

Kongaut, Chatchai; Bohlin, Erik

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

Chatchai Kongaut¹, Erik Bohlin

Division of Technology and Society, Department of Technology Management and Economics

Chalmers University of Technology, Gothenburg, Sweden

Abstract

Looking back at the last decade, the mobile phone has been greatly developed from only voice call and text message to a multi-purpose device, including camera, music player, games, and even small computer. The development of internet features in mobile phones has also continuously and extensively changed from providing only limited internet browsing in the early 2000s to watching high quality video on demand nowadays. The speed of internet is also significantly increased since the introduction of smartphones. After the implementation of 3G networks in the last decade and recently the LTE networks of 4G technology in the last few years, the transmission speed of mobile internet supports the use of mobile phones to be able to provide high-speed internet services which is called mobile broadband. Furthermore, recent studies have also suggested that mobile broadband positively affect economic outputs (see Thompson Jr. and Garbacz, 2011) as well as reduce the digital divide problem, especially in the rural where fixed broadband infrastructure is limited or not available (see Srinuan, C. et al., 2012 and Prieger, 2013).

With a number of possible benefits from mobile internet/broadband, it is interesting to analyse how mobile internet adoption has developed in the last decade and what factors are currently determining mobile broadband adoption in this current stage where smartphones are highly developed and transmission speed is much improved. To understand an adoption and a usage of one service, the case study of one country is more suitable than a cross-country analysis. In this paper, Sweden is selected as a case study for representing a developed country with well-developed mobile and broadband services. The method of this paper is applying bivariate probit with sample selection since the dataset consist of two sets of binary outcomes (adoption and usage). The data used in this paper is mainly based on the annual questionnaire conducted by the Swedish Post and Telecom Authority (PTS) in 2013.

Keywords: mobile broadband, mobile diffusion, mobile adoption, Sweden

¹ Corresponding author's email address: chatchai@chalmers.se

1. Introduction

In the last decade, mobile phones have been continuously and substantially developed from only a communicating device to a multimedia device. From only voice call and text message, a mobile phone nowadays can be used as a music player, as a camera as well as a mini personal computer. With continuous improvement of internet service for mobile phones, transmission speed of mobile internet has been increased significantly in recent years. The mobile phone has currently transformed into a so-called *smartphone* which can be used for many purposes including providing broadband service. According to the Swedish Post and Telecom Authority (PTS), a smartphone, which is used for both calls and mobile broadband, is referred to as mobile broadband as an add-on service.

At the early stage, one of the obstacles for mobile internet adoption is the transmission speed when compared to fixed broadband speed, especially in developed countries (Westlund and Bohlin, 2008). However, after the development of 3G technology in the last decade and recently the introduction of 4G technology in the last few years, mobile internet now can provide faster speed and become mobile broadband. Furthermore, mobile broadband adoption has been significantly growing in recent years due to a massive increase of smartphone use. Even though mobile broadband currently still cannot provide transmission speed as fast as in comparison to fixed broadband, several studies suggested that mobile broadband has a significantly positive impact on economic growth. For example, Thompson Jr. and Garbacz (2011) found that mobile broadband has a direct positive effect on the GDP. In addition, scholars suggested that mobile broadband can be applied as one of the regulatory tools to reduce the digital divide problem especially in the rural where fixed broadband infrastructure is limited or not available (see for example, Srinuan, C. et al., 2012 and Prieger, 2013).

With a number of possible benefits from mobile broadband, it is important to understand what factors are determining mobile broadband adoption in this current stage when smartphones are highly developed and transmission speed is much improved. By understanding the factors of mobile broadband adoption and usage, the government are able to initiate their broadband policy to increase its adoption while the business sector can use the knowledge for their market strategies by targeting particular applications for a particular group of users. In this paper, Sweden has been chosen as a case study because Sweden is one of the first countries that early adopts 4G/LTE technology. Hence, the significant growth of mobile broadband adoption is increased and the dataset has become more available which is enough for conducting empirical study. This paper aims to investigate the determinants and relevant socio-economic factors of smartphone adoption as a representative for mobile broadband in Sweden. This study aims to recommend policy implementation for the public sector to increase the use of mobile broadband in the future. This paper consists of 7 sections. Following this introduction, section 2 provides an overview of Swedish mobile internet and mobile broadband market. Section 3 discusses previous studies related to broadband and mobile internet adoption while the data and model specification are explained in section 4. The empirical results and the discussion of the findings are presented in section 5 and 6. Finally, section 7 provides a conclusion, recommends policies and suggests future research.

2. Swedish mobile internet overviews

2.1 Mobile internet in early-2000s to mid-2000s

The infrastructure for mobile internet has been developed in Sweden for more than a decade. At the early stage, the first step of mobile internet is in a form of GPRS (General Packet Radio Service). Three mobile operators in Sweden at that time; TeliaSonera, Tele2 and Vodafone (later become Telenor), are able to provide GPRS since autumn 2001; however, the use of GPRS at that time was still at the early stage. There were only around 105,000 subscribers who use GPRS at the end of 2002 (PTS, 2003). In 2003, the users of GPRS had increased to around 516,000 subscribers although the usage was limited with averagely 0.16 Mb per month per user (PTS, 2004). In spring 2004, the 3G/UMTS² technology has finally commercially launched by main mobile operators (TeliaSonera, Tele2 and Vodafone). Before that, even though 3G technology has been rolled out since 2001 and continuously developed for greater transmission speed for mobile phone, there was only mobile operator 3 which has launched 3G until the end of 2003. As a result of commercial 3G services to provide faster internet, the users of mobile data or internet services were increased to 983,000 with average speed 0.8 Mb per month per user. Nevertheless, comparing with the numbers of mobile subscribers, there was only 10% of mobile users who used mobile internet at the end of 2004 (PTS, 2005). Finally, mobile users have gradually started to use more mobile internet as mobile data service account for 2.6 million subscribers in 2005 and 3.7 million subscribers in 2006 respectively. These were results that individuals start to connect to internet via their mobile phone (PTS, 2007). Nevertheless, at that time, approximately 70% of Swedish population still have not used mobile internet. The reasons for low adoption are that mobile internet was too slow and difficult to get an overview of the contents. Furthermore, there was still a concern on the future cost of using mobile internet as well. Users of mobile internet at that early stage were mainly male, teenagers and young adults (Westlund, 2007 and Westlund and Bohlin, 2008).

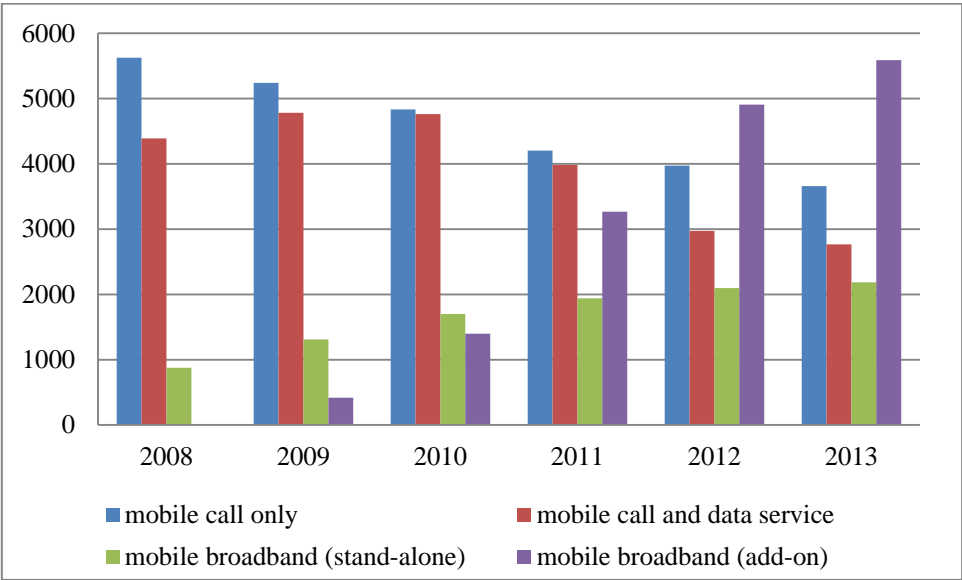
2.2 Mobile broadband market

With the development of 3G/UMTS technology which has increased the transmission speed for commercial 3G mobile internet services, mobile internet has gradually turned into mobile broadband. Mobile broadband was first introduced in Sweden in 2006 with less than 100,000 subscribers. Later, the number of mobile broadband subscriptions has been continually growing in every year. In particular, the introduction of LTE technology for 4G network has been implemented along with an explosive growth of smartphone usage. Hence, at the end of 2013, there were almost 8 million subscriptions for mobile broadband in Sweden, 11% increase from 2012. Particularly, smartphone or mobile broadband as an add-on service, which is introduced for the first time in 2009, increases in a highest portion which accounts for 14% increase from 2012. Moreover, there were significantly increase of 4G network (LTE) from 252,000 subscriptions at the end of 2012 to more than 1.5 million subscriptions at in the end of 2013 (PTS 2014a). Figure 1 presents the number of different types of mobile subscriptions from 2008 to 2013. According to figure 1, mobile broadband subscriptions have

² UMTS = The Universal Mobile Telecommunications System

been continuously growing from 2009 onwards, especially mobile broadband as an add-on service. On the other hand, mobile subscriptions for only voice service have been gradually decreased in the recent years.

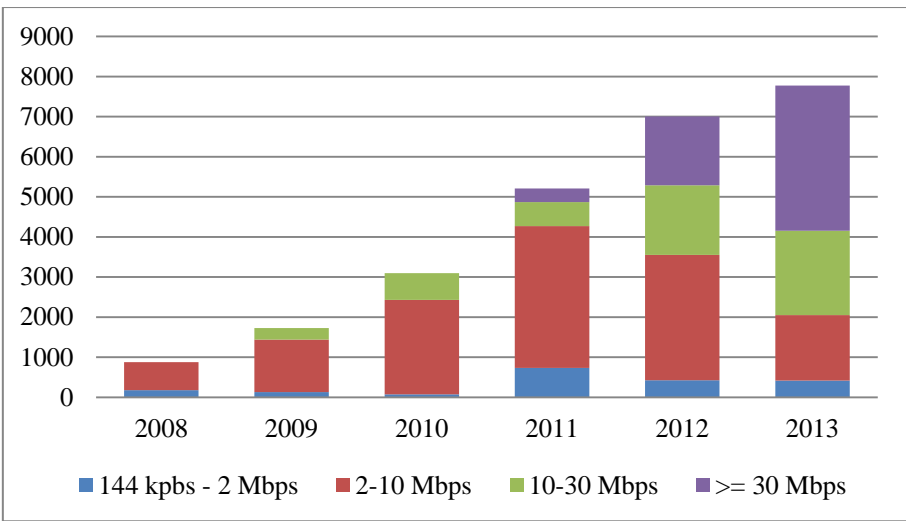
Figure 1 Mobile subscriptions for voice and data services (thousands) in Sweden from 2008- 2013



Source: PTS (2014b)

Not only the continuing growth of Swedish mobile broadband subscriptions, the transmission speed of mobile broadband in Sweden has also been constantly improving over years. According to the data provided by PTS (2014b), at the end of 2013, there have been already more than 5.7 million mobile broadband subscribers with (download) speed more than 10 Mbps and approximately 3.6 million mobile broadband subscribers with (download) speed over 30 Mbps. Figure 2 presents the development of mobile broadband transmission speed (download) from 2008-2013.

Figure 2 Download speed of mobile broadband subscriptions (thousands) in Sweden from 2008- 2013



Source: PTS (2014b)

As in figure 1 and 2, these imply an important of the introduction of LTE technology which improves not only quantity of the services (mobile broadband subscriptions) but also one of the qualities of the services (transmission speed). In addition, the competition of mobile broadband market in Sweden is also reasonably competitive. There are four main telecom operators accounting for almost 97% of the market, TeliaSonera, Tele2, Telenor, and Hi3G, providing mobile broadband in Sweden. TeliaSonera is the largest operators with 34% of market share at the end of 2013; however, TeliaSonera market share of mobile broadband is slightly decreased about 0.5% from 2012. Tele2 is the second biggest market share accounting for 24.4%, closely following by Telenor which has about 23% of market share. Lastly, Hi3G has 15.3% of mobile broadband market share and other operators together have market share of 3.3%³ (PTS, 2014a). As a result of LTE/4G early development⁴ and competitive market, mobile broadband have been widely adopted in Sweden with average speed higher than most countries.

As suggested by figure 1, mobile broadband as an add-on service or smartphone become the main contribution for mobile broadband subscriptions since 2010. Hence, this suggests how technology such as UMTS and LTE can affect mobile broadband adoption in Sweden. This development of UMTS and LTE can be seen as the development from the supply side. The success of mobile broadband in Sweden, however, came from both demand and supply side. To understand on the demand side, this study investigates how socio-economics factors as well as user behaviour and perception on using internet can affect mobile broadband adoption as well as its usage.

3. Previous literature

To understand the adoption and usage of mobile broadband in Sweden, it is worth to consider previous literature related to an adoption of new technology especially broadband, mobile internet or smartphone. In the last decade, there have been several studies focused on the factors of broadband adoption in general or analysed on mobile internet use and access; however, until recently, there were still limited studies regarding to particularly mobile broadband or smartphone. Previous studies are summarised in this section.

Among other literatures, an early broadband adoption study was conducted by Madden and Simpson (1997). The authors found that household income and the installation fee are important determinants of broadband adoption in Australia. During 2000s period, several scholars have conducted more broadband adoption studies in different countries or areas as the data have become more available. Their results were slightly different depending on the area and characteristics of variables they focused on. For example, Savage and Waldman (2005) studied on an American nationwide mail survey and suggested that households with higher income and higher education have a preference for an access of high speed internet. Cerno and Pérez Amaral (2006) applied a binary probit model with selection bias and stated that income and technological attributes have positive effects on broadband access while age

³ The two largest for other operators are Alltele and Netett

⁴ According to the report by TeliaSonera, TeliaSonera is the first operator in the world who commercially launch LTE/4G technology in Stockholm (Sweden) and Oslo (Norway) in 2009

and habitat have negative impacts. Flamm and Chaudhuri, (2007) mentioned that broadband price has significant impact on broadband demand while living area (urban/suburban) also have significant effect on broadband choice. Furthermore, many scholars in the last decade have conducted studies not only on broadband/internet adoption but also broadband/internet usage. For instance, Goldfarb and Prince (2008) used an American survey and found that internet adoption and usage have different pattern. The authors found that income and education have positive effect on internet adoption; however, they have negative effect on the time people spending online. Recently, Srinuan and Bohlin (2013) studied fixed broadband adoption and usage in Thailand. The authors suggested that the available of infrastructure and income have significantly impact on broadband adoption while the advancement of contents plays a major role to drive broadband usage, especially for low and mid-income users.

Regarding to previous mobile internet or mobile broadband adoption studies, Japan, in particular, is one of the countries with early using and massively growing of mobile internet; hence, early mobile internet literature is mainly from Japanese mobile internet. For example, Funk (2005) applied technological trajectories and lead users concepts to forecast an evolution of mobile internet while Okazaki (2006) applied cluster analysis to identify the determinants of mobile internet adoption in Japan. Later, mobile internet studies have been done in other countries as well. In developing country case, Srinuan, C. et al., (2012) analysed the mobile internet access in Thailand with binomial logit regression. The authors found that age, living area and availability of fixed telephone are among important determinants of mobile internet access in Thailand. Back to Sweden, Sweden is an interesting country case study due to its well-developed of mobile networks, along with great broadband coverage (Westlund, 2008). Example of previous literatures focusing on mobile internet access and use in Sweden is Westlund and Bohlin (2008). The authors analysed mobile internet adoption and use in Sweden as a case study of a developed countries with high ICT diffusion. The authors found that user-friendliness, such as slower transmission speed when compared with fixed broadband, is one of the crucial obstacles for mobile internet adoption. Despite of this disadvantage of mobile internet, in the past recent year, the transmission speed of mobile internet has significantly increased. Furthermore, another study (Srinuan, P. et al., 2012) also found that mobile broadband can be considered in the same relevant market with fixed broadband if the area has more than DSL and mobile broadband technology.

With the data from PTS for smartphone adoption and usage in Sweden now become available; this study therefore attempts to fill the gap as an early study for Swedish mobile broadband market by investigating on the main determinants of mobile broadband adoption and usage in Sweden. Identifying these factors can also provide some knowledge which can be useful for broadband policy related to increasing mobile broadband adoption. This study therefore adapts methodology from finding determinants of broadband adoption and usage (as previous describe by Cerno and Pérez Amaral, 2006, Goldfarb and Prince, 2008 and Srinuan and Bohlin, 2013) to be able to point out what are the determinants of smartphone adoption and usage in Sweden.

4. Model specification and data

4.1 Model specification

The data used in this paper determine the model specification applied in this study. The dependent variables are categorised into two parts, adoption in the first part and usage in the second. The first part (selection stage) is a binary outcome which determines the probability of a respondent whether or not to adopt smartphone ($Y_1 = 1$ if a respondent adopts smartphone; otherwise $Y_1 = 0$). The second part (outcome stage) is a binary outcome which determine the probability of a respondent whether or not to use a smartphone for a particular purpose (for example, music application, video, application or social network application; $Y_2 = 1$ if a respondent use a smartphone for a particular purpose; otherwise $Y_2 = 0$). In general, the probit or logit model is applied to estimate the observations which the dependent variable is a binary outcome. However, in this case, a binary outcome of the second part can be observed if and only if the answer for a binary outcome of the first part is that a respondent adopt smartphone. Thus, the probability of a respondent using a smartphone for a particular purpose fully depends on if a respondent adopts a smartphone. Since the observations on the second part of analysis are not random, a sample selection bias can be occurred (Heckman, 1979). To be able to estimate this model, a model specification which can cope with sample selection is chosen. This model specification is called bivariate probit with sample selection (alternatively it can be also called censored probit or double probit). The bivariate probit with sample selection model has been adapted from the Heckman's selection model⁵ (see Van de Ven and Van Praag, 1981). The difference of them are that bivariate probit with sample selection estimation can be simplified as two probit regressions connected with correlated error; Heckman's selection estimation, on the other hand, can be seen as an OLS⁶ regression and a probit regression linked with correlated error (ρ)⁷. Regarding to ICT studies, bivariate probit with sample selection has also been applied by Vergara and Grazzi (2011) to estimate an access to computer and internet.

In this specification, there can be three types of observations; 1) a respondent does not adopt smartphone ($Y_1 = 0$), 2) a respondent adopt smartphone but does not use a particular service on smartphone ($Y_1 = 1, Y_2 = 0$), and 3) a respondent adopt smartphone and use a particular service on smartphone ($Y_1 = 1, Y_2 = 1$). These three groups of observations can be written in probability equations and illustrated as in figure 3 as follow.

$$Y_1 = 0 \quad \text{then } Pr(Y_1 = 0) = \Phi(-X_1\beta_1) \quad (1)$$

$$Y_1 = 1, Y_2 = 0 \quad \text{then } Pr(Y_1 = 1, Y_2 = 0) = \Phi(X_1\beta_1) - \Phi_2(X_1\beta_1, X_2\beta_2, \rho) \quad (2)$$

$$Y_1 = 1, Y_2 = 1 \quad \text{then } Pr(Y_1 = 1, Y_2 = 1) = \Phi_2(X_1\beta_1, X_2\beta_2, \rho) \quad (3)$$

where Pr presents the probability of individual making binary decisions, Y presents dependent variables in both first (selection) and second (outcome) equations, X presents the vector of

⁵ More explanation in detail for Heckman's selection model can be found in Heckman (1976, 1979)

⁶ Ordinary Least Squares (OLS)

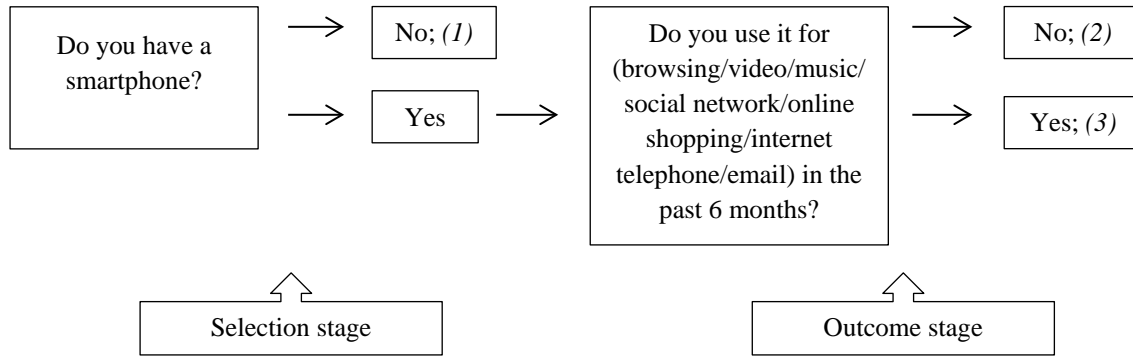
⁷ The comparison to probit and OLS regression is for simplification purpose; in fact, the likelihood functions for both bivariate probit with sample selection model and Heckman's selection are more complicated

independent variables for both parts, β presents estimated coefficients of each independent variable, Φ present a cumulative of the unit-normal distribution function, and ρ present correlated errors of two equations.

Thus, the log-likelihood function can be generated for estimation as in (4).

$$\ln L = \sum_{i=1}^N \{ Y_{i1}Y_{i2} \ln \Phi_2(X_1\beta_1, X_2\beta_2, \rho) + Y_{i1}(1 - Y_{i2}) \ln [\Phi(X_1\beta_1) - \Phi_2(X_1\beta_1, X_2\beta_2, \rho)] + (1 - Y_{i1}) \ln \Phi(-X_1\beta_1) \} \quad (4)$$

Figure 3 Three groups of observations for bivariate probit with sample selection model



4.2 Data and variables

This paper uses data taken from annually national surveys from Swedish Post and Telecom Authority (PTS). Since 2002, PTS have annually asked respondents to answer the survey consisting of several questions related to telecommunications services, fixed telephone, mobile phone, broadband and television, including their socio-economic information. Although mobile broadband services have been introduced since 2006 in Sweden, an immense growth of mobile broadband adoption started to have significant impact since 2010 due to the rise of smartphone use (see mobile broadband as an add-on service from figure 1). In 2013, PTS added a new question regarding to an adoption of smartphone and its usage. To capture smartphone adoption, data in this paper is taken from the PTS national survey on 2013. There are 1,732 observations in this dataset; however, 1,616 observations are used for estimation. In this paper, the dataset of several socio-economic variables and internet behaviour are used to determine both adoption and usage. The usage of smartphone considered in this paper are the use for watching TV/video/clip, the use for listening to music (streaming/radio), the use for buying tickets and online shopping (e.g. train/bus/movie), the use for browsing website, the use for sending email, the use as internet telephone (Skype), and the use for social media (facebook/twitter/linkedin). Socio-economic variables consist of gender, age, income, education, living area, and resident type. In addition, some internet behaviours such as usage frequency, transmission speed preference and having fixed broadband are used as explanatory variables in this study as well. The description of variables is depicted and discussed as follow.

Table 1 Variables description

Variable	Description	Mean	Std. Dev.
<i>Dependent Variable(s):</i>			
Smartphone adoption	= 1 if a respondent use a mobile phone with surfing capabilities (smartphone); = 0 if otherwise	0.6905	0.4624
Smartphone usage (Mean and Std. Dev. are shown as a ratio when smartphone adoption = 1):			
Browsing	= 1 if a respondent use a mobile phone for browsing the internet in the past 6 months; = 0 if otherwise	0.9365	0.2440
Video	= 1 if a respondent use a mobile phone for watching video via internet in the past 6 months; = 0 if otherwise	0.7333	0.4424
Music	= 1 if a respondent use a mobile phone for listening to radio or streaming music via internet in the past 6 months; = 0 if otherwise	0.6538	0.4759
Social	= 1 if a respondent use a mobile phone for social media in the past 6 months; = 0 if otherwise	0.6697	0.4705
Shop(ticket)	= 1 if a respondent use a mobile phone for buying tickets or shopping online in the past 6 months; = 0 if otherwise	0.3829	0.4863
Internet phone	= 1 if a respondent use a mobile phone for internet telephone in the past 6 months; = 0 if otherwise	0.3177	0.4658
E-mail	= 1 if a respondent use a mobile phone for sending e-mail in the past 6 months; = 0 if otherwise	0.7860	0.4103
<i>Independent Variable(s)</i>			
Freq.Use	= 1 if a respondent use internet almost everyday; = 0 if otherwise	0.8171	0.3867
Fixed	= 1 if a respondent has fixed broadband; = 0 if otherwise	0.6732	0.4692
Speed	= 1 if a respondent think transmission speed is important; = 0 if otherwise	0.5508	0.4976
Gender	= 1 if a respondent is male; = 0 if female	0.4775	0.4996
L.income	= 1 if a respondent has the combined annually income after taxes for the household less than 200,000 SEK; = 0 if otherwise	0.1534	0.3605
H.income	= 1 if a respondent has the combined annually income after taxes for the household more than 600,000 SEK; = 0 if otherwise	0.3014	0.4590
Over60	= 1 if the age of a respondent is older than 60; = 0 if otherwise	0.2962	0.4567
Under30	= 1 if the age of a respondent is 30 or younger than 30; = 0 if otherwise	0.2113	0.4084
University	= 1 if a respondent has an education at least at the university level; = 0 if otherwise	0.4215	0.4939
Sthlm	= 1 if a respondent live in Stockholm; = 0 if otherwise	0.2073	0.4055
Apartment	= 1 if a respondent live in an apartment; = 0 if otherwise	0.3885	0.4875

The independent variables chosen for this study are mainly socio-economic background of the respondents. Age, income, gender, education, and living area have been used in several previous literature (see, for example, Savage and Waldman, 2005, Cerno and Pérez Amaral, 2006, Goldfarb and Prince, 2008 and Srinuan and Bohlin, 2013) related to internet/broadband adoption. In addition, this paper also adds some internet behaviours of the respondents to determine either smartphone adoption or smartphone usage. These characteristics are frequent use of internet, having fixed broadband, and thinking that transmission speed of internet is important.

According to Table 1, the application which respondents use the most on their smartphones are browsing (more than 90% of smartphone adopters have used it in the past six months), followed by sending e-mail, watching video, social media, listening to music, online shopping, and lastly using as internet telephone. In addition, respondents with different socio-economic background tend to use smartphone differently. Table 2 depicts the preliminary summary of smartphone adoption and usage by socio-economic background to provide more understanding of the dataset before an econometric estimation.

Table 2 Summary of the percentage of smartphone adoption and usage by socio-economic background

Socio-economic Background	Smart-phone Adoption	Smartphone usage (percentage of smartphone users)						
		Browsing	Video	Music	Social	Shop (ticket)	Internet phone	E-mail
Gender:								
Male	69.77	93.76	74.35	64.82	61.35	41.07	31.20	78.34
Female	68.40	93.54	72.37	65.91	72.21	35.70	32.31	78.84
Income								
Below 200K	52.57	90.23	69.92	66.17	72.93	46.62	44.36	75.94
200K-600K	67.19	93.21	71.36	62.09	65.40	35.93	29.30	75.17
Above 600K	83.70	96.15	77.40	69.95	66.59	40.38	30.05	84.62
Age								
16-30	88.25	99.07	89.16	81.42	88.85	52.94	45.82	85.14
31-60	79.72	94.41	75.15	65.29	66.32	36.76	29.41	81.03
Above 60	37.62	81.87	40.41	38.86	32.64	19.17	16.58	59.07
Education								
Below uni.	62.18	92.62	70.63	59.23	63.40	32.42	29.53	74.00
University	78.49	94.76	76.27	72.08	70.86	44.68	34.21	83.60
Living area								
Stockholm	77.44	93.17	75.54	68.35	69.78	41.73	36.69	85.61
Others	66.86	93.79	72.66	64.49	66.12	37.25	30.28	76.47
All samples	69.05	93.65	73.33	65.38	66.97	38.29	31.77	78.60

Table 2 generally explains the relationship between socioeconomic background and smartphone adoption and usage. According to Table 2, male and female have almost the same ratio for smartphone adoption and most applications except social network and online shopping. Age, education and living area suggest the similar direction in both smartphone adoption and usage. Respondents who are younger, have higher education, and live in Stockholm have higher ratio for adopting smart and using most applications. Income is the most interesting variable. While respondents with higher income have higher ratio of adopting smartphone, the ratio for smart usage vary depending on the application.

5. Empirical results

Table 3 estimates the determinants for smartphone adoption and usage by using bivariate probit with sample selection method. The first row of estimated coefficients is the coefficients of independent variables for smartphone adoption. From the second to the seventh rows of coefficients are for different smartphone usages. Nevertheless, due to the identification issue, the model identification for independent variables in the selection stage and outcome stage are slightly different. *Freq.Use* and *Fixed* variables are excluded in the outcome stage because frequent use of internet and having fixed broadband characteristics are likely to affect the adoption process but not the usage criteria. In addition, *Speed* is added in the selection stage

since different applications require different transmission speed; therefore, transmission speed may affect the respondents' decision to use different smartphone applications.

Table 3 Regression results of smartphone adoption and usage in Sweden

Variable	Adoption (selection stage)	Usage (outcome stage)						
		Browsing	Video	Music	Social	Shop (ticket)	Internet phone	E-mail
Freq.Use	0.7288*** (0.1002)	-	-	-	-	-	-	-
Fixed	0.1117 (0.0814)	-	-	-	-	-	-	-
Speed	-	-0.0892 (0.1319)	-0.0001 (0.0807)	0.0500 (0.0746)	0.0364 (0.0791)	-0.0031 (0.0680)	-0.0211 (0.0664)	0.2071** (0.0834)
Gender	0.0379 (0.0741)	-0.0259 (0.1227)	0.0666 (0.0792)	-0.0017 (0.0752)	-0.2579*** (0.0773)	0.1402** (0.0715)	-0.0056 (0.0695)	-0.0358 (0.0829)
L.income	-0.2470** (0.1067)	-0.3006 (0.1989)	-0.0754 (0.1384)	0.0727 (0.1326)	0.2115 (0.1372)	0.2666** (0.1139)	0.3761*** (0.1095)	0.0188 (0.1358)
H.income	0.2611*** (0.0912)	0.1707 (0.1410)	0.0271 (0.0881)	0.0597 (0.0841)	-0.1142 (0.0847)	-0.0527 (0.0800)	-0.1192 (0.0795)	0.1411 (0.0949)
Over60	-0.8422*** (0.0845)	-0.4110** (0.1774)	-0.3459*** (0.1263)	-0.1748 (0.1372)	-0.3651*** (0.1401)	0.0757 (0.1366)	0.2472* (0.1387)	-0.1860 (0.1419)
Under30	0.4242*** (0.1104)	0.9137*** (0.2667)	0.5210*** (0.1101)	0.4416*** (0.0995)	0.6636*** (0.1094)	0.2575*** (0.0896)	0.1652* (0.0884)	0.1495 (0.1088)
University	0.1523** (0.0776)	0.0282 (0.1225)	0.0808 (0.0820)	0.2292*** (0.0788)	0.1413* (0.0802)	0.1957*** (0.0752)	0.0368 (0.0723)	0.2156** (0.0861)
Sthlm	0.2964*** (0.1009)	0.0346 (0.1535)	0.0658 (0.0974)	0.0441 (0.0927)	0.0715 (0.0938)	0.0105 (0.0860)	0.0850 (0.0861)	0.2708** (0.1090)
Apartment	0.0497 (0.0826)	-	-	-	-	-	-	-
Constant	-0.0884 (0.1215)	1.7178*** (0.1552)	0.7404*** (0.0994)	0.3771*** (0.0968)	0.6463*** (0.0988)	-0.2267** (0.1025)	-0.2180** (0.1017)	0.6815*** (0.1077)
ρ	-	-0.4457 (0.2284)	-0.7708 (0.0963)	-0.6968 (0.1098)	-0.7220 (0.1021)	-0.8246 (0.0824)	-0.8912 (0.0745)	-0.6347 (0.1426)
Wald test ($\rho = 0$)	-	2.83*	18.55***	16.29***	18.29***	20.70***	15.57***	9.84**
χ^2	361.32***	19.55**	34.10***	30.17***	76.02***	28.97***	32.05***	22.13**
No. of Obs.	1616	1616	1616	1616	1616	1616	1616	1616

The significant level is reported using ***, ** and *.

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

The first stage or the selection stage provides the determinants which are likely to encourage respondents adopting smartphone in Sweden. These estimations include command *vce(robust)* to correct errors for heteroscedasticity. The Wald test of $\rho = 0$ in all regressions indicated that the hypothesis of $\rho = 0$ is rejected at least at 10% significant level for all results in the outcome stage. Thus, they suggest that the use of sample selection method is appropriate. The results in the first stage⁸ suggest that the respondents who tend to often use internet (using everyday or almost everyday) are likely to adopt smartphone compared to those who use less. In addition, the results in the first stage also suggest several socio-economic factors which significantly affect the probability of the respondents to adopt smartphone. Income, age and education significantly have an impact. The results show that respondents with young age, high income and have education at the university level are more likely to adopt smartphone than those who are elder, having low income and have education below university level. Furthermore, respondents who live in the capital city, Stockholm, have more probability to adopt smartphone than those who live outside as well. However, in Sweden, gender as well as

⁸ The values of the coefficients in each first stage as well as the significant level are quite similar; therefore, the figures shown in Table 3 are estimated from normal probit regression with only first stage variables.

the type of residence (e.g. apartment or house) does not have significant effect on smartphone adoption. Interestingly, insignificant result of coefficient for fixed broadband may imply that smartphone is neither substituted nor complement to fixed broadband. Nevertheless, the substitution issue between fixed and mobile broadband need more specific demand analysis than regression which is out of the scope of this study.

On the estimation of smartphone usage (outcome stages), the bivariate probit with sample selection method suggests various results depending on the purpose of usage. Age turns out to be an important factor to determine the purpose of smartphone usage. The results show that young respondents tend to use more for browsing, video application, music application, social network, and online shopping. Conversely, the elder respondents are less likely to use smartphone for browsing, video application and social network. In addition, education also has an effect on smartphone usage. The results suggest that respondents with education at university level have more probability to use smartphone for e-mail, music application, online shopping and social network. Results on gender and income on smartphone usage are quite interesting and slightly surprising. While respondents who have low income are less likely to adopt smartphone, those who have, nevertheless, are more likely to use smartphone for online shopping and internet telephone (e.g. skype) than high income respondents who have smartphone. For gender, female have more probability to use smartphone for social network than male; however, according to Table 3, male respondents are surprisingly more likely to buy products online than female. Lastly, email and internet telephone applications also have interesting results. Respondents who have education at university level, live in Stockholm and believe that transmission speed is important tend to use email services on smartphone than those who do not. For internet telephone, such as Skype, service, not only younger respondents have more probability to use internet telephone, but elder respondent are more likely to use internet telephone as well, compared to those in the middle age (30-50).

6. Discussion

The findings in section 5, especially on the adoption stage which higher income, higher education and lower age respondents have more probability to adopt internet or broadband (smartphone for our study), are consistent with previous literatures; for example, Goldfarb and Prince (2008), Orviska and Hudson (2009), Vergara and Grazzi (2011) and Srinuan and Bohlin (2013). Nevertheless, the findings on the usage stage tend to be varying compared to previous literatures since services and applications of smartphone have been significantly improved in the last few years. Also, this study is a specific case for Swedish mobile market. The results on the usage part are therefore different from those who analysed for fixed internet in different countries. In a similar way to the findings, the discussion of the implication of the results also divides into two parts, smartphone adoption and smartphone usage.

Smartphone adoption

Smartphone adoption is less likely in a group of respondents who are older, have lower income, have lower education and living outside Stockholm, compared to those who are younger, have higher income, have higher education and living in Stockholm. Despite the success of mobile broadband adoption in Sweden, it is still important to have broadband

policy to encourage non-adopters in order to reduce the digital divide of a country⁹. Thus, these findings suggest that mobile broadband adoption should emphasis and support more to the previous group. With the current development of mobile broadband from the private sector, people will more or less be indirectly forced to use many applications through mobile broadband in the near future (Not yet in a mobile broadband case, but in a broadband case, a clear example in Sweden is online banking which several services require fee for in-person services at the bank, but they can be done online for free). At least, the policy makers should make sure that mobile broadband is affordable and the citizens are knowledgeable if they would like to use. The policy can be various from tax subsidy to reduce the cost mobile broadband adoption or supporting in particular campaign or applications and services to make the non-adopters aware of the benefits of using mobile broadband. Moreover, the coefficient of frequent use of internet significantly and positively affects mobile broadband adoption. Hence, policy makers, or even a private sector, can support the frequent use of internet through activities which related to everyday life; for example, online public service and e-banking. By pointing out the benefits of using those online services, citizen will be likely to increase the use of internet more frequently.

Smartphone usage

Even though the results on smartphone usage are different depending on the applications, some findings can have implication for developing broadband policy. The interesting one is the results that lower income respondents tend to use more on online shopping and internet telephone than those who has more income. The reasons could be explained that, unlike the applications for entertainment, these applications can reduce the cost for users in comparison to using an offline service. For instance, using skype call instead of normal telephone call can reduce a lot of calling cost, especially if the other receivers live outside of Sweden. Similarly, many services and products in Sweden usually offer lower price in the online service, such as bus tickets and train tickets. Thus, online shopping and internet telephone are more popular to those with lower income. With these results, policy makers can persuade the lower income non-adopters to consider adopting mobile broadband if they realise these benefits of using mobile broadband. Therefore, the support for these applications to help those with low income can support country economy as well as reduce digital divide for non-adopters. In addition, coefficients of age show significant effects on many purposes of smartphone usage. While young population tend to use more smartphone due to the entertainment applications, it is important to point out to the elder population that mobile broadband can provide a lot of benefits; for example, searching for health information, watching news and documentary programs, or keeping in touch with relatives who live far away.

Furthermore, this study not only suggests practical contribution, but also provides academic contribution by extending the research area on determining broadband adoption and usage to mobile broadband, in this case presenting by smartphone. Compared to previous studies, the overall findings show that the determinants of mobile broadband adoption are more or less

⁹ More information for literature on digital divide are Fuchs and Horak (2008) Orviska and Hudson (2009) and Srinuan, C. et al. (2013)

consistent to the determinants of internet/broadband adoption; however, the determinants of mobile broadband usage vary.

7. Conclusion

Broadband policy to support ultra-high speed internet recently have been emphasised in several regions and countries, and focuses on the development of fibre network. Despite of providing lower transmission speed in comparison to fibre network, mobile broadband, now with 4G/LTE technology, is able to generate higher transmission speed which is currently sufficient enough to use for many applications and services. This implies that, similar to fixed broadband, mobile broadband can be also use as a driver to expand economic outputs of a country as well as bridging digital divide. Sweden can be a good example for this case. Sweden, which has low population density, has very low ratio of the coverage of fixed ultra-high speed broadband in the rural area (as of 2012, only 6.3% compared to 12.4% for average Europe). However, the coverage of LTE in Sweden is as high as 93% (as of 2012) can significantly decrease the digital divide in the country. On the other hand, Sweden is considered as one of the leading countries in Europe when it comes to high speed broadband and LTE technology.

The reason of the success of mobile broadband in Sweden is that the development of mobile internet/broadband in Sweden has been done for more than a decade and still keeps continuing. From 2007, according to Westlund and Bohlin (2008), their survey showed that 70% of respondents still have not adopted mobile internet. Six years later, PTS survey in this study show that almost 70% has already adopted smartphone which can be considered as mobile broadband. Furthermore, there are also other types of mobile broadband adopted by Swedish as well; for example, USB modem or built-in tablet. This implies that majority of Swedish has currently adopted mobile broadband. Therefore, mobile broadband has become more and more a crucial factor for broadband policy of a country. Nevertheless, it is important to not ignore non-adopters and, instead, encourage them to adopt mobile broadband or at least make sure that non-adopters can adopt mobile broadband if they want to.

Mobile broadband policy can be supported through the demand side for higher adoption and usage. Although the policy on the spectrum management and LTE development are very important to mobile broadband adoption, identifying the determinants of mobile broadband adoption and usage, as shown in this study, can also be very useful for broadband policy, especially a policy related to reducing digital divide. For example, policy makers can for encourage the population to use the applications and services, especially to those who are still non-adopters. Lastly, one could argue that the explosive of smartphone adoption may lead to the so-called smartphone addiction or use in an inappropriate way. We believe that the benefits of using mobile broadband will overall outweigh the drawbacks. Though, this leaves the room for a future research.

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