is to fill the knowledge gaps mentioned above by examining factors influencing mobile broadband adoption. Specifically, what are the roles of policies with regard to mobile broadband uptake? Having adequate policies that help build up the infrastructure and the market can be critical to broadband penetration. Policy and regulation have important effects on the investment in broadband markets (Bauer & Shim, 2012; Cawley, 2014; Dkhil, 2014). Although many countries plan to increase broadband penetration rates, there is no clear evidence as to what kind of policies and regulations are necessary and/or sufficient for improving mobile broadband (high speed Internet) penetration rates. Past studies of fixed

[2] Since most data is collected from service providers, it is in the form of subscriptions. As a result, it is challenging to estimate the numbers of subscribers because some users may subscribe to more than one service. The numbers for subscriptions are normally bigger than the numbers for subscribers, therefore the total subscriptions can exceed 100% of the population even though not everyone in the country subscribes to the services.

broadband access found that the availability of broadband universal service, public private partnership (PPP), local loop unbundling, competition, and other supply and demand-side economic factors such as prices, affected penetration rates (ACPLI, 2009; Bauer, Kim, & Wildman, 2003; Briglauer & Gugler, 2013; Cava-Ferreruela & Alabau-Munoz, 2006; Cava-Ferreruela & Alabau-Muau-Munoz, 2006; Cava-Ferreruela & Alabau-Muñoz, 2004, SeMurillo, 2005; Haucap, Heimeshoff, & Lange, 2014; Jakopin, 2009; S. Lee, 2006; S. Lee & Brown, 2008). Many studies have also been done with regard to factors related to mobile voice service penetration (Gruber, 2001; Gruber & Verboven, 2001). However, few studies have paid attention to the factors influencing mobile broadband penetration (Lee, Marcu, & Lee, 2011; Lee & Lee, 2014; Yates, Gulati, & Weiss, 2013) or adoption[3] (Gerpott, 2011; Liu & Li, 2010).

Past studies found that policies, regulatory factors and economic factors impacted mobile broadband penetration rates. Mobile broadband-related policies such as spectrum policies (Chapin & Lehr, 2011), broadband universal service, and standardization policies (S. Lee, Marcu, et al., 2011) were found to affect mobile broadband penetration. S. Lee et al. (2011) examined the factors affecting fixed and mobile broadband penetration by using OECD data and found that standardization policies and urban population were the most important factors for mobile broadband diffusion, while income, education, and prices were not statistically significant predictors to mobile broadband penetration. Yates et al. (2013) found that countries with higher mobile broadband penetration rates generally had encouraged competition in telecommunication markets. Lee and Lee (2014) found that platform competition was important for smartphone adoption in OECD countries while platform openness and prices were critical for both OECD

[3] Penetration is normally analyzed at the macro level (e.g., a city, a country) and it usually focuses on the subscriptions of services. Adoption often focuses on the individual level, such as how to make non-users start to use mobile broadband. Some studies use these terms interchangeably.

and BRICS (Brazil, Russia, India, China, and South Africa) countries (Lee & Lee, 2014). Gerpott (2011) and Liu and Li (2010) both conducted surveys to understand what affected individuals' decisions on adopting mobile broadband and found that the perceived advantages of mobile Internet were critical for mobile Internet adoption. Basically, competition and platform openness, prices (which are related to the degree of competition with more intense competition typically related to a lower level of prices and/or a higher degree of price differentiation), and the perceived advantages of mobile broadband are important factors for mobile broadband adoption.

Several of the factors affecting mobile broadband penetration are likely similar to those affecting fixed broadband (e.g., the intensity of competition). However, mobile broadband is probably also affected by additional factors that are unique to mobile services. Compared with fixed broadband, mobile broadband penetration is likely also influenced by factors such as spectrum management policies. Therefore, lessons for the design of good policy for mobile broadband cannot necessarily be drawn from insights on fixed broadband studies alone. Developments in broadband markets are outcomes of the interplay between supply and demand (Lemstra & Melody, 2014b). From the findings of previous studies on fixed broadband penetration, one would expect that supply-side economic factors, such as competition (Gruber, 2001) and population density (Lee et al., 2011), which influence the cost and price of service provision will also affect the penetration of mobile broadband. Demand-side factors, such as income, education, and digital skills, also affect mobile broadband penetration. However, the relative importance of individual factors and of their interaction has not yet been identified clearly. Therefore, in this study, our overarching research question is: whether policy choices are instrumental for higher mobile broadband penetration. If so, this study aims at understanding whether any policies and policy combinations are sufficient or at least necessary for having higher mobile broadband penetration rates.

To examine the factors affecting mobile broadband penetration, a novel approach will be used in the dissertation. Most broadband penetration studies were conducted by using regression analyses and case studies. Especially the former set of studies typically focuses on the effects of single policy choices on outcomes. However, policy interventions and other factors are typically related to each other. Specifically, looking at policy-related factors, they are most of time interacting with other supply and demand factors. In principle, this can be captured by interaction terms in regression analyses. Practically, given the large number of variables and potential combinations involved, this may be practically impossible to use interaction terms to analyze policy factors. It was also found that the factors affecting broadband diffusion vary at different stages of adoption (Kyriakidou, Michalakelis, & Sphicopoulos, 2012). The factors affecting broadband diffusion in technologically developed countries and technologically developing countries differed (Gulati & Yates, 2012).

This empirical challenge can be overcome by using Qualitative Comparative Analysis (QCA), which combines the advantages of quantitative analyses and case studies. Primarily developed by Charles Ragin (1987; 1994; 2000), QCA is a relatively new method to analyze data. It has been used in several fields in social science (Marx, Rihoux, & Ragin, 2014), such as political science (Bennich-Björkman, 2012) and business management (Greckhamer, Misangyi, Elms, & Lacey, 2008). In QCA, cases are converted into a set of “conditions” and “outcomes” to analyze causal relations using principles of set theory. QCA is effective in examining the interdependence and complexity of various conditions/policies and stakeholders. This comparative method is especially useful for policy discussions, because policy-making is related to many different institutions, often of great diversity. By examining the patterns of similarities and differences across cases, QCA seeks to systematically uncover the causal relationships among conditions and outcomes (Basurto & Speer, 2012). Therefore, a QCA policy comparison study will be included as part of this dissertation.

In order to identify the relationship among predictors and mobile broadband penetration rates, longitudinal data will be analyzed in this dissertation. Both QCA and penal data analyses will be used for data analyses. For the QCA analysis, the focus will be on examining whether and how different broadband-related regulations/policies, such as mobile broadband universal service, spectrum management policies, and other economic factors (competition, education, and income) affect mobile broadband penetration in OECD countries. In 2014, 34 countries were members of the OECD[4]. By using panel data from these 34 countries for years 2009-2013, we can examine the importance of individual predictors and of interactions between them.

Overall, this dissertation aims to improve our understanding of the roles of policy choices on technology adoption (at the national rather than individual level). It has theoretical, empirical, and practical contributions. Theoretically, acquiring a deeper understanding of the factors driving mobile broadband adoption will enhance our understanding about the factors influencing mobile broadband adoption and help formulate more sophisticated theories of mobile broadband penetration. This will help improve our understanding of the roles of policy choices on technology adoption (at the national rather than individual level). Empirically, by using empirical data, this dissertation tests how previous theories on broadband penetration can be applied. Furthermore, by adopting both QCA and econometric approaches, the interaction among various

[4] These 34 countries are Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and the United States (OECD, 2015c).

factors can be revealed and the strengths of the contributions of each factor can also be presented. Practically, by examining the necessary and sufficient conditions for different mobile broadband penetration outcomes, the findings can inform decision makers seeking to improve mobile broadband penetration rates. By using a promising methodological approach (QCA) that combines the advantages of quantitative and qualitative methods to examine how constellations of different policies (paths) affect mobile broadband penetration in different countries, we can see how various policy combinations relate to mobile broadband penetration.

The dissertation is structured as follows. Chapter 2 briefly describes mobile broadband deployment in OECD countries. Chapter 3 reviews previous research on broadband penetration to develop the theoretical framework of the dissertation. Chapter 4 explains the methods and data used in this dissertation. Chapter 5 presents the results. Chapter 6 discusses the findings and the dissertation ends with an assessment of implications for mobile broadband policies.

Chapter 2

Mobile Broadband in OECD Countries

Mobile broadband is commonly defined as "any mobile (or cellular) technology that delivers minimum data rates in the hundreds of kilobits per second (kb/s) to end users and peak rates in the Megabits per second (Mb/s)" (Bold & Davidson, 2012, p. 68). At the time this dissertation was written, this definition included third generation mobile technology (3G) and subsequent more advanced technologies (such as HSPA and 4G/LTE; see Figure 1).

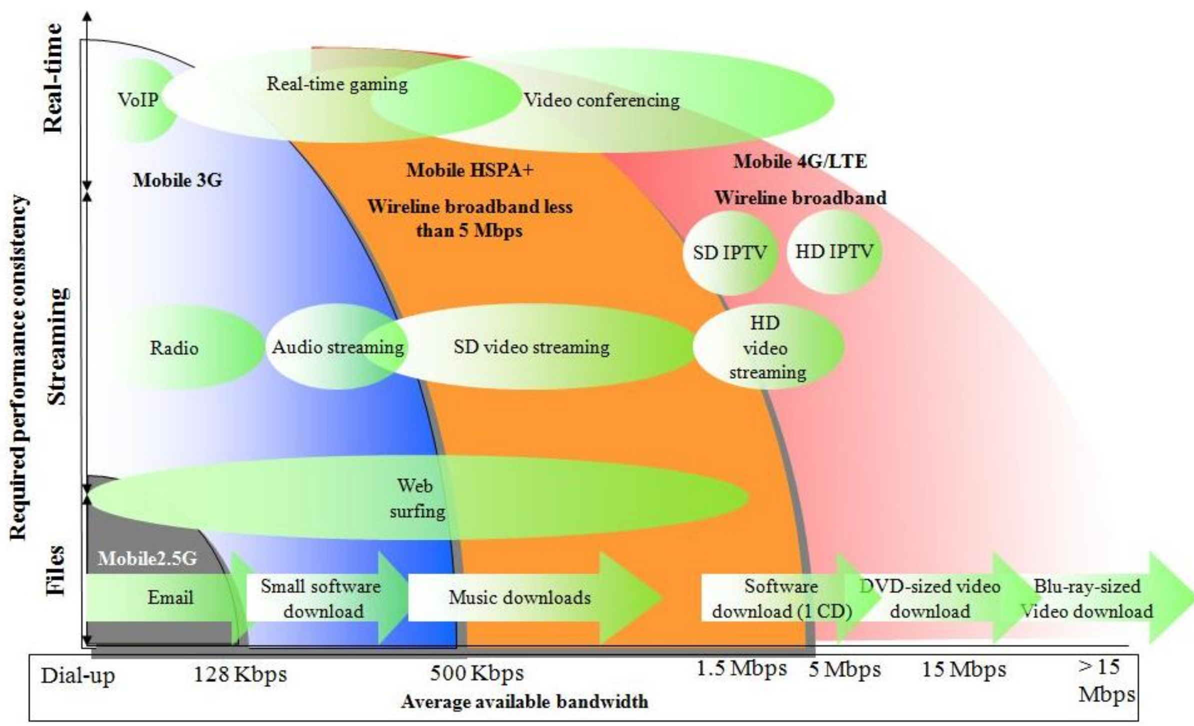

Figure 1 Mobile Broadband Technologies (CRTC)
Source: CRTC: http://www.crtc.gc.ca/eng/publications/reports/policymonitoring/2014/cmr5.htm

It is predicted that, around the world, mobile data traffic will increase 10-12 times between 2010 and 2015(Bold, & Davidson, W. , 2012). Forecasts anticipate that by 2017, 80% of adults in the world will access broadband via mobile technologies (GSMA, 2013). Among the 34 OECD countries, by June 2014, seven countries had reached 100% mobile broadband subscriptions (i.e. the number of broadband subscriptions exceeded the population; since some subscribers may have two or more subscriptions, the penetration rates will typically be below the subscription rates). The countries in this group include Finland, Japan, Australia, Sweden, Denmark, South Korea, and the United States. On the other end of the spectrum, seven countries had lower than 50% mobile broadband subscriptions (including Slovenia, Chile, Mexico, Greece, Portugal, Turkey, and Hungary) (see Figure 2, OECD, 2015c). Below, we will briefly describe mobile broadband deployment in OECD countries.

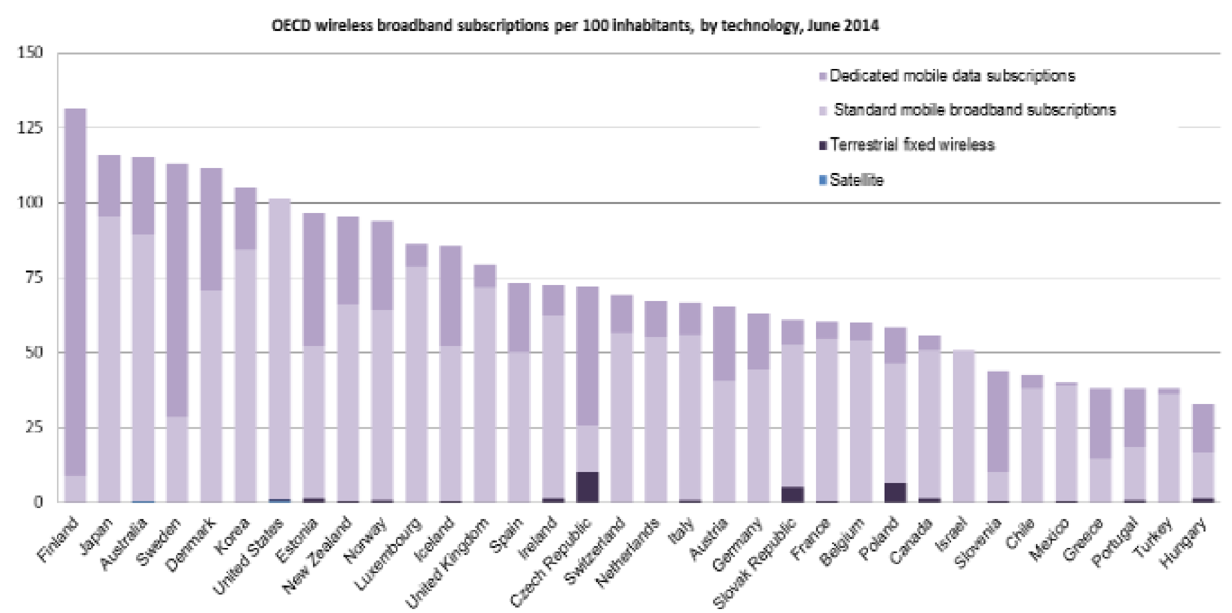

Figure 2 OECD Mobile Broadband Subscriptions per 100 Inhabitants (2014)
Source: OECD Broadband Portal, http://www.oecd.org/sti/broadband/oecdbroadbandportal.htm

European Countries

Twenty-five of the 34 OECD countries are located in Europe and nine are from outside this region: Australia, New Zealand, Japan, Korea, United States, Canada, Israel, Chile, and Mexico. 21 of the 25 European countries are members of the European Union[5]. The average penetration rate for these 21 EU countries in 2013 was 68.2%. However, six of these countries actually had lower than 50% penetration rates (including Belgium, Germany, Slovenia, Portugal, Greece, and Hungary).

The European Union and the European Commission announced the Digital Agenda for Europe in 2000 (EC, 2015b; Lemstra & Melody, 2014a). In the Digital Agenda, several goals are related to broadband penetration: 1) Broadband will be available for all Europeans by 2013; 2) By 2020, Europe will be covered by broadband above 30 Mbps; 3) By 2020, half of EU people will subscribe to broadband at speeds above 100 Mbps (EC, 2015b; Marcus & Elixmann, 2012). That is to say, by 2013, broadband penetration rate should reach 100%; by 2020, the speeds for broadband will reach 30Mbps all over EU countries and half of EU population will use broadband at 100 Mbps or above. However, in 2013, the EC published the scoreboard for the Digital Agenda (EC, 2013). It showed that by the end of 2012, about 25% of EC countries were covered by LTE 4G services and over 98% were covered by satellite mobile technology.

In 2013, EC countries adopted a package of legislative change to develop a “Connected Continent: Building a Telecoms Single Market" (EC, 2015a). These changes aimed to increase the coordination of spectrum allocation in EC countries and also create a single EC telecom

[5] Including Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, the Netherlands, and United Kingdom.

market with new roaming regulation. The overall goal was to end roaming and to allow customers to use the local services while traveling to another EC country.

Specifically, four northern European countries, including Finland, Sweden, Denmark, and Norway, all have very high mobile broadband penetration rates. All of these countries had relatively high income (GDP/capita). Finland had the highest mobile broadband penetration rate among OECD countries in 2013, while Sweden, Denmark, and Norway all had high fixed and mobile broadband penetration rates. Denmark's fixed broadband regulation had focused on competition issues, especially service-based competition and technology neutral rule (Henten & Falch, 2015). Sweden also emphasized service-based competition by employing local loop unbundling regulation (Forzati & Mattsson, 2015).

As for the Netherlands, it also had high GDP/capita and high fixed broadband penetration rates. For the fixed broadband, it had intense facility-based and access-based competitions (Lemstra, 2015). The United Kingdom also had high GDP/capita and high urbanization that probably facilitated the penetration of mobile broadband (Yoo, 2014). It had similar mobile broadband penetration rate with the Netherlands in 2013. The Digital Britain report was announced in 2009 and broadband universal service of speed above 2 Mbps (including using DSL, fiber, or mobile technologies) was included in the initiative (BIS, 2009). 4G service was launched in 2012 and it was available in 70% of areas in UK in 2014 (Ofcom, 2014). As for 3G services, about 98% of UK areas were covered. Four major mobile providers have committed to provide mobile broadband services in rural UK by participating in a rural infrastructure project in order to narrow the digital divide in UK (Curtis, 2013). It has been found that mobile broadband has been an "effective alternative" to fixed broadband but also remains its own market strength in UK (Deshpande, 2014, p. 39). According to the Oxford Internet Survey, the number of mobile Internet users doubled from 2009 to 2011 in the U.K. (Dutton & Blank, 2011).

In France, owing to the increasing use of voice services via fixed broadband and instant messaging, mobile voice use has been decreasing (Loridan-Baudrier, 2015). However, mobile voice and SMS services are still the main sources of revenues for mobile providers. With the cost of unlimited use of data services provided to consumers, there is a concern on the sustainability of mobile broadband services because providers receive revenues from other services but spent most of their money on providing data (Loridan-Baudrier, 2015).

Germany has a relatively low mobile broadband penetration rate among the European OECD member countries. Although a 3G UMTS auction was conducted in 2000, owing to the lack of smartphones and other reasons (for example, network operators also paid very high prices), the service started only in 2004. In 2010, Vodafone and Telekom Deutschland announced the first 4G LTE service in Germany (Schneir & Batura, 2015). Greece also had lower than 50% mobile broadband penetration rate in 2013. The deployments of fixed broadband infrastructure and service have been very challenging to the Greek government. The government invested in broadband infrastructure because of the lack of incentives of providers(Constantelou, 2015). Poland, compared with the EU average, has a lower fixed broadband penetration rate. Poland went through several years of inefficient telecommunication regulation and started to increase service-based competition after UKE (Urzqd Komunikacji Elektronicznej) promulgated new regulations (Windekilde & Ladny, 2015).

Generally speaking, there exists a wide range of mobile broadband penetration rates among these OECD countries in Europe. As for the relationship between fixed and mobile broadband in EU countries, with the increase usage of mobile broadband, the fixed-mobile broadband substitute (people who use both fixed and mobile broadband at home) has been decreasing in years 2005-2010 (Grzybowski, 2014).

United States and Canada

The United States adopted its national broadband policy in 2010 (Broadband Commission, 2014). In the United States, although mobile Internet use has increased rapidly in the past five years, about half of all Americans did not use mobile Internet in 2013. There is still a gap between use/non-use and there are differences on how people use it. According to a study conducted by the Pew Research Center, in 2013, 91% of adults in the U.S. had cell phones and 63% of them accessed the Internet via their cell phones (Duggan & Smith, 2013). That is to say, 57% of adults in the U.S. use mobile Internet and 21% of cell phone owners primarily accessed the Internet on their phones (Duggan & Smith, 2013). The numbers of adults accessing the Internet via cell phones doubled in four years (increasing from 31% in 2009 to 63% in 2013). Additionally, for tablets, 42% of U.S. adults owned a tablet by January 2014 (Zickuhr, 2014; Zickuhr & Rainie, 2014). This number increased by 8% from 2013 to 2014 (Zickuhr, 2013). In 2010, mobile broadband subscriptions exceeded fixed broadband subscriptions worldwide (Bold & Davidson, 2012). In 2010, the National Broadband Plan was announce by the Federal Communications Commission in the United States (FCC, 2010a). Both fixed and mobile broadband were included in this new form of broadband universal service objective. For mobile broadband, spectrum policies were identified as the most critical policy that the government had to make in order to increase mobile broadband penetration (FCC, 2010a). Specifically, a mobility fund was set up to increase the coverage of 3G network to ensure all states could be covered by 3G services. Roaming was also one of the focuses included in the plan to build up a seamless network for mobile broadband.

Canada adopted its national broadband policy relatively late (in 2014) (Broadband Commission, 2014). In Canada, in 2009, 96% of households were covered by 3G service and the number increased to 99% after 2011 (CRTC, 2014). In 2014, about half (45%) of households were covered by LTE, while in 2013, it increased to 81%. In general, there are at least 2 mobile broadband service providers (in rural areas, it was 3-6 providers in urban areas). Similar to the United States and Finland, broadband has been included in the universal service definition in Canada (ITU, 2013).

Australia and New Zealand

Similar to most OECD countries, both Australia and New Zealand adopted their national broadband policies in around 2010 (Australia started in 2009 and New Zealand in 2010) (Broadband Commission, 2014). Australia had the second highest mobile broadband subscriptions (114%) among OECD countries in 2013. Voice universal service was introduced in Australia since 1991. Since 2009, the government invested in the deployment of the National Broadband Network to provide open-access and wholesale only broadband network cross Australia (ITU, 2009; OECD, 2012b). Mobile broadband was also mentioned in the project as a supplement of fiber network in rural areas.

In New Zealand, there are two major mobile broadband providers (Spark and Vodafone) and one small provider. 3G service is almost available everywhere in New Zealand and 4G is available in about half of areas in New Zealand (Wikipedia, 2015). As other countries in the world, digital divides also exist in New Zealand. To narrow the digital divide, the government initiated a rural broadband initiative to invest $300 million dollars for increasing rural broadband deployment, either via fixed or mobile networks (Ministry of Business, 2014).

Japan and South Korea

Both Japan and Korea have been leading broadband countries in the world. These countries both have over 100% mobile broadband penetration rates. Both countries adopted their national broadband policies in around 2010 (Japan, 2010; Korean, 2009) (Broadband Commission, 2014). In Japan, NTT DoCoMo is the largest mobile provider and it initiated the first mobile Internet service in Japan in 1999 (Freedom House, 2013). Unlike most other OECD countries, Japan does not have an independent telecommunication regulator. The Ministry of Internal Affairs and Communications (MIC) is the main regulatory agency for broadband regulation. In Korea, 3G service was launched in 2003 and 4G was launched in 2011 (BuddeComm, 2011). It was claimed that half of mobile broadband users used 4G network. According to Akamai, South Korea has the highest average mobile broadband speeds (18.2 Mbps, Akamai, 2015).

South America: Chile and Mexico

Both Chile and Mexico had lower mobile broadband penetrations in OECD (below 40%). Chile adopted its national broadband policy relatively late (in 2013) and Mexico started in 2011 (BroadbandCommission, 2014). Chile has the geographical constraint for rural areas to have access to broadband network (Zaballos & Foditsch, 2014). In response to the request from telecommunication providers and the society, the Chile government added broadband into its universal service project and subsided the deployment of broadband network in rural areas (Zaballos & Foditsch, 2014). As for Mexico, several digital initiatives had been made in years 2006-2013 (e.g., National Digital Agenda in 2010 and Digital Agenda Mexico in 2012) . By 2013, mobile service (voice) is available in 50% of population in Mexico (Marcus & Kuhlmann, 2013). The lack of competition in both fixed and mobile Internet services in Mexico has been identified as a major problem with regard to its telecommunication regulation (OECD, 2012a). Both fixed and mobile markets are dominated by the biggest provider (Telmex).

Fixed and Mobile Broadband

Looking at the relationship between fixed and mobile broadband subscriptions in 2014 (as shown in Figure 3 below) (OECD, 2015b), it seems that fixed and mobile broadband subscriptions are positively related. However, it is obvious that there are some variances among countries. As mentioned in Chapter 1, past studies have made different conclusions on the relationship between fixed and mobile broadband. This might indicate the complexity of their relationships. Hence this dissertation also explores the relationship between fixed and mobile broadband. By using a mixed-method approach, this dissertation aims to shed light on our understanding of the relationship between fixed and mobile broadband.

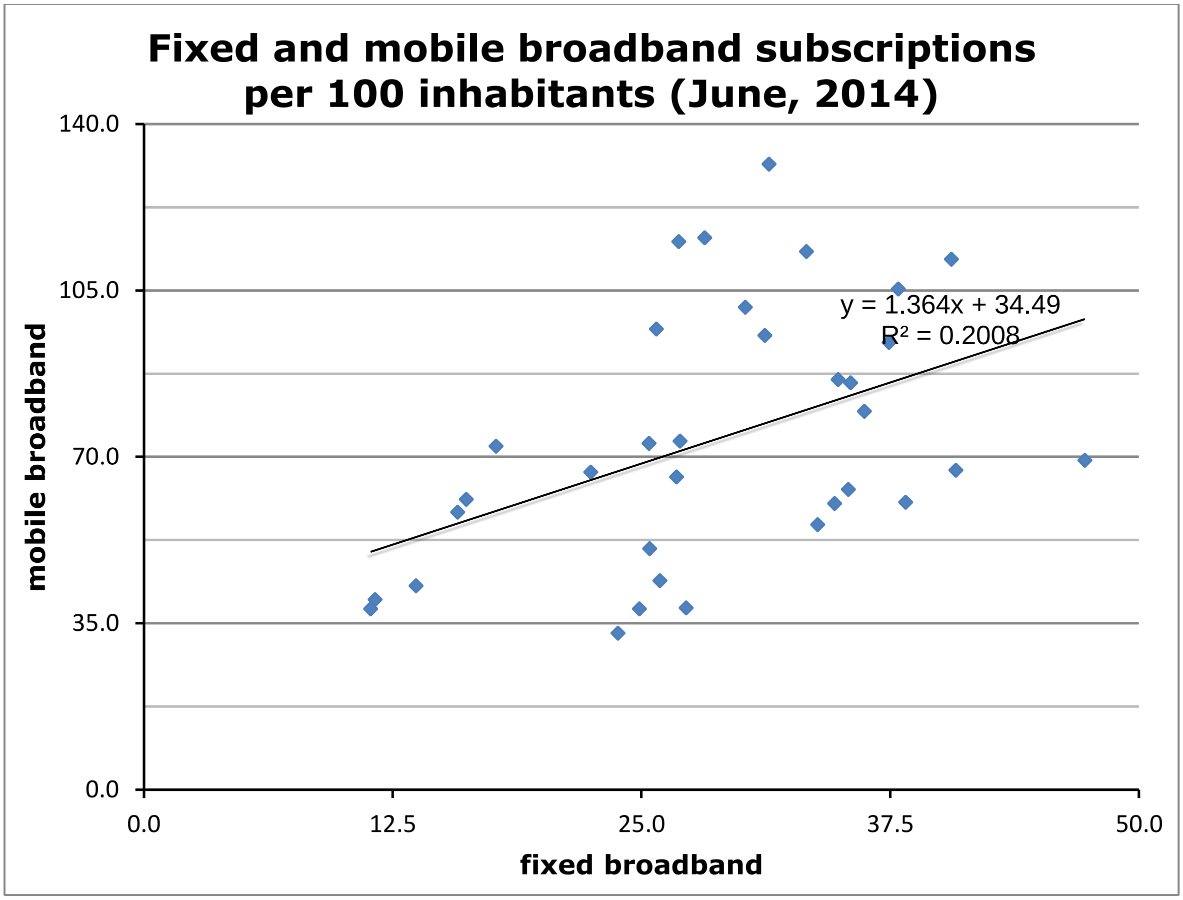

Figure 3 Fixed and Mobile Broadband Subscriptions in OECD Countries, 2014
(Source: Own calculations based on OECD data, OECD, 2015b)

These countries also differed in their fixed broadband subscriptions: Switzerland was 47.3%, Netherlands was 40.8 %, and Denmark was 40.6%, while Mexico and Turkey only had about 11 % fixed broadband subscriptions (OECD, 2015b). As for broadband policies, although all of these 34 countries have developed their national broadband policies, some started early (e.g., Norway started in 2000, Finland in 2005, Estonia, Greece, Slovak all started in 2006) and some started late (e.g., Chile and Czech started in 2013, Canada and Poland adopted their national broadband policies in 2014) (Broadband Commission, 2014). The majority of OECD countries adopted their national broadband policies in 2009 or 2010 (e.g., the U.S., Japan, Korea). The GDP/capita also differed among these countries: Mexico had the lowest GDP/capita

(17,952 in 2012) and Luxembourg had the highest GDP/capita (89,417 in 2012). Generally speaking, northern European countries had higher GDP/capita (except Iceland), but southern American countries (Mexico and Chile) and other eastern-southern European countries had lower GDP/capita (e.g., Turkey, Hungary) (OECD, 2014).

These differences in fixed and mobile broadband subscriptions beg the question of which policies and other country-specific features among these OECD countries can explain them. The next chapter discusses factors that might affect mobile broadband penetration. We will review the pertinent literature as we explore those policy variables in the next chapter.

Chapter 3

The Role and Effects of Mobile Broadband Policy: Theoretical Foundations

As mentioned above, mobile broadband allows accessing the Internet from anywhere. Among the many benefits of ubiquity is that mobile broadband can narrow the digital divide between urban and rural areas, especially in areas where fixed broadband is not available (Srinuan et al., 2012). To harness its benefits, increasing the penetration rates of mobile broadband is a policy goal for many countries. For policy makers, it is important to have a clear understanding of the relationship between mobile broadband related policies and broadband penetration. Is policy a main factor that affects mobile broadband penetration? Are there policies that are necessary conditions for a country to deploy mobile broadband? What are the necessary or sufficient conditions for a country to increase its mobile broadband penetrate rates? Are there policies that inadvertently slow down mobile broadband deployment and adoption? These and other questions need to be answered in order to craft effective policies. Understanding the necessary conditions for increasing mobile broadband penetration can help policy makers know what condition must be satisfied so it is possible to enhance penetration rates. Policies and other factors often interact with each other as specific policies often are a response to these conditions. For example, countries with lower income and countries with higher income per capita might need different policies to generate higher broadband penetration rates. Understanding the sufficient conditions can help policy makers to examine their current policies and to develop approaches that can result in higher penetration rates. Therefore, the overarching research question that motivates this dissertation is:

RQ: What are the necessary and sufficient conditions for a country to have higher mobile broadband penetration rates?

Recent studies have modeled ICT as an ecosystem in which a dense network of direct and indirect relations links an increasing number of player, such as network operators, content providers, application developers, and users (Bauer, 2010b; Bauer, 2014; Cherry & Bauer, 2004; Fransman, 2007, 2010; Kim, Kelly, & Raja, 2010). The research framework proposed in this dissertation is rooted in these recent conceptualizations of the ICT system. Factors influencing mobile broadband penetration can be categorized into policy/regulatory factors and economic factors (supply and demand). For the policy/regulatory factors, three groups of factors will be included in this study: 1) policies that aim to increase universal access/availability for the public (more related to the public-interest concern), 2) policies that aim to increase the competition and cooperation among service providers (more related to suppliers, with regard to increasing their efficiency, performance, and the quality of their services/products, and 3) the performance and efficiency of regulator itself. Based on past research (e.g., Tsai & Bauer, 2014), a framework for broadband penetration that integrates the policy/regulation, supply side factors, and demand side factors is proposed in this dissertation (see Figure 4).

In this mobile broadband ecosystem, policies work because they can change the incentives of players (e.g., service providers and consumers), but they may add constraints to the players. For example, spectrum policies can affect the cost for providers to provide services. This can also lead to the changes of prices and affect the incentives of consumers. All of these facts change an individual player's choices. Therefore, policies can change the decisions of individual players. As for the economic factors, supply and demand interact and depend on each other. For example, when the cost (supply) decreases, providers may lower the price of services/products, hence increase consumers' incentives for using the service.

Mobile Broadband Penetration = *f* (Policies/Regulatory factors, Supply-side factors, Demand-side factors)

Policy and regulatory factors: 1) universal access policies; 2) policies related to the competition and cooperation among service providers, including spectrum policies; 3) regulatory quality

Supply-side factors: competition, cost of providing access

Demand-side factors: income, education, digital skills

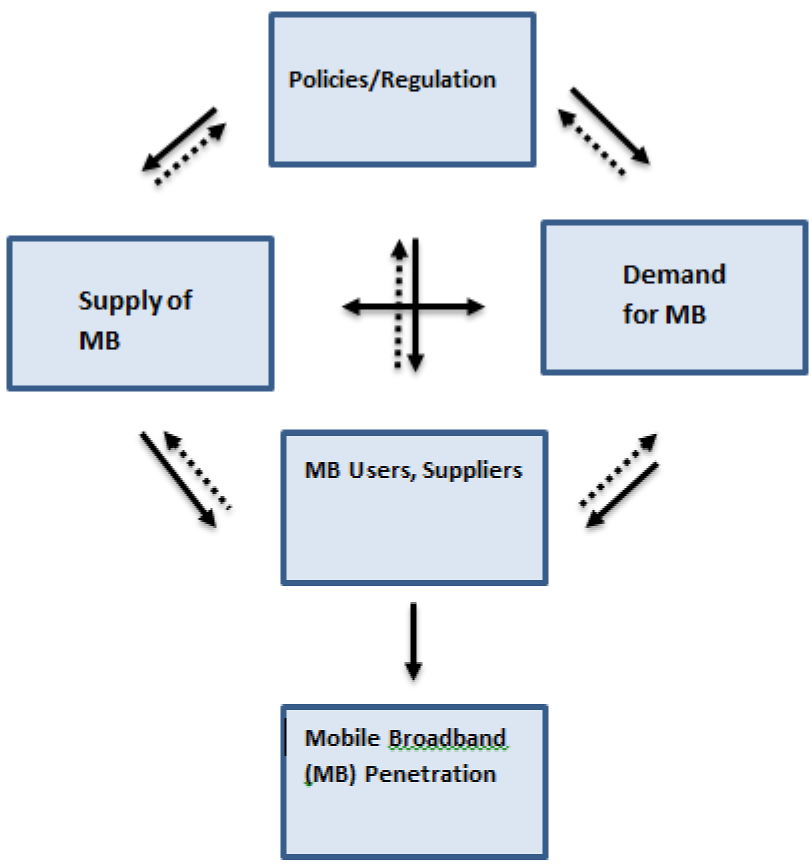

Figure 4 Research Framework[6]

[6] Arrows with solid lines mean the influences are direct, while arrows with dotted lines mean these influences are

In this dissertation, the main variable of interest (the dependent variable) is mobile broadband penetration rates. As mentioned earlier, mobile broadband is accessing high speed Internet (at least 256 Kbs) via mobile devices. The definition used in this dissertation is the same as the definition of wireless broadband provided by OECD. According to OECD (OECD, 2011, p. 128), "wireless broadband includes satellite, terrestrial fixed wireless and terrestrial mobile wireless. This last is divided into two sub-categories: standard mobile subscriptions (with active use) and dedicated data subscriptions. All components include only connections with advertised data speeds of 256 Kbps or greater." There are many different ways to measure mobile broadband development, such as using total subscriptions, subscribers, the quality of broadband (e.g., speeds or performance), total coverage, etc. In this dissertation, the dependent variable is measured by using mobile broadband subscriptions per 100 inhabitants because it is the only comparable measure available and indicative of mobile broadband adoption and use.

As mentioned earlier, mobile broadband works in an ecosystem. This dissertation takes the ecosystem approach that the actors in the system seek to maximize their benefits (profits, utility) subject to the action of other players and of the policy conditions. In this system, policy makers/regulators, service providers, and users interact and affect each other. That is how policy affects individual players and the subsequent outcomes (in this dissertation, mobile broadband penetration) at the sector level. Such a theoretical framework has not been articulated in a comprehensive way in mobile broadband-related studies and that this is one of the unique contributions of the dissertation. As shown in Figure 4, in each broad group of factors, multiple aspects play a role. Based on this overarching framework, we will examine each individual factor that might affect mobile broadband adoption below.

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more indirect.

Policy and Regulatory Factors

Three kinds of policy and regulatory factors can affect mobile broadband penetration: 1) universal access policies (typically related to public-interest concerns associated with mobile broadband), 2) policies related to competition and cooperation among service providers (including spectrum policies), and 3) the performance and efficiency of regulator itself.

Universal Access Policies

Mobile Broadband Universal Service

Universal service is a policy that seeks to make important and basic communication services available and affordable for everyone in a certain country (Griffin, 2014; OECD, 2012b). Many countries have basic voice phone universal service that allows people to access public telephone networks or have access to landline phones at an affordable price[7]. More and more countries have started a discussion on adding broadband services to their universal service objectives (e.g., the European Commission and the United States) (Griffin, 2014; Nucciarelli, Sadowski, & Ruhle, 2014). In Europe, during 2009-2012, several countries (e.g., Sweden, UK, Spain, Italy, and Australia) initiated a review of their national broadband policies. However, many governments struggle with whether they should intervene with the market structure to use public money to guarantee the availability of broadband services. Even countries with a broadband universal policy or a national broadband plan have different ways to enhance penetration rates, e.g., subsidies, tax breaks, and Public-Private Partnerships (PPP). The debates on the public-goods and competition-related perspectives of universal service are still undergoing (Nucciarelli et al., 2014). There is great divergence among authors as to whether

[7] For example, Australia, Canada, European Union, Finland, Japan, Korea, Norway, Spain, Switzerland, Turkey, UK, and the U.S.

Universal Service Policies are effective (e.g., Cherry, Wildman, & Hammond, 1999; Hudson, 2009, 2014; Mueller, 1997).

Among OECD areas, most countries that had fixed broadband universal service also included both fixed and mobile broadband services (e.g., Finland, Spain, Switzerland, Turkey, U.S.) in the definition of universal service. Having an adequate national broadband policy has been identified in some studies as a key factor for broadband adoption (Yamakawa, Cadillo, & Tornero, 2012). Since the main goal of broadband universal service is to make broadband services affordable and increase penetration rates, one would expect that countries with broadband universal service objective will have better broadband penetration rates. Nevertheless, the results are not guaranteed. Different policy combinations seem to affect the penetration rates. It is also important to note that there may be an endogeneity problem as countries with low broadband penetration may be more likely to initiate broadband universal service policies (e.g., Turkey and Mexico). Thus, there is the possibility of reverse causality that needs to be taken into account in empirical analysis. To examine the relationship between mobile broadband universal service and mobile broadband penetration, H1[8] will be stated as:

H1: Countries with mobile broadband universal service policies have greater mobile broadband penetration rates.

In addition to mobile broadband universal service policy, voice universal service might also be related to the adoption of mobile broadband, since it is related to the adoption of mobile phones. However, the relationship between having a more comprehensive universal service

[8] All hypotheses are formulated assuming all other factors are being equal.

objective and mobile phone adoption is not clear. It will be interesting to examine how it relates to mobile broadband penetration as well.

Policies Related to Competition and Cooperation among Service Providers

Spectrum Management Policy

Spectrum policy is related to the development and penetration of mobile broadband in several ways. First , spectrum is a limited but essential resource for mobile broadband deployment. It is essential for regulators to ensure there is enough spectrum available for wireless network providers to allow as many uses as possible (Cave, Doyle, & Webb, 2007; Chapin & Lehr, 2011; OECD, 2007). Second, issues related to spectrum management, including the requirement on technologies, the methods adopted to assign licenses (e.g., spectrum auction), and the rules governing spectrum sharing/trading, directly and indirectly affect the use of mobile broadband. Especially, with the increasing demand of mobile broadband, it is important for regulators to make effective spectrum policies to ensure the efficiency of spectrum use (CISCO, 2015). As indicated by Cooper's Law, the spectral efficiency has been increasing in the last 90 years. With the improvement of technologies (ArrayComm, 2011), the efficiency of personal communication spectrum use has increased more than a trillion times in the past 90 years and more than a million times in the past 45 years (ArrayComm, 2011). Among these "one million times" improvement, only 25 out of one million were contributed by using more spectrum and 5 out one million were by dividing the spectrum, and the main improvement came from spectrum re-use (ArrayComm, 2011). This highlights the importance of spectrum re-use and spectrum sharing (in other words, spectrum management). In this dissertation, two spectrum related policies, technological neutrality and spectrum sharing ,will be examined.

Technological Neutrality. One important aspect of spectrum policy is the adoption of technological neutrality (for example, Australia, U.S., and Canada have adopted this policy) (OECD, 2007). Technology neutrality implies that any technology can be used to provide a certain service using a frequency band (Frullone, 2007). In contrast, a non-neutral spectrum assignment policy would earmark a certain band for a specific service, e.g. 2G or 3G mobile services. Having technologically neutral policy might lower the costs of rolling out networks, allow gradual network upgrades, and permit greater competition when the service providers have other more advanced technologies available. Other things being equal, this will reduce the cost of service provision and lower mobile broadband prices as well as increased use of mobile broadband services. This will also allow providers to offer services that users want and need. Service providers can upgrade their networks and services as technology evolves. Hence providers can do better to serve the market. The will also allow the flexibility for the providers to upgrade their network when improvement is available. Therefore, hypothesis 2 is derived:

> H2: Countries that rely on technologically neutral spectrum assignment have higher mobile broadband penetration rates.

Spectrum Sharing/Trading. Another factor to be explored is spectrum sharing. Spectrum sharing is a potential solution for the increasing demand for spectrum use. There are several techniques for spectrum sharing, including band sharing, leasing, and spectrum trading (ITU). Spectrum trading is a mechanism that can allow the market force to work on its own (Cave et al., 2007). Other things being equal, this will reduce the cost of service provision and lower mobile broadband prices as well as increased use of mobile broadband services. This will also allow providers to offer services that users want and need, hence increase the penetration rates. Therefore, the application of spectrum trading can also affect mobile broadband penetration.

Several countries have enabled mobile operators to trade their spectrum (e.g., Australia, Canada, New Zealand, Norway, the U.S., and the U.K.) (GSMA, 2012; Horton, 2012). Spectrum trading aims to improve efficiency of spectrum use by allowing more flexibility and reducing the sunk cost of current spectrum owners (Freyens & Yerokhin, 2011). It might also facilitate the introduction of new services (Crocioni, 2009; GSMA, 2012; Valletti, 2001). Secondary spectrum trading might also fix the inefficiency of the first spectrum allocation/auction (FCC, 2004; Crocioni, 2009; Mayo & Wallsten, 2010). However, it may also bring the risk of hindering competition if current operators will not sell extra spectrum to their real competitors. If they do, they will sell the spectrum at a higher price (Bykowsky, 2003). This may lead to consolidation of operators. Furthermore, the importance of spectrum sharing policy might vary among countries. For example, (Quiroz, Ahmed, & Markendahl, 2014) concluded that spectrum sharing might be important to Europe for it has higher mobile broadband penetration rates, while the importance for this policy in Chile and other Latin American countries was not as significant for there was sufficient spectrum to be utilized. Similar to H2, we hypothesize the relationship between spectrum trading and mobile broadband:

H3: Countries that allow spectrum sharing/trading have greater mobile broadband penetration rates.

In addition to these spectrum-related policies, the availability of spectrum for mobile broadband providers, especially new entrants, is critical for the competition and performance of mobile broadband. If more spectrum is made available for mobile broadband services, other things being equal more providers can provide services. If this intensifies competition, it could lower the prices for broadband services and facilitate adoption. In contrast, when there is a spectrum shortage the costs of rolling out the mobile broadband network will increase. This may result in bigger business consolidation and hinder competition (Chapin & Lehr, 2011). Even if the numbers of providers are the same, with more bandwidth of spectrum, mobile broadband service providers will have more flexibility to use their spectrum and offer a wider range of services. Furthermore, more people will be able to use mobile broadband services with less congestion.

Besides, the frequency bands used for mobile broadband will affect mobile broadband penetration to a certain degree. Give the propagation characteristics of electromagnetic waves, infrastructure rollout costs are lower using lower frequency bands. However, lower frequency bands might results in longer signal-fading and affect the quality of phone calls or mobile broadband access (FCC, 2010b). Besides, lower frequency like the low VHF bands might require larger antennas for mobile phones. These might affect mobile broadband penetration negatively. Furthermore, the implementation of spectrum auctions might affect mobile broadband penetration.

Many OECD countries have utilized spectrum auctions to assign usage rights (e.g., Austria, Germany, Mexico, U.S., Chile, Spain, etc.). The main goal of spectrum auctions is to allow companies that value the spectrum most use the spectrum and to find providers that can provide best services to customers (Cave et al., 2007). This can facilitate the function of market and minimize the intervention of governments (Cave et al., 2007). This should lead to improved mobile broadband adoption. However, spectrum auctions may increase the cost of rolling out networks as they increase the upfront costs (the sunk costs) and hinder the rollout of mobile broadband (e.g., the 3G auctions in Germany that was mentioned in Chapter 2). Spectrum auctions may also be manipulated by big companies (Rose & Lloyd, 2006) and hinder competition of mobile broadband services. If this kind of market failure exists, the initial goal of spectrum auction, to enhance the efficiency of spectrum use, will not be achieved (Cave et al., 2007). Owing to the potentially conflicting forces mentioned above, the relationship between spectrum auction and mobile broadband penetration is hard to establish theoretically. However, since this study examines the overall mobile broadband penetration instead of the penetration of a certain mobile technology, simply examining the existence of spectrum auction does not help us understand the complicated relationship between auction and mobile broadband penetration (because all OECD countries have auctions to some degrees). It will be helpful to examine the penetration of a certain technology and how it relates to the auction of certain spectrum auction.

Roaming Regulation

Another factor that may affect broadband penetration is roaming regulation. Whether the regulator has implemented roaming policies to decrease the charge of roaming services or not might affect the use of mobile broadband. When roaming is not allowed, users will either not have signals when they travel in an area that is not covered by his/her mobile provider, or the user will have to pay extremely high amount of money to make international phone calls.

In February 2014, the European Union (EU) published the result of a survey regarding mobile data roaming. The survey found that only one in ten people used their mobile Internet for emails as often as they did in their home countries when traveling in other EU countries and 47% of people had never used mobile Internet for emails or social media when they were not in their home countries (EurActiv, 2014). The low mobile usage abroad, in the view of the European Commission, indicated a need to change the roaming policies in EU countries (EurActiv, 2014). According to a recent report, the EU plans to eliminate roaming charge or “end roaming” in the future so the goal of having only one telecom market can be realized (EC, 2015a). In the United

States, there are no separate roaming charges for consumers (rather they are folded into the pricing plans). In 2011, the FCC started to require facilities-based operators to provide “reasonable” terms for roaming and this resulted in a lot of debates (FCC, 2011). Having roaming policy means that it is easier for competitors to get full coverage of mobile signals, which may give users more incentives to use mobile broadband. Therefore, it is hypothesized that:

H4: Countries that have mandatory roaming obligations on mobile wireless service providers have greater mobile broadband penetration rates.

Regulatory Quality/Government Effectiveness

The quality of regulation and the effectiveness of governments are critical to the outcomes of regulation. To ensure the efficiency of regulation, regulators need to ensure the transparency and independence of their rules and decision-making. The independence and ability of regulators are important to having high quality of regulation (Falch, 2007). The independence and credibility of regulators also result in the confidence that the regulation/rules can be made more objectively, and hence increase the investment of operators (Intven, Oliver, & Sepulveda, 2000; OECD, 2014). Regulatory quality can directly and indirectly affect mobile broadband penetration. Therefore, in order to assure the implementation of the policies and regulation, we need to consider the quality of regulation for each country. As Cherry and Bauer (2004) pointed out, it is essential for regulators to evaluate the policy-making system to ensure the efficiency of policies. Specifically, regulation and policies interact with other factors in a “complex interdependent system” (Bauer, 2014), keeping a robust and efficient regulatory mechanism can be important for policy implementation. However, research also showed that strict regulation might hinder the development of broadband in some cases (Bauer, Schneider, & Zenhäusern, 2013). In a study examining mobile broadband diffusion, some countries that faced corruption issues still had high mobile broadband diffusion (Yates et al., 2013). This indicates the complexity of regulation and performance. It will be important to consider the impacts of regulatory quality on mobile broadband adoption. In this study, regulatory quality will be examined by stating the hypothesis as:

H5: Countries with higher regulatory quality have greater mobile broadband penetration.

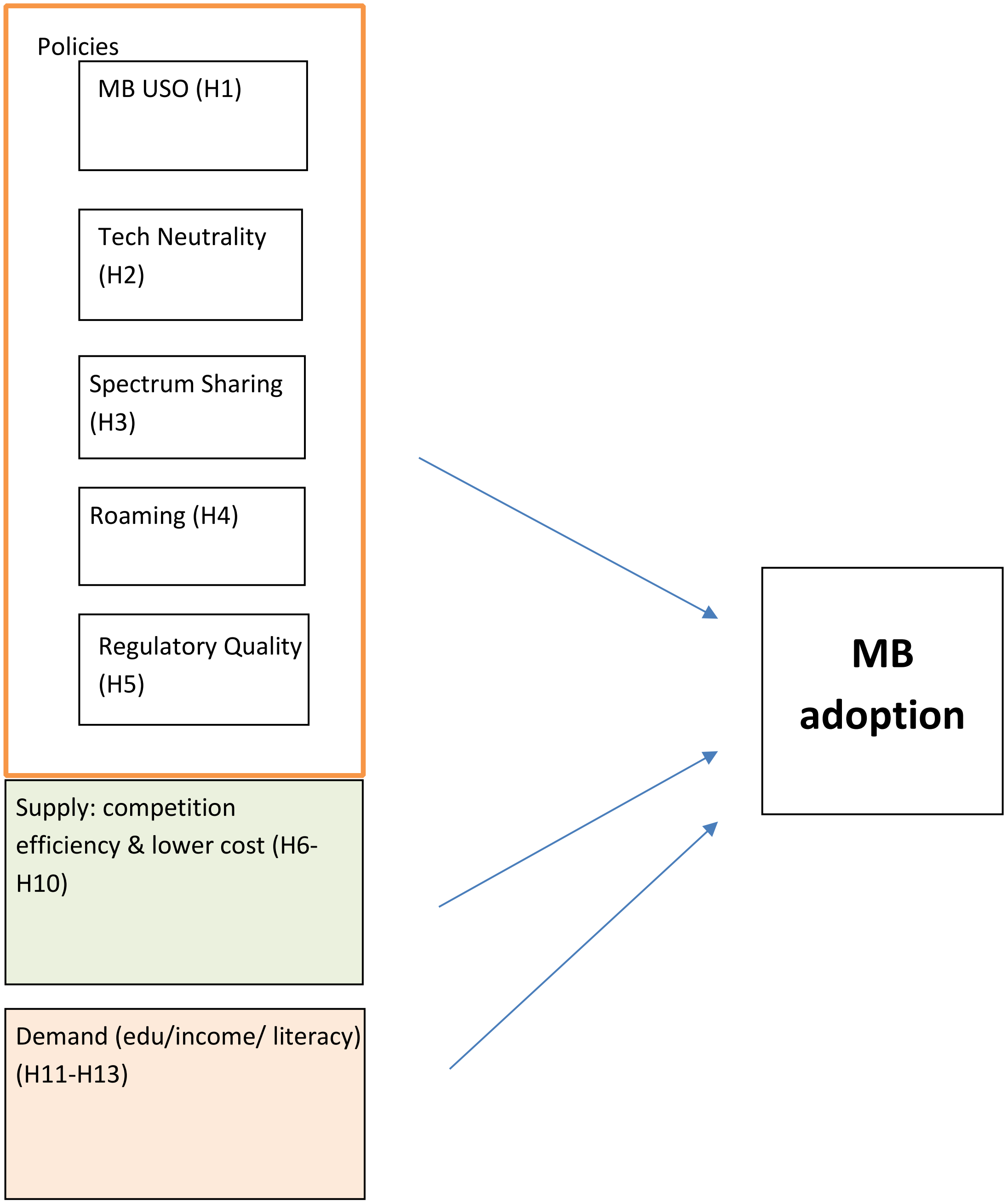

Figure 5 Variables

In addition to the regulatory factors, other factors on the demand and supply side of the mobile broadband markets should also be considered (Kim et al., 2010). Supply and demand interplay and interact in a systemic fashion.

Supply-side Factors

Competition issues and related policies are more complicated in the age of technology convergence and multi-sided market relations (Upton & Walden, 2014). Competition and the cost of providing mobile broadband services are both related to mobile broadband suppliers. Competition is one of the key factors that drive broadband prices down (ITU, 2003, p. 7) and it is critical to broadband penetration (Belloc, Nicita, & Rossi, 2012). The number of mobile providers is a first proxy of the degree of competition among different providers but other factors influence competitive intensity. Population density, which indicates the cost of broadband deployment, will be used in this study to measure cost.

Competition

Competition is one of the factors that drive broadband prices down and hence increase the affordability of mobile broadband (Weiss, Gulati, Yates, & Yates, 2015). Even though government subsidies and other regulations may also lower prices, they often only affect the market only temporarily and "cannot replace a well-functioning market" (ITU, 2003, p. 7). Competition is both a supply-side market feature and a dimension that can be influenced by regulation and public policy. For example, the number of licenses issued has a direct effect on the number of players in the market and hence the intensity of competition. Moreover, with appropriate antitrust and merger policies can also contribute to effective competition. At the same time, there are aspects of competition that are beyond the control of the regulator but are part of business strategy and corporate decision making (e.g., the aggressiveness of pursuing customers, innovation strategies, etc.).

With regard to telecommunications industries, two kinds of competition are typically distinguished: service-based competition (also known as access-based competition) and facilities-based competition (also known as platform-based competition)[9]. Service-based competition is "competition among companies that rely partially or entirely on the facilities or the services of other operators" (Choi, 2011, p. 806; Nucciarelli et al., 2014). The effects of service-based competition have been demonstrated in multiple studies. For fixed broadband, one common way to increase service-based competition is by establishing local-loop unbundling regulation. For mobile broadband, increasing the competition among mobile service providers could lower the prices and increase the efficiency of providers, and improve the quality of services, hence increasing the competition among mobile broadband service providers should facilitate mobile broadband penetration (Lehr, 2014). Mobile broadband is typically provided by mobile voice/data service providers. Therefore, the concentration of (and competition in) the mobile market in general can be considered a proxy for the concentration of mobile broadband market. Hence we state H6 as:

H6: Countries with more intense competition among mobile providers have higher mobile broadband penetration rates.

Facilities-based competition is that "of multiple, vertically integrated platforms providing closely substitutable services entirely over their own infrastructure'' (Maldoom, Marsden, Sidak,

[9] Competition has been categorized differently in past studies. For example, it was divided into inter-platform competition, facilities-based intro-platform competition, and service-based intra-platform competition in another study on broadband penetration (Bouckaert, Van Dijk, & Verboven, 2010).

& Singer, 2005, p. 33). Facilities-based competition can be "intra-modal" or "inter-modal." Competition between two cable companies or two mobile phone companies is a form of "intra-modal" competition; while the competition between DSL and cable companies is a form of "inter-modal" competition (Maldoom et al., 2005).

Past studies have reached different conclusions with regard to the effectiveness of facility-based competition and service-based competition. Some researchers found that facility-based competition can enhance broadband penetration (Bauer, Madden, & Morey, 2014; Bouckaert et al., 2010; Bourreau & Doğan, 2004; Choi, 2011; Distaso, Lupi, & Manenti, 2006; S. Lee, Brown, & Lee, 2011; Denni & Gruber, 2007; Dauvin & Grzybowski, 2014; Layton, 2014; Nardotto, Valletti, & Verboven, 2014) while some had different conclusions on competition (Gruber & Koutroumpis, 2013). For example, Gruber & Koutroumpis (2013) found that competition between firms (firm competition) increased broadband penetration while the competition among technologies did not help increase broadband adoption. Broadband diffusion is faster in a one-platform market if there is fierce competition. Haucap et al. (2014) also found that inter-platform competition was not a significant predictor to fixed broadband penetration. Another study on broadband penetration in Spain also found that inter-platform competition was not a significant predictor to broadband penetration, while intra-platform competition was important for broadband adoption (Fageda, Rubio-Campillo, & Termes-Rifé, 2014). With convergence, the intra versus inter-platform differentiation will become less relevant.

The effectiveness of facility-based and service-based competitions might vary at different stages of broadband adoption. Specifically, facilities-based competition could increase broadband penetration in the earlier stage, while service-based competition could increase the quality of services after adoption (Choi, 2011). Further studies are needed to understand how competition affects broadband adoption. To understand how competition over different technologies relates to broadband adoption is one of the main goals of this study. Two kinds of competition will be discussed: the competition among mobile broadband providers (intra-platform/facility competition) and the competition between fixed and mobile broadband (inter-platform competition).

With regard to inter-platform competition, some scholars argued that mobile broadband might simply be an extension of fixed broadband (e.g., Nielsen & Fjuk, 2010), some argued that mobile broadband might be a substitute for fixed broadband (Grzybowski, Nitsche, Verboven, & Wiethaus, 2014; Srinuan et al., 2012), or a complement (Lee, Marcu, et al., 2011; Wulf, Zelt, & Brenner, 2013) to it. For example, Grzybowski et al. (2014) conducted a survey in Slovakia and found that the demand for broadband was highly price-sensitive and mobile broadband was a substitute for fixed broadband. Lehr (2014) concluded that mobile broadband can be both a substitute and a complement to fixed broadband, depending (Nielsen & Fjuk, 2010) on the market context and its users. When the quality of fixed broadband is not good, mobile broadband can be a substitute for it (Chapin & Lehr, 2011) (e.g., in Slovakia). However, if the quality of mobile broadband is not good, instead of being a substitute for fixed broadband, it will be a complement to fixed broadband (Chapin & Lehr, 2011; Zickuhr & Smith, 2013). Similarly, McDonough (2012) also found that mobile and fixed broadband can be both substitutes and complements. In developing countries that had high fixed broadband penetration rates, mobile broadband tend to be complements because it cannot compete with the prices and quality for fixed broadband. However, in developing countries that do not have fixed broadband infrastructure everywhere, mobile broadband could be a substitute for fixed broadband. The study also pointed out that bundling strategies affect the relationship between mobile and fixed broadband. If bundle packages allow users to switch different technologies easily, then mobile and fixed broadband will be complements to each other (McDonough, 2012).

To illustrate, if fixed broadband and mobile broadband are substitutes, inter-platform competition is relevant. If an individual chooses to subscribe fixed broadband, he or she would not subscribe to mobile broadband in this case. Therefore, fixed and mobile broadband subscriptions would be negatively correlated. In contrast, if fixed and mobile broadband services are complements, then fixed and mobile broadband subscription would be positively correlated. The relationship is ambiguous and depends on empirical evidence. In this study, a hypothesis is proposed based on previous studies (Grzybowski et al., 2014):

H7: Countries that have higher fixed broadband penetration rates have higher mobile broadband penetration rates.

Cost

The cost of broadband deployment is critical to broadband adoption (Bauer et al., 2003; Belloc et al., 2012). When the cost of providing broadband services is low, prices can be lower and more users can afford the services. However, the cost often cannot be measured directly, therefore, population density will be used as an indicator of cost. Many studies have found that population density is positively related to broadband deployment (Bauer et al., 2003; Garcia-Murillo, 2005), however, there is still a debate on the importance of population density to broadband adoption rates (DeMaagd, 2009 January). Areas that have lower population density are rural areas. These areas are sparcely populated, so the cost to provide broadband services could be higher. Hence a similar indicator, urban population (an indicator of the portion of urban population), can be an important predicator of mobile broadband penetration. Therefore, we state H8 and H9 as:

H8: Countries with higher population density have greater mobile broadband penetration.

H9: Countries with higher population concentration in urban areas have greater mobile broadband penetration.

In addition to the competition indicators above, the prices of mobile broadband services can be critical to consumers' demand. Lower prices will increase the quantity consumed along a demand curve. Grzybowski et al. (2014) pointed out that the broadband market is highly price sensitive. However, some studies found that even though prices are important, the effects of prices on Internet access were small (Chaudhuri, Flamm, & Horrigan, 2005) and the price elasticity of demand for Internet access varied across technologies (it was more elastic for ADSL Internet access and inelastic for the dial-up Internet, see Rappaport, Kridel, & Taylor, 2002). With the increase of penetration rates of a certain Internet technology, the price elasticity of demand might decrease (Rappaport et al., 2002). Still, a lower price is related to higher demand and hence higher penetration. Therefore, H10 in this study is:

H10: Countries with lower prices for mobile broadband services have greater mobile broadband penetration.

Demand-side Factors

In addition to the supply side, demand side factors, such as income and how consumers perceive broadband services, are critical to broadband adoption rates (Belloc et al., 2012; LaRose et al., 2012; Peronard & Just, 2011; Shieh, Chang, Fu, Lin, & Chen, 2014; Shin & Jung, 2012).

Economic factors such as income (Weiss et al., 2015) and demographic variables (e.g., education) have also been identified as influencing fixed broadband penetration. This argument will likely hold for mobile broadband services as well. Based on the conclusion drawn from most broadband adoption studies (e.g., Smith, 2014; Weiss et al., 2015), we can assume that people who have a higher income will be more capable to afford mobile broadband services. Another demographic factor, education, is also an important factor for fixed broadband and ICT adoption (Pick, Sarkar, & Johnson, 2014). Applying the logic to mobile broadband, people who are more highly educated might have better skills and more need to use mobile broadband services. Hence our hypotheses H11, and H12 state:

H11: Countries with higher income per capita have greater mobile broadband penetration.

H12: Countries with higher education levels have greater mobile broadband penetration.

Another factor for the demand-side is digital literacy/digital skills. When talking about the digital divide, most people refer to the first level digital divide, the gaps on the access to digital devices. Researchers have found that in addition to access digital literacy also affects how people benefit from the digital devices and services. Gaps in digital literacy/digital skills have been identified as second-level digital divides (Park & Kim, 2014). It has been found as one of the main barriers for broadband adoption (Hauge & Prieger, 2010; Layton & Horney, 2014). Similarly, Internet self-efficacy and the expected outcomes of using broadband services have been found to be critical to broadband adoption (LaRose et al., 2012; LaRose, Gregg, Strover, Straubhaar, & Carpenter, 2007; Shim, 2013). Although these studies were based on fixed broadband adoption, we can apply these insights to mobile broadband adoption. Therefore, digital skills will be included in this study as well. H13 is stated as below:

H13: Countries with a population that has higher digital skills have greater mobile broadband penetration.

Examining the Effects of Mobile Broadband Policies

Most broadband penetration studies were conducted using quantitative analyses (e.g., Cambini & Jiang, 2009; Garcia-Murillo, 2005; Grosso, 2006; Gruber & Koutroumpis, 2013; Gulati & Yates, 2012; S. Lee & Brown, 2008) or qualitative case studies (e.g., Beltrán, 2012; Choi, 2011; Ganesh & Zorn, 2011; Ganuza & Viecens, 2011; Gómez-Torres & Beltrán, 2011; Lee & Chan-Olmsted, 2004; Menon, 2011; Peronard & Just, 2011; Shin & Jung, 2012; Yamakawa et al., 2012; Yu, Zhang, & Gao, 2012). Quantitative analyses such as regression are helpful to figure out the relationships between independent variables and dependent variables. In cross-national comparisons, two principal approaches are available: to assume that each country has unique conditions and capture those in a country-specific fixed effect, or to specify a process that holds across all countries equally. These approaches quickly run into limits in situations when different combinations of conditions are important for the observed outcomes. Moreover, comparative analyses have revealed the problem of "institutional equivalence" – the fact that different combinations of policies may result in similar outcomes. These unique aspects of how policy and other institutional variables interact with dependent variables (e.g., broadband penetration) greatly complicate or even jeopardize the use of econometric models.

Furthermore, one important assumption of regression analysis, independent observations, is at odds with what we know of the effects of institutional arrangements on outcomes. In many situations, policy factors are related to each other. In principle, this can be captured by interaction terms in regression analysis; however, given the large number of variables and potential combinations involved, this may be practically impossible. It was also found that the factors affecting broadband diffusion vary at different stages of adoption (Kyriakidou, Michalakelis, & Sphicopoulos, 2012). The factors affecting broadband diffusion in technologically developed countries and technologically developing countries differed (Gulati & Yates, 2012). These complications challenge comparative analyses using traditional panel models.

An alternative approach is case studies, which help to develop deep analyses of individual cases. By using case studies, we can examine the context of policy-making and the special social-economic situation of each country (e.g., Lee & Chan-Olmsted, 2004). However, whereas case studies can help us understand each individual case, it is often difficult to compare multiple countries and derive generalizable conclusions.

These limitations can be overcome by a method, named Qualitative Comparative Analysis (QCA), which combines the advantages of quantitative analyses and case studies and was used in this study. QCA and econometric analyses are largely complementary methods for finding patterns in empirical relationships. Using multiple approaches can help us have deeper understanding of the use and effects of mobile broadband policies (Bauer, 2010b). Thus, both QCA and econometric approaches will be used in this dissertation.

Challenges of Cross-country Comparative Studies

As mentioned above, this dissertation is a cross-national comparative study. Cross-national comparison method is commonly used in policy research because of the need and usefulness of policy learning from other countries. Specifically, many policy interventions happen at a national level. Doing cross-national research can help a country predict the causal relationships between a certain policy and the outcome (Bauer, 2010a). However, there are several challenges in cross-country comparative research (Kittel, 2006).

First of all, as Bauer (2010a) mentioned, finding meaningful indicators and metrics is one of the major challenges for cross-national research. A lot of time the measures used in cross-country comparison are ad hoc measures or aggregated measures that might result in the concern of weighting. Taking national broadband performance as an example, there are at least six measures to compare broadband performances among different countries, such as broadband availability, penetration, capacity, price, quality, and how broadband fits the needs of users (Fransman, 2006). It will be the researchers' responsibility to identify the most meaningful indicator. Because the OECD's data is more standardized than information from other sources and based on unified collection methods, it provides a more solid basis for empirical analysis.

In addition, policies always interact with other socioeconomic characteristics that a country has. When considering the effects of certain policies, it is important to consider the national differences and the interaction involved (Bauer, 2010a). Institutions are very complicated. Williamson (Williamson, 2000) identified four levels of institutional analyses: embeddedness (information institutions, norms, customs, etc.), institutional environment (formal rules of games), governance (play of the game), and resource allocation and employment. Dealing with the complexity of institutions can be challenging for cross-country comparison research.

These are the constraints of cross-country comparison research but also important elements to consider when designing a cross-country study. In the next chapter, we will explain how using QCA can help deal with the complexity of institutions. We will also explain the measures used in this study in details in the next chapter.

Chapter 4

Methods

To examine the causal relationships among mobile broadband penetration and the factors that influence it, a dual approach, employing two methods that allow complementary insights, will be used in this dissertation. First a fuzzy-set qualitative comparative analysis (fsQCA) will be conducted for the 34[10] OECD countries in order to examine whether individual policies or such policies in combination affect broadband penetration. Second, to gain a better understanding of the strength of relationships between policy interventions and outcomes, a panel regression analysis will be conducted. QCA and panel regression analysis have different advantages and shortcomings. QCA allows for a systematic examination of which, if any, kinds of policies are necessary and/or sufficient for having higher mobile broadband adoption. By conducting a panel regression analysis, quantitative parameter estimates can be derived for the importance of factors. The variables reflecting policies as well as supply- and demand-side conditions discussed in chapter 3 will be included in the model. The list of variables is provided in the section describing data collection.

This chapter is organized as follows. First, it introduces QCA and how to conduct QCA analyses. Second, it briefly explains the econometric approach used in the dissertation. Third, it presents the data collection and the measurements used in the dissertation.

[10] In the year this study was conducted, there are 34 members in OECD, including Australia, Austria, Belgium, Canada, Chile, Czech, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak, Slovenia, Spain, Sweden, Switzerland, Turkey, UK, and the United States.

Qualitative Comparative Analysis (QCA)

QCA is a relatively new method to analyze data. QCA is both case-oriented (Kim & Lee, 2008) and variable-oriented (Ragin, 2008a). On the one hand, similar to case studies, QCA looks into cases and compares the similarities and differences among cases (Basurto & Speer, 2012). On the other hand, similar to econometric approaches, QCA also takes variables into consideration and examines the relationship among variables (including the independent and dependent variables). Therefore, QCA can be considered a combination of quantitative and qualitative analyses. Different from case studies, in QCA, cases are described as a set of conditions and outcomes to analyze causal relations (Ragin, 1987, 2000; Rihoux & Ragin, 2009). In QCA, the independent variables (factors) are called "conditions" (Basurto & Speer, 2012). The relationship between these conditions and the outcomes (the dependent variables) is examined using set theoretical relations. Causality in this context is a "multiple conjectural causation" (Rihoux & Ragin, 2009, p. 17) that, different from traditional statistical techniques, is nonlinear and non-probabilistic.

QCA is good for examining the interdependence and complexity of various conditions/policies and stakeholders (Ragin & Strand, 2008). This comparative method is especially useful for policy discussions because policy-making is related to many different institutional arrangements (Finger, Groenewegen, & Kunneke, 2005; Künneke, Groenewegen, & Ménard, 2010). By examining the patterns of similarities and differences across cases (Ragin, 1994), the causal relationships among conditions and outcomes will be unraveled (Basurto & Speer, 2012). QCA combines the strengths of both quantitative and qualitative approaches (Ragin, 1987, 2000, 2008a, 2008b), and it can be used in situations with a small-*N* sample, even if a large number of variables are at play.[11] However, it is not limited to these research scenarios. It helps us understand the complexity of different conditions (Rudel & Roper, 1996) while it is analytical, replicable, and transparent in its data-analysis.

QCA allows analyzing institutional arrangements as combinations of factors that can include multiple policy decisions, not just a single component (e.g., a single variable). OCA is based on set theoretical relations (Ragin, 1987). It has been formulated using crisp sets (csQCA, a unit is either a member of a set or not) and fuzzy sets (fsQCA, membership in a set is a matter of degree) (Ragin, 2000). csQCA uses Boolean logic and assigns each condition a 0 (absence) or 1 (presence) for set membership. In contrast, fuzzy-set QCA uses the interval between 0 and 1 for each condition (Kent, 2008b). Fuzzy-set QCA is good for institutional analysis because it recognizes that policy and institutional variables are not always dichotomous (e.g., present or absent). Taking the universal service objective as an example, if we only use a dummy variable to represent the policy, we might find that all countries have this policy. However, there is a degree of difference on the scope of this objective. Some countries might only include private land lines into their universal service objective while some might include the private land lines, public pay phones, public cell phones, and private cell phones into the objective. In this case, using fsQCA will be more appropriate than using csQCA because it can better capture the variety of policies.

[11] Small-*N* refers to the size of the sample (the cases). For regression analyses, we need to have a certain size of *N* in order to run analyses, but QCA is not limited by the sample size. It can also be used to analyze many variables (the combination of various conditions, such as various broadband policies) at the same time.

Fuzzy-set QCA (fsQCA)

In this dissertation, fuzzy-set QCA analyses were conducted in order to capture the variety of the conditions and outcomes. Fuzzy-set uses calibration to assign a range from 0 (full exclusion) to 1 (full inclusion) for both conditions and outcomes. The 0.5 midpoint indicates the "maximum ambiguity (fuzziness) in the assessment of whether a case is more 'in' or 'out' of a set" (C. C. Ragin, 2008b, p. 90). Researchers have to decide the threshold of the midpoint based on theories. For example, the midpoint for mobile broadband penetration rates can be the average (mean) penetration rates across all cases.

Types of Fuzzy Sets

QCA researchers typically use four kinds of fuzzy sets (see Table 1). (a) Three-Value Fuzzy Sets: These are based on "three-value logic," which is using 0, 0.5 or 1 to identify non-membership, partial membership, or full membership in a set (a condition or an outcome). (b) Five-Value Fuzzy Sets: A "five-value scheme" is adopted by using 0, 0.25, 0.5, 0.75, or 1 to indicate fully out, more out than in, crossover, more in than out, and fully in, respectively. (c) Seven-Value Fuzzy Sets: These use 0, 0.17, 0.33, 0.5, 0.67, 0.83, and 1 to identify the degrees of membership. (d) "Continuous" Fuzzy Set: by using 0 (= fully out), $0 < x < .5$ (numerical scores to indicate the membership that is more "out" than "in"), .5 (crossover), $.5 < x < 1$ (to indicate being more "in" than "out"), and 1 (= fully in). Given our knowledge of institutional arrangements, this dissertation will use the continuous fsQCA approach.

Table 1 Crip versus Fuzzy Sets
Source: Ragin, 2000, p. 156

Crisp Set	Three-Value Fuzzy Set	Five-Value Fuzzy Set	Seven-Value Fuzzy Set	"Continuous" Fuzzy Set
1 = fully in	1 = fully in	1 = fully in	1 = fully in	1 = fully in
		.75 = more in than out	.83 = mostly but not fully in .67 = more or less in	Numerical scores indicating being more "in" than "out" (.5 < x < 1)
	.5 = not fully out or fully in	.5 = crossover: not fully out or fully in	.5 = crossover: not fully out or fully in	.5 = crossover: not fully out or fully in
		.25 = more out than in	.33 = more or less out .17 = mostly but not fully out	Numerical scores indicating being more "out" than "in" (0 < x < .5)
0 = fully out	0 = fully out	0 = fully out	0 = fully out	0 = fully out

Calibration

To conduct fsQCA analyses, it is essential to calibrate the degree of membership of the conditions and outcomes in the respective sets. Three qualitative anchors are required: the threshold for non-membership, threshold for full membership, and the crossover point (the point that is the maximum ambiguity to decide whether a case is in or out of a set). fsQCA software can perform the calibration once researchers set up these three anchors[12]. fsQCA software can analyze both the calibrated data and crisp-set data (dichotomous data).

Data Analyses Using fsQCA

By using fsQCA, two sets of solutions can be provided by: the necessary and sufficient solutions for the outcomes to be present. Necessary solutions present the factors/conditions that are always present when the outcome is present (Y ≤ A, A is the condition and Y is the outcome) (Figure 6; Legewie, 2013). Sufficient solutions provide the factors that whenever these conditions are satisfied, the outcome will be present (see Figure 8; Bauer & Kim, 2013). The relationships can also be represented by plots (see Figure 7; Legewie, 2013).

Figure 6 Necessary & Sufficient Conditions (X A = Condition, Y = Outcome)
(Source: Legewie, 2013)
Left: Necessary Conditions (A ≥ Y); Right: Sufficient Condition (Y ≥ A**)**

[12] The formula for the membership calibration is: Degree of membership = exp (log odds) / [1 + exp (log odds)]. Please see Ragin (2008b, p. 89) for a detailed illustration of how to do calibration.

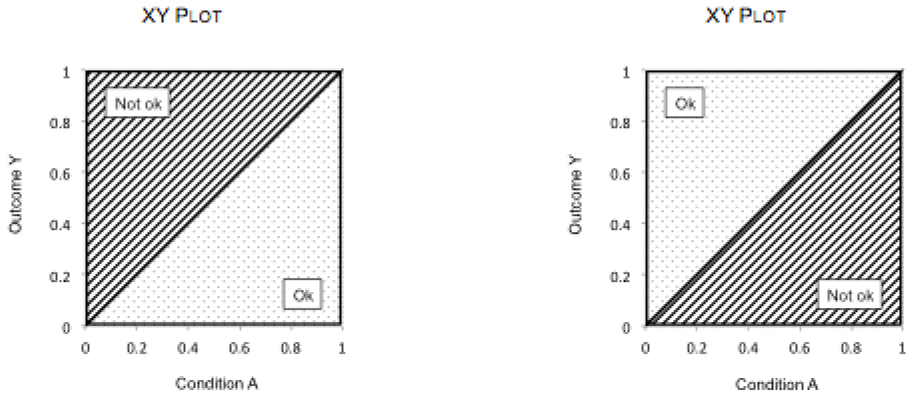

Figure 7 Necessary and Sufficient Conditions (left: necessary; right: sufficient)
(Source: Legewie, 2013)

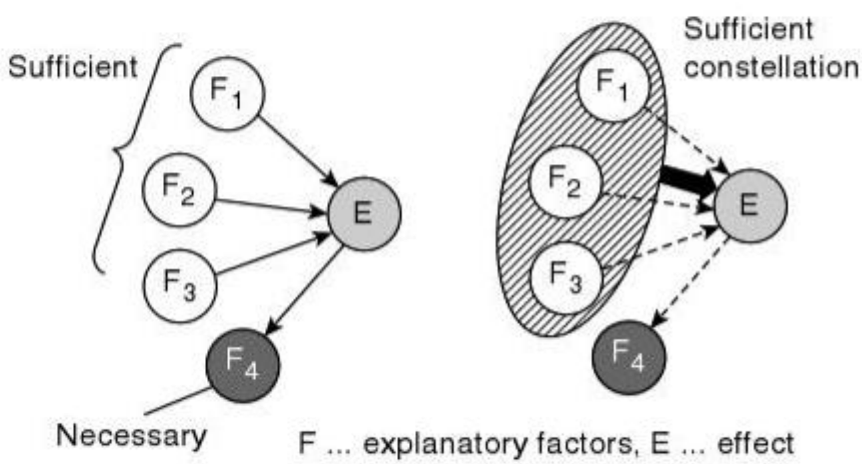

Figure 8 Complex Patterns of Causation
(Source: Bauer and Kim, 2013, p. 100)

To generate the sufficient solutions, the fuzzy-set data need to be transformed into a truth table that shows all possible conditions and outcomes (see Table 2; Eng & Woodside, 2012; Ragin, 2008b). For example, Table 2 shows all possible combinations of broadband universal service (bbuso), voice universal service (vuso_cal), and quality (quality_cal). When the value equals to 1, that means the variable/condition has membership closer to 1. And the column "number" shows how many cases shared this combination. Therefore, in Table 2, the last row has no case since the "number" was "0". A truth table is an "intermediate" result presenting the similarities and differences among the conditions and outcomes (Kent, 2008b).

Table 2 Truth Table

bbuso	vuso_cal	quality_cal	number	mb_cal	raw consist.	PRI consist.	SYM consist
0	1	1	46 (34%)		0.738343	0.464558	0.590831
0	1	0	44 (68%)		0.607185	0.217836	0.549504
0	0	1	15 (79%)		0.729605	0.442857	0.586367
0	0	0	7 (84%)		0.731721	0.289396	0.540341
1	1	0	7 (90%)		0.653641	0.220000	0.540382
1	1	1	7 (95%)		0.836903	0.414201	0.536998
1	0	1	6 (100%)		0.917853	0.814815	0.622585
1	0	0	0 (100%)		0.832381	0.473054	0.549686

After generating the truth table, researchers have to set up the consistency standard (e.g., 0.8 or 0.9) and perform the analyses. In the results of analyses, "*" indicates "and," while "~" indicates "absence" of a condition. For example, "A*~B" represents that A is present and B is absent in the condition (Ragin & Strand, 2008). The data can be analyzed at three levels of differentiation by using QCA: complex, parsimonious, and intermediate. These three solutions differ in how the "remainders" (the combinations of conditions that are not presented by any cases in the sample) are treated. A complex solution is the preferred solution that puts all combinations of causal conditions and the outcomes into consideration. The "remainders" are coded as "false" in a complex solution. While in a parsimonious solution, remainders were coded as "don't care." For example, if none of the cases in the data has a certain combination of a certain condition, it will be counted as a remainder. At the complex level, this combination will be counted as a negative (false) example while at the parsimonious level this condition will be excluded from consideration. An intermediate solution is a subset of the parsimonious solution and provides a balance of the complex and parsimonious solutions (Ragin, 2008a). With these different levels of solutions, we can identify what conditions are the "must haves" and what conditions are less important. For example, the parsimonious solution is the simplest solution for the outcomes to be present. Normally most conditions will be excluded from the solutions. On the contrary, in the complex solutions, all possible combinations are included in order to have a comprehensive picture of how different conditions relate to the outcomes.

Evaluation of QCA results

After analyzing the data, researchers need to provide an overview of the descriptive analyses first, and then describe the sufficiency of causal conditions. Consistency is the "degree to which the cases sharing a given combination of conditions agree in displaying the outcome in question" (Ragin, 2008b, p. 44). Coverage assesses "the degree to which a cause or causal combination 'account for' instances of an outcome" (Ragin, 2008b, p. 44). Three kinds of coverage scores will be provided in the results: solution coverage, raw coverage, and unique coverage. Solution coverage is how much of the membership of the outcome can be explained by all solutions. Raw coverage is the proportion of the membership of the outcome explained by a certain solution. Unique coverage is the proportion of the membership of the outcome solely explained by an individual solution (not covered by any other solutions). Normally the solution coverage equals to the raw coverage of one solution plus the unique coverage of all other solutions (for a detailed illustration of how to calculate each score, please see Ragin, 2008c, p. 86).

Limitations of QCA

QCA shares the limitations of other cross-sectional analyses (Caren & Panofsky, 2005; Kent, 2008a), including limitations in controlling for endogeneity. Sometimes it will be helpful if researchers can detect the time sequences of the conditions and the outcomes. Therefore, TQCA (temporal QCA) (Caren & Panofsky, 2005) and TS/QCA (time-series QCA) (Kent, 2008a) were developed to overcome the shortcomings. TQCA can be used to identify the time sequences of the conditions and the results that come after the conditions by adding a dash ("—") to indicate the temporal relationship between two conditions. For example, A—B will illustrate that A happens before B. However, TQCA is only suitable for simple conditions (Caren & Panofsky, 2005, p. 163). In addition, as Ragin and Strand (2008) pointed out, with the complexity of more conditions, it is difficult to avoid human mistakes using pen and pencil to identify the sequenced conditions. Furthermore, the sequence of the conditions can be pointed out by using the fsQCA software (Ragin & Strand, 2008). Still, researchers may want to limit the numbers of sequenced conditions to a maximum of four, otherwise the sequences of conditions will be too complicated to deal with (Ragin & Strand, 2008). In addition, TQCA can only be applied to csQCA data. In this study, given the complexity of the conditions (with at least 10 conditions included in the models) and the temporal sequences of the conditions are not clearly identifiable, TQCA is not a suitable approach for this study.

As for TS/QCA, three kinds of TS/QCA can be conducted: Pooled QCA, Fixed Effects QCA, and Time Differencing QCA (Hino, 2009). For example, in a cross-country comparison analysis, pooled QCA treats all countries equally, while fixed effects QCA considers the differences among countries when applying a threshold to decide the membership of all conditions and outcomes. Time differencing QCA considers both the spatial and temporal differences in all cases. However, TS/QCA technique can only be used to analyze dichotomous data (csQCA). For fsQCA, so far, the technique of TS/QCA is still underdeveloped (Hino, 2009). Since this study focuses on fsQCA, it is not feasible to apply the TS/QCA technique.

Econometric Approach – Regressions and Panel Analyses

Although QCA allows us to examine the interaction among different variables/conditions, it does not produce a quantitative estimate for the strength of a relationship. Therefore, in order to examine the relative importance of each factor, quantitative regression analyses will also be conducted.

Pooled Regression Model

There are several possible ways to analyze the available data econometrically. One option is to pool the observations (Cava-Ferreruela & Alabau-Munoz, 2006). A simple OLS regression can be conducted (see equation 2).

$$MBi = \beta_0 + \beta_i * X_i + \varepsilon_i \qquad (2)$$

Where MBi = mobile broadband adoption rates; X = independent variable; ε_i *= error term*

Panel Data Model

Another second option is to take a multi-level approach to examine the fixed and random effects (see equation 3). As mentioned in some studies (e.g., DiPietro, 2014), country-specific factors, such as culture, can affect mobile broadband adoption. By entering repeated measures for each year as level one units (time variant) in the multi-level model, we can see the within-individual country variation. By adding country level data as level two units (time invariant), we will be able to examine the between-individual country variation (Nurmi-Lawton et al., 2004).

Multi-level modeling can account for the time-invariant differences among individual entities (countries). It also accounts for the hierarchical structure of panel data (Nurmi-Lawton et al., 2004; Torres-Reyna, 2010) (See equation 3). To capture the specific effect of time, typically time is introduced as a separate dummy variable. When there are N*time periods, N-1 dummy variables will be introduced. For example, when there are five years, then four dummy variables will be introduced in the model.

A Hausman test can be conducted to see if the random effects specification is more appropriate than a fixed effects specification. When the Chi square of the Hausman test is significant ($p < .05$), then a fixed effect model should be used. This indicates that country-specific features have impacts on the relationship between the independent variables and dependent variables. On the contrary, when the Chi square is not significant, then a random effect model should be used. This indicates that the relationship between the independent variables and dependent variables is not influenced by country-specific features.

$$MB_{it} = \beta_0 + \beta_1 * X_{it} + \delta_t * T_t + u_{it} + \varepsilon_{it} \qquad (3)$$

Where

β 0 (i=1….n) is the unknown intercept for each country (n country-specific intercepts).

MBit is the dependent variable (DV) where i = country and t = time.

X = independent variable

T t is time as binary variable (dummy), so there will be t-1 time periods

δ_t is the coefficient for the binary time regressors

u is the between-country error

ε is the within-country error

In this dissertation, both the pooled and panel (fixed and random) data analyses will be used. The pooled method allows test the relationship among the independent variables and the dependent variables based on more cases (34 countries for 5 year observation). Given missing observations, the panel models are challenged by small numbers of observations. This needs to be taken into account by interpreting findings with caution. Nonetheless, the panel data analysis can shed additional light on the patterns of relations among the independent and dependent variables.

Data Collection

Data

The data to test our hypotheses was collected from the OECD (Organisation for Economic Co-operation and Development) Communications Outlook, ITU (International Telecommunication Union) websites, the United Nations website, WTO (World Trade Organization) website, the World Bank, and the websites of telecommunication regulators in the countries studies. In order to analyze how various combinations of factors will result in different outcomes of broadband penetration, data on policies including spectrum policies, mobile broadband universal service, mobile broadband competition, cost (population density), and social-demographic aspects of the 34 OECD[13] countries were collected. Mobile broadband started to grow rapidly during 2008-2009 (OECD, 2007, 2009). Comparative analyses often face challenges as data may not be available consistently or only available behind paywalls. Within the funding constraints of a dissertation project, the longest time series of available data were used (years 2009-2013). To increase the sample size for the regression analyses and also to capture the development of mobile broadband, a longitudinal approach was used in this dissertation. The same data set was used in QCA and regression analytical approaches. fsQCA (Ragin, Drass, Davey, 2006) was used to conduct QCA analyses. SPSS 22.0 (IBM, 2013) was used to analyze the pooled data analyses. Stata 13.0 (StataCorp, 2013) was used to analyze the fixed-random effects models.

Operational Measures

A detailed description of all variables used in this study is shown below (also shown in Table 3).

Mobile Broadband Penetration (MB). The main outcome variable – mobile broadband penetration rate – was the OECD wireless broadband subscriptions per 100 inhabitants. Mobile broadband subscription is "mobile subscriptions that advertise data speeds of 256 kbit/s or greater" (OECD, 2015a). The data were retrieved from the OECD website (for year 2009-2013).

[13] In the year this study was conducted, there are 34 members in OECD, including Australia, Austria, Belgium, Canada, Chile, Czech, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak, Slovenia, Spain, Sweden, Switzerland, Turkey, UK, and the United States.

For year 2003-2009, the available data are the total 3G cellular mobile subscriptions in OECD countries. However, more than half of the countries did not have mobile broadband until 2008. Therefore, data for years 2009-2013 were analyzed in this study. The lowest subscription was calibrated to 0.05 and the highest was calibrated to 0.95, while the average score was calibrated to 0.5. The reasons that 0.05 and 0.95 were used were because that using 0.0 and 1.0 as the membership values will correspond to negative (0.0) and positive (1.0) infinity for the log of the odds. Therefore, in fsQCA, 0.05 and 0.95 are used as a full non-membership and a full membership, respectively (Ragin, 2007).

Universal Service – Mobile Broadband Universal Service (MBUSO). Countries with mobile broadband universal service policies were coded as 1 and countries without mobile broadband universal service policies were coded as 0. Data were collected from the ITU website (available for year 2009-2013).

Voice Universal Service (VUSO). Four kinds of voice universal services were counted, including fixed line private residential service, fixed line public payphone service, public mobile payphone service, and individual mobile cellular service. Countries with only one service included in their universal service definition received the score of 1, with two services received the score of 2, etc. For their membership calibration, the membership for countries with only one service included was calibrated to 0.05, with two services was calibrated to 0.5, and for those with three services was 0.95. The cut-off point is having two services included in their universal service definition.

Spectrum Policies. Spectrum sharing and the presence of policies supporting of technological neutrality was included in the analysis.

- *Technology neutrality (TECH):* Technology neutrality implies that any technology can be used to provide a certain service using a frequency band (Frullone, 2007). In contrast, a non-neutral spectrum assignment policy would earmark a certain band for a specific service, e.g. 2G or 3G mobile services. Data for 2012-2013 were collected from the ITU. Countries with technologically neutral regulation for mobile broadband services were coded as 1 and countries without such provisions were coded as 0.
- *Spectrum sharing (SHARE):* Spectrum sharing refers to having "two or more radiocommunication services effectively use the same frequency band" (ITU, 2001, p.1). Data were collected from the ITU (available for year 2013 only). Countries with spectrum sharing regulation for mobile broadband services were coded as 1 and countries without the regulation were coded as 0.

Roaming Regulation (ROAM). Countries with roaming regulation for mobile broadband services were coded as 1 and countries without the regulation were coded as 0. Data for 2012 and 2013 were collected from the ITU website.

Regulatory Quality (QUALITY). The indicator used for regulatory quality was collected from the World Bank (Government Effectiveness, for years 2009-2013). The indicator was measured based on the government's quality of public services and civil service, its independence from political pressures, the quality of policy-making and implementation, and the credibility of the government's commitment to such policies. Over 40 concepts were measured to construct the variable (e.g., quality of bureaucracy/institutional effectiveness, quality of public administration, government handling of public services) (World Bank, 2015). Thirty-one sources were used to collect the data. For QCA analysis, the original scores ranged from -2.5 (weak performance) to 2.5 (strong performance). The minimum score was calibrated to 0.05 and the maximum was calibrated to 0.95, while the average score was calibrated to 0.5.

Competition among Mobile Broadband Providers (MHHI). Mobile broadband competition was measured by calculating the competition of major mobile networks (years 2009-2013). The data were collected from the Ovum database. Ovum is an international telecommunication research organization (http://www.ovum.com). The competition indicator used in this study is the HHI (Herfindahl-Hirschman Index) of the mobile market share of subscriptions in a country. The minimum HHI was calibrated to 0.05 and the maximum was calibrated to 0.95, while the average score was calibrated to 0.5. *Fixed Broadband Inter-platform Competition (FBHHI).* Fixed broadband competition was measured by using an inter-platform HHI (Herfindahl–Hirschman Index). Inter-platform HHI was calculated by squaring the subscriptions for each broadband technology (including DSL, Cable, Fiber, and other) divided by the total subscriptions of all technologies, and then adding all of these squared values (see below Equation 4):

$$HHI = (S_{DSL}/S_{total})^2 + (S_{cable}/S_{total})^2 + (S_{fiber}/S_{total})^2 + (S_{other}/S_{total})^2 \qquad (4)$$

with S_{total} = subscriptions of all technologies

Similar to the mobile competition HHI, the minimum HHI was calibrated to 0.05 and the maximum was calibrated to 0.95, while the average score was calibrated to 0.5. The data was collected from the OECD.

Fixed Broadband Penetration (BB). As mentioned in Chapter 2 and 3, the relationship between fixed broadband subscription and mobile broadband and mobile broadband use will also be examined (available for year 2003-2013). The OECD fixed broadband subscriptions per 100 inhabitants was used to measure fixed broadband penetration. The data was retrieved from the

OECD website. The lowest subscription was calibrated to 0.05 and the highest was calibrated to 0.95, while the average score was calibrated to 0.5.

Price (PRICE). This is operatinonalized as the price for subscribing to monthly mobile broadband service (price per MB, US Dollars). The information was retrieved from Informa (http://www.informa.com). Data were available for the years 2012 and 2013. The lowest price was calibrated to 0.05 and the highest was calibrated to 0.95, while the average price was calibrated to 0.5.

Cost (approximated by Population Density) (PD). Population density was collected from the United Nations (http://data.un.org/Data.aspx?d=PopDiv&f=variableID%3A14) (for year 2000, 2005, and 2010). It was calibrated by using the minimum population density of OECD countries as 0.05 (non-membership) and the maximum as 0.95 (full membership). The average of population density was calibrated to 0.5.

Urban Population (URBAN). The portion of urban population was collected from World Bank. The lowest score was calibrated to 0.05 and the highest was calibrated to 0.95, while the average score was calibrated to 0.5.

Income (INCOME). Gross national income per capita (GDP/capita, US Dollar, current prices, PPPs[14]) was collected from the OECD website (for year 2005-2013) (OECD, 2014). Income was calibrated by using the minimum income as 0.05 (non-membership) and the maximum as 0.95 (full membership). The average of income of OECD countries was calibrated to 0.5.

Education (EDU). Share of population with tertiary education attained by ages 25-64 was used for the measure of education (OECD, 2013a) (for year 2000, 2005, and 2010). Education

[14] Purchasing Power Parities

was calibrated by using the minimum as 0.05 (non-membership) and the maximum as 0.95 (full membership). The average of education of OECD countries was calibrated to 0.5.

Digital Skills (SKILL). Problem solving in technology-rich environments was used to indicate digital skills of each country (OECD, 2013b). This skill measures "the ability to use digital technology, communication tools and networks to acquire and evaluate information, communicate with others and perform practical tasks" (OECD, 2013, p. 2). Data are available for year 2012. The lowest score was calibrated to 0.05 and the highest was calibrated to 0.95, while the average score was calibrated to 0.5.

Table 3 Measurement

Category	Variable	Abbreviation	Sources	Year	Definition
Outcome	**Mobile Broadband Penetration**	MB	OECD website	2009-2013	OECD mobile broadband subscriptions per 100 inhabitants
Policy/ Regulation	**Mobile Broadband Universal Service**	MBUSO	ITU	2009-2013	Countries with broadband universal service were coded as 1 and countries without broadband universal service was coded as 0.
	Voice Universal Service	VUSO	ITU	2009-2013	the presence of fixed line private residential service, fixed line public payphone service, public mobile payphone service, and individual mobile cellular service included in the universal service definition
	Spectrum Policy-Technology Neutrality	TECH	ITU, Regulatory websites	2013	1= present, and 0=absent
	Spectrum Sharing	SHARE	ITU	2013	1 = secondary trading allowed, and 0 = trading not allowed
	Roaming Regulation	ROAM	ITU	(yr 2012 & 2013	1= present, and 0=absent

Table 3 (cont'd)

	Regulatory Quality	QUALI TY	World Bank	2009-2013	
Supply	**Fixed Broadband Penetration**	BB	OECD	2009-2013	OECD fixed broadband subscriptions per 100 inhabitants
	Cost (Population Density)	PD	United Nations	2000, 2005, 2010	Population density
	Price	PRICE	Informa	2012-2013	Monthly mobile broadband traffic per access (MB, US Dollars)
	Urban Population	URBAN	World Bank		Portion of urban population (%)
	Mobile Competition	MHHI	Ovum	2009-2013	HHI (Herfindahl-Hirschman Index) of the mobile market share of subscriptions in the country
	Fixed Broadband Competition	FBHHI	OECD	2009-2013	Inter-platform HHI (Herfindahl–Hirschman Index)

Table 3 (cont'd)

Demand	**Income**	INCOME	OECD website (OECD Factbook 2014)	2008-2012	GDP/capita (US Dollars, Current Prices, and PPPs)
	Digital Skills	SKILL	OECD Skill Outlook	2012	The ability to use digital technologies to solve problems (Problem solving in technology-rich environment)
	Education	EDU	OECD website	2000, 2005, 2010	Portions of populations with tertiary education attained by ages 25-64

One aspect worth mentioning is that feedback effects might exist. In QCA, no formal method has yet been developed to control for these effects. Therefore, the causality of the relationships among variables mentioned above cannot be tested. So, in the end, this dissertation only can assess the co-existence of factors and use theory to assess the direction of causation.

By using both econometric approaches and QCA, this study aims to examine the most important policies and the combination of policies that can increase mobile broadband penetration. This study is by far the first study that utilizes QCA for mobile broadband policies and identifies the necessary and sufficient conditions for having higher mobile broadband penetration. Besides, there are relatively few studies that have examined factors affecting mobile broadband penetration.

Chapter 5

Results

To examine the effects of mobile broadband policies, this dissertation used economic approaches to identify the independent variables affecting outcomes. It used QCA to examine in greater detail whether and how combinations of these factors relate to the outcome. QCA is a good complement for the traditional econometric approach because it presents the set of relationships that allows us to see how various factors interact with each other.

Descriptive Statistics

The descriptive statistics and Pearson product correlations are shown in Table 4 and 5. As shown in Table 4, there are some missing values for some of the variables. This is challenging for our statistical analyses, especially the panel data explorations. However, because QCA also works with smaller data sets, some of these challenges could be mitigated.

Table 4 Descriptive Analyses

	N	Min	Max	MEAN	S.D.
MB	170	0.05	123.28	49.92	28.90
MBUSO	170	0	1	0.12	0.33
VUSO	170	1	3	1.87	0.57
TECH	44	0	1	0.80	0.31
SHARE	20	0	1	0.75	0.44
ROAM	45	0	1	0.18	0.39
QUALITY	170	0.14	2.26	1.32	0.52
BB	170	8.39	44.86	26.03	8.45
PD	170	2.66	498.3	134.24	124.83
URBAN	170	49.76	97.78	77.67	11.44
FBHHI	170	0.32	1	0.58	0.18
MHHI	170	0.23	0.55	0.35	0.06
PRICE	15	0	0	0.02	0.01
INCOME	170	14550	89417	35455.56	13510.29
EDU	168	10.2	50.6	29.24	9.89
SKILL	38	19	44	34.11	6.45

Table 5 Pearson Product Correlation

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	MB															
2	MBUSO	.191*														
3	VUSO	-.250**	-0.04													
4	TECH	0.032	0.008	-0.025												
5	SHARE	0.212	-0.126	-0.417	0.293											
6	ROAM	-0.214	0.16	-0.004	0.187	-0.265										
7	QUALITY	.441**	.172*	-.417**	0.094	0.246	-0.178									
8	BB	.488**	0.122	-.348**	0.1	0.252	-0.129	.734**								
9	PD	0.08	-0.108	.258**	.300*	-0.319	0.176	-0.007	.313**							
10	URBAN	.285**	0.047	-0.071	0.211	-0.153	-0.238	.492**	.449**	.226**						
11	FBHHI	-.183*	-0.005	.160*	0.012	-0.002	0.011	-.170*	-0.027	-0.025	.155*					
12	MHHI	-.262**	0.012	.226**	-0.09	-0.111	-0.017	-.188*	-0.12	-0.011	-0.089	0.048				
13	PRICE	-0.127	0.243	-0.15	0.27	0.432	0.227	0.33	0.167	-0.269	0.405	-0.038	0.179			
14	INCOME	.402**	0.124	-.332**	0.269	0.218	-0.127	.641**	.627**	0.04	.330**	0.05	-0.053	0.184		
15	EDU	.531**	0.116	-.352**	.351*	0.429	-.342*	.669**	.618**	0.117	.613**	-0.136	-.255**	0.411	.419**	
16	SKILL	.352*	0.128	-0.163	-0.183	0.291	-0.287	.844**	.696**	-0.026	.732**	0.144	0.312	0.243	.579**	.343*

** CORRELATION IS SIGNIFICANT AT THE 0.01 LEVEL (2-TAILED)
* CORRELATION IS SIGNIFICANT AT THE 0.05 LEVEL (2-TAILED).

QCA Analyses

Using traditional econometric approaches can provide researchers with the parameters for each individual factor. However, it is not easy to have a complete picture of how the combinations of different factors affect the outcome (dependent variable, in this study, the outcome is mobile broadband penetration). To conquer this challenge, QCA was used to examine the relationships between the conditions and the outcomes. QCA allows examining whether conditions are necessary, sufficient or both necessary and sufficient for an outcome. For the sufficient solutions, as mentioned above, three kinds of solutions can be generated (complex, parsimonious, and intermediate). However, in situations that there are no simple patterns, only complex or intermediate solutions will be generated. Below we will explain the results of the analyses for necessary conditions first and then the sufficient conditions for higher mobile broadband penetration.

Necessary Conditions

In QCA, a consistency score of .8 (or above) is normally used to identify the necessary conditions for an outcome. As mentioned above, necessary conditions are present whenever the outcome is present (but they may also be present in other cases with other outcomes). In the language of set theory: outcomes (in this study, mobile broadband penetration is the outcome of interest) are subsets of the necessary conditions. By using QCA analysis, we found that for the observations in the studied sample, having technology neutrality (consistency = .87), higher quality of regulation (consistency = .82), higher fixed broadband penetration rates (consistency = .8), higher urban population (consistency = .81), higher mobile market competition (a less concentrated market, consistency = .83), and higher education level (consistency = .87) had consistency scores higher than .8. Therefore, in the countries in our dataset these are necessary conditions to have higher mobile broadband penetration rates (see Table 6). These are conditions that most countries that had higher mobile broadband penetration share. In other words, countries that had higher mobile broadband penetration rates also exhibited these conditions.

Table 6 Necessary Conditions

	Consistency	Coverage
MBUSO	0.177339	0.594762
VUSO	0.652301	0.618640
TECH	**0.866511**	**0.634286**
SHARE	0.774380	0.624667
ROAM	0.149618	0.490000
QUALITY	**0.824816**	**0.715878**
BB	**0.808543**	**0.745429**
PD	0.787694	0.589309
URBAN	**0.806509**	**0.692199**
FBHHI	0.580092	0.630162
~ FBHHI[15]	0.783371	0.631417
MHHI	0.635774	0.666978
~MHHI[16]	**0.825451**	**0.683330**
PRICE	0.547030	0.622535
EDU	**0.830744**	**0.784109**
INCOME	0.731248	0.805941
SKILL	0.695603	0.895873

Sufficient Conditions

In addition to the necessary solutions, QCA can also examine whether any conditions are sufficient for the outcome to happen. As mentioned above, sufficient conditions are conditions that once are satisfied, the outcome can be present. These conditions are subsets of the set of all outcomes (as shown in Figure 6 and 7). When these conditions are present, a country will have

[15] "~" indicates the absence (non-membership) of a factor/condition. In this case, it indicates lower fixed broadband HHI (a more competitive fixed broadband market).
[16] In this case, ~MHHI indicates a more competitive mobile market.

higher mobile broadband penetration rates.[17] As mentioned earlier, both QCA and econometric approaches were used to analyze data. Based on the theoretical framework mentioned in Chapter 2 and 3, we estimated two models to compare the findings we retrieved from different approaches and to capture the complicated interaction among the factors in the theoretical framework. Model 1included variables that had more than 45 observations (so we can compare the results of QCA with the results of econometric approaches), and model 2 is a model that included all variables of interest.

Model 1

In this model, as in the specifications used in the econometric approaches, ten conditions were added to the basic model, including mobile broadband universal service, voice universal service, regulatory quality, fixed broadband penetration rates, fixed broadband competition, mobile competition, population density, urban population, education, and income. Normally, three levels of solutions could be generated by using fsQCA: complex, parsimonious, and intermediate solutions. However, owing to the complexity of the relations, only the complex and intermediate solutions were generated.

1. Complex Solutions

In the complex solutions, using .95 as the threshold for consistency, five paths were identified as the sufficient conditions for having high mobile broadband penetration rates (higher than the average mobile broadband penetration rates). These solutions in total had consistency of 0.97 (Table 7). That means these solutions can consistently result in the same outcomes (in this

[17] Having higher mobile broadband penetration means that the membership score of mobile broadband penetration is higher than 0.5.

study, the outcome is having higher mobile broadband penetration rates). However, the tradeoff of high consistency can be a lower coverage (Elliot, 2013). These five solutions in total only explained 38% (the solution coverage) of the outcome (mobile broadband penetration). The unique coverage for each solution (indicating the percentage of membership in the outcome solely explained by an individual solution and not covered by other solutions), was about 1%–5%.

In all of these conditions, education was present. Most of the conditions also had income in the models. That means that both education and income are important factors in the sufficient conditions. However, in the intermediate solution (path 2), income was not present. That is to say, where a country had lower income, as long as all other conditions were satisfied, it also could have high mobile broadband penetration rates. These other conditions included: higher urban population and population density, a more competitive mobile market, a more concentrated fixed broadband technology, lower regulatory quality, and the adoption of mobile broadband universal service policy.

COMPLEX SOLUTION

Table 7 Complex solutions (Model 1)

--- COMPLEX SOLUTION ---

FREQUENCY CUTOFF: 1

CONSISTENCY CUTOFF: 0.96

		RAW COVERAGE	UNIQUE COVERAGE	CONSISTENCY
1	MBUSO*VUSO*~QUALITY*FBHHI*~MHHI*PD*URBAN*~INCOME*EDU	0.04	0.01	1.00
2	MBUSO*~VUSO*QUALITY*BB*~FBHHI*~MHHI*URBAN*INCOME*EDU	0.10	0.03	0.97
3	MBUSO*VUSO*QUALITY*BB*~MHHI*PD*URBAN*INCOME*EDU	0.08	0.01	1.00
4	~MBUSO*VUSO*QUALITY*~BB*~FBHHI*~MHHI*PD*~URBAN*INCOME*EDU	0.20	0.03	0.97
5	~MBUSO*VUSO*QUALITY*BB*~FBHHI*MHHI*PD*URBAN*INCOME*EDU	0.23	0.05	0.96

SOLUTION COVERAGE: 0.38

SOLUTION CONSISTENCY: 0.97

2. Intermediate Solution

In addition to the complex solutions, intermediate solutions were also generated (see Table 8). Five paths were identified in the solutions. The total solution coverage was 0.38 and the consistency score was 0.97.

As shown in Table 8, most of the paths included the presence (i.e., having higher than 0.5 as the membership score) of higher education, higher income, higher urban population, higher population density, more fierce competition in the mobile market, higher quality of regulation, and a more comprehensive voice universal service objective. However, if a country has lower (less than 0.5 membership score) urban population concentration, if it has higher education (above the average), higher income, higher population density, a more competitive mobile market and fixed broadband market, higher fixed broadband penetration rates, higher quality of regulation, a more comprehensive voice universal service objective, and have no mobile broadband universal service, it can also have higher mobile broadband penetration.

Table 8 Intermediate Solutions (Model 1)

--- INTERMEDIATE SOLUTION ---

FREQUENCY CUTOFF: 1

CONSISTENCY CUTOFF: 0.96

		RAW COVERAGE	UNIQUE COVERAGE	CONSISTENCY
1	EDU*INCOME*URBAN*~MHHI*~FBHHI*BB*QUALITY*~VUSO*MBUSO	0.10	0.03	0.97
2	EDU*~INCOME*URBAN*PD*~MHHI*FBHHI*~QUALITY*VUSO*MBUSO	0.04	0.01	1.00
3	EDU*INCOME*URBAN*PD*~MHHI*BB*QUALITY*VUSO*MBUSO	0.08	0.01	1.00
4	EDU*INCOME*~URBAN*PD*~MHHI*~FBHHI*~BB*QUALITY*VUSO*~MBUSO	0.20	0.03	0.97
5	EDU*INCOME*URBAN*PD*MHHI*~FBHHI*BB*QUALITY*VUSO*~MBUSO	0.23	0.05	0.96

SOLUTION COVERAGE: 0.38

SOLUTION CONSISTENCY: 0.97

Model 2

In addition to model 1, a more comprehensive model was estimated, presented in Table 8. Owing to the complexity of the combinations of various factors (15 factors in total), similar to model 1, only complex and intermediate solutions were generated by QCA (see Tables 9 and 10).

In this solution, broadband universal service was absent, but a more comprehensive voice universal service policy was present, along with higher regulatory quality, higher fixed broadband penetration, a more concentrated fixed broadband market, lower urban population, high income, lower education, the presence of technology neutrality policy and spectrum sharing, no roaming regulation, high digital skills, and low prices. This solution had coverage 0.35 and consistency score of 0.77. That is to say, 35% of the membership of the outcome (mobile broadband penetration) could be explained by this solution. This path points out the complexity of the combination of these 15 factors.

As indicated in the necessary conditions, having technology neutrality policy, high regulatory quality, high fixed broadband penetration, intense mobile market competition, high education, and high urban population were necessary conditions. In this model, we found that education and urban population were absent. However, this solution had a relatively low coverage (.35). However, as shown in the model 1 above, we can tell that the combination of education, income, population density were very complicated. When education was absent (having lower education level), it is important to have higher income and lower price for mobile broadband services (as shown in model 2) to increase the demand for subscribing mobile broadband, and the mobile market needs to be more competitive and the voice universal service policy should be more comprehensive.

Table 9 Complex Solutions for the Complete Model (Model 2)

--- COMPLEX SOLUTION ---

FREQUENCY CUTOFF: 1

CONSISTENCY CUTOFF: 0.77

		RAW COVERAGE	UNIQUE COVERAGE	CONSISTENCY
1	~MBUSO*VUSO*QUALITY*BB*FBHHI*~MHHI*~PD*~URBAN*INCOME*~EDU*TECH*SHARE*~ROAM*SKILL*~PRICE	0.35	0.35	0.77
	SOLUTION COVERAGE: 0.35 SOLUTION CONSISTENCY: 0.77			

Table 10 Intermediate Solutions for the Complete Model (Model 2)

--- INTERMEDIATE SOLUTION ---

FREQUENCY CUTOFF: 1

CONSISTENCY CUTOFF: 0.77

		RAW COVERAGE	UNIQUE COVERAGE	CONSISTENCY
1	~PRICE*SKILL*~ROAM*SHARE*TECH*~EDU*INCOME*~URBAN*~PD*~MHHI*FBHHI*BB*QUALITY*VUSO*~MBUSO	0.35	0.35	0.77
	SOLUTION COVERAGE: 0.35 SOLUTION CONSISTENCY: 0.77			

Econometric Approaches

For econometric approaches, two techniques were utilized in the dissertation: pooled regression analyses and panel date analyses. By using pooled regression analyses, we can identify the relationship among the independent variables and the dependent variable without considering the differences among countries. While using panel data analyses, we can examine the country and time effects on the relationship among the independent and dependent variables. By using plural methods, we could gain deeper understanding of the relationships among various variables and mobile broadband penetration rates (Bauer, 2010a).

Pooled Regression Analyses

For the pooled regression analyses, when putting all 15 variables of interest into the model, we found that there were not enough observations to run the analyses (because several variables had less than 45 cases). As mentioned in Chapter 2, it is always challenging to find meaning indicators for cross-country comparison. To conquer the constraints of missing data, a model that included all variables (10 variables in total) that had more than 45 observations was generated (see Table 11 below).

Table 11 Pooled Regression

	B	S.E.	β	t	Sig.
(CONSTANT)	33.695	18.062		1.866	
MBUSO	10.247	5.534	0.119	1.852	
VUSO	2.046	3.862	0.041	0.53	
QUALITY	-9.448	6.661	-0.173	-1.418	
BB	**0.88**	**0.401**	**0.255**	**2.196**	*****
PD	-0.016	0.018	-0.068	-0.862	
URBAN	0.067	0.223	0.027	0.299	
FBHHI	**-28.21**	**10.957**	**-0.181**	**-2.575**	*****
MHHI	**-80.966**	**31.131**	**-0.172**	**-2.601**	******
INCOME	**0**	**0**	**0.193**	**2.22**	*****
EDU	**0.964**	**0.29**	**0.332**	**3.32**	*******

R = .63, R^2 = .39, adjusted R^2 = .35; F (10, 157) = 10.057 (p < .001)
*p < .05, **p < .01, ***p <.001

In this model, mobile broadband universal service, voice universal service, regulatory quality, urban population, population density, fixed broadband penetration rate, fixed broadband inter-platform competition (fixed broadband market HHI), mobile competition (mobile HHI), income, and education were entered. The model could explain 39% variance of mobile broadband penetration rates (R = .63, R^2 = .39, adjusted R^2 = .35; F (10, 157) = 10.057, p < .001). Five out of ten variables were significant predictors of mobile broadband penetration rates: fixed broadband penetration rate (β = 0.26, p < .05), fixed broadband inter-platform market concentration (fixed broadband HHI, β = -0.18, $p < .05$), mobile market concentration (β = -0.17, $p < .01$), income (β = 0.19, $p < .05$), and education (β = 0.33, $p < .001$) were significant.

Looking at the coefficients of these independent variables, it was shown that, controlling for other factors, when fixed broadband subscriptions increase by 1% of the total population in a country (that is, the total subscriptions per 100 inhabitants increase one unit), its mobile broadband subscriptions will increase 0.88 % (the total subscriptions per 100 inhabitants will increase 0.88 unit). As for fixed broadband and mobile markets, the less concentrated the markets are, the higher the mobile broadband penetration rates. As for education , controlling for other factors, when the portions of populations with tertiary education attained by ages 25-64 increase 1% of the population, mobile broadband penetration rate will increase 0.96% (the total subscriptions per 100 inhabitants will increase 0.96 unit).

Fixed and Random Effect Specifications

In addition to the pooled regression models, fixed and random effects models were also estimated. To examine whether one specification (the fixed or random effects models) was more appropriate than the other, a Hausman test was performed (see Table 12 and 13).

Similar to the pooled data analyses, some variables did not have enough observations (the limitation of sample size) for the panel data analyses , therefore, following the same rule used for the pooled data analyses, variables that had fewer than 45 observations could not be included in the model. The results were shown in Table 12 below. In this model ($R^2 = .67$, F (10,107) = 21.44), regulatory quality, fixed broadband penetration rates, income, and education were significant. Fixed broadband competition (fixed broadband HHI) had *p*-value less than 0.1 (although not less than 0.5) and it was negatively related to mobile broadband penetration. The result was overall consistent with the results we had for the pooled data analyses. However, urban population and mobile competition were not significant in the fixed effects models.

A random effects model was estimated and the Hausman test was performed to compare the fixed and random effect models. With $Chi^2 = 164.22$ ($p < .001$), the null hypothesis that the difference in coefficients is not systematic was rejected. Rather, the difference in coefficients was systematic. That is to say, the relationship among these independent variables and the dependent variable was related to the characteristics of each country suggesting that the fixed-effect model shown in Table 12 should be used.

Table 12 Fixed Effects Model

Fixed-effects (within) regression Number of obs = 151

Group variable: country **Number of groups = 34**

R^2:

within = 0.6670 avg = 4.4

overall = 0.0070 max = 5

$F(10,107)$ = 21.44

corr(u_i, Xb) = -0.9409 Prob > F = 0.0000

MB	COEF.	S.E.	t	P>t	[95% CONF. INTERVAL]	
MBUSO	6.31	6.54	0.97	0.34	-6.66	19.28
VUSO	-5.06	4.93	-1.03	0.31	-14.83	4.71
QUALITY	-68.85	18.94	-3.64	0.00	-106.39	-31.31
FBHHI	-25.83	14.32	-1.80	0.07	-54.23	2.56
MHHI	39.56	68.61	0.58	0.57	-96.46	175.57
BB	3.33	0.90	3.71	0.00	1.55	5.11
PD	-0.36	0.24	-1.53	0.13	-0.83	0.11
URBAN	-4.85	3.42	-1.42	0.16	-11.63	1.92
EDU	1.77	0.74	2.39	0.02	0.30	3.23
INCOME	0.00	0.00	4.43	0.00	0.00	0.01
_CONS	298.15	259.17	1.15	0.25	-215.62	811.92

sigma_u | 80.738321

sigma_e | 11.93157

rho | .9786276 (fraction of variance due to u_i

F test that all u_i=0: $F(33, 107)$ = 13.63 Prob > *F* = 0.0000

Table 13 Hausman Test

	Coefficients			
	(b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
MBUSO	6.31	7.43	-1.12	2.33
VUSO	-5.06	-0.46	-4.60	1.03
QUALITY	-68.85	-59.55	-9.30	16.11
FBHHI	-25.83	-35.07	9.24	6.09
MHHI	39.56	-71.67	111.23	44.11
BB	3.33	2.52	0.81	0.64
PD	-0.36	-0.07	-0.29	0.23
URBAN	-4.85	-0.18	-4.68	3.39
EDU	1.77	2.16	-0.39	0.56
INCOME	0.00	0.00	0.00	0.00

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(9) = (b-B)'[(V_b-V_B)^(-1)](b-B) = 164.22

Prob>chi2 = 0.0000

(V_b-V_B is not positive definite)

Chapter 6

Discussion

Findings and Discussion

This dissertation aims to understand what factors are the main reasons for the differences of mobile broadband penetrations among OECD countries, specifically with a focus on whether mobile broadband policies play an important role or not. Using multiple methods, this dissertation extended our understanding of factors related to mobile broadband penetration and how the interaction among these factors relates to the outcomes. By using QCA analyses, this dissertation also examined the necessary and sufficient solutions for a country to have higher mobile broadband penetration.

Research Question

To answer the overarching research question in this dissertation, whether any conditions can be identified as necessary or sufficient for high mobile broadband penetration, fsQCA analyses were conducted. As shown in Chapter 5, the results of QCA presented various paths towards having higher mobile broadband penetration rates.

Necessary Conditions

For the necessary solutions, six conditions were presented in the results: 1) technology neutrality, 2) higher quality of regulation, 3) higher urban population, 4) higher fixed broadband penetration rates, 5) higher mobile competition, and 6) higher education (shown in Table 6). By adopting 1) technology neutrality policy, service providers would have more flexibility to utilize the spectrum to provide more updated services with latest technologies. This also decreases the transaction cost for them when switching the technologies because they do not need to apply for another license and pay for some extra fees accordingly. In addition, indirectly, it can also facilitate the competition among providers if some of the providers start to provide services with more advanced technologies. As for 2) higher quality of regulation, it can indicate the effectiveness of policy deployment. That is to say, having effective policy deployment is necessary for having higher mobile broadband penetration rates. Although the results of the econometric analyses did not support this argument conclusively, the consistency score of having higher regulatory quality did meet the requirement to be qualified as a necessary condition. As for 3) urban population, it can be an indicator of cost of providing mobile broadband services in urban areas. Having higher urban population represented having lower cost and this might also indicate a higher incentive for mobile broadband providers to offer services in urban areas. This result was consistent with the conclusion made in S. Lee et al. (2011). As for 4) higher fixed broadband penetration rates, it could be an indicator of technology development and also showed the maturity of broadband technology and environment in a certain country. However, it might also indicate that fixed broadband and mobile broadband could be compliments to each other. More research is needed to examine the relationship between fixed and mobile broadband. And 5) higher mobile market competition, a competitive market normally has products and services with lower prices, more service options for consumers, and better performances of mobile broadband. Finally, 6) having higher education can be an indicator of the development of technologies and the demand for broadband. In a country that people are highly educated, the demand for mobile broadband can be higher because they may have stronger needs for using the service.

Among these necessary conditions, 1) technology neutrality, 2) higher quality of regulation, 3) higher fixed broadband penetration rates, and 4) higher mobile competition, are more directly related to policy-making. Specifically, having technology neutrality rule should be the easiest way for a country to improve mobile broadband penetration. In addition, developing policies that increase the competition among mobile providers is also relatively feasible for a country to increase mobile penetration. As for increasing the quality of regulation and fixed broadband penetration rates, there are some challenges to be conquered in order to increase these two conditions. To increase fixed broadband penetration, as mentioned in Chapter 1 and 3, many studies found that having local loop unbundling policies and increasing income, education, public-private cooperation, and the competition among providers, were important (e.g., ACPLI, 2009; Bauer et al., 2003; Briglauer & Gugler, 2013; Cava-Ferreruela & Alabau-Munoz, 2006; Cava-Ferreruela & Alabau-Muau-Munoz, 2006; Cava-Ferreruela & Alabau-Muñoz, 2004, SeMurillo, 2005; Haucap et al., 2014; Jakopin, 2009; S. Lee, 2006; S. Lee & Brown, 2008). However, some of these might not be achieved in a short period of time. Furthermore, this dissertation has found some inconsistent findings with regard to the effects of regulatory quality on mobile broadband penetration. More studies are needed to further understand the importance of regulatory quality.

As for the sufficient conditions for higher mobile penetration, we found various paths to having higher mobile broadband penetration rates. Most of these paths required the presence of higher income, higher education level, higher broadband penetration rates, higher mobile competition, higher regulatory quality, higher population density, and higher urban population. In addition, technology neutrality and spectrum sharing were also present in most cases. Digital skills were also present in most cases. Mobile broadband universal service, a comprehensive voice universal service objective, and roaming policy were not critical for a country to have higher mobile broadband penetration rates.

However, for countries that had lower income, if they had a more competitive mobile market and a more comprehensive voice universal service policy, higher urban population and population density , with the mobile broadband universal service, it is possible to have higher mobile broadband penetration rates (see Tables 6 and 7).

Sufficient Conditions

From the sufficient condition analyses, this dissertation found that there were five paths presented in the complex and intermediate solutions (Table 7 and 8). This indicated that having 1) higher education, 2) higher income, 3) high fixed broadband penetration rates, 4) higher fixed broadband penetration rates, 5) higher population density, 6) higher urban population, and 7) a competitive mobile market were included in most of the sufficient conditions for a country to have higher mobile broadband penetration rates. When a country does not have high income, it is important for it to have higher education, higher urban population, higher population density (lower cost for broadband deployment), mobile broadband universal service, and a more competitive mobile market. Among these factors, having mobile broadband universal service and increasing the competition among mobile providers should be a relatively feasible for a country to achieve. Among these factors, population density, urban population, and education might not be changed easily by policy-makers in a short term.

Looking at the complete model (model 2 in the sufficient conditions analyses), it was found that having technology neutrality policy, allowing for spectrum sharing, having higher regulatory quality, having lower price and a more technology-concentrated fixed broadband market, but a more competitive mobile broadband market, and higher income and higher digital skills were included in the sufficient condition for a country to have higher mobile broadband penetration rates. In this condition, we found that having roaming policy and mobile broadband universal service were not required.

Overall, the results of both the necessary and the sufficient solutions indicate the importance of having more intense service-based competition in mobile market. Having higher service-based competition in fixed broadband has been identified as one of the main reasons that Denmark and Sweden had high fixed broadband penetration rates (Forzati & Mattsson, 2015; Henten & Falch, 2015). For mobile broadband, this dissertation also found similar conclusion from both the QCA analyses and the pooled data regression analyses.

Hypotheses

As for the hypotheses in this study, based on the results of pooled regression analyses, these following hypotheses were supported (See Table 14 for the list of results):

H6: Countries with more intense competition among mobile providers have higher mobile broadband penetration rates.

H7: Countries that have higher fixed broadband penetration rates have higher mobile broadband penetration rates.

H11: Countries with higher income per capita have greater mobile broadband penetration rates.

H12: Countries with higher education levels have greater mobile broadband penetration rates.

However, the relationship between regulatory quality and mobile broadband penetration was negative. Therefore, H5: countries with higher regulatory quality have greater mobile broadband penetration rates, was not supported.

In the panel data analyses, H7, H11, and H12 were also supported in the fixed effect analysis (See Table 14), while H6 was not supported in the fixed effect model. Therefore, H6 was only partially supported. Another indicator of competition, fixed broadband inter-platform competition, was found to be an important condition for a country to have higher mobile broadband penetrations in the pooled regression analyses and QCA. This might be because of the effects of country-specific features such as cultures and other economic or social status of a country. In the pooled model, all countries and years were treated equally.

The results of pooled regression analyses and panel analyses yielded different conclusions regarding the relationship between regulatory quality and mobile broadband penetration rates. Based on the pooled regression analyses, regulatory quality was positively related to mobile broadband penetration rates; while in the panel analyses the relationship was negative. Hence we examined the scatter plots of regulatory and mobile broadband penetrations for each year. The results showed that the relationship between regulatory quality and mobile broadband penetration rates was not completely linear. Especially in year 2009, their correlation was extremely low ($r = .01$). More research is needed to examine the relationship between regulatory quality and mobile broadband penetration.

Although we were not able to test the H2 in the econometric approaches owing to the constraint of sample size, based on the results of necessary solutions we identified by using QCA, we found that an alternative, weaker hypotheses was supported: H2a) countries that have higher mobile broadband penetration rates tend to have technology neutrality policy. Following the same logic, alternative hypotheses H5a, H6a, H7a, H9a, and H12a were supported as well (see Table 14 below). Furthermore, although H10 and H13 could not be tested in this study either, the results of QCA analyses (the sufficient solutions of the complete model, see Table 9 and 10) showed the importance of having lower prices and higher digital skills for a country to have higher mobile broadband penetration (although the coverage and consistency for this solution were relatively low). These results demonstrated how using QCA could help us explore the relationships and analyses that could not be tested by using traditional economic approaches. Therefore, as mentioned earlier, QCA should be a good complement to econometric approaches when conducting a cross-country comparison study.

Table 14 Hypotheses Tests

Hypothesis		Supported		
		Pooled	Panel	QCA
H1	Countries with mobile broadband universal service objectives have greater mobile broadband penetration rates.	No	No	No
H2	Countries that have technologically neutral spectrum assignment have greater mobile broadband penetration rates.	N/A	N/A	No
H2a	*Countries that have greater mobile broadband penetration tend to have technologically neutral spectrum assignment.*	*N/A*	*N/A*	*Yes*
H3	Countries that allow spectrum trading have greater mobile broadband penetration rates.	N/A	N/A	No
H4	Countries that have roaming regulation for mobile wireless services have greater mobile broadband penetration rates.	N/A	N/A	No
H5	Countries with higher regulatory quality have greater mobile broadband penetration rates.	No	No (opposite direction)	No
H5a	*Countries that have greater mobile broadband penetration tend to have higher regulatory quality.*	*N/A*	*N/A*	*Yes*
H6	Countries with more intense competition among mobile providers have higher mobile broadband penetration rates.	Yes	No	No

Table 14 (cont'd)

H6a	*Countries that have greater mobile broadband penetration tend to more intense competition among mobile broadband providers.*	*N/A*	*N/A*	*Yes*
H7	Countries that have higher fixed broadband penetration rates have higher mobile broadband penetration rates.	Yes	Yes	No
H7a	*Countries that have higher mobile broadband penetration tend to have higher fixed broadband penetration rates*	*N/A*	*N/A*	*Yes*
H8	Countries with higher population density have greater mobile broadband penetration rates.	No	No	No
H9	Countries with higher urban population density have greater mobile broadband penetration rates.	No	No	No
H9a	*Countries have greater mobile broadband penetration rates tend to have higher urban population density.*	*N/A*	*N/A*	*Yes*
H10	Countries with lower prices for mobile broadband services have greater mobile broadband penetration.	N/A	N/A	No
H11	Countries with higher income per capita have greater mobile broadband penetration rates.	Yes	Yes	No
H12	Countries with higher education levels have greater mobile broadband penetration rates.	Yes	Yes	No

Table 14 (cont'd)

H12a	*Countries that have higher mobile broadband penetration tend to have higher education level.*	*N/A*	*N/A*	*Yes*
H13	Countries with a population that have higher digital skills have greater mobile broadband penetration.	N/A	N/A	No

Synthesis

Interestingly, the results of econometric approaches and QCA indicated different directions for the relationship between regulatory quality and mobile broadband penetrations. From the econometric approaches, we found that regulatory quality was negatively related to mobile broadband penetration rates. However, from QCA, we found that having higher regulatory quality was a necessary condition for a country to have higher mobile broadband penetration rates (see Table 7 and 8). We also found a positive relationship of regulatory quality and mobile broadband penetration in the Pearson product correlation analyses (r = .441, p < .001). It is worth mentioning that both the necessary analysis and the correlation analysis look at the pure relationship between these two variables. The impacts of other variables are excluded. However, in reality, regulatory factors interact with each other and also interact with other economic factors. As shown in the pooled data and panel data analyses and the sufficient solutions, the relationship between regulatory quality and mobile broadband penetration rate is very complicated. This also was illustrated in the first model in the QCA analyses. Future study is needed.

As for mobile competition, it was shown in the necessary condition and was shown in most sufficient conditions for a country to have higher mobile broadband penetration rates. It was also significant in the pooled regression analyses. This shows the importance of having a more competitive mobile market. Meanwhile, this also means that having service-based competition for mobile broadband is important.

Similar to the results we got from the pooled regression and panel data analyses, we found that having higher fixed broadband penetration was an important condition for a country to have higher mobile broadband penetration (H7, the relationship between fixed and mobile broadband). In most cases that had higher mobile broadband penetration rates, higher fixed broadband penetration rates were present. From the correlation table (Table 5), we found that the correlation between fixed and mobile broadband penetration rates was moderately correlated ($r = .441$, $p < .01$). The coefficient of fixed broadband penetration rates was also significant in the panel data analyses (both the random and fixed effects models, see Table 12). Therefore, the relationship for fixed and mobile broadband penetration rates seemed to be more complementary in this study. However, more research is needed to examine the complicated relationship between fixed and mobile broadband.

In addition, education was also a necessary and sufficient condition in most paths for a country to have higher mobile broadband penetration. However, if a country does not have high education level, as long as it has the technology neutrality rule, allows for spectrum sharing, has higher regulatory quality, higher fixed broadband penetration rates, higher income, higher digital skills, and a more competitive mobile market and lower cost for mobile broadband services, it can still have higher mobile broadband penetration rates (as shown in Table 9 and Table 10). By using fsQCA, the usually hidden relationship among various variables/factors was revealed.

One aspect worth mentioning is that previous studies found that different policies are required at different stages (Belloc et al., 2012; Lestage & Flacher, 2014). This might be the reason why we found inconsistent results with regard to the relationship between regulatory quality and mobile broadband penetration rates in the pooled regression analyses and panel data analyses. However, by looking at the results generated by QCA, we could easily detect that in most cases that had higher mobile broadband penetration rates, the quality of regulation was present. However, there were also cases that countries had low quality of regulation but still could have higher mobile broadband penetration rates (e.g., path 2 in the intermediate solution of model 1). These countries could have lower income but needed to have higher education level and a more competitive mobile market.

However, the results of the correlation analyses showed that income, education, population density, and regulatory quality were highly correlated (See Table 5). This revealed the statement mentioned earlier: in reality, many conditions are related to each other and it is hard to test the interaction simply using regression analyses. By using QCA, we could detect the combination of various conditions. Therefore, QCA could be a complement to traditional regression analyses in cross-country comparison studies.

By using econometric approaches, this dissertation examined the importance of individual factor on mobile broadband penetration. By using QCA, it explored the necessary and sufficient conditions for a country to have higher mobile broadband penetration. Based on the results of these analyses, some policy implication and suggestions were provided below for policy makers' consideration.

Suggestions for Regulatory Agencies

Universal Access-related Policies

Although the main purpose of mobile broadband universal service is to make access to mobile broadband universal and thus an option for all citizens in a country, this dissertation did not find strong support for the necessity of this policy. It was not a significant predictor in the regression analyses. However, regulatory agencies can use the solutions provided in the sufficient conditions by QCA to identify whether the country should have mobile broadband universal service or not. For example, if a country did not have high GDP/capita, it should consider adopting mobile broadband universal service as formal policy (as shown in the path 2 in the intermediate sufficient solution for model 1 in the QCA analyses, see Table 8). As for having a comprehensive voice universal service objective, it was not shown significantly important in the econometric approaches. However, having a more comprehensive voice universal service is important for a country that has either low income or low urban population (see Table 7 and 8). For regulators, universal access-related policies are relatively easy and feasible to adopt.

Service Efficiency & Competition Related Policies

Based on the results of QCA, it is essential for most governments to have technology neutrality policy as it was one of the necessary conditions for a country to have higher mobile broadband penetration. Therefore, policy makers should try to adopt technology neutrality rules for their spectrum management. As for spectrum sharing, it was present in the sufficient condition. As spectrum sharing could allow and encourage service to utilize their spectrum more efficiently and this might also increase the competition among providers, this should be a policy that regulatory agencies should consider to adopt. However, a requirement on roaming was found not very important in this study, as it was not a necessary condition or required in the sufficient condition.

With regards to competition, having a more competitive mobile market was a necessary condition for a country to have higher mobile broadband penetration (see Table 6). This was consistent with the results found in the pooled data analyses (shown in Table 11). With the increase of service-based competition, providers might lower their prices in order to attract consumers to purchase their products/services. They might also try to increase the quality of their services and products. Therefore, regulatory agencies should consider measures that can facilitate competition among mobile providers in order to increase mobile broadband subscriptions. For example, increasing the number of licenses can be achieved in a shorter period of time (compared to increasing the overall and per capita income of a country).

Suggestions for other Government Agencies

From the results of both the econometric approach and QCA, the dissertation found that having higher education and higher income are both necessary and important conditions in the sufficient solutions for a country to have higher mobile broadband penetration rates. It is important for governments to increase the overall level of education and income in a country. However, increasing the income and educational level cannot be achieved in a short period of time. These will be long-term goals for governments to achieve. One thing worth mention is that we found that countries that had either lower education levels or lower income per capita would especially need a competitive mobile market and a more comprehensive voice universal service policy in order to have higher mobile broadband penetration rates. It is also important for a country to try to improve people’s digital skills in order to increase their intention and ability to use mobile broadband services.

It is worth mentioning that mobile broadband might generate new challenges for society. For instance, recent studies (e.g., Rotman, 2013, 2014 and The Economist, 2015) have pointed out the new technologies (especially big data and artificial intelligence) could decrease job opportunities for human beings. While increasing mobile broadband might increase the national income, the governments should still be aware of the risks and take actions to prevent these risks and increase job opportunities.

Limitations and Future Research

One major limitation for this study is the size of the sample and the constraints on the information of public policy interventions. Although the data used for analyses covered five years' data (years 2009-2013), there are only 34 countries in the OECD. That made the maximum sample size equaled to 170. With some unavoidable missing values, when conducting the panel data analyses and pooled regression analyses, it was easy to run into the constraint of limited observations. Therefore, future research should increase the sample size by including more countries into the analyses or including more years of data. For QCA, sample size is not as seriously a constraint because it can be used with smaller numbers of observations. Therefore, using QCA is a good way to overcome the constraints of regression analyses.

There are also some constraints on the measures. As mentioned above, the competition indicator used in this study is the service-based competition in the mobile market. It would be interesting and important for future studies to explore the role of service-based competition and facility-based competition in the mobile broadband market on mobile broadband penetration. In this dissertation, by using dichotomous measures, we still examined the basic relationships between these variables and mobile broadband penetration. It will increase the depth of the analyses if researchers can explore other kinds of measurements for mobile broadband universal service, technology neutrality, spectrum sharing, and roaming regulation to make some continuous measures. Other factors such as licensing areas and standardization might have the potential to affect mobile broadband penetration. Future studies could also consider examining the relationship between some other factors mentioned in Chapter 2, such as the capacity of spectrum, and mobile broadband penetration.

In addition, in social systems there is the possibility of reverse causality (endogeneity), as policy makers respond to the state of the system. There are several ways to detect the endogeneity. For example, lagged variables and instrumental variable econometric techniques can be used to ensure the time sequence of causality. However, owing to the lack of time-series data, these could not be done in this dissertation. Furthermore, given the complexity of interactions, there might be other potential variables that could affect the relationships among these predictors and mobile broadband penetration. Such other variables could include social capital, previous experiences of using the Internet, employment rates in a country, can potentially mediate or moderate the relationships among the predictors and mobile broadband penetration. Most of these variables (e.g., social capital and previous experiences of using the Internet) are related to individual adoption. Owing to the lack of systematic data across countries, these could not be included in this dissertation. More studies are needed.

Furthermore, more research has to be done to examine the relationship between regulatory quality and mobile broadband penetration. In this dissertation, both the necessary analyses on QCA and the Pearson correlation showed the regulatory quality was positively related to mobile broadband penetration. However, in the pooled data analyses, regulatory quality was negatively related to mobile broadband penetration. In Chapter 5, some discussions have been made with regard to the effects of country and time specific features. Maybe using different kinds of regulatory quality indicators can help us understand the complicated relationship between regulatory quality and mobile broadband penetration rates.

In addition, having access to mobile broadband does not guarantee the benefits of using this technology. The quality of services is also critical in order to benefit from using the technology (Bauer & Tsai, 2014; Kongaut, Rohman, & Bohlin, 2014; Mack, 2014). Few studies have been done (e.g., Bauer & Tsai, 2014) and more work in this direction is needed. Future research should also be conducted with regard to factors affecting mobile broadband quality.

Finally, as mentioned in Chapter 2, international comparative studies raise unique challenges. It may be difficult to collect meaningful and consistent data and to make sure that formal policies actually have been implemented. Therefore future research would be facilitated if international organizations were to formulate standardized measures that would allow generating consistent measures that better meet the needs of scientific research designed to be applied to solve real world policy dilemmas. It is also important for every country to respond to the requests of data with candor and honesty. We all learn from others and learn from other countries in the world. Having enough standardized measures and updated data set will not only help researchers to do better and meaningful research, but also help governments to achieve some meaningful goals that are important to the country and the society.

APPENDIX

Appendix A: Calibration

Table 15 Calibration of the Data

NAME	YR	MB	TECH	SHARE	ROAM	MBUSO	VUSO	QUALITY	BB	MHHI	PRICE	PD	URBAN	INCOME	SKILL	EDU
Australia	2009	0.1				0	0.57	0.77	0.37	0.28		0.95	0.84	0.57		0.59
Austria	2009	0.15				0	0.57	0.75	0.3	0.32		0.69	0.22	0.55		0.14
Belgium	2009	0.07				0	0.57	0.7	0.61	0.45		0.14	0.95	0.52		0.56
Canada	2009	0.05				0	0.05	0.8	0.64	0.28		0.95	0.61	0.53		0.91
Chile	2009	0.06				0	0.57	0.44	0.06	0.5		0.93	0.83	0.06		
Czech	2009	0.08				0	0.95	0.25	0.1	0.45		0.53	0.39	0.2		0.07
Denmark	2009	0.23				0	0.05	0.95	0.83	0.32		0.55	0.79	0.54		0.65
Estonia	2009	0.06				0	0.05	0.32	0.35	0.5		0.92	0.27	0.1		0.64
Finland	2009	0.73				1	0.57	0.95	0.61	0.41		0.94	0.7	0.51		0.68
France	2009	0.2				0	0.57	0.63	0.68	0.56		0.63	0.52	0.45		0.35
Germany	2009	0.05				0	0.57	0.7	0.67	0.21		0.3	0.4	0.51		0.32
Greece	2009	0.09				0	0.57	0.14	0.18	0.5		0.76	0.45	0.3		0.22
Hungary	2009	0.07				0	0.57	0.16	0.2	0.5		0.64	0.27	0.1		0.13
Iceland	2009	0.24				0	0.57	0.74	0.75	0.59		0.95	0.91	0.53		0.54
Ireland	2009	0.35				0	0.57	0.52	0.24	0.32		0.85	0.15	0.57		0.49
Israel	2009	0.54				0	0.95	0.46	0.39	0.28		0.2	0.89	0.2		0.91
Italy	2009	0.14				0	0.57	0.09	0.26	0.25		0.37	0.27	0.4		0.06
Japan	2009	0.73				0	0.57	0.61	0.44	0.53		0.15	0.86	0.37		0.82
Korea	2009	0.82				0	0.57	0.37	0.76	0.56		0.05	0.65	0.21		0.58
Luxembourg	2009	0.16				0	0.57	0.8	0.62	0.67		0.41	0.83	0.92		0.39

Table 15 (cont'd)

NAME	YR	MB	TECH	SHARE	ROAM	MBUSO	VUSO	QUALITY	BB	MHHI	PRICE	PD	URBAN	INCOME	SKILL	EDU
Mexico	2009	0.05				0	0.95	0.05	0.05	0.91		0.85	0.5	0.05		0.1
Netherlands	2009	0.06				0	0.57	0.79	0.85	0.59		0.1	0.78	0.58		0.53
New Zealand	2009	0.06				0	0.05	0.84	0.37	0.79		0.94	0.78	0.31		0.8
Norway	2009	0.69				0	0.57	0.83	0.78	0.72		0.94	0.54	0.75		0.62
Poland	2009	0.42				0	0.57	0.12	0.1	0.21		0.59	0.14	0.09		0.13
Portugal	2009	0.15				0	0.57	0.4	0.2	0.53		0.61	0.13	0.19		0.07
Slovak	2009	0.13				0	0.57	0.24	0.08	0.67		0.64	0.08	0.14		0.08
Slovenia	2009	0.05				0	0.57	0.4	0.32	0.83		0.69	0.05	0.23		0.19
Spain	2009	0.3				0	0.57	0.27	0.31	0.41		0.75	0.52	0.39		0.46
Sweden	2009	0.69				0	0.05	0.91	0.71	0.36		0.93	0.75	0.53		0.49
Switzerland	2009	0.29				1	0.57	0.89	0.82	0.77		0.41	0.39	0.65		0.48
Turkey	2009	0.06				0	0.57	0.07	0.05	0.65		0.75	0.31	0.05		0.05
UK	2009	0.26				0	0.57	0.64	0.63	0.08		0.28	0.62	0.49		0.52
US	2009	0.45				0	0.05	0.64	0.48	0.1		0.91	0.61	0.65		0.8
Australia	2010	0.62				0	0.57	0.81	0.41	0.28	0.87	0.95	0.84	0.59		0.59
Austria	2010	0.27				0	0.57	0.84	0.37	0.28		0.69	0.22	0.57		0.14
Belgium	2010	0.08				0	0.57	0.7	0.68	0.45		0.14	0.95	0.54		0.56
Canada	2010	0.24				0	0.05	0.82	0.68	0.25		0.95	0.62	0.55		0.91
Chile	2010	0.08					0.57	0.46	0.07	0.45		0.93	0.84	0.08		
Czech	2010	0.09				0	0.95	0.26	0.12	0.41		0.51	0.38	0.2		0.07
Denmark	2010	0.65				0	0.05	0.92	0.86	0.28		0.53	0.8	0.58		0.65

Table 15 (cont'd)

NAME	YR	MB	TECH	SHARE	ROAM	MBUSO	VUSO	QUALITY	BB	MHHI	PRICE	PD	URBAN	INCOME	SKILL	EDU
Estonia	2010	0.14				0	0.05	0.37	0.39	0.45		0.92	0.26	0.1		0.64
Finland	2010	0.81				1	0.57	0.95	0.6	0.45		0.94	0.71	0.52		0.68
France	2010	0.3				0	0.57	0.6	0.75	0.56	0.05	0.61	0.53	0.48		0.35
Germany	2010	0.19				0	0.57	0.69	0.72	0.16	0.12	0.31	0.41	0.54		0.32
Greece	2010	0.18				0	0.57	0.12	0.27	0.59		0.75	0.46	0.26		0.22
Hungary	2010	0.08					0.57	0.16	0.25	0.5		0.65	0.28	0.11		0.13
Iceland	2010	0.45					0.57	0.7	0.77	0.5		0.95	0.92	0.52		0.54
Ireland	2010	0.44				0	0.57	0.52	0.29	0.32		0.83	0.15	0.58		0.49
Israel	2010	0.48				0	0.95	0.54	0.41	0.28		0.15	0.89	0.23		0.91
Italy	2010	0.33				0	0.57	0.1	0.32	0.25	0.07	0.36	0.27	0.41		0.06
Japan	2010	0.75				0	0.57	0.65	0.52	0.5	0.08	0.16	0.87	0.44		0.82
Korea	2010	0.87				0	0.57	0.44	0.8	0.56		0.05	0.65	0.26		0.58
Luxembourg	2010	0.5					0.05	0.78	0.68	0.65		0.37	0.84	0.94		0.39
Mexico	2010	0.06				0	0.95	0.05	0.06	0.91		0.85	0.51	0.06		0.1
Netherlands	2010	0.33					0.57	0.79	0.87	0.56	0.06	0.1	0.8	0.58		0.53
New Zealand	2010	0.35				0	0.05	0.83	0.45	0.67		0.94	0.78	0.32		0.8
Norway	2010	0.74				0	0.57	0.85	0.79	0.7		0.94	0.55	0.78		0.62
Poland	2010	0.5					0.57	0.15	0.11	0.16		0.59	0.14	0.1		0.13
Portugal	2010	0.18				0	0.57	0.32	0.26	0.5	0.77	0.6	0.14	0.2		0.07
Slovak	2010	0.18				0	0.57	0.22	0.1	0.59		0.63	0.08	0.16		0.08
Slovenia	2010	0.18				0	0.57	0.32	0.37	0.81		0.68	0.05	0.23		0.19

Table 15 (cont'd)

NAME	YR	MB	TECH	SHARE	ROAM	MBUSO	VUSO	QUALITY	BB	MHHI	PRICE	PD	URBAN	INCOME	SKILL	EDU
Spain	2010	0.42				0	0.57	0.3	0.39	0.36		0.73	0.53	0.37		0.46
Sweden	2010	0.42				0	0.05	0.9	0.72	0.36	0.92	0.93	0.75	0.56		0.49
Switzerland	2010	0.43				1	0.57	0.86	0.87	0.77	0.07	0.39	0.39	0.68		0.48
Turkey	2010	0.44				0	0.57	0.07	0.06	0.62		0.72	0.32	0.06		0.05
UK	2010	0.44				0	0.57	0.68	0.7	0.28		0.26	0.63	0.47		0.52
US	2010	0.45				1	0.05	0.68	0.53	0.1		0.91	0.61	0.67		0.8
Australia	2011	0.85				0	0.57	0.77	0.42	0.36	0.91	0.95	0.84	0.61		0.76
Austria	2011	0.44				0	0.57	0.72	0.17	0.28		0.68	0.22	0.6		0.17
Belgium	2011	0.14				0	0.57	0.75	0.73	0.45		0.13	0.95	0.56		0.69
Canada	2011	0.34				0	0.05	0.81	0.71	0.18		0.95	0.63	0.57		0.95
Chile	2011	0.13				0	0.57	0.46	0.08	0.45		0.93	0.84	0.1		0.41
Czech	2011	0.44				0	0.95	0.27	0.15	0.41		0.51	0.38	0.23		0.12
Denmark	2011	0.8				0	0.05	0.93	0.86	0.32		0.53	0.8	0.59		0.64
Estonia	2011	0.42				0	0.05	0.36	0.45	0.41		0.92	0.26	0.14		0.7
Finland	2011	0.82				1	0.57	0.95	0.63	0.45		0.94	0.71	0.54		0.78
France	2011	0.4				0	0.57	0.54	0.8	0.56	0.07	0.61	0.53	0.51		0.49
Germany	2011	0.29				0	0.57	0.68	0.76	0.16	0.13	0.31	0.42	0.58		0.4
Greece	2011	0.32				0	0.57	0.11	0.34	0.59		0.75	0.47	0.22		0.32
Hungary	2011	0.13					0.57	0.16	0.3	0.5		0.65	0.29	0.13		0.19
Iceland	2011	0.59				0	0.57	0.7	0.79	0.41		0.95	0.92	0.54		0.61
Ireland	2011	0.61				0	0.57	0.6	0.32	0.28		0.83	0.16	0.6		0.76

Table 15 (cont'd)

NAME	YR	MB	TECH	SHARE	ROAM	MBUSO	VUSO	QUALITY	BB	MHHI	PRICE	PD	URBAN	INCOME	SKILL	EDU
Israel	2011	0.52				0	0.95	0.51	0.42	0.28		0.14	0.89	0.27		0.91
Italy	2011	0.42				0	0.57	0.08	0.34	0.25	0.08	0.36	0.27	0.44		0.09
Japan	2011	0.79				0	0.57	0.62	0.55	0.45	0.18	0.15	0.88	0.46		0.9
Korea	2011	0.89				0	0.57	0.46	0.83	0.56		0.04	0.66	0.28		0.81
Luxembourg	2011	0.64					0.05	0.79	0.71	0.65		0.37	0.84	0.95		0.71
Mexico	2011	0.07				0	0.95	0.07	0.06	0.88		0.85	0.52	0.07		0.13
Netherlands	2011	0.53					0.57	0.82	0.89	0.53	0.07	0.09	0.82	0.61		0.61
New Zealand	2011	0.67				0	0.05	0.86	0.52	0.56		0.94	0.78	0.36		0.83
Norway	2011	0.75				0	0.57	0.84	0.81	0.56		0.94	0.56	0.81		0.76
Poland	2011	0.53					0.57	0.14	0.13	0.13		0.57	0.14	0.12		0.27
Portugal	2011	0.21				0	0.57	0.29	0.3	0.5	0.78	0.61	0.15	0.2		0.1
Slovak	2011	0.3				0	0.57	0.22	0.11	0.53		0.63	0.08	0.19		0.13
Slovenia	2011	0.22				0	0.57	0.3	0.4	0.77		0.68	0.05	0.26		0.29
Spain	2011	0.65				1	0.57	0.32	0.43	0.32	0.24	0.73	0.54	0.38		0.55
Sweden	2011	0.87				0	0.05	0.89	0.72	0.36	0.95	0.93	0.75	0.59		0.67
Switzerland	2011	0.51				1	0.57	0.85	0.91	0.77		0.38	0.39	0.71		0.7
Turkey	2011	0.14				1	0.57	0.08	0.06	0.59		0.71	0.33	0.07		0.07
UK	2011	0.57				0	0.57	0.68	0.75	0.25	0.05	0.27	0.64	0.49		0.78
US	2011	0.76				1	0.05	0.65	0.57	0.1		0.91	0.62	0.69		0.85
Australia	2012	0.89	1		0	0	0.57	0.72	0.45	0.41	0.91	0.95	0.84	0.62	0.76	0.76
Austria	2012	0.58	1		1	0	0.57	0.68	0.46	0.28		0.68	0.22	0.62	0.4	0.17

Table 15 (cont'd)

NAME	YR	MB	TECH	SHARE	ROAM	MBUSO	VUSO	QUALITY	BB	MHHI	PRICE	PD	URBAN	INCOME	SKILL	EDU
Belgium	2012	0.27	1			0	0.57	0.7	0.76	0.45		0.13	0.95	0.57	0.57	0.69
Canada	2012	0.45	1		0	0	0.05	0.8	0.73	0.18		0.95	0.63	0.58	0.71	0.95
Chile	2012	0.22			0	0	0.57	0.46	0.09	0.41		0.93	0.84	0.12		0.41
Czech	2012	0.54	0.5		0	0	0.95	0.27	0.17	0.41		0.51	0.38	0.24	0.45	0.12
Denmark	2012	0.88			0	0	0.05	0.89	0.89	0.28		0.53	0.8	0.6	0.82	0.64
Estonia	2012	0.73				0	0.05	0.29	0.44	0.45		0.92	0.26	0.17	0.23	0.7
Finland	2012	0.91	0.5			1	0.57	0.94	0.67	0.41		0.94	0.71	0.55	0.92	0.78
France	2012	0.5	0		0	0	0.57	0.51	0.84	0.32		0.61	0.54	0.52		0.49
Germany	2012	0.37	1		0	0	0.57	0.69	0.78	0.16		0.31	0.42	0.59	0.64	0.4
Greece	2012	0.44	1		1	0	0.57	0.07	0.42	0.56		0.75	0.48	0.2		0.32
Hungary	2012	0.18	1				0.95	0.14	0.33	0.5		0.65	0.3	0.14		0.19
Iceland	2012	0.71	0		0	0	0.57	0.63	0.8	0.36		0.95	0.92	0.55		0.61
Ireland	2012	0.66			0	0	0.57	0.66	0.36	0.28		0.83	0.16	0.61	0.14	0.76
Israel	2012	0.51	1			0	0.95	0.46	0.44	0.28		0.14	0.89	0.29		0.91
Italy	2012	0.53				0	0.57	0.09	0.34	0.25		0.36	0.27	0.45		0.09
Japan	2012	0.81	1		0	0	0.57	0.56	0.56	0.41	0.56	0.15	0.89	0.5	0.57	0.9
Korea	2012	0.9				0	0.57	0.42	0.84	0.56		0.04	0.66	0.31	0.31	0.81
Luxembourg	2012	0.77	1				0.05	0.75	0.72	0.65		0.37	0.85	0.95		0.71
Mexico	2012	0.08				0	0.95	0.07	0.07	0.88		0.85	0.53	0.08		0.13
Netherlands	2012	0.61					0.57	0.82	0.9	0.53	0.08	0.09	0.84	0.61	0.92	0.61
New Zealand	2012	0.71			0	0	0.05	0.82	0.61	0.5		0.94	0.78	0.41		0.83

Table 15 (cont’d)

NAME	YR	MB	TECH	SHARE	ROAM	MBUSO	VUSO	QUALITY	BB	MHHI	PRICE	PD	URBAN	INCOME	SKILL	EDU
Norway	2012	0.8			0	0	0.57	0.86	0.84	0.59		0.94	0.57	0.85	0.89	0.76
Poland	2012	0.63					0.57	0.16	0.15	0.11		0.57	0.14	0.14	0.05	0.27
Portugal	2012	0.26	0.5		1	0	0.05	0.32	0.36	0.5	0.8	0.61	0.15	0.2		0.1
Slovak	2012	0.36			0	0	0.57	0.22	0.13	0.5		0.63	0.07	0.2	0.17	0.13
Slovenia	2012	0.32	0.5		0	0	0.05	0.32	0.43	0.7		0.68	0.05	0.27		0.29
Spain	2012	0.54	1			1	0.57	0.37	0.44	0.25		0.73	0.55	0.4		0.55
Sweden	2012	0.9			0	0	0.05	0.88	0.73	0.32		0.93	0.76	0.6	0.95	0.67
Switzerland	2012	0.56	1		0	1	0.57	0.86	0.93	0.77		0.38	0.4	0.73		0.7
Turkey	2012	0.19			0	1	0.57	0.09	0.07	0.59		0.71	0.35	0.08		0.07
UK	2012	0.68				0	0.57	0.66	0.78	0.21	0.11	0.27	0.65	0.5	0.57	0.78
US	2012	0.84	1			1	0.05	0.65	0.61	0.11		0.91	0.63	0.71	0.35	0.85
Australia	2013	0.93	1	1	0	0	0.57	0.72	0.5	0.5		0.95	0.85	0.62	0.76	0.76
Austria	2013	0.65	1	0	1	0	0.95	0.68	0.5	0.5		0.68	0.22	0.62	0.4	0.17
Belgium	2013	0.44	1	0	1	1	0.05	0.7	0.79	0.45		0.13	0.95	0.57	0.57	0.69
Canada	2013	0.53	1	1	0	0	0.05	0.8	0.77	0.18		0.95	0.64	0.58	0.71	0.95
Chile	2013	0.3	1	1	0	0	0.05	0.46	0.1	0.41		0.93	0.85	0.12		0.41
Czech	2013	0.63	0.5	0	0	0	0.57	0.27	0.19	0.41		0.51	0.38	0.24	0.45	0.12
Denmark	2013	0.91			0	0	0.05	0.89	0.9	0.28		0.53	0.81	0.6	0.82	0.64
Estonia	2013	0.84			0	0	0.05	0.29	0.48	0.45		0.92	0.26	0.17	0.23	0.7
Finland	2013	0.95	0.5	1		1	0.57	0.94	0.68	0.45		0.94	0.72	0.55	0.92	0.78
France	2013	0.56	0.5	1	0	0	0.57	0.51	0.86	0.28		0.61	0.55	0.52		0.49

Table 15 (cont'd)

NAME	YR	MB	TECH	SHARE	ROAM	MBUSO	VUSO	QUALITY	BB	MHHI	PRICE	PD	URBAN	INCOME	SKILL	EDU
Germany	2013	0.43	1	1	0	0	0.57	0.69	0.8	0.16		0.31	0.43	0.59	0.64	0.4
Greece	2013	0.3	1	1	0	0	0.57	0.07	0.51	0.56		0.75	0.49	0.2		0.32
Hungary	2013	0.21	1				0.95	0.14	0.38	0.5		0.65	0.31	0.14		0.19
Iceland	2013	0.75	0.5	0	0	0	0.57	0.63	0.83	0.36		0.95	0.92	0.55		0.61
Ireland	2013	0.69	0.5	1	0	0	0.57	0.66	0.43	0.25		0.83	0.17	0.61	0.14	0.76
Israel	2013	0.51	1			0	0.95	0.46	0.46	0.28		0.14	0.89	0.29		0.91
Italy	2013	0.65			0	0	0.57	0.09	0.35	0.21		0.36	0.28	0.45		0.09
Japan	2013	0.93	1		0	0	0.57	0.56	0.58	0.41		0.15	0.9	0.5	0.57	0.9
Korea	2013	0.9				0	0.57	0.42	0.86	0.56		0.04	0.66	0.31	0.31	0.81
Luxembourg	2013	0.81	1				0.05	0.75	0.74	0.65		0.37	0.86	0.95		0.71
Mexico	2013	0.1			0	0	0.95	0.07	0.08	0.88		0.85	0.54	0.08		0.13
Netherlands	2013	0.64					0.57	0.82	0.91	0.53		0.09	0.85	0.61	0.92	0.61
New Zealand	2013	0.81			0	0	0.05	0.82	0.66	0.45		0.94	0.78	0.41		0.83
Norway	2013	0.84	1	1	0	0	0.57	0.86	0.85	0.59		0.94	0.58	0.85	0.89	0.76
Poland	2013	0.61	1				0.57	0.16	0.15	0.11		0.57	0.14	0.14	0.05	0.27
Portugal	2013	0.32	0.5	1	1	0	0.05	0.32	0.42	0.5		0.61	0.16	0.2		0.1
Slovak	2013	0.55			1	0	0.57	0.22	0.15	0.5		0.63	0.07	0.2	0.17	0.13
Slovenia	2013	0.39	0.5	1	0	0	0.05	0.32	0.46	0.67		0.68	0.05	0.27		0.29
Spain	2013	0.68	1	1	1	1	0.57	0.37	0.51	0.25		0.73	0.55	0.4		0.55
Sweden	2013	0.92	0.5	1	0	0	0.05	0.88	0.73	0.32		0.93	0.76	0.6	0.95	0.67
Switzerland	2013	0.64	1	1	0	1	0.57	0.86	0.95	0.77		0.38	0.4	0.73		0.7

Table 15 (cont'd)

NAME	YR	MB	TECH	SHARE	ROAM	MBUSO	VUSO	QUALITY	BB	MHHI	PRICE	PD	URBAN	INCOME	SKILL	EDU
Turkey	2013	0.26	0	0	0	1	0.95	0.09	0.07	0.56		0.71	0.36	0.08		0.07
UK	2013	0.75				0	0.57	0.66	0.81	0.21		0.27	0.66	0.5	0.57	0.78
US	2013	0.89	1	1		1	0.05	0.65	0.65	0.11		0.91	0.63	0.71	0.35	0.85

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