

Leurcharusmee, Supanika; Sirisrisakulchai, Jirakom; Suriya, Komsan; Keesookpun, Chutipong; Srinuan, Pratompong

## Conference Paper

# Fixed-to-Mobile Substitution: Effects of Mobile Broadband Subscription on Fixed Broadband Termination

14th Asia-Pacific Regional Conference of the International Telecommunications Society (ITS): "Mapping ICT into Transformation for the Next Information Society", Kyoto, Japan, 24th-27th June, 2017

### Provided in Cooperation with:

International Telecommunications Society (ITS)

*Suggested Citation:* Leurcharusmee, Supanika; Sirisrisakulchai, Jirakom; Suriya, Komsan; Keesookpun, Chutipong; Srinuan, Pratompong (2017) : Fixed-to-Mobile Substitution: Effects of Mobile Broadband Subscription on Fixed Broadband Termination, 14th Asia-Pacific Regional Conference of the International Telecommunications Society (ITS): "Mapping ICT into Transformation for the Next Information Society", Kyoto, Japan, 24th-27th June, 2017, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/168513>

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# Fixed-to-Mobile Substitution: Effects of Mobile Broadband Subscription on Fixed Broadband Termination

Supanika Leucharusmee<sup>†</sup>, Jirakom Sirisrisakulchai<sup>†</sup>, Komsan Suriya<sup>†</sup>  
Chutipong Keesookpun<sup>‡</sup>, Pratompong Srinuan<sup>‡</sup>

## Abstract

*Motivation, background and problem statement:* Fixed and mobile broadband substitutability has recently been a debate in the telecom industry as the issue affects infrastructure investment decisions of service providers and service obligation regulation decision of telecom authorities. Previous studies have debated over both the definition of substitutability, measurement and the conclusions. Theoretically, substitution is the demand side concept measured using the cross-price elasticity. With a unique dataset, this study takes a simpler approach to examine the fixed-to-mobile substitution. Instead of examining the problem through the estimation of cross-price elasticity, this study estimates the impact of users' mobile broadband subscription on their decision to terminate fixed broadband subscription.

*Data and methodology:* The data used in this study are from the 2016 Telecom Consumption Survey of Thailand by the National Broadcasting and Telecommunications Commission of Thailand. This study estimates the fixed to mobile substitution using the concept of average treatment effect of mobile broadband usage on the fixed broadband termination. Without random assignment, the estimation of factors determining the fixed broadband termination decision, focusing on the mobile broadband subscription, faces the endogeneity problem. Therefore, we applied the endogenous switching Probit model to estimate the average treatment effect.

*Results and concluding remarks:* From the survey, 1949 respondents subscribed to a fixed broadband service at home at one point. Among them, 85.48 percent remain subscribed to the service and 14.52 percent has canceled the service prior to 2016. The regression analysis shows that mobile broadband subscription has a positive significant effect on the decision to cancel fixed broadband service. The contribution of the study lies on the heterogeneity of the level of fixed to mobile substitution across different groups of internet users. For those who are online for less than 40 hours per day, mobile broadband is considered as a substitute for fixed broadband to a certain level. For those whose lifestyle requires a higher usage of internet, the results show no substitution. As telecom regulations normally target to help users with lower telecom accessibility rather than those with higher level of usage, the higher level of fixed and mobile substitution for individuals with low usage should imply the possibility to unify regulatory framework for fixed and mobile broadband markets.

*Keywords:* Fixed to mobile substitution, fixed broadband termination, endogenous switching regression.

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<sup>†</sup> Faculty of Economics, Chiang Mai University, Thailand.

<sup>‡</sup> Office of The National Broadcasting and Telecommunications Commission, Thailand.

## 1. Introduction

Fixed to mobile substitutability for broadband services has recently been a debate in the telecom industry. This is an important issue as it affects the landscape of competition in the broadband market through inter-platform competition (Distaso, 2006). The substitutability also affects infrastructure investment decisions of service providers and service obligation regulation decision of telecom authorities (Alleman et al., 2010). If the fixed and mobile broadband services are substitutes, the definition of the market for broadband has to include both networks and both services should be subject to the same regulatory framework (Oğuz et al., 2015). The issue of fixed to mobile substitutability is complex as the level of substitutability can be heterogeneous across different groups of internet users. Therefore, this study measures the fixed to mobile substitutability and allows the value to be different across users with different levels of internet usage.

Previous studies on the fixed to mobile substitutability have debated over both the definition of substitutability, measurement and the conclusions. Theoretically, substitution is the demand side concept measured using the cross-price elasticity. If the price of a good positively affect the quantity of another good yielding a positive cross-price elasticity, the two goods are said to be substitutes. On the other hand, if the price of a good negatively affect the quantity of another good yielding a negative cross-price elasticity, the two goods are said to be complements. In the context of fixed and mobile broadband, the substitution relationship is due to the similar usage function and, thus, one good can replace the other good to a certain level. The complement relationship can be explained using the concept of network effects. A market exhibits network effects when the value of a good depends on the quantity of consumers of other goods (Albon, 2006; Berry et al., 2014). In this case, the likelihood of adoption of mobile broadband depends on the user base of fixed broadband, or vice versa.

For empirical works, Wulf et al. (2013) examined fixed to mobile substitutions in the OECD countries and the results suggest that the majority of consumers do not view fixed broadband as a substitute for mobile broadband but rather a complement. Several other studies found different results. Srinuan et al. (2012) studied the Sweden case and found fixed and mobile broadband to be substitutes. For studies in the Eurasia and Asia regions, Oğuz et al. (2015) studied the fixed to mobile substitutability in Turkey used time series aggregate data to estimate cross price elasticities and found that the level of substitutability increased over time as differences between speed, reliability and price of the fixed and mobile broadband services diminish. Bae et al. (2014) applied a multi-level demand model to estimate the cross-price elasticities for fixed broadband and mobile broadband using firm level data in Korea. The results show that mobile broadband is a substitute for fixed broadband. However, fixed broadband is a complement to mobile broadband. Most studies focused on the average level of fixed to mobile substitutability. Cincera et al. (2015) introduced heterogeneity in the substitutability study. Cincera et al. (2015) estimated the impact of mobile broadband speed evolution through 4G adoption on the fixed to mobile substitution in 18 European countries and found that the substitution effect is almost doubled after a country adopts 4G.

With a unique dataset from the 2016 Telecom Consumption Survey of Thailand by the National Broadcasting and Telecommunications Commission of Thailand, this study takes a simpler approach to examine the fixed to mobile substitution. Instead of examining the problem through the estimation of cross price elasticity, we estimate the impact of users' mobile broadband subscription on their decision to cancel fixed broadband subscription. The survey collected data on telecom usage from telecom users from 70 provinces in Thailand. The key

contribution of the survey data to the issue is that it asked, “Have you ever used and canceled a fixed broadband service?”. The survey also asked the respondents to provide the explanation for the termination decision. Realizing the importance of heterogeneous effects of fixed to mobile substitutability and the availability of data, this study also allows the level of the fixed-to-mobile substitution to vary across internet users with different hours of usage per day.

This study estimates the fixed to mobile substitution using the concept of average treatment effect of mobile broadband usage on the fixed broadband termination. If the average treatment effect is positive or users with mobile broadband are more likely to terminate their fixed broadband service, then it can be said that mobile broadband on average can substitute the fixed broadband service. On the other hand, if the average treatment effect is not positive, then internet users do not consider mobile broadband as a substitute for the fixed broadband service.

Without random assignment, the estimation of factors determining the fixed broadband termination decision, focusing on the mobile broadband subscription, faces the endogeneity problem. There may exist unobserved user characteristics that affect both the mobile broadband subscription and fixed broadband termination decisions. Therefore, we applied the endogenous switching Probit model to estimate the average treatment effects, which uses the full information MLE method to simultaneously estimate the binary treatment and the binary outcome equations parameters with consistent standard errors of the estimates (Loshkin and Sajaia, 2011).

The regression analysis shows that mobile broadband subscription has a positive significant effect on the decision to cancel fixed broadband service. The contribution of the study lies on the heterogeneity of the level of fixed to mobile substitution across different groups of internet users. For those who are online for less than 40 hours per day, mobile broadband is considered as a substitute for fixed broadband to a certain level. For those whose lifestyle requires a higher usage of internet, the results show no substitution. As telecom regulations normally target to help users with lower telecom accessibility rather than those with higher level of usage, the higher level of fixed and mobile substitution for individuals with low usage should imply the possibility to unify regulatory framework for fixed and mobile broadband markets.

## **2. Data**

The data used in this study are from the Telecom Consumption Survey of Thailand 2016 by the National Broadcasting and Telecommunications Commission of Thailand. The survey collected data on telecom usage from telecom users from 70 provinces in Thailand. Variables used in this study are shown in Table 1.

Table 1: Variables and statistics for fixed broadband service termination and determinants.

<b>Variables</b>	<b>Description</b>	<b>N</b>	<b>Mean</b>	<b>SD</b>
<b>Telecom Usage</b>				
d_stopFBB	1 if used and terminated fixed broadband service 0 if currently use fixed broadband	1949	0.15	0.35
d_mbb	1 if use mobile internet 0 if do not use mobile internet	1949	0.82	0.38
<b>Individual characteristics</b>				
xfemale	1 if female 0 if male	1941	0.56	0.50
xage	Age	1949	31.50	12.53
xmarried	1 if married 0 if not married	1949	0.38	0.48
xedu_hs	1 if have high school degree or higher 0 if do not have high school degree or higher	1949	0.91	0.28
xocc_bus	1 if business owner 0 if not business owner	1949	0.33	0.47
xocc_agri	1 if work in agriculture sector 0 if do not work in agriculture sector	1949	0.01	0.08
xlninc	Logarithm of monthly income	1896	9.26	1.95
xbkk	1 if live in Bangkok 0 if do not live in Bangkok	1949	0.20	0.40
Xprepaid	1 if use prepaid mobile voice service 0 if use postpaid mobile voice service	1949	0.52	0.50
xnetusage	All internet usage (hours per day)	1949	11.82	9.76

### 3. Methodology

From the data, this study estimates factors determining the fixed broadband termination decision, focusing on the mobile broadband subscription. The estimation faces the endogeneity problem as there may exist unobserved user characteristics that affect both the mobile broadband subscription and fixed broadband termination decisions. This problem always arises in estimation of treatment effects (here is individual choice of mobile broadband subscription) when treatment is not randomly assigned. In our situation, the choice of mobile broadband subscription is made by individual own decision and not randomly assigned to the sample. This endogeneity problem causes the mobile broadband subscription to correlate with the regression errors causing bias in all estimated parameters for binary outcome equations.

In the literature, there are four different kinds of convenient estimators that can be applied to binary choices models with one endogenous binary regressor. These estimators consist of linear probability model estimators, maximum likelihood estimation, control function based estimation, and special regressor methods (Lewbel et al., 2012). Linear probability model (LPM) is estimated by two-stage least squares with instrumental variables. The major drawback in the LPM is that the error terms cannot be independent of any regressors because

of the binary response nature of dependent variable. For practical use of marginal effect approximation, LPM can be seriously biased in some cases as point out by Lewbel et al. (2012). Maximum likelihood estimation (MLE) makes assumption on the joint distribution of unobserved user characteristics that may correlate with the regression errors in binary outcome equation. MLE is generally more efficient than other estimators when researchers can correctly specify the joint distribution and model specifications. However, in the case of model misspecification, MLE usually becomes inconsistent.

Control function estimators are more general than MLE because they can have semi-parametrically or non-parametrically identification. However, researchers have to be able to solve for the first-stage equations to get the estimated unobserved user characteristics to be used as a control variable in binary outcome equation. Like MLE, the control function methods require that the first-stage model be correctly specified. One major limitation of control function methods is that they generally require the endogenous regressors to be continuous. Therefore, these methods cannot be applied in our empirical study.

Special regressor methods are less well known than the other methods. Readers are referred to Dong and Lewbel (2012) and references therein for more details on the methods. The main drawback of the special regressor method is the restrictions it imposes regarding its special regressor. This special regressor must be conditionally independent of the error terms in the binary outcome equation, conditioning on instruments and exogenous variables. This assumption could be easily violated because of the way in which this special regressor might affect other endogenous variables. The main advantage of using special regressor methods is that they do not require the correct model specification and the joint distribution assumption for the error terms. This makes the methods more robust to model misspecification when compares with the other methods. However, researchers have to be careful when selecting the special regressor to be included in the estimation process.

In this paper, we applied the MLE to the model with endogenous switching of treatment. This model can be implemented by the full information MLE method to simultaneously estimate the binary treatment and the binary outcome equations parameters with consistent standard errors of the estimates (Loshkin and Sajaia, 2011). The main advantage of this model is that it does not assume an equality of coefficients in the binary outcome equations for both treatment and control regimes.

### **3.1. Endogenous Switching Regression for Binary Outcomes**

In this section, we consider a parametric model to investigate the effect of a binary treatment variable on a binary outcome. The treatment variable can be viewed as a self-selection indicator that determines which regime an individual self-selects his/herself into. Specifically, in our study, it is an individual choice of mobile broadband subscription.

Let  $T_i = \{0,1\}$  indicates a binary treatment variable for individual  $i = 1, 2, \dots, N$ , where  $T_i = 1$  implies the receipt of treatment (an individual subscribes to mobile broadband services) and  $T_i = 0$  implies the non-receipt or control (an individual does not subscribe to any mobile broadband services). Suppose that we can observe only one of the two potential binary outcomes:  $Y_{1i} = \{0,1\}$  and  $Y_{0i} = \{0,1\}$  for each individual  $i$  and never observe both outcomes together. We can model this situation using a latent-variable approach as follows:

$$\begin{aligned}
T_i &= 1 \text{ if } Z_i\gamma + v_i > 0, \\
T_i &= 0 \text{ if } Z_i\gamma + v_i \leq 0, \\
Y_{1i}^* &= X_{1i}\beta_1 + \varepsilon_{1i}, \\
Y_{0i}^* &= X_{0i}\beta_0 + \varepsilon_{0i}, \\
Y_{1i} &= I(Y_{1i}^* > 0), \\
Y_{0i} &= I(Y_{0i}^* > 0),
\end{aligned}$$

and observed  $Y_i$  can be defined as  $Y_i = T_i Y_{1i} + (1 - T_i) Y_{0i}$ ; where  $Y_{1i}^*$  and  $Y_{0i}^*$  are the latent variables that determine the observed binary outcomes  $Y_i$ ;  $X_{1i}$  and  $X_{0i}$  are vectors of exogenous variables;  $Z_i$  is a vector of variables that determines a switch between the treatment and control;  $\beta_1, \beta_0$ , and  $\gamma$  are vectors of parameters; and  $\varepsilon_{1i}, \varepsilon_{0i}$ , and  $v_i$  are the random error terms.

The model parameters can be estimated by making an assumption on the joint distribution of  $\varepsilon_{1i}, \varepsilon_{0i}$ , and  $v_i$ . Assume that  $\varepsilon_{1i}, \varepsilon_{0i}$ , and  $v_i$  are distributed as multivariate normal distribution with a mean-zero vector and the following correlation matrix:

$$\Omega = \begin{bmatrix} 1 & \rho_0 & \rho_1 \\ & 1 & \rho_{10} \\ & & 1 \end{bmatrix},$$

where  $\rho_0$  are the correlations between  $\varepsilon_{0i}$  and  $v_i$ ;  $\rho_1$  are the correlations between  $\varepsilon_{1i}$  and  $v_i$ ; and  $\rho_{10}$  are the correlations between  $\varepsilon_{0i}$  and  $\varepsilon_{1i}$ . Notice that  $Y_{1i}$  and  $Y_{0i}$  are never observed simultaneously. Therefore, the joint distribution of  $\varepsilon_{0i}$  and  $\varepsilon_{1i}$  is not identified and  $\rho_{10}$  cannot be estimated. The log-likelihood function for this model is

$$\begin{aligned}
LL = & \sum_{T_i=1, Y_i=1} \ln \{ \Phi_2(X_{1i}\beta_1, Z_i\gamma, \rho_1) \} + \sum_{T_i=1, Y_i=0} \ln \{ \Phi_2(-X_{1i}\beta_1, Z_i\gamma, -\rho_1) \} + \\
& \sum_{T_i=0, Y_i=1} \ln \{ \Phi_2(X_{0i}\beta_0, -Z_i\gamma, -\rho_0) \} + \sum_{T_i=0, Y_i=0} \ln \{ \Phi_2(-X_{0i}\beta_0, -Z_i\gamma, \rho_0) \},
\end{aligned}$$

where  $\Phi_2(\cdot)$  is a bivariate normal distribution function. After the parameters estimation, the following statistics can be calculated (Aakvik, Heckman, and Vytlacil, 2000):

### 3.2. Treatment Effects

- The expected effect of the treatment on treated individuals with observed characteristics  $x$ :

$$\begin{aligned}
TT(x) &= \Pr(Y_1 = 1|T = 1, X = x) - \Pr(Y_0 = 1|T = 1, X = x) \\
&= \frac{\Phi_2(X_1\beta_1, Z\gamma, \rho_1) - \Phi_2(X_0\beta_0, Z\gamma, \rho_0)}{F(Z\gamma)},
\end{aligned}$$

where  $F$  is a cumulative function of the univariate normal distribution.

- The expected effect of the treatment on untreated individuals with observed characteristics  $x$ :

$$\begin{aligned}
TU(x) &= \Pr(Y_1 = 1|T = 0, X = x) - \Pr(Y_0 = 1|T = 0, X = x) \\
&= \frac{\Phi_2(X_1\beta_1, -Z\gamma, -\rho_1) - \Phi_2(X_0\beta_0, -Z\gamma, -\rho_0)}{F(-Z\gamma)},
\end{aligned}$$

- The average treatment effects:

$$\begin{aligned}
ATT &= \frac{1}{N_T} \sum_{i=1}^{N_T} TT(x_i), \text{ for the treated and;} \\
ATU &= \frac{1}{1 - N_T} \sum_{i=1}^{1-N_T} TU(x_i), \text{ for the untreated,}
\end{aligned}$$

where  $N_T$  is the number of treated individuals.

## 4. Results

### 4.1. Determinants of fixed broadband termination

The results for the endogenous switching probit model by Loshkin and Sajaia (2011) composes of the estimations of three regression equations. Equation (1) is the switching regression, which is the decision to use mobile broadband. Equations (2) and (3) are the fixed broadband termination regressions for individuals who use and do not use mobile broadband respectively.

For Equation (1), the probability of using mobile broadband is different across groups of telecom users. Specifically, younger and unmarried individuals living in the capital city with at least high school degree and higher income are more likely to subscribe to a mobile broadband service. Moreover, users with high demand for internet who use post-paid mobile voice service are more likely to also subscribe to mobile broadband service.

Equation (2) estimates the probability of fixed broadband termination for users who also subscribe to a mobile broadband service. The results show that only the quantity of internet usage (hours per day) significantly determines the fixed broadband termination. That is, among users with mobile broadband, users who spend longer hours online are less likely to unsubscribe their fixed broadband service. Equation (3) estimates the probability of fixed broadband termination for users who do not subscribe to a mobile broadband service. The results show that, among users without mobile broadband, older female users who are not a business owner are more likely to terminate their fixed broadband service. In addition, pre-paid mobile voice users who spend fewer hours online are also more likely to terminate their fixed broadband service.



Table 2: Results for the endogenous switching Probit model estimation

VARIABLES	(1) MBB Usage	(2) FBB termination if use MBB	(3) FBB termination if not use MBB
xfemale		0.06 (0.08)	0.37* (0.20)
xage	-0.02*** (0.00)	-0.00 (0.01)	0.04*** (0.01)
xmarried	-0.41*** (0.10)	-0.18 (0.12)	-0.21 (0.25)
xedu_hs	0.54*** (0.12)	-0.06 (0.19)	0.03 (0.24)
xocc_bus		-0.07 (0.10)	-0.48** (0.20)
xocc_agri		-0.15 (0.65)	-0.25 (0.58)
xlninc	0.06*** (0.02)	-0.01 (0.02)	-0.03 (0.05)
xbkk	0.29** (0.12)	0.04 (0.10)	-0.55 (0.35)
xprepaid	-1.38*** (0.10)	0.26 (0.19)	0.67** (0.31)
xnetusage	0.04*** (0.01)	-0.05*** (0.01)	-0.05*** (0.02)
Constant	1.40*** (0.25)	-0.34 (0.30)	-3.43*** (0.63)
Observations	1,888	1,888	1,888

Standard errors in parentheses  
 \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

#### 4.2. The average treatment effect of mobile broadband usage on fixed broadband termination.

From the estimation results in Section 4.1, we can estimate the average treatment effect of mobile broadband usage on fixed broadband termination for each individual. The average treatment effect in this study is used as a proxy for fixed to mobile substitution.

Table 3: Hypothesis testing for the significance of the average treatment effect.

Variable	N	Mean	Std. Error	t - statistic	p - value
Average Treatment Effect	1888	0.1638	0.0021	77.0618	0.0000

From the estimation, the average treatment effect is 0.1638 and it is statistically significant. That is, on average, users with mobile broadband are 16.38 percent more likely to terminate their fixed broadband service. The result implies the fixed to mobile substitution.

As the level of fixed to mobile substitution should be heterogeneous among different groups of internet users, this study also examines factors determining the level of the average treatment effect. For determinants of the fixed to mobile substitutability, the level of the substitutability is higher for older, unmarried, no high-school degree, business owner, low income, Bangkok internet users. Moreover, users with

Table 4: Determinants of the average treatment effect of mobile broadband usage on fixed broadband termination.

VARIABLES	Average Treatment Effect
xfemale	0.000 (0.002)
xage	-0.003*** (0.000)
xmarried	-0.026*** (0.003)
xedu_hs	-0.009** (0.004)
xocc_bus	0.008*** (0.003)
xocc_agri	-0.017 (0.014)
xlninc	-0.001*** (0.001)
xbkk	0.017*** (0.003)
xprepaid	0.045*** (0.002)
xnetusage	-0.007*** (0.000)
Constant	0.336*** (0.007)
Observations	1,888
R-squared	0.754

Standard errors in parentheses  
 \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

### 4.3. Reasons for fixed broadband termination

Table 5 shows number of samples using and not using fixed and mobile broadband services. Those who did not use the fixed broadband service at the time of survey were also asked whether they had used fixed broadband service before. To use simple statistics to illustrate the relationship between mobile broadband usage and fixed broadband termination, it can be seen that 0.155 percent of the sample with mobile broadband had canceled their fixed broadband service, but only 0.099 percent of the sample with mobile broadband had canceled their fixed broadband service.

For the reasons for fixed broadband termination, the survey specifically asked the respondents to provide the explanation for their termination decision. The results show that 41.70 percent of the respondents reported that the fixed broadband service was not necessary for their low level of internet usage. 26.50 percent reported that their mobile broadband service is suffice for their daily usage. Other reasons include termination along with the fixed-line telephone service, the high fee, the lower than promised speed and the availability of internet at the work place. More complete statistics regarding fixed broadband usage and termination for respondents who use and do not use mobile broadband are shown in Table 5.

Table 5: Number of samples using and not using fixed and mobile broadband services.

Fixed broadband usage	Mobile broadband usage		
	Yes	No	Total
1. Use fixed broadband at the time of survey	1357	309	1666
2. Do not use fixed broadband at the time of survey	2510	1112	3622
2.1 Never use fixed broadband	2261	1078	3339
2.2 Used fixed broadband but already terminated the service	249	34	283
<b>Main reasons for terminating:</b>			
– Terminated along with the fixed line telephony	48	6	54
– Not necessary due to low level of internet usage	104	14	118
– Expensive service fee	22	5	27
– Network quality lower than expected	19	2	21
– Enough internet service from mobile broadband	74	1	75
– Accessibility of fixed broadband at other places (eg. Work place)	14	1	15
– Other reasons	24	8	32
<b>Total</b>	<b>3,867</b>	<b>1,421</b>	<b>5,288</b>

## 5. Conclusion

From the survey, 1949 respondents subscribed to a fixed broadband service at home at one point. Among them, 85.48 percent remain subscribed to the service and 14.52 percent has canceled the service prior to 2016. The regression analysis shows that mobile broadband subscription has a positive significant effect on the decision to cancel fixed broadband service. From the average treatment effect, a mobile broadband user who also has fixed broadband service at home is 16.38 percent more likely to cancel the fixed broadband service comparing users with no mobile broadband service. The contribution of the study lies on the heterogeneity of the level of fixed to mobile substitution across different groups of internet users. From the results in Section 4.2, a key determinant of the substitutability is users' hours per day of internet usage. Figure 1 illustrate the negative relationship between internet usage and the average treatment effect. For those who are online for less than 40 hours per day, mobile broadband is considered as a substitute for fixed broadband to a certain level. For those whose lifestyle requires a higher usage of internet, the results show no substitution.

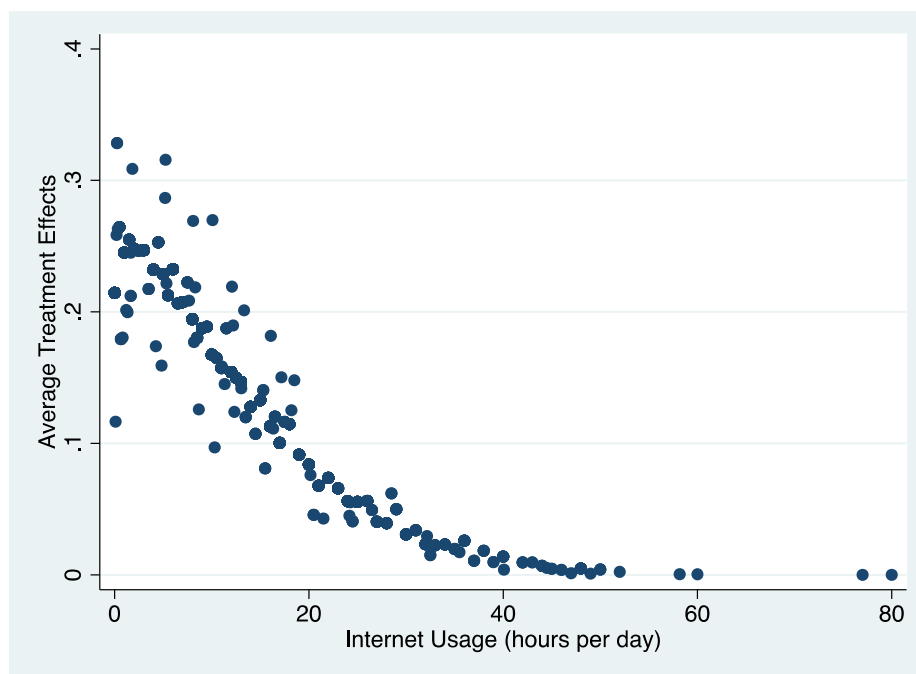


Figure 1: Average treatment effect of mobile broadband usage on fixed broadband termination by hours of internet usage per day

As for the reasons for termination, survey respondents reported that the key reasons to cancel fixed broadband service was (1) not necessary for their low level of internet usage, (2) their mobile broadband services suffice for their daily usage and (3) termination along with the fixed-line telephone service.

The results show evidence of fixed-to-mobile substitutability for individuals with a low level of internet usage and the survey respondents also confirmed the regression results. As telecom regulations normally target to help users with lower telecom accessibility rather than those with higher level of usage, the higher level of fixed and mobile substitution for individuals with low usage should imply the possibility to unify regulatory framework for fixed and mobile broadband markets. For example, the complete set of communications methods should be

considered as universal services when updating policies regarding the universal service obligation (USO) (Oğuz et al., 2015; Alleman et al., 2010).

It should be noted that the substitutability on the demand side of the fixed and mobile broadband markets does not imply the substitutability on the supply side and, thus, does not necessarily lead to a replacement of one market to the other. With different costs of the two technologies to service providers in different geographical areas, the higher level of substitutability on the demand side implies that the choice of service will be determined more significantly by the supply side variables and this can enhance efficiency in the broadband markets.

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