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Working Paper #07-33

September 2007

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CROWDING OUT OR COMPLEMENTARITY IN THE TELECOMMUNICATIONS MARKET?*

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Abstract

There is a substantial number of cases where the *a priori* relationship between products is not at all clear in the sense that although apparent to be clear substitutes may turn out to be in fact complements, or vice-versa. This paper aims to study the relationship between fixed and mobile telephony in the United Kingdom and, in particular, address the question if mobile communications crowded out fixed telephony or if, on the other hand, the two types of communications are in fact complements. We estimate a structural continuous-choice demand model following Pinkse *et al.* (2002), Pinkse and Slade (2004), and Slade (2004) and we find that at the current diffusion stage, fixed and mobile communications appear to be complements. Given that the model is micro-founded, we also address the question of how the evolution of the price differential between the two types of communication may, respectively, affect the welfare of consumers and firms. We find that the continuation of these price trends have substantial welfare benefits for subscribers and at the same time have no significant impact on the profits for firms. Finally, we present some economic policy implications, especially about the need to (de)regulate telecommunications provision.

JEL Classification: C13, D12, L51, L96

Keywords: Telecommunications, Mobile, Fixed, Demand, Substitution, Complementarity

*We thank the NET Institute www.NETinst.org for financial support. Ricardo Ribeiro gratefully acknowledges financial support from the Fundação para a Ciência e a Tecnologia.

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1 INTRODUCTION

There is a substantial number of cases where the *a priori* relationship between products is not at all clear in the sense that although apparent to be clear substitutes may turn out to be in fact complements, or vice-versa. Examples include print and online newspapers (Gentzkow, 2007), free file-sharing services and recorded music (Oberholzer and Strumpf, 2004; Blackburn, 2004; Rob and Waldfogel, 2006; Zentner, 2005), file-sharing services and live concerts (Mortimer and Sorensen, 2005), public and private broadcast channels (Berry and Waldfogel, 1999; Prat and Stromberg, 2005), and online and offline retailing (Goolsbee, 2001; Sinai and Waldfogel, 2004).

This paper aims to study the relationship between fixed and mobile telephony and, in particular, address the question if mobile communications crowded out fixed telephony or if, on the other hand, the two types of communications are in fact complements.

Historically, mobile phone service did not pose an attractive alternative to fixed service. Given its high relative price, mobile service was a luxury, not a substitute for fixed line. Mobile technology also lagged significantly in nonprice terms: transmission quality and geographic coverage were poor by fixed-line standards. However, with time, the costs of mobile telephony start dropping, allowing prices to fall and quality to rise. Therefore, mobile became an increasingly attractive alternative to fixed-line service. Technically, mobile is a substitute because users can place and receive voice calls just as they do with fixed service. Ultimately, users can even opt for the mobile phone network only.

An alternative view is that fixed and mobile services are complementary. Indeed, a call originating from mobile phones benefits fixed phone subscribers. Moreover, they are also being benefited by the increase in mobile phones because the number of phones that can be reached is increased.

There have been some prior studies analyzing the fixed-mobile substitution. Rodini *et al.* (2003) use a US household annual survey to study the mobile and fixed telephony, and find only modest substitution between mobile subscription and the demand for second lines. Sung *et al.* (2000) find that the number of Korean mobile subscribers is positively correlated with the number of fixed-line disconnects, but negatively related to the number of new fixed-line connections, suggesting net substitution between the two services. This pattern occurs even while the stock of fixed lines is positively correlated with the number of mobile subscribers, offering evidence that the two services are complements. Ahn and Lee (1999) estimate demand for mobile access in Korea using more recent wireless subscription data for 64 countries, and find evidence of complementarity also using aggregate data.

The empirical literature on telephony communications is also significant in what modelling is concerned, Doganolu and Grzybowski (2006) estimate a nested logit model to estimate the demand for subscriptions of mobile telephony, whereas Lee *et al.* (2006) estimate switching costs in the Korean mobile telecommunications using a random coefficients multinomial model. Okada and Hatta (1999) estimate an almost ideal demand system for the Japanese telephony industry.

However, and even though in some settings the above approaches are clearly reasonable, in cases where the identification of the degree of substitutability or complementary among products is the key parameter of interest, they may be inappropriate. The main drawback of the discrete-choice literature is that it tends to *a priori* restrict the different products to be either strong substitutes, independent or strong complements, whereas the continuous-choice setting, on the other hand, typically incorporates an add-hoc (and not a structural) error term.

We propose to estimate a structural continuous-choice demand model following Pinkse *et al.* (2002), Pinkse and Slade (2004), and Slade (2004). Our starting point is the specification of an indirect utility function from which, via Roy's identity, a demand system is derived. We estimate the model using market-level data on the UK fixed and mobile communications. The data consists of a rich market-level panel that includes information on call volume, call revenues and network size from Ofcom - Office of Communications. We complemented that data with information on the number of employees, operational costs and costs with employees from the AMADEUS database. Lastly, income information was obtained from the ONS - Office for National Statistics.

The UK market is of particular interest as the raw data is inconclusive about the relationship between fixed and mobile communications. On one hand, the overall slowdown in the proportion of mobile-only homes and the fact that calls to fixed lines still constitute the biggest share of an average subscriber's mobile use suggests that mobile remains primarily a complement to fixed-line rather than a direct substitute for most consumers. On the other hand, survey figures show that there is some element of substitution as around a fifth of consumers claim that they use their mobile as the main method of making and receiving calls. The solution to the nature of this relationship is therefore an empirical issue we propose to address. Given that the model is micro-founded, we also address the question of how the evolution of the price differential between the two types of communication may, respectively, affect the welfare of consumers and firms. Finally, we aim to propose some economic policy implications.

We find that at the current diffusion stage, fixed and mobile communications appear to be complements and that the continuation of these price trends have substantial welfare benefits for subscribers and ta the same time have no significant impact on the profits for firms.

The paper would proceed in five sections. The UK communications market would briefly be described in section 2, whereas in section 3 we would discuss the relevant literature. In section 4, we would present the continuous-choice demand model and establish estimation issues. In section 5, we would introduce the data, discuss identification and present the results. Section 6 would conclude.

2 THE UK TELECOMMUNICATIONS MARKET

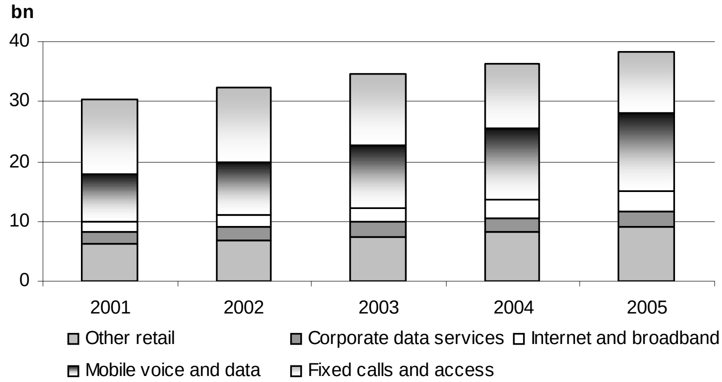
Currently, the telecommunications industry in the UK is represented by six main network operators, two fixed and four mobile.

In the mobile telephony market, the operators are Vodafone, O2 (acquired by Telefonica in January 2006), T-Mobile (belonging to Deutsche Telecom) and Orange (belonging to France Télécom). Vodafone and O2 (then as BT Cellnet) launched their networks in 1985 (analog at first). Orange and T-Mobile (then designated as One2One) entered the market in 1994. After a slow start from these two last networks, since 2000 the four operators became very similar in terms of market shares.

In the fixed telephony market BT is still the biggest player with more 56% of the volume of fixed calls in 2005. NTL: Telewest, UK's largest cable-provider, with more than 90% of the market, is the main rival of BT with a market share of near 14%. NTL: Telewest resulted from the merger between NTL and Telewest in 2006, after discussions commenced in late 2003. However, thanks to their geographically distinct areas, NTL and Telewest had co-operated previously, as in re-directing potential customers living outside their respective areas.

In 2005, the UK telecommunications market revenue was £46.6 billion, of which £38.3 billion was retail revenue, which rose by 26,4% compared to 2001. Mobile telecoms

FIGURE I - UK TELECOMS INDUSTRY RETAIL REVENUE



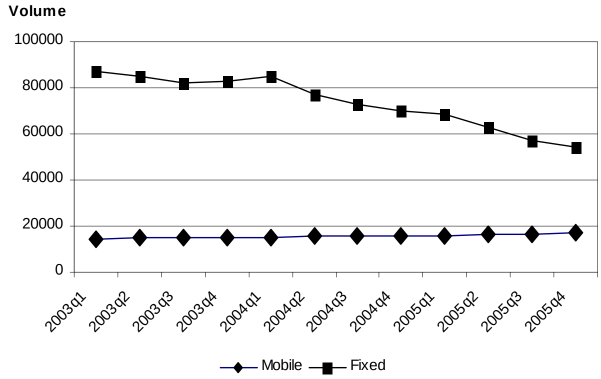
Source: Ofcom, 2006

comprised £13.1 billion (34%) of total retail telecoms revenue – up from £7.9 billion in 2001 – and fixed line revenue fell from £12.4 billion in 2001 to £10.1 billion in 2005. Internet (including broadband) rose by 100% to £3.4billion in the same period (see Figure I). The Office for National Statistics estimates that the industry contributed £22.4 billion in value added in 2003, equating to 2.2% of total UK gross value added.

The key driver of growth of the UK telecoms industry between 2001 and 2005 was the mobile sector. This is most obviously demonstrated by the continued rise in the total number of active subscriptions and call volumes (see Figure II). According to the Ofcom annual report, the enhanced position of the mobile industry in the UK telecoms landscape was achieved to some degree at the expense of the fixed voice industry, suggesting the existence of substitutability between these two types of services. Indeed, the total number of fixed exchange lines in the UK fell by 1.7% during 2005 to 34 million (compared with 2001, the fall was of 4.5%). Fixed voice volumes also fell by 13,5% since 2001. These falls had been attributed to an increase in the number of households who rely on mobile telephony as their sole means of access, but this trend appears to have been halted in the last years. A new explanation is that it may be the reflection of a reduction in the number of second lines for internet access following continued migration to broadband services.

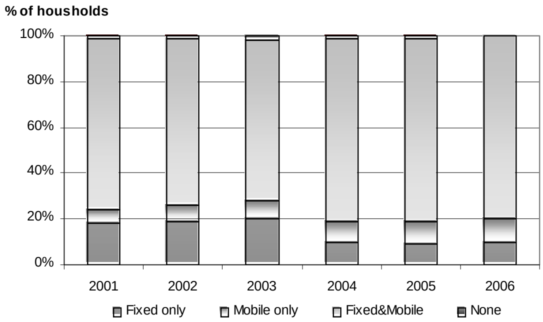
The number of households that owned a fixed phone but not a mobile phone dropped to just 10% by 2006. However the proportion of homes that relied on mobile as their sole

FIGURE II - TOTAL CALL VOLUMES



Source: Ofcom, 2006

FIGURE III - HOUSEHOLD PENETRATION OF FIXED AND MOBILE TELEPHONY

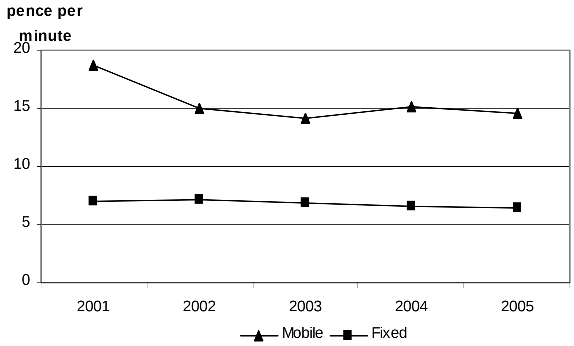


Source: Ofcom, 2006

means of telephony remained relatively small, standing at just 10% (see Figure III). And it seems unlikely that mobile will replace fixed telephone as the main household access technology in the foreseeable future. The overall slowdown in the proportion of mobile-only homes suggests that mobile remains primarily a complement to fixed-line rather than a direct substitute for most consumers. In fact, despite their continuing decline, calls to fixed lines still constitute the biggest share of an average subscriber's weekly mobile use, at 35% of all mobile calls (down from 48% in 2001). Nevertheless, survey figures show that there is some element of substitution. Around a fifth of consumers claim that they use their mobile as the main method of making and receiving calls.

An interesting element of the debate on fixed and mobile substitution is the price differential between the two services. The price differential between average fixed and

FIGURE IV- COMPARISON OF AVERAGE AND MOBILE CALLS CHARGES



Source: Ofcom, 2006

mobile per-minute charges decreased slightly during 2005, however, mobile calls still cost on average 2.3 times more per minute than fixed calls, which may suggest that the two technologies are not substitutes (see Figure IV).

3 RELEVANT LITERATURE

There is a substantial number of cases where the *a priori* relationship between products is not at all clear in the sense that although apparent to be clear substitutes may turn out to be in fact complements, or vice-versa. Examples include print and online newspapers (Gentzkow, 2007), free file-sharing services and recorded music (Oberholzer and Strumpf, 2004; Blackburn, 2004; Rob and Waldfogel, 2006; Zentner, 2005), file-sharing services and live concerts (Mortimer and Sorensen, 2005), public and private broadcast channels (Berry and Waldfogel, 1999; Prat and Stromberg, 2005), and online and offline retailing (Goolsbee, 2001; Sinai and Waldfogel, 2004).

There have been some prior studies analyzing the fixed-mobile substitution. Rodini *et al.* (2003) use a US household annual survey to study the mobile and fixed telephony, and find only modest substitution between mobile subscription and the demand for second lines. Sung *et al.* (2000) find that the number of Korean mobile subscribers is positively correlated with the number of fixed-line disconnects, but negatively related to the number of new fixed-line connections, suggesting net substitution between the two services. This pattern occurs even while the stock of fixed lines is positively correlated with the number of mobile subscribers, offering evidence that the two services are complements. Ahn and Lee (1999) estimate demand for mobile access in Korea using more recent wireless subscription data for 64 countries, and find evidence of complementarity also using aggregate data.

There is also a literature that analyses the impact of fixed phone on mobile phone diffusion. Gruber and Verboven (2001a), using a panel data on the whole history of the industry for all members of the European Union, find that the stock of fixed phones has a negative influence on the diffusion of mobile phones. On the other hand, Gruber (2001) obtains the opposite result that mobile telecommunications are a complement to fixed line telecommunications rather than a substitute in Central and Eastern Europe. Gruber and Verboven (2001b) extend the analysis to world data and look at a different set of issues. Barros and Cadima (2000) study a complementary question, and find a negative effect of the mobile phone diffusion on the fixed-link telephony penetration rate.

Taubman and Vagliasindi (2004) explore the substitution effects between traditional fixed line and mobile services across Eastern Europe and Former Soviet Union, and find evidence of some substitution in place at country level, but, at the enterprise level, the complementary effects dominate. Hamilton (2003) studies the African telecommunications market and shows that is possible that mobile and main lines are sometimes substitutes, and at other times complements in consumption, even where fixed-line access is low. Okada and Hatta (1999) show that, for the Japanese market, the substitution effect is substantial.

The empirical literature on telephony communications is also significant in what modelling is concerned. Doganolu and Grzybowski (2006) estimate a nested logit model to estimate the demand for subscriptions of mobile telephony, whereas Lee *et al.* (2006) estimate switching costs in the Korean mobile telecommunications using a random coefficients multinomial model. Grzybowski (2007) uses a multinomial and mixed logit model to estimate switching costs in mobile telephony. On the other hand, under the continuous-choice setting Okada and Hatta (1999) estimate an Almost Ideal Demand System for the Japanese telephony industry. Parker and Roeller (1997), though focused on the mobile phone industry, estimate a structural model for the US mobile telephony industry to analyze the determinants of market conduct in the mobile telecommunications industry, and Hausman (1999, 2000) estimates the elasticity of aggregate subscription to mobile service in the 30 largest U.S. markets over the period 1988-1993.

However, and even though in some settings the above approaches are clearly reasonable, in cases where the identification of the degree of substitutability or complementary among products is the key parameter of interest, they may be inappropriate. The main drawback of the discrete-choice literature is that it tends to *a priori* restrict the different products to be either strong substitutes, independent or strong complements, whereas the continuous-choice setting, on the other hand, typically incorporates an add-hoc (and not a structural) error term. We propose to estimate a structural continuous-choice demand model following Pinkse *et al.* (2002), Pinkse and Slade (2004), and Slade (2004) with distinct advantages over the models under the standard approaches.

4 THE DEMAND MODEL

We propose to estimate a structural continuous-choice demand model following Pinkse *et al.* (2002), Pinkse and Slade (2004), and Slade (2004) with distinct advantages over the models under the standard approaches.

Consider a choice framework with J inside options, $j = 1, \ldots, J$, and an outside option, $j = 0$, that aggregates all other products. Within this setup, consumers choose quantities for the set $\Im$ of those $J + 1$ options.

The hth consumer, with $h = 1, \ldots, H$, chooses a vector $q_h = (q_{h1}, \ldots, q_{hJ})'$ of quantities for the inside options, with $q_{hj} \geq 0$, $j = 1, \ldots, J$, and q_{h0} for the outside option, with $q_{h0} > 0$. Furthermore, this consumer has nominal income y_h and indirect utility function $u_h(\tilde{p}, \tilde{y}_h)$, where $\tilde{p} = (p_0, \tilde{p}_1, \ldots, \tilde{p}_J)'$ denotes the vector of nominal prices for the inside options and p_0 denotes the nominal price of the outside option.

We approximate the unknown functional form of the consumer indirect utility function, u_h, by a second-order approximation that does not restrict the price-substitution patterns. In particular, we follow Berndt, Fuss and Waverman (1977) and McFadden (1978), and opt to work with a symmetric quadratic functional form, where nominal prices and income are normalized by the price of the outside option p_0,

$$u_h(p, y_h) = \sum_{i=1}^{J} \gamma p_i y_h - \sum_{i=1}^{J} a_{hi} p_i - \sum_{i=1}^{J} \sum_{j=1}^{J} b_{hij} p_i p_j, \tag{1}$$

where for notational convenience, we denote $p_i = \frac{\tilde{p}_i}{p_0}$, $y_h = \frac{\tilde{y}_h}{p_0}$ and $p = (p_1, \ldots, p_J)'$.

Proposition 1 *Suppose $u_h(p, y_h)$ satisfies $\gamma \geq 0$ and $\gamma y_h - a_{hm} - 2\sum_{i=1}^{J} b_{hmi} p_i \leq 0$ for all m and h. Then the above indirect utility function is a member of the class* *of consistent indirect utility functions, as it is i) a continuous function at all positive nominal prices and income, ii) non-increasing in a given nominal price, non-decreasing in nominal income, and homogeneous of degree zero in nominal prices and income, and iii) a convex function of nominal prices with income normalized to one.*

Proof. *Follows straightforward from the derivatives of $u_h(p, y_h)$.* ■

Given proposition 1, the demand system can, therefore, be derived by Roy's identity. The demand function from individual h for a given product m is, then, given by,

$$q_{hm}(p, y_h) = -\frac{\partial u_h(p, y_h)/\partial p_m}{\partial u_h(p, y_h)/\partial y_h} = -\frac{\gamma y_h - a_{hm} - 2\sum_{i=1}^{J} b_{hmi} p_i}{\sum_{i=1}^{J} \gamma p_i}, \tag{2}$$

where for notational convenience, we denote $p_m = \frac{\tilde{p}_m}{p_0}$, $y_h = \frac{\tilde{y}_h}{p_0}$ and $p = (p_1, \ldots, p_J)'$.

The summation $\sum_i \gamma p_i$ can be interpreted as a price index that can, without loss of generality, be normalized to one in a cross-section or very short time series, yielding the following demand function,

$$q_{hm}(p, y_h) = a_{hm} + 2\sum_{i=1}^{J} b_{hmi} p_i - \gamma y_h. \tag{3}$$

Because the indirect utility function is in Gorman polar form, the market-level demand functions can be obtained by simply aggregating the individual demand functions across consumers,

$$q_m(p, y) = \sum_{h=1}^{H} q_{hm}(p, y_h) = \sum_{h=1}^{H} a_{hm} + 2\sum_{j=1}^{J} p_j \sum_{h=1}^{H} b_{hmj} - \gamma \sum_{h=1}^{H} y_h, \tag{4}$$

where q_m denotes the market-level demand function for product m, and $y = \sum_{h=1}^{H} y_h$ denotes aggregate income. Let us denote also for notational convenience, $a_m = \sum_{h=1}^{H} a_{hm}$ and $b_{mj} = 2\sum_{h=1}^{H} b_{hmj}$. Following this definitions, we can now rewrite the market-level demand function as,

$$q_m(p, y) = a_m + \sum_{j=1}^{J} b_{mj} p_j - \gamma y. \tag{5}$$

At this point, the aggregate demand function is completely deterministic. As it is clear that some randomness exists in a applied demand model, we introduce the random utility hypothesis in a way akin to Pinkse *et al.* (2002). We assume, therefore, that a_m is a function defined in the characteristics space of product m, $a_m = a(x_m, \xi_m)$, where x_m denotes a K-dimensional vector of characteristics of product m, observed by both the consumer and the econometrician, and ξ_m denotes the value of product's m characteristics observed by the consumer but not by the econometrician. Although many functional forms for $a(x_m, \xi_m)$ are possible, we will assume the function to be linear in its arguments,

$$a(x_m, \xi_m) = \sum_{k=1}^{K} \beta_k x_{mk} + \xi_m. \tag{6}$$

Given the above mapping of the market-level demand function can be rewritten as a function not only of prices and income, but also of a vector of characteristics $x = (x_1, \ldots, x_J)'$,

$$q_m(x, p, y) = \sum_{k=1}^{K} \beta_k x_{mk} + \sum_{j=1}^{J} b_{mj} p_j - \gamma y + \xi_m. \tag{7}$$

The unobserved characteristics ξ_m ensure that the error term is structurally embedded in the model.

An important econometric issue that arises when the model is taken to data refers to the substantial number of parameters to be estimated. This may lead to a dimensionality problem. To see this do note that, in addition to the $\{\beta_k\}$ and $\{\gamma_i\}$ parameters, the number of $\{b_{ij}\}$ parameters to be estimated is $J(J+1)/2$. We address this point by following Pinkse *et al.* (2002), Pinkse and Slade (2004), and Slade (2004), and map the $\{b_{ij}\}$ parameters in the characteristics space. We assume, therefore, the $\{b_{ii}\}$ parameters to be a function of own-characteristics, $b_{ii} = b(x_i)$, and similarly the $\{b_{ij}\}$ parameters, for $i \neq j$, to depend on own- and cross-characteristics, $b_{ij} = g(x_i, x_j)$. In particular, we will work with the following functional forms,

$$\begin{aligned} b_{ii} &= \sum_{k=1}^{Kd} \lambda_k x_{ik} \\ b_{ij} &= \sum_{k=1}^{Kc} \delta_k \left(\frac{1}{1 + 0.01 \left| x_{ik} - x_{jk} \right|} \right), \end{aligned} \tag{8}$$

where Kd and Kc denote the number of characteristics included in the mapping of the own- and cross-price terms, respectively.

Given availability of data with both cross-sectional $m = 1, \ldots, J$ and time series $t = 1, \ldots, T$ variation, the model to be estimated becomes,

$$q_{mt}(x,p,y) = \sum_{k=1}^{K} \beta_k x_{mkt} + \sum_{k=1}^{Kd} \lambda_k x_{mk} p_{mt} + \sum_{k=1}^{Kc} \sum_{j \neq m} \delta_k \left(\frac{1}{1 + 0.01 \left| x_{mk} - x_{jk} \right|} \right) p_{jt} - \gamma y_t + \xi_{mt}, \tag{9}$$

A second econometric issue relates to an hypothetical correlation between the regressors and the error term. We would expect prices and unobserved characteristics to be correlated as prices are typically set taking into account some information that the econometrician does not possess and, thereby, has to include in the econometric error term. Due to this hypothetical correlation, OLS estimates may not be consistent and instrumental variables techniques are, therefore, required. We assume, however, as it is standard in the literature, the unobserved characteristics to be mean independent of the observed ones (please see Berry, 1994).

In many policy applications, including merger simulation, the key object of interest is the matrix of own- and cross-price elasticities. The analytical expressions for the own- and cross-price elasticities predicted by the model for any given products m and n, are the following,

$$\varepsilon_{mn}(x,p,y) = \begin{cases} \left(\sum_{k=1}^{Kd} \lambda_k x_{mk} \right) \left(\frac{p_m}{q_m(x,p,y)} \right) & \text{for} \quad m = n \\ \\ \sum_{k=1}^{Kc} \delta_k \left(\frac{1}{1+0.01 \left| x_{mk} - x_{jk} \right|} \right) \left(\frac{p_n}{q_m(x,p,y)} \right) & \text{for} \quad m \neq n \end{cases} \tag{10}$$

As the model is flexible in the sense that there exists a vector of parameters that can match any matrix of own- and cross-price elasticities (please see Pinkse *et al.*, 2002, Pinkse and Slade, 2004 and Slade, 2004), it can be instrumental in determining the relationship between two given products.

Definition 1 *Products m and n, for all $m \neq n$, are substitutes if $\frac{\partial q_m(x,p,y)}{\partial p_n} > 0$, independent if $\frac{\partial q_m(x,p,y)}{\partial p_n} = 0$, and complements if $\frac{\partial q_m(x,p,y)}{\partial p_n} < 0$.*

5 EMPIRICAL ANALYSIS

5.1 Data Description

The empirical application of the above estimation procedure relies on the availability of data on prices, income, observed quantities and characteristics for a set of J products across time.

In what refers to our UK communications application, we collected information on call volume, call revenues and network size from Ofcom - Office of Communications. The data is on the form of a market-level cross-sectional time series for the United Kingdom telecoms market, and it is disaggregated by operator (BT, Vodafone, O2, ...) and quarter (from 2003:1 to 2005:4). Furthermore, we complemented that data with information on the number of employees, operational costs and costs with employees from the AMADEUS database. Lastly, income information was obtained from the ONS - Office for National Statistics.

Table I presents some summary statistics for call volumes, call revenues, network size and, lastly, for a derived price variable computed as the ratio of revenues to the respective volume. The last two columns show the percentage of the standard deviation due to product and quarterly differences, with most of the variation being due to differences across products.

TABLE I - SUMMARY STATISTICS

	Mean	Std	Product Variation	Quarter Variation
Call Volume (millions of minutes)	12,092	16,781	106%	24%
Call Revenue (£millions)	776	538	107%	15%
Price (£)	0.115	0.055	108%	11%
Network (000's)	14,550	6,883	108%	12%

Given the high degree of product differences we present in Table II again the mean and standard deviation of the above variables, but now disaggregated between mobile and fixed communications.

TABLE II - DISAGGREGATED MEANS AND STANDARD DEVIATIONS

	Mean		Std	
	Mobile	Fixed	Mobile	Fixed
Call Volume (millions of minutes)	3,891	28,493	461	21,160
Call Revenue (£millions)	594	1,140	117	811
Price (£)	0.152	0.041	0.169	0.004
Network (000's)	13,707	16,235	948	11,831

Table II shows *i*) that in fact exist a structural difference between mobile and fixed communications, *ii*) that within mobile firms the similarity, apart from revenues and consequently price, tends to be relatively high whereas *iii*) the same does not happen for fixed products as BT remains the biggest player with more than 56% of the volume of the fixed calls market in 2005. As a result our model has to take this aspect into consideration.

5.2 Reduced-form Results

Figure II shows that during these last years, the volume of fixed voice calls has been declining, while the volume of mobile voice calls has been increasing. A simple OLS regression of fixed voice volume on mobile voice volume and a time trend gives a significantly negative coefficient. Results are presented in Table III. Although it might be tempting to take this as direct evidence that the fixed and mobile telephony are substitutes, several factors make such a conclusion dubious. Our goal is to use a micro-founded demand model to answer this question.

TABLE III - FIXED/MOBILE CORRELATION

Variable	
MOBILE VOLUME	-3.070 **
	(-2.20)
TREND	-2,230 ***
	(-8.65)
CONSTANT	119,257 ***
	(5.71)
R-squared	0.957

FIXED VOLUME as independent variable.

Asymptotically robust t-ratios in parentheses.

We can also find evidence about the extent of substitutability among operators offering different products. Table IV reports correlation coefficients for each pair of mobile/fixed operator.

TABLE IV - VOLUME CORRELATIONS

Pairs	Correlation	$p - value$
BT/Vodafone	-16.915	0.000
BT/O2	-3.825	0.161
BT/T-mobile	12.113	0.030
BT/Orange	-7.932	0.098
ntl:Telewest/Vodafone	-1.981	0.000
ntl:Telewest/O2	-0.774	0.019
ntl:Telewest/T-mobile	1.347	0.118
ntl:Telewest/Orange	-0.736	0.309

Calls from BT are significantly negatively correlated with calls from Vodafone. However, they are significantly positively correlated with calls from T-Mobile. With respect to the other mobile operators the correlation is not significant.

The correlation between ntl:Telewest and Vodafone is also significantly negative, as is the correlation between ntl:Telewest and O2. The other correlations are not significantly different from zero. These results suggest some ambiguity about the relationship between mobile and fixed calls. Again, this is exactly the question we propose to address with our paper by estimating a structural continuous-choice demand model. Let us proceed now with the econometric issues of its estimation.

5.3 Identification

The demand specification from equation (9) may give rise to an hypothetical correlation between the regressors and the error term .First, we would expect prices and unobserved characteristics to be correlated as prices are typically set taking into account some information that the econometrician does not possess and, thereby, has to include in the econometric error term. Furthermore, in a dynamic setting, an hypothetical correlation problem between observed and unobserved characteristics may also exist. As a result of these hypothetical problems, OLS estimates could be inconsistent and instrumental variables techniques are, therefore, required.

Our estimation procedure relies on two identification assumptions. First, we will assume, as it is standard in the literature, the unobserved characteristics to be mean independent of the observed ones (please see Berry, 1994). Second, in what relates to the hypothetical correlation between prices and unobserved product characteristics, we will assume two operational ratios to be valid instruments: the ratio of operational costs to volume and the ratio of costs with employees to their respective number. The justification for these instruments relies on their likelihood to be simultaneously correlated with prices (via the firms' cost structure) and uncorrelated with unobserved product characteristics.

5.4 Demand Estimation

Table V presents the OLS and IV results for the estimation of the continuous-choice demand model[1]. As we described before, both the intercepts and the own-price terms are functions of observed characteristics, whereas the cross-price terms depend on distance measures. The first column presents, for comparison purposes, the OLS results, whereas the second column presents the IV estimates. The table shows that the OLS estimates of the coefficients tend to be smaller than the IV estimates, as in Slade (2004).

[1]For the estimation results presented, the revenues include also those from fixed fees included in the price schemes. As a robustness check, we re-estimated the model using only revenues from the variable part of the price schemes. The results do not change significantly.

For the intercepts, the only observed characteristics included were product dummies to control for all those product specific characteristics that do not vary with time and time period dummies to control for time variations.

TABLE V - DEMAND ESTIMATION RESULTS

Variable	(OLS)	(IV)
PRICE	-1,250,688 ***	-1,293,902 ***
	(-11.83)	(-9.44)
PRICEM	1,092,271 ***	1,028,032 ***
	(8.05)	(4.84)
PRICEN	9.417 **	11.710 *
	(2.28)	(1.98)
DIFNSAME	5,656	24,329 *
	(1.49)	(1.75)
DIFNOTOHER	-611,257 ***	-614,913 ***
	(-6.46)	(-5.32)
INCOME	-0.044	-0.055
	(-1.03)	(-0.93)
Product Dummies	yes	yes
Time Dummies	yes	yes
First stage F	—	—
R-squared	0.997	—

All regressions are based on 128 observations.

Asymptotically robust t-ratios in parentheses.

In what the own-price effects is concerned, we considered the following specification for the mapping of the $\{b_{ii}\}$ parameters,

$$b_{ii} = \lambda_0 + \lambda_1 DMOBILE_i + \lambda_2 NETWORK_i, \tag{11}$$

where $DMOBILE_i$ denotes a dummy variable that takes the value one if the product i is a mobile network and zero otherwise, and $NETWORK_i$ denotes the number of subscribers of product i. Given this specification, an estimate of the $\{\lambda\}$ parameters can be obtained as the estimated coefficients on price, on price interacted with the $DMOBILE$ variable ($PRICEM$) and lastly on price interacted with the $NETWORK$ variable ($PRICEN$), respectively. The price coefficient is negative and significant. The coefficients on both $PRICEM$ and $PRICEN$ are positive and significant (although the later only at at 6%) suggesting that own-price sensitivity is lower for mobile and large size networks, respectively.

Turning to the cross-price effects, captured by the $\{b_{ii}\}$ parameters, we assumed the following mapping which incorporates a mixture of a discrete- with a continuous-distance measure,

$$b_{ij} = (\delta_0 DSAME_{ij} + \delta_1 DOTHER_{ij}) \left(\frac{1}{1 + 0.01 \left| NETWORK_i - NETWORK_j \right|} \right), \tag{12}$$

where $DSAME_{ij}$ denotes a dummy variable that takes the value one if products i and j are of the same type, for example both fixed or mobile operators and zero otherwise, and conversely $DOTHER_{ij}$ denotes a dummy variable that takes the value one if products i and j belong to different types. This mapping gives rise to two rival price variables. One that considered the weighted average of those products that are of the same type ($DIFNSAME$) and another considering the weighted average of those products that are of different types ($DIFNOTOHER$). In summary, the former variable allows us to obtain the cross-price effects intra-categories, while the later gives us the inter-categories cross-price effects, in our case, between mobile and fixed calls. The coefficient on $DIFNSAME$ is positive and significant (although only at at 9%) implying that products of the same type are estimated to be substitutes. Conversely, the coefficient on $DIFNOTOHER$ is negative and significant suggesting that products of different types are estimated to be complements.

A caveat should be emphasized about the validity of the estimated relationship between mobile and fixed communications. The data used in this paper refers to a mature diffusion stage of mobile communications. We do not argue that mobile and fixed communications are and always have been complements in what the UK market is concerned. Our point, in contrast, is that at this stage of mobile communication diffusion characterized by a stabilization of the relative market shares, the data suggests that the two types of communications are complements.

TABLE VI - MEDIAN OWN- AND CROSS-PRICE ELASTICITIES

		1	2	3	4	5	6
1	Vodafone (mobile)	-4.647	0.531	0.355	0.494	-0.354	-0.611
2	O2 (mobile)	0.698	-3.993	0.530	0.814	-0.403	-0.631
3	T-Mobile (mobile)	0.577	0.655	-3.926	0.749	-0.478	-0.679
4	Orange (mobile)	0.623	0.779	0.580	-3.961	-0.401	-0.611
5	BT (fixed)	-0.115	-0.119	-0.115	-0.124	-0.767	0.001
6	ntl:Telewest (fixed)	-1.071	-1.009	-0.878	-1.019	0.004	-5.522

Each cell gives the % change in market share of the row's product with a 1% change in the price of the column's product.

Lastly, the coefficient on income is not significant, implying that at the current stage of diffusion income tends to not be important in explaining the volume of minutes.

Table VI presents the implied demand elasticities for the continuous-choice model. According to our empirical specification, own-price elasticities vary with the characteristics of the products, whereas cross-price elasticities depend on distance measures.

The implied own-price elasticities show that consumers tend to react in a similar way to own-price changes from mobile firms. In contrast, in the fixed communications market, there is a substantial within difference as the own-price elasticity for BT implies a relatively high degree of market power. In what the implied cross-price elasticities is concerned, the results suggest communications of the same type are demand substitutes, whereas communications of different types are demand complements. Furthermore, within each type the results also imply that consumers tend to switch more towards products with similar network sizes.

If we use the individual firms elasticities to compute elasticities for fixed and mobile telephony in aggregate terms, we obtain the median own- and cross-price elasticities presented in Table VII.

TABLE VII - MEDIAN AGGREGATED ELASTICITIES

	Mobile	Fixed
Mobile	-2.319	-1.036
Fixed	-1.011	-1.497

Each cell gives the % change in market share of the row's product with a 1% change in the price of the column's product.

In aggregated terms, mobile calls demand is therefore slightly more elastic than fixed calls with respect to own-price. A caveat should be emphasized about these results: their magnitude of these results seem somewhat higher than some previous studies in the literature. However we have to emphasize that we were *a priori* expecting this qualitative result as the elasticities refer to *i*) volume and not subscription and *ii*) quarterly and not monthly data. Rodini *et al.* (2003) estimate a own-price elasticity of mobile access demand with respect to the monthly charge is -0.43. Hausman (1999) reports a price elasticity of subscription of -0.51 in the 30 largest U.S. markets. From the Ahn and Lee (1999) study it is possible to infer a elasticity of -0.36. Regarding fixed lines subscription, the own-price elasticity is -0.65 for the second fixed line and -0.1 for first fixed line, according to Rodini *et al.* (2003). Parker and Röller (1997) apply a structural model in order to examine the competitive behavior of mobile operators, and find an own-price elasticity of -2.5 using data on the United States covering the period 1984-1988. Doganoglu and Grzybowski (2005) estimate demand for subscription and finds own-price elasticities between -4.2 and -5.04.

Turning to the cross-price, it seems there is no significant difference between how the volume of fixed communications reacts to changes in the mobile and vice-versa. Again a similar caveat applies as the data refers to *i*) volume and not subscription, *ii*) quarterly and not monthly data and *iii*) to a mature diffusion stage for mobile communications. Rodini *et al.* (2003) estimates a cross-price elasticity of fixed access price on mobile demand of 0.13-0.18 and a cross-price elasticity from mobile access to fixed line subscription of 0.06-0.08.

5.5 Welfare Evaluation

Figure IV presents the evolution from 2001 to 2005 of the price differential between fixed and mobile communications. The price differential has decrease around 30% during that period and it was mainly due to the 22% decrease in the price of mobile communications (against a decrease of 7% in the price of fixed communications). It would be therefore of interest to evaluate the welfare change for both consumers and producers if those past trends in prices were to continue.

In what consumer welfare is concerned, when all consumers have indirect utility functions of the Gorman polar form, the preferences of the representative consumer are independent of the social welfare function used. In particular, the following is an admissible indirect utility function for the normative representative consumer (Mas-Colell *et al.,* 1995),

$$u\left(p,y\right)=\sum_{h=1}^{H}u_{h}\left(p,y_{h}\right)=\sum_{i=1}^{J}\gamma p_{i}y-\sum_{i=1}^{J}a_{i}p_{i}-\sum_{i=1}^{J}\sum_{j=1}^{J}b_{ij}p_{i}p_{j}, \tag{13}$$

As a result, we can use our demand side estimates of γ, $\{a_i\}$ and $\{b_{ij}\}$ to compute the impact the price trends had on utility. However, given changes in utility have no direct interpretation, it is necessary to translate those utility variations into a monetary measure. A well-known measure of monetary welfare change is the equivalent variation

(EV) following Hicks (1939). This measure gives us the change in income that would be equivalent to the price change in order for the welfare to be kept unchanged,

$$u\left(p^0, y + EV\right) = u\left(p^1, y\right), \tag{14}$$

where p^0 and p^1 denote the vector of prices for all communication products in the market before and after the price changes, respectively.

Let us now turn to producer welfare. For firms the change in welfare can be computed as the change in profit. Assume that the profit of a given firm f can be expressed as follows,

$$\Pi_f = \left(p_f - mc_f\right) D_f\left(p\right) - C_f, \tag{15}$$

where p_f, mc_f and C_f denote respectively price, constant marginal cost and fixed cost of production for firm f. Additionally $D_f\left(p\right)$ denotes the volume demand of firm f, which is a function of prices of all communication products in the market, p. Given the above, the impact on profit from a price change would be,

$$\Delta\Pi_f = p_f^1 D_f\left(p^1\right) - p_f^0 D_f\left(p^0\right) - mc_f\left(D_f\left(p^1\right) - D_f\left(p^0\right)\right), \tag{16}$$

where the superscript 0 and 1 refer to variables before and after the price changes, respectively. The demand after the price changes can be predicted using the estimates from the demand side. However data on marginal costs, which we do not have, is instrumental. As a result we can only perform a scenario analysis where we compute the change in profits conditional on different marginal costs. We can argue that the marginal cost of a minute of communication is very close to zero if there are no capacity constraints issues. For this reason, we analyzed the impact on profits for the cases where the marginal costs are 5%, 10% and 20% of the consumer price.

Table VIII presents the welfare impact results for both consumers and producers as a result of hypothetical future price trends. The first column presents the impact if past trends were to continue for a year, whereas the second column presents the results if those trends were to continue for a five year period.

TABLE VIII - WELFARE IMPACT OF COMMUNICATION PRICE TRENDS

	1 Year	5 Years
Consumer welfare change in £ per subscriber per day	£0.45	£3.13
Profit change in £ per subscriber per day for mobile firms		
$mc_f = 0.05p_f$	£0.00	£0.00
$mc_f = 0.10p_f$	£0.00	£0.00
$mc_f = 0.20p_f$	£0.00	£0.00
Profit change in £ per subscriber per day for fixed firms		
$mc_f = 0.05p_f$	£0.00	£0.00
$mc_f = 0.10p_f$	£0.00	£0.00
$mc_f = 0.20p_f$	£0.00	£0.00

The welfare impact was computed using 2005:4 values as comparison.

We find that on average a subscriber would be willing to pay £0.45 per day for the observed past decrease in prices to continue at the same rate for one year and £3.13 per day for the continuation of those price trends to continue for a five year period. In what the supply side is concerned, we find that firms have no benefit in continuing in the future with price trends of the same magnitude. This finding is consistent with a reasonable range of marginal costs.

6 CONCLUSIONS

This paper studies the relationship between fixed and mobile telephony in the United Kingdom and, in particular, addresses the question if mobile communications crowded out fixed telephony or if, on the other hand, the two types of communications are in fact complements.

We estimate a structural continuous-choice demand model following Pinkse *et al.* (2002), Pinkse and Slade (2004), and Slade (2004) and find that at the current diffusion stage, fixed and mobile communications appear to be complements. Furthermore, we find the continuation observed price trends for both types of communications would have substantial welfare benefits for subscribers, at the same time it would not decrease profits for firms.

It is a known fact that competition generally tends to improve industry performance and productivity. Studies that looked at the telecommunications industry have find that competition in basic services is associated with increased telecom growth and development. By this reason, substitutability between fixed and mobile telephony services impacts public policy toward competition in both these markets. The main concern over competition in these markets derives from the market power held by incumbent fixed network. Our estimates indicate that mobile calls are not substitute, but a complement for fixed calls. Therefore we cannot expect the mobile services to constrain the market power of BT. On the contrary, the two services appear to coexist in households, each providing consumers with particular advantages. Hence, policies promoting the opening up of incumbent's network aided by regulatory intervention are still necessary.

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