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Fixed mobile substitution: a simultaneous equation model with qualitative and limited dependent variables

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Fixed-mobile substitution: a simultaneous equation model with qualitative and limited dependent variables

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Abstract

We analyse survey data on over 7,000 British telephone users in order to investigate the link between mobile phone ownership and fixed telephone usage. We use an endogenous switching model to control for self-selection effects that might otherwise result in observing higher fixed usage amongst owners of mobile phones because of taste effects, regardless of whether fixed and mobile telephony are substitutes or complements. For example, individuals with mobile phones may use their fixed lines more intensely than people without mobile phones simply because they have greater demand for telephony services in general and not because of any underlying complementarity between the services. In order to test for substitutability, therefore, it is necessary to strip out underlying taste differences affecting both fixed and mobile demands. Controlling for such self-selection effects, we find that using a mobile phone significantly depresses the use of fixed lines. This strongly supports the notion that fixed and mobile phones are substitutes.

Keywords: mobile telephony, self-selection, discrete choice models, substitution.
JEL classification: C35, D12, L19, L96

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1 Introduction

Mobile phone take-up is increasing rapidly across the world. Mobile telephony is a service that creates substantial benefits for its users.[1] With penetration levels as high as 70% in several developed countries, mobile telephony may now present a significant alternative to traditional fixed telephony.

It is essential for future regulatory policy towards fixed services to determine whether there is indeed any link between fixed and mobile telephony. If fixed and mobile telephony are substitutes then less stringent regulation of fixed telephony may be warranted, as competition is fiercer than appears from only looking at the market shares of fixed competitors.

There is very little academic work on this subject due to the limited availability of sufficiently detailed data. As it is very difficult to assess the cross-price elasticities between fixed and mobile telephony in the absence of sufficiently detailed cross-linked consumer billing data, conclusions regarding the substitutability/complementarity of fixed and mobile communication are generally based on interpreting survey data.

Naïve interpretation of UK survey data suggests that fixed and mobile usage are complementary as people who own mobile phones tend to use their fixed phones more intensively than individuals without mobile phones. Maybe this is the reason why Oftel, the UK telecoms regulator, currently believes that fixed and mobile services lie in separate economic markets. Even though there is a sizeable proportion of UK households without fixed line access who use a mobile phone connection as an alternative, Oftel believes that the fact that the rise in mobile ownership has resulted in an increase in the number of households with both a fixed and a mobile line suggests that *"mobiles are seen by most customers as a complement to the fixed line rather than as a substitute for it."* Oftel has also argued that *"the advent of the mobile has, to a significant degree, expanded the market for making calls, rather than substituting fixed calls, implying that a large majority of mobile calls are complementary to fixed calls"* (Oftel 2001).

However, some studies have reached contrary conclusions:

- Pita Barros and Cadima (2000) investigate the possibility of fixed-mobile substitution estimating diffusion curves for both fixed and mobile telephony, allowing for cross-effects. While they find that essentially technological advances determine the diffusion of mobile telephony, the number of mobile phones inversely affects fixed penetration.

[1] Hausman (1997) analyses the consumer surplus impact of regulatory delay in the US in introducing cellular services only in 1983 while the technology was already available in the early 1970s. He estimates that the annual lost consumer welfare was between 16.7-49.8 billion in 1994 dollars.

- Minges (1999) in his review of mobile telephony in the Southern African region concludes: "*One of the main factors driving mobile growth is substitution for fixed lines. Mobile is taking customers off the long waiting list for fixed line service.*"

This paper considers the extent to which mobile usage actually substitutes for fixed usage. We show that fixed-mobile substitution is a reality, and that its impact is significant.

We use data from three surveys commissioned by BT and carried out by FDS International. These surveys provide a rich dataset for *systematically* testing hypotheses about the relationships of fixed and mobile services. We use this data to test Oftel's hypothesis that fixed and mobile services are complements, in the sense that owning a mobile leads to greater fixed line expenditure. We find that, in Oftel's terms, the services are in fact strong substitutes, as mobile ownership is associated with a large *reduction* in fixed line expenditure once we controlled for taste effects.

We examine this question using an econometric method to control for self-selection effects that might otherwise result in mistaken conclusions. Across individuals there may be a positive association between fixed and mobile usage even if the two services are in fact substitutes for each individual. This is because of the underlying taste differences and self-selection effects. We find that individuals with mobile phones on average tend to use their fixed lines more intensely than people without mobile phones simply because they have a generally greater demand for telephony services and not because of any underlying complementarity between the services. An appropriate test for substitutability would require one to establish the consumption of fixed telephony services of a mobile customer if this person hypothetically did not have a mobile phone and vice-versa. We use a so-called *endogenous switching model* to compare fixed and mobile usage holding tastes constant and stripping out any biases due to self-selection of those with and without mobiles.

The problem is similar to the problem of establishing the link between union membership and wages or between labour market participation and wages. Probably the best-known example of such an endogenous switching model is that of Lee (Lee 1978). He estimated the impact of union membership on wages in the United States and found that unionism had a significant effect in raising wages. He also found that mostly people who can expect higher wage increases join unions. Trost (1981) interpreted the error covariances that are particular to selectivity models using an illustration of returns to college education. His work provided an approach to assessing the validity of using endogenous switching models in the estimation of a particular problem.

Our analysis provides strong statistical evidence that mobile and fixed phone services are substitutes, not complements as Oftel has asserted. This paper is structured as follows. Section 2 describes the data used for the analysis. Section 3 presents the theory behind the empirical analysis while section 4 deals with the estimation method. Section 5 exhibits the results and section 6 concludes.

2 Data

We use data from three consecutive market research surveys conducted by FDS International on behalf of BT. The data is in a repeated cross-section format as respondents of the three surveys cannot be linked to each other. The survey was undertaken by randomly contacting respondents by telephone, both via fixed lines and mobile telephones. Respondents of the three surveys are divided into five categories, according to the combination of telephony services that they subscribe to (see Table 1).

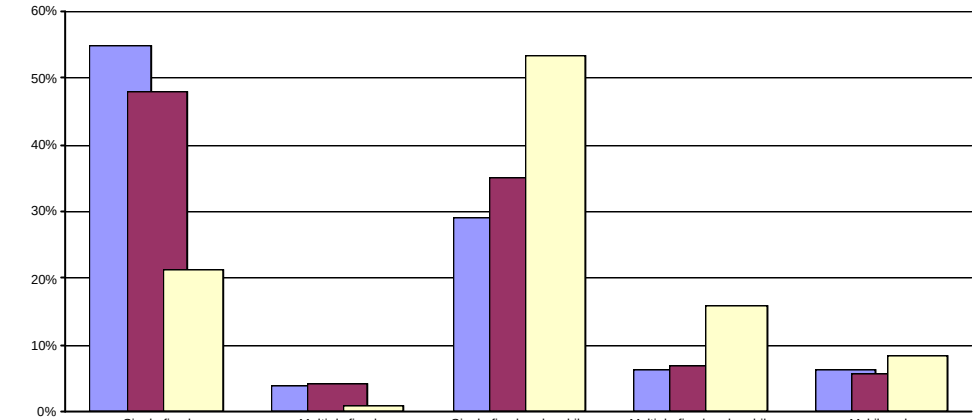
Table 1: Sample sizes for respondent categories

SURVEY	Single fixed line	Multiple fixed lines	Single fixed and mobile	Multiple fixed and mobile	Mobile only	*Total*
September 1999	983	99	990	346	182	2,600
February 2000	1,000	160	999	581	263	3,003
September 2001	600	42	902	405	150	2,099

2.1 General trends

Based on the relative proportion of respondents in our sample, the proportion of each category in the general population can be estimated. We can estimate the true population proportions using a maximum likelihood method, which computes the probability of obtaining the observed sample sizes depending on the population parameters, and take the values that maximise this probability as the best estimates of these parameters. The results are displayed in Figure 1, which also includes the respective population proportions from our earlier surveys.

Figure 1: Estimated population proportions



	Single fixed	Multiple fixed	Single fixed and mobile	Multiple fixed and mobile	Mobile only
Sep-99	54.8%	3.8%	29.0%	6.2%	6.2%
Feb-00	47.9%	4.3%	35.0%	7.0%	5.8%
Sep-01	21.3%	1.0%	53.5%	15.8%	8.4%

Starting from our first survey, there has been a clear trend towards higher mobile take-up. The single fixed and mobile category has increased at the expense of single fixed line use, and, multiple fixed line and mobile has grown at the expense of multiple fixed users.

Unlike in the earlier surveys, in September 2001 mobile-only households were found no longer to be predominantly single person households and instead now represent a greater variety of household sizes. Mobile-only has broadened its appeal to larger households who use a mobile instead of a fixed line.

Mobile take-up is negatively associated with age. For example almost 40% of respondents using only a single fixed line are aged above 65, whereas more than half of all mobile-only users are younger than 30. More generally, the age profile of mobile users has a higher proportion of younger people than the age profile of the corresponding fixed-only user groups.

However, relative to the earlier surveys mobile use has grown throughout most age groups: the age profile of those without a mobile has shifted dramatically towards people over 65, implying that mobile usage has become more widespread amongst middle-aged customers (and in particular the group between 25 and 45).

The broadening appeal of mobile telephony and the growth of pre-paid packages is reflected in a clear trend over time between the three surveys: mobiles are being increasingly used relatively more for personal purposes, and relatively less often for work. This contrasts with fixed line use where the relative importance of different uses has remained largely unchanged over the same period. We estimated the sample bias resulting from mobile users and non-mobile users not being equally likely to answer calls on a fixed line in the same household. We found that mobile users are indeed less likely than non-mobile users to answer fixed line calls, and that this probability has decreased since our first survey. This suggests that mobile users are increasingly regarding the mobile as their main connection for making and receiving calls.

2.2 Qualitative indicators of substitution

Call substitution occurs when users have a choice of access to both fixed and mobile phones and they choose which one to use depending on cost and convenience. Users may have a choice between making a call on a fixed or a mobile phone if they are in the workplace or from home where both are available.

We found that only 26% of users with access to both fixed and mobile lines never make mobile calls from home. More than 40% make mobile calls at least sometimes. Similarly, more than one third of users claiming to have easy access to a fixed line at work use their mobile at least sometimes for making calls.

The main reason given by users making mobile calls from home is that mobile calls are often cheaper (more than 50% of respondents). By comparison, other reasons such as increased convenience appeared much less important. In elucidating the reasons for use of mobiles in preference to fixed phones, our survey did not prompt respondents with particular possible answers, but rather allowed respondents to articulate their own reasons that were then coded by the market researchers.

The reported impact of getting a mobile on fixed usage again suggests that there is substitution of fixed and mobile services. More than one quarter of respondents say that as a result of getting a mobile they use their fixed line less (compared to less than 5% saying that mobile ownership has increased their fixed line usage). Similarly, more than 30% of respondents without a mobile report that as a result of getting a mobile they would expect their fixed line usage to fall (with around 12% expecting fixed line usage to increase). This rejects the presumption of complementarity.

In general, a significant proportion of users indicated that they would respond to a fall in the relative price of mobile usage by reducing their fixed line usage – the 'cross-price elasticity' is positive. The large majority of mobile users consider the mobile service to be good value for money, and neither call quality nor battery life would appear to be an issue with regard to using mobiles rather than fixed phones.

In addition to being able to substitute a fixed voice call by a mobile voice call, respondents also reported using SMS and e-mail instead of making voice calls. Between 25% and 53% of respondents who reported using e-mail in each category stated that this reduced the number of voice calls they made. More than a half of mobile users using SMS stated that this reduced the number of voice calls they made.

Evidence of substitution between fixed and mobile lines, i.e. at the access level, is more difficult to establish because such substitution may not necessarily imply that subscribers cancel their fixed line subscription as a result of getting a mobile. More often it may mean that demand for additional connectivity (e.g. as a result of fax and Internet use) is satisfied by getting a mobile, migrating voice traffic onto the mobile and freeing the fixed line for data traffic. Comparing the use of fax, Internet and e-mail across single fixed and single fixed plus mobile users, and multiple fixed and multiple fixed plus

mobile users, we find that in every single case mobile users are more likely to use these services.

Again, when confronted with a number of questions about the hypothetical choice between a fixed/additional fixed line and a mobile, respondents clearly show price sensitivity, suggesting that the choice between fixed and mobile access is affected by their relative price.

3 Fixed line usage and mobile ownership – theoretical background

Our objective is to confirm or reject the existence of substitution between fixed and mobile telephony. In the absence of billing data we use survey data to study the effect of mobile ownership on fixed line telephone usage, which we measure by the reported amount spent on fixed telephony services. When deciding whether to get a mobile phone a customer can be expected to take into account the likely impact of mobile phone usage on fixed line expenditure: an expected reduction in expenditure on fixed telephony would count as a benefit of mobile ownership (in addition to other benefits such as being able to make and receive calls when away from the fixed line), whilst an expected increase would count as a further cost (in addition to the expected mobile bill and the price of the connection/handset). If fixed line expenditure is expected to decrease as a result of mobile ownership, then fixed and mobile telephony are substitutes. Conversely, if mobile ownership is expected to increase fixed line expenditure, mobile and fixed telephony would be complements.

More specifically, let Y_{mi} and Y_{ni} be individual i's fixed bill if she had or did not have a mobile phone respectively. The effect of having a mobile phone on the fixed bill is $Y_{ni} - Y_{mi}$. We assume that the individual buys a mobile phone if:

$$Y_{ni} - Y_{mi} > h_i \qquad (1)$$

where $?_i$ is a threshold value that captures the expected benefits from mobile phone usage net of the expected costs of mobile ownership (e.g. the size of the mobile bill).[2] Both expected benefits and expected costs depend on personal characteristics X_i. Assuming a simple functional relationship between the threshold value and these individual characteristics, we can write $?_i$ as:

$$h_i = a X_i + e_i \qquad (2)$$

where e_i stands for a number of unobservable and random factors. We assume that e_i is normally distributed with zero mean and variance s_e^2.

[2] $?_i$ can be positive or negative.

Using equations (1) and (2) the following inequality must hold for those who have decided to use a mobile phone:

$$(Y_{ni} - Y_{mi}) - a\,X_i - e_i > 0 \qquad (3)$$

We can write this inequality in the form of a probit equation for mobile adoption decision:

$$I_i^* = l_0 + l_1(Y_{ni} - Y_{mi}) + l_2 X_i - e_i \qquad (4)$$

where we observe *I=1* (i.e. mobile phone ownership) if and only if *I*>0* and *I=0* (i.e. no mobile phone) otherwise. If in estimating this relationship we find the value of *?1* to be positive this indicates fixed-mobile substitution at the access level: the expectation of a reduced fixed bill increases the likelihood that a customer decides to become a mobile user.

Unfortunately, we cannot estimate this equation directly. This is because for any given individual we cannot observe both Y_{ni} and Y_{mi}. Rather, we observe:

$$Y_{mi} \quad \text{when } I_i = 1 \text{ and}$$
$$Y_{ni} \quad \text{when } I_i = 0.$$

Therefore, we have to predict the fixed telephony expenditure of mobile phone owners in case they would not have a mobile phone. Similarly, we need to forecast how the fixed expenditure of non-mobile customers would change if they became mobile users.

In order fully to capture the differences in calling habits between the two groups, we specify a separate equation for each of the two groups for how fixed line expenditure depends on personal characteristics (which ultimately also drive mobile ownership):

$$Y_{mi} = d_{m0} + d_{m1} X_{mi} + e_{mi} \qquad (5)$$

$$Y_{nj} = d_{n0} + d_{n1} X_{nj} + e_{nj} \qquad (6)$$

where X_{mi} and X_{nj} are individual characteristics of person *i* owning a mobile, and for person *j* not owning a mobile. The error terms e_{mi} and e_{nj} are assumed to be normally distributed with zero mean and variances s_m^2 and s_n^2 respectively. Estimating these equations from our survey data, we can then predict a given individual's fixed line spending with and without owning a mobile phone. As our data does not include the exact spending but rather an interval in which an individual's average spending lies, we have to use a special technique developed for interval regressions. In particular, we use a generalised tobit model to predict expected spending. These predictions then can be used to estimate the probit model in equation (4).

4 Estimation method

The theoretical model is given in the simultaneous equations system given in (4)-(6). We want to accomplish two tasks by estimating the above system:

- we want to compare the predicted fixed line expenditure of a given individual under the two scenarios. That is, we want to calculate the effect of mobile ownership on the fixed bill. If mobile ownership reduces the fixed bill then fixed and mobile are substitutes, if it increases, they are complements; and
- using the predicted expenditures, we want to examine whether a higher expected reduction in the fixed bill is associated with greater probability of having a mobile phone (i.e. whether $?_1$ is positive). If this were the case, then the decision to become a mobile phone user is at least partly motivated by an expected reduction in the fixed bill as a result of substituting mobile for fixed telephony.

4.1 Estimation of fixed telephony expenditure

The fixed line expenditure equations in (5) and (6) have zero-mean error terms on the overall sample. However, we do not observe Y_{mi} and Y_{ni} for the whole sample. Therefore, equations (5) and (6) cannot, in general, be consistently estimated using estimation methods that assume error terms with zero mean (such as the interval regression or ordinary least squares). The problem is caused by the *selectivity bias*, namely that only specific segments of the spending distribution are observed for the two scenarios, that is:

$$E(e_{mi} \mid I_i = 1) \neq 0 \text{ and}$$
$$E(e_{ni} \mid I_i = 0) \neq 0.$$

In particular, for individuals who have mobile phones the following inequality holds:

$$Y_{ni} - h_i > Y_{mi}$$

Therefore, the mean of fixed expenditure for people with mobile phones can be expressed as:

$$E(Y_{mi} \mid I_i = 1) = E(Y_{mi} \mid Y_{mi} < Y_{ni} - h_i) = \overline{Y}_m + s_{me*} \frac{f(\Psi_i *)}{1 - \Phi(\Psi_i *)}$$

The fixed line expenditure equations in (5) and (6) have zero-mean error terms on the overall sample. However, we do not observe Y_{mi} and Y_{ni} for the whole sample. Therefore, equations (5) and (6) cannot, in general, be consistently estimated using estimation methods that assume error terms with zero mean (such as the interval regression or ordinary least squares). The problem is caused by the *selectivity bias*, namely that only specific segments of the spending distribution are observed for the two scenarios, that is:

where $\overline{Y}_m$ is the overall mean of fixed spending of mobile phone owners (i.e. the expected fixed spending if everyone had a mobile phone), f is the density and F is the distribution function of the standard normal distribution and $s_{me}=cov(e_m,e^*)$ is the covariance of e_m and e^* (see below). $?_i^*$ stands for the consistent estimate of the probability of person i having a mobile phone.

Similarly, the expected fixed expenditure of fixed line users without mobile phones is:

$$E(Y_{ni} \mid I_i = 0) = \overline{Y}_n - s_{ne^*} \frac{f(\Psi_i^*)}{\Phi(\Psi_i^*)}.$$

If we add the appropriate selectivity terms to the fixed bill equations they can be consistently estimated by standard interval regression techniques. In particular, we can estimate equations (5) and (6) using the following two-step procedure. First we estimate the probability of having a mobile phone. This probability is estimated using the reduced form of the model in equation (4). Reduced form refers to the fact that we substitute the fixed expenditure equations (Y_{ni} and Y_{mi}) into the probit equation:

$$I_i^* = g_0 + g_1 Z_i - e_i^* \qquad (7)$$

where Z_i is the matrix of all individual characteristics that appear in the theoretical model (X_i, X_{mi} and X_{ni}). In this case $e^*=(e+?_1(e_n-e_m))/s^*$ where s^* is the standard deviation of $(e+?_1(e_n-e_m))$.

Using the consistent estimates of the probability $(?_i^*=?_o^*+?_1^*X_i)$ we can calculate the selectivity variables. Subsequently, we can consistently estimate the two fixed telephony spending equations:

$$Y_{mi} = d_{m0} + d_{m1} X_{mi} + s_{me} \frac{f(\Psi_i^*)}{1 - \Phi(\Psi_i^*)} + V_{mi} \quad \text{for } I_i = 1 \qquad (8)$$

$$Y_{ni} = d_{n0} + d_{n1} X_{ni} - s_{ne} \frac{f(\Psi_i^*)}{\Phi(\Psi_i^*)} + V_{ni} \quad \text{for } I_i = 0 \qquad (9)$$

where V_{mi} and V_{ni} are zero mean error terms.

After obtaining the consistent estimates of the parameters of equations (8) and (9), we can predict the fixed line spending for the two scenarios for each individual in the sample using:

$$Y_{mi}^* = d_{m0}^* + d_{m1}^* X_{mi} \quad \text{and}$$

$$Y_{ni}^* = d_{n0}^* + d_{n1}^* X_{ni}.$$

This allows us to compare the average fixed telephone expenditure of different groups (such as present mobile owners, home workers, females, etc) under the two scenarios. Likewise, we can compare the average fixed bills under the different scenarios for the whole sample. We are then able to

determine whether fixed and mobile telephony are substitutes or complements. In particular, if the predicted fixed bill is lower with than without a mobile, leaving personal characteristics unchanged, then we can conclude that fixed and mobile telephony are substitutes, i.e. mobile owners use their fixed phones less than they would if they did not have a mobile phone.

4.2 Estimation of the mobile take-up equation

Once we have the consistent predictions of Y_{ni} and Y_{mi} the probit model in equation (4) can be estimated consistently:

$$I_i^* = l_0 + l_1(Y_{ni}^* - Y_{mi}^*) + l_2 X_i - e_i \qquad (10)$$

The estimation of this equation can shed light on the underlying reasons to buy a mobile phone. Particularly, if coefficient l_1 is positive then we can conclude that one of the incentives to buy a mobile phone is the expected reduction in the fixed bill.

4.3 Specification

Because we want to analyse the impact of mobile ownership on fixed line expenditure we only use the subset of fixed line subscribers (with and without mobile phones) and exclude mobile-only individuals.

In our preferred specification the probit equation in (4) is estimated using the following variables:

$$\begin{aligned} I_i^* &= l_0 + l_1(Y_{ni} - Y_{mi}) + l_2 WWW_i + l_3 FAX_i + \\ &+ l_4 HOMEW_i + l_5 GENDER_i + l_6 AGEDUM_i + \\ &+ l_7 INCDUM_i - e_i \end{aligned} \qquad (11)$$

where Y_{ni} - Y_{mi} is the difference between fixed bill without and with mobile phone usage. *WWW* captures Internet usage, taking the value 1 if the subscriber has an Internet connection and 0 otherwise. Similarly, *FAX* takes the value 1 if the subscriber has a fax machine connected to the fixed line, 0 otherwise. *GENDER* equals 1 if the subscriber is male and is 0 if the subscriber is female. *HOMEW* equals 1 if the subscriber works primarily from home and 0 otherwise. *AGEDUM* is a set of dummy variables for the age group of the subscriber and *INCDUM* is a set of income dummies.

Equations (5) and (6) take the following form:

$$\begin{aligned} Y_{mi} &= d_{m0} + d_{m1} WWW_i + d_{m2} FAX_i + \\ &+ d_{m3} HOMEW_i + d_{m4} AGEDUM_i + \\ &+ d_{m5} SCDUM_i + d_{m6} HSIZEDUM_i + e_{mi} \end{aligned} \quad \text{for } I_i = 1 \qquad (12)$$

$$\begin{aligned} Y_{ni} &= d_{n0} + d_{n1} WWW_i + d_{n2} HOMEW_i + \\ &+ d_{n3} HSIZEDUM_i + e_{ni} \end{aligned} \quad \text{for } I_i = 0 \qquad (13)$$

where *SCDUM* is a set of dummy variable for the social class of individual *i* and *HSIZEDUM* is a set of dummy variables for the size of household of the subscriber.

The two fixed expenditure equations include different explanatory variables. The independent variables in the preferred specifications are selected in order to obtain the best diagnostic results. This enables us to pin down the drivers of change in fixed telephony spending as a result of getting a mobile phone.

5 Results

We first present the results for the estimation of the fixed expenditure equations. This is followed by the analysis of the incentives of buying mobile phones. We estimate the above equations separately for data taken from the latest survey and the two previous surveys. This is mostly because the income variable is not available for the earlier surveys. While the 2001 results demonstrate that income dummies play a significant role, there are important conclusions to derive from the earlier two waves, as well.

5.1 Estimation of fixed telephony expenditure

5.1.1 September 2001 survey

The results of the reduced form probit equation, estimating the probability of having a mobile phone depending on individual characteristics, are presented in Table 2. They suggest that Internet usage increases the probability of having a mobile phone (as a mobile phone would provide the ability to make and receive calls while the fixed line is busy with a dial-up connection). Men are more likely to have mobile phones. The test of joint significance of different groups of dummy variables suggests that income and age play an important role in mobile take-up.

Table 2: Reduced form probit (3rd survey)

Variable	Coefficient	z-value
WWW	0.59	5.47
FAX	0.11	0.71
GENDER	0.26	2.75
HOMEW	-0.00	-0.02
SC_2	-0.47	-1.63
SC_3	-0.18	-0.62
SC_4	-0.13	-0.43
SC_5	-0.16	-0.48
SC_6	-0.28	-0.86
AGE_2	-0.10	-0.22
AGE_3	-0.37	-0.86
AGE_4	-0.57	-1.35
AGE_5	-0.60	-1.44
AGE_6	-0.84	-1.99
AGE_7	-0.90	-2.16
AGE_8	-1.23	-2.92
AGE_9	-1.67	-3.89
HSIZE_2	0.15	1.19
HSIZE_3	-0.04	-0.30
HSIZE_4	-0.17	-1.03
HSIZE_5	0.17	0.71
HSIZE_6	-0.22	-0.71
INC_2	0.05	0.28
INC_3	0.07	0.33
INC_4	0.21	0.98
INC_5	0.47	1.98
INC_6	0.40	1.70
INC_7	0.50	2.20
INC_8	0.86	3.02
Constant	0.97	1.94
Wald Chi2 (df=29)	213.68	
Observations	1048	

Z-values are calculated using robust standard errors.

The number of observations used in the estimation of the reduced form probit is determined by the number of respondents who gave complete answers for the questions referring to the variables in the specification (which is obviously smaller than the sample size).

The results of the fixed spending equations are presented in Table 3 and Table 4. In the two equations we use different sets of explanatory variables. More

specifically, we have selected the independent variables in order to identify the drivers of change in fixed expenditure as a result of a customer getting a mobile phone. In the selection process we have dropped variables that were not significant at the 15% level.

For example, ownership of a fax machine does not have any significant impact on the telephone bills of people not owning a mobile phone. On the other hand, in the equation for mobile users this variable is positive and significant. This indicates that even though having a fax machine does not significantly influence fixed spending without a mobile phone, the extent to which fax owners getting a mobile phone substitute fixed by mobile usage is less than the extent to which subscribers without a fax substitute fixed by mobile usage. This is to be expected, as it may be more difficult to substitute fixed fax calls by mobile ones than it is to substitute fixed voice calls by mobile ones.

Similarly, age and social class impact on the extent to which fixed usage is substituted by mobile usage. Unsurprisingly, Internet usage tends to increase the size of the fixed bill. Similarly, people who work from home have higher fixed line expenditure. Larger households tend to spend more, confirming that fixed phones are used by all members of a household (whereas mobile phones are more likely to be used by individuals).

The selectivity parameter is positive and significant in both equations.[3] Therefore, the selectivity terms are positive and negative, respectively:

$$s_{me^*}\frac{f(\Psi_i^*)}{1-\Phi(\Psi_i^*)} > 0 \text{ and}$$

$$-s_{ne^*}\frac{f(\Psi_i^*)}{\Phi(\Psi_i^*)} < 0 .$$

The signs of the selectivity terms indicate that mobile owners spend more than average under both scenarios (with and without mobile phones). Therefore, people who actually own mobile phones have a higher usage of fixed telephony as well, but this is due to underlying taste parameters rather than some form of complementarity between fixed and mobile telephony.

[3] The following inequality has to hold for the selectivity parameters by definition: $s_{me} > s_{ne}$. In our case the inequality holds confirming that indeed there is selectivity bias.

Table 3: Fixed telephony spending (selectivity adjusted for mobile phone owners, 3rd survey)

Variable	Coefficient	z-value
WWW	**7.36**	**1.54**
FAX	**23.53**	**5.65**
HOMEW	**13.81**	**3.14**
SC_2	**5.38**	**0.72**
SC_3	**-1.10**	**-0.15**
SC_4	**-5.84**	**-0.79**
SC_5	**0.19**	**0.02**
SC_6	**7.72**	**0.83**
AGE2	**-12.72**	**-1.32**
AGE3	**-10.23**	**-1.07**
AGE4	**-4.00**	**-0.43**
AGE5	**-14.55**	**-1.58**
AGE6	**-7.24**	**-0.74**
AGE7	**1.03**	**0.11**
AGE8	**-0.17**	**-0.01**
AGE9	**0.25**	**0.02**
HSIZE_2	**7.82**	**1.93**
HSIZE_3	**14.19**	**3.25**
HSIZE_4	**21.92**	**4.98**
HSIZE_5	**23.69**	**3.70**
HSIZE_6	**27.21**	**2.89**
Constant	**-6.89**	**-0.17**
Selectivity parameter	**51.75**	**1.87**
Wald Chi2 (df=22)	265.00	
Observations	751	

Z-values are calculated using robust standard errors.

Table 4: Fixed telephony spending (selectivity adjusted for non-mobile users, 3rd survey)

Variable	Coefficient	z-value
WWW	10.80	1.81
HOMEW	12.90	1.50
HSIZE_2	3.98	0.95
HSIZE_3	20.26	3.11
HSIZE_4	13.46	2.14
HSIZE_5	32.69	2.13
HSIZE_6	10.70	0.89
Constant	67.41	5.43
Selectivity parameter	33.23	1.64
Wald Chi2 (df=8)	68.87	
Observations	297	

Z-values are calculated using robust standard errors.

Having estimated the fixed bill equations we are able to compute the predicted spending of mobile users if they did not have a mobile phone as well as the predicted expenditure of non-mobile users if they decided to use a mobile phone. We find that for both groups the effect of (actual/potential) mobile phone ownership is a similar reduction in the size of the fixed bill. However, this reduction in fixed expenditure is not sufficient for people who do not buy mobile phones to offset the expected net costs of mobile ownership (expected mobile bill less benefits from mobile usage). The expected reduction in the fixed bill as a result of getting a mobile for whole sample is around £74 per quarter. However, this figure is only indicative as we do not have the exact spending for our observations, only the interval to which the spending belongs.

5.1.2 1999 and 2000 surveys

In case of the first two waves of the survey we also find that owning a mobile phone decreases fixed telephony expenditure. The following tables present the results estimated on these samples. On this occasion, fax usage remains significant in both fixed expenditure equations.

Table 5: Reduced form probit (1st and 2nd survey)

Variable	Coefficient (probit)	z-value
WWW	0.31	5.81
FAX	0.39	5.82
GENDER	0.38	8.64
HOMEW	0.28	4.37
Constant	0.72	3.92
Wald Chi2 (df=25)	861.62	
Observations	4220	

The estimation includes jointly significant age, social class and household size. Z-values are calculated using robust standard errors.

Table 6: Fixed telephony spending (selectivity adjusted for mobile users, 1st and 2nd survey)

Variable	Coefficient	z-value
WWW	17.96	8.02
FAX	22.76	2.86
HOMEW	13.58	4.93
Constant	15.10	0.85
Selectivity parameter	28.34	2.07
Wald Chi2 (df=20)	729.62	
Observations	2324	

The estimation includes jointly significant age and household size dummies. Z-values are calculated using robust standard errors.

Table 7: Fixed telephony spending (selectivity adjusted for non-mobile users, 1st and 2nd survey)

Variable	Coefficient	z-value
WWW	18.23	6.73
FAX	12.96	3.34
HOMEW	15.85	4.78
Constant	68.58	2.97
Selectivity parameter	25.20	2.97
Wald Chi2 (df=12)	360.23	
Observations	1896	

The estimation includes jointly significant household size dummies. Z-values are calculated using robust standard errors.

The expected reduction in the fixed bill for the whole sample is around £39.50 per quarter.

5.2 Estimation of the mobile take-up equation

5.2.1 September 2001 survey

Using the predicted fixed line expenditure we can consistently estimate the structural probit model to test whether the expected saving on the fixed bill is one of the reasons for getting a mobile phone. The results are presented in Table 8. In order to quantify the effect of the explanatory variables on the probability of having a mobile phone we present the marginal effects of the coefficients around the means of explanatory variables (dprobit estimates).

Table 8: Structural probit estimates (3rd survey)

Variable	Coefficient (probit)	Coefficient (dprobit)	z-value
Yn-Ym	0.01	0.003	1.70
WWW	0.53	0.16	4.95
FAX	0.40	0.11	1.86
GENDER	0.26	0.08	2.76
HOMEW	-0.01	0.00	0.04
AGE2	-0.21	-0.07	-0.45
AGE3	-0.45	-0.16	-1.01
AGE4	-0.58	-0.20	-1.37
AGE5	-0.74	-0.26	-1.66
AGE6	-0.91	-0.33	-2.12
AGE7	-0.84	-0.29	-2.04
AGE8	-1.13	-0.41	-2.72
AGE9	-1.58	-0.57	-3.77
INC_2	0.05	0.02	0.26
INC_3	0.06	0.02	0.30
INC_4	0.22	0.06	1.12
INC_5	0.44	0.12	2.12
INC_6	0.36	0.10	1.70
INC_7	0.42	0.12	2.11
INC_8	0.77	0.19	3.30
Constant	-0.05		-0.09
Wald Chi2 (df=20)	210.43		
Observations	1048		

Z-values are calculated using robust standard errors.

Indeed, we find that an increase in the expected saving on the fixed bill increases the probability of getting a mobile phone. Therefore, we can conclude that the expected saving on fixed expenditure provides one incentive for buying a mobile phone. The dprobit results suggest that an expected quarterly saving of £10 increases the probability of getting a mobile phone by 3% for the average individual.

Similarly, having an Internet connection increases the probability of having a mobile phone by 16%. Having a fax machine increases this probability by 11%. This is consistent with the view that access substitution often takes place through migration of voice traffic onto the mobile in order to free up the fixed line for data traffic.

The results presented in Table 8 are estimated for the whole sample. However, the sample includes people whose mobile phones were bought by their employer or were gifts. We would expect the anticipated saving on fixed bills to play an even more important role in the decision of people who buy their own mobile phones. Therefore, we estimate the last equation for a different dependent variable that is set equal to 1 for mobile users who have bought the mobile themselves, and 0 otherwise. Table 9 presents the results of this estimation (without the dummy groups).

Table 9: Structural probit estimates (people who buy their own mobile phones, 3rd survey)

Variable	Coefficient (probit)	Coefficient (dprobit)	z-value
Yn-Ym	0.02	0.006	2.76
WWW	0.33	0.13	3.46
FAX	0.40	0.16	2.25
GENDER	0.42	0.17	5.06
HOMEW	-0.10	-0.04	-0.74
Constant	-1.35		-2.84
Wald Chi2 (df=20)	173.16		
Observations	1048		

The estimation includes jointly significant age and income dummies. Z-values are calculated using robust standard errors.

As expected, the anticipated saving in the fixed bill plays a more important role: an expected quarterly saving of £10 increases the probability of buying a mobile phone by 6%.

5.2.2 1999 and 2000 surveys

Whilst mobile ownership reduces the fixed line bill also for the first two waves of the survey, there is no evidence to suggest that the expected saving on the fixed bill is a significant incentive for getting a mobile. Even focusing on mobile users who have bought the mobile themselves, we find no significant effect of Y_n-Y_m on mobile take-up (see Table 10).

Table 10: Structural probit estimates (people who buy their own mobile phones, 1st and 2nd survey)

Variable	Coefficient (probit)	Coefficient (dprobit)	z-value
Yn-Ym	0.00	0.000	0.06
WWW	0.25	0.09	5.09

FAX	0.22	0.08	2.18
GENDER	0.41	0.15	9.62
HOMEW	0.23	0.08	3.63
Constant	-0.46		-1.21
Wald Chi2 (df=14)	586.10		
Observations	4220		

The estimation includes jointly significant age dummies. Z-values are calculated using robust standard errors.

However, the failure to find a significant effect may be due to the fact that income, which is highly significant in the mobile take-up equation in 2001, had to be omitted from our estimation for the earlier sample as these surveys did not include income information. Therefore, no robust conclusions can be drawn from the failure to find a statistically significant relationship between the first two and the third samples. However, there is an alternative explanation for the structural change between the first two and the third sample. The difference in the results of the structural probit equations together with the fact that the expected saving on the fixed line bill has increased considerably between the first/second and third wave of the survey is consistent with the view that, as the cost of using mobile telephony has fallen, the extent to which customers replace fixed line use with mobile use and the consequent reduction in the fixed bill have increased so much that they have changed from being a pure side-effect of mobile ownership into a significant reason for getting a mobile. According to this interpretation, the extent of access level substitution has increased greatly since the 1999 survey.

6 Conclusion

In this paper we presented strong evidence for call-level substitution between fixed and mobile telephony. We find that individual's spending on fixed telephony significantly decreases when they start using mobile phones.

Furthermore, we find some indirect evidence for access-level substitution: results for our 2001 sample indicate that the fall in fixed telephony spending acts as an incentive to buy mobile phones.

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Appendix: Descriptive Statistics

Table 11: 3rd survey

Variable	Mean	Standard deviation
MOBILE	0.72	0.45
WWW	0.47	0.50
FAX	0.18	0.38
GENDER	0.49	0.50
HOMEW	0.12	0.33
SC_2	0.21	0.41
SC_3	0.30	0.46
SC_4	0.22	0.42
SC_5	0.10	0.29
SC_6	0.13	0.34
AGE_2	0.08	0.27
AGE_3	0.09	0.28
AGE_4	0.13	0.33
AGE_5	0.12	0.33
AGE_6	0.12	0.33
AGE_7	0.21	0.41
AGE_8	0.11	0.32
AGE_9	0.11	0.31
HSIZE_2	0.30	0.46
HSIZE_3	0.19	0.39
HSIZE_4	0.20	0.40
HSIZE_5	0.07	0.26
HSIZE_6	0.03	0.17
INC_2	0.12	0.32
INC_3	0.13	0.34
INC_4	0.14	0.34
INC_5	0.11	0.32
INC_6	0.10	0.31
INC_7	0.18	0.39
INC_8	0.13	0.33
Observations	1048	

Table 12: 1st and 2nd survey

Variable	Mean	Standard deviation
MOBILE	0.55	0.50
WWW	0.31	0.46
FAX	0.18	0.39
GENDER	0.47	0.50
HOMEW	0.16	0.37
SC_2	0.18	0.38
SC_3	0.32	0.47
SC_4	0.24	0.43
SC_5	0.11	0.31
SC_6	0.11	0.31
AGE_2	0.07	0.26
AGE_3	0.09	0.29
AGE_4	0.12	0.33
AGE_5	0.14	0.34
AGE_6	0.12	0.32
AGE_7	0.17	0.38
AGE_8	0.12	0.32
AGE_9	0.12	0.32
HSIZE_2	0.32	0.46
HSIZE_3	0.20	0.40
HSIZE_4	0.20	0.40
HSIZE_5	0.08	0.28
HSIZE_6	0.03	0.16
HSIZE_7	0.01	0.08
HSIZE_8	0.01	0.09
Observations	4220	

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