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Estimating the value of mobile telephony in mobile network not-spots

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1. Introduction

Over the past decade mobile phone usage has increased substantially, accompanied by a rise in the number of mobile-only households (Ofcom, 2012). A recent Ofcom report (2016) shows that household take-up of mobile phones now stands at 95% and exceeds fixed telephony, which has fallen from 91% take-up in 2005 to 84% in 2016. Some 16% of UK adults now live in mobile-only homes. Amongst businesses, mobile usage (measured in call minutes) has now overtaken that of fixed lines. Allied to this, development of 'smart' phones with new capabilities, and broader cultural changes, has meant mobile access is often regarded by users as a necessity rather than a premium service. The value of mobile network connectivity has been recognised by the UK government and effective use of mobile services has become part of the wider digital inclusion agenda.

In general, 2G (voice and basic data) mobile coverage is high in the UK. Ofcom's Connected Nations Report (2015) shows that over 99% of premises are covered outdoors by at least one Mobile Network Operator (MNOs) and 93% are covered by all three MNOs that operate 2G networks. But areas without any coverage, referred to as 'not-spots', persist. Research has suggested that in a number of cases it has not been a commercial priority for mobile operators to extend their coverage to these areas due to low forecast levels of traffic discouraging investment (PA Consulting Group, 2010). Mobile network not-spots are often highly localised and they generally, though not exclusively, affect geographically isolated rural communities (Ofcom, 2012). A publication by Department for Culture, Media & Sport (DCMS, 2013) indicates that there are approximately 80,000 premises in not-spot locations, affecting around 3% of the population of the UK.

The impacts of being in a mobile network not-spot are varied, ranging from the inconvenience of a missed call, to loss of business opportunities for rural enterprises, to limiting immediate access to emergency responses. Lack of mobile phone connectivity thus affects different aspects of life, but the impact is most acutely felt in particularly isolated rural communities and by those rural businesses that require a degree of mobility for their activities (Illuminas, 2010).

The need for better mobile network connectivity can also be set in the wider public debate concerning the importance of investment in communications infrastructure (Ofcom, 2013a). This debate is taking place across Europe (for instance, European Commission 2014), and is a key policy issue for the UK government and local authorities. There has been much recent focus within the UK on the availability of high-speed services such as superfast broadband or deployment of 4G broadband networks – with the Government expecting that competition is driving the fastest 4G network rollout in Europe. Meanwhile it should also be recognised that apparently high levels of 2G coverage in the UK may disguise the fact that a lack of universal mobile connectivity remains a serious issue for those living in, or visiting, not-spot areas.

To date, UK government and regulator efforts to enhance coverage have focused on a range of approaches. Firstly, in October 2011, the government pledged £150m to improve mobile coverage and remove mobile not-spots, through the Mobile Infrastructure Project (MIP). This project was

intended to improve mobile phone coverage through the building of additional mobile phone masts in uncovered areas. However, it faced a number of challenges meaning that around 60 masts are expected to be provided by the end of the 2015-2016 financial year, around one-tenth of the potential 600 sites (Rathbone and Hirst, 2016). Challenges arose due to difficulty in identifying not-spot areas (exacerbated by the introduction of the 4G auction which changed coverage criteria), finding sites suitable for masts (and taking into account that the mobile operators needed to meet ongoing operating costs) and local opposition to masts. Secondly, the MIP programme and mobile infrastructure deployment generally has benefited from changes to the planning laws in place since August 2013. Thirdly, Ofcom has, and continues to look at areas where provision of further information may help consumers (and which also helps promote effective competition by better facilitating consumer choices). Such remedies have to be seen in the context of wider regulatory and market developments, such as the introduction of a 4G coverage obligation which applies to O2 to provide 98% 4G indoor population coverage by 2017 and network sharing agreements within the industry. Finally it should also be noted that the Government has been working with the rail industry to significantly improve mobile coverage for rail passengers.

Despite these various measures to improve coverage it is likely that some complete not-spots will persist in isolated rural areas. It is in this context, and against the backdrop of Defra's commitment to grow the rural economy, that this research was commissioned by the UK Department for Environment, Food & Rural Affairs (Defra) and The Department for Culture Media & Sport (DCMS) to estimate the social and economic impacts associated with the elimination of rural not-spot areas for residents and businesses in these areas and for tourists and other local visitors to these areas. At the core of the study is a survey conducted with people in these population groups. The survey questionnaire collected information on the characteristics of the respondents and their communication practices. It also included a stated preference discrete choice experiment (SPDCE) in which respondents were asked to make choices between hypothetical mobile phone services, described by service characteristics and cost. From the data collected, discrete choice models were developed to quantify the importance of the mobile phone service characteristics and price. The outputs from these models were used to estimate the value respondents place on mobile phone services (their willingness to pay). Qualitative interviews were conducted with residents and local visitors to not-spot areas, providing further information on people's mobile phone needs.

The study provides empirical evidence supporting practical guidance for the methodological use of stated choice experiment for valuing the mobile phone usage in the not-spots in the telecommunications field and across various industries.

The remainder of the paper is organised as follows: Section 2 provides a literature review. Section 3 describes briefly the stated preference survey design. Section 4 discusses the data collection and profile of the collected sample. Section 5 presents the model results. Section 6 discusses the policy implications and Section 7 provides conclusions.

2. Literature Review

Ofcom has commissioned a range of reports on the nature of the mobile not-spot problem and the reasons not-spots exist (Ofcom, 2013a), as well as qualitative research across the UK to understand the impacts of not-spot areas (Illumas, 2010). This body of work has identified five distinct types of problem – complete not-spots (no coverage at all and the focus of this research), 3G not-spots (no

mobile broadband coverage), partial (operator-specific) not-spots, interrupted coverage on the move, and indoor coverage (Ofcom, 2013a). However, there is limited research quantifying the impacts of living, visiting or conducting business in a not-spot area.

On the other hand, there is a body of research quantifying the value of mobile and digital communications more generally. For example, Ida et al. (2008) use a conjoint analysis method to investigate the demand of internet protocol telephony in Japan which includes voice quality, number portability, emergency calls or fax usage. They find that consumers are willing to pay most for emergency calls and voice securing quality.

Research by Parks Associates (Wang 2010), finds a large proportion of mobile consumers in the U.S. find femtocells¹ attractive and survey data confirms a long-held hypothesis that boosting in-home service coverage is the main driver of interest. Their study found that better coverage is twice as important as the next most important factor (enhanced online media streaming/ downloading) influencing purchase. If a femtocell product were available without any upfront costs but rather a monthly equipment fee, the willingness to pay for monthly equipment fee is approximately \$15/month (with +/-2.95% error at a 95% confidence interval)..

Further, the study of Nam et al. (2006b) investigated what wireless internet technology Korean consumers preferred on their mobile phone – Wi-Fi (public WLAN) versus cellular networks (3G) – and what features they value. Using a conjoint analysis approach, they tested attributes like technology, price, service and service coverage in a pairwise trade-off analysis. Their results indicate that Korean consumers consider speed and price more important than service coverage. Ahn (2001) estimated access demand for mobile telephone services in Korea and found that age, gender, and education are important determinants.

There is also research that shows that mobile subscribers consider the size of a particular network as an additional source of value. Birke and Swann (2005) and Kim and Kwon (2003) identified a strong relationship between individuals' valuations of the operator service and the number of its subscribers. Kim and Kwon (2003) argue that the network effects can be explained either by quality signalling or by price discounts for calls between people on the same network. Unfortunately, this hypothesis is not explicitly verified in Kim and Kwon's model, since price differences are not controlled for between on-net and off-net calls. Birke and Swann (2005) build on this by examining the network effect while introducing the interaction of price and network size into their model. The evidence of a pure network effect was found, which is independent of on-net price discounts.

In the current study, we focus on quantifying the value associated with elimination of rural mobile not-spot areas for the public who are being impacted, i.e. residents, local visitors, business in the not-spot areas and tourists who have travelled to not-spot areas.

3. Methodology

The HM Treasury Green Book recognises a number of different approaches for the valuation of non-market goods.² Mobile signal provision can be considered such a good: while consumers pay for

¹ Femtocell is a low-power cellular base station providing enhanced domestic mobile coverage indoors.

² See HM Government (2014).

mobile phone services, they do not pay for the provision of the signal directly. Moreover, there is no market for these goods in not-spot areas, because providing these services is not commercially viable. As a consequence, demand from people living in not-spot areas cannot be revealed except indirectly. In such cases, valuation methods rely on estimates of people's 'willingness to pay' (WTP) for a new good or service, inferred from their behaviour in a similar or related market. WTP is the amount individuals would be willing to pay for a good or service.

The market-based approaches consist of revealed preference (RP) or stated preference (SP) methods. Revealed preference approaches infer WTP from observed market choices, for example how much people are observed to pay for other products, such as femtocell products³ to obtain mobile phone services in a not-spot (see Wang 2010, for example). Stated preference approaches describe a hypothetical choice in a hypothetical market to infer WTP. Two approaches generally used under the banner of stated preference approaches are contingent valuation (CV) methods and discrete choice experiments (DCE). CV studies elicit WTP via direct questions such as 'What is the maximum amount you would be willing to pay for mobile phone services in your home location?' DCEs elicit values by presenting respondents with a series of alternatives and then asking which is most preferred.

For this study, we use an SPDCE for two reasons. Firstly, SPDCEs allow us to value different levels of mobile phone service provision, for example 2G, 3G and 4G services, which would be more difficult using CV approaches. Secondly, the construct of a choice experiment is less open to manipulation by respondents, and may therefore produce less-biased estimates of WTP than CV methods. Within the SPDCE framework, it is possible to investigate and quantify the importance of a range of drivers of consumers' choices (for example, how much their WTP depends on the quality of the service, ease of access, etc.).

In an SPDCE, hypothetical choice situations – in which each alternative is described by a set of attributes (for example, quality of mobile phone services, cost of these services, etc.) – are presented to each individual. Each of the attributes in the experiment is described by a number of levels. The attribute levels are combined using principles of experimental design to define different service packages, which respondents evaluate in surveys by choosing one of the alternatives within the choice set. When cost is included as an attribute, as in this study, values can be provided for each characteristic in terms of WTP, which provides a quantification of the user benefits.

Stated preference data have many useful statistical properties. For example, because the researcher controls the choices that are presented to respondents, correlation between explanatory variables, such as quality and price, can be reduced or limited. Also, a greater range of explanatory variables can be tested, which may not be possible in the real world. For example, we were able to test a wider range of costs than might be provided to people who live in not-spot areas. The technique is also data efficient: more than one choice scenario can be presented to each respondent within one interview. Its main drawback, however, is that such data are based around what individuals say they would do in hypothetical situations, not real world choices. Thus the results may be subject to the criticism that they may overestimate willingness-to-pay benefits because individuals do not actually

³ Femtocell is a low-power cellular base station providing enhanced domestic mobile coverage indoors.

have to make real payments. Careful design, ensuring that realistic choices are offered to respondents, can help reduce such biases.

The SPDCE was incorporated in a general survey, undertaken with residents and businesses in not-spot areas and visitors to not-spots areas. The survey and design of the SPDCE are described in further detail below.

3.1 Defining the SPDCE attributes and levels

The SPDCE was designed to explore respondents' WTP for a mobile signal in not-spot areas. In order to improve the realism of the choice experiments, and because WTP is likely to depend on the quality of the services provided, service quality attributes were included explicitly in the choice experiments, together with the associated cost. The complete set of attributes (and levels) tested in the choice experiment are summarised in Table 1.

Table 1 Summary of attributes and levels in the discrete choice experiment

Attributes and levels	
Distance to get mobile phone signal	There are parts of your local area that do not have a mobile phone signal. On average, you and others in the area need to travel 5 miles or more (more than 60 minutes walking or 15 minutes driving each way) to get a signal to make or receive calls.
	There are parts of your local area that do not have a mobile phone signal. On average, you and others in the area need to travel 1 mile (around 25 minutes walking or 5 minutes driving each way) to get a signal to make or receive calls.
	There are parts of your local area that do not have a mobile phone signal. On average, you and others in the area need to travel 1/2 mile (around 15 minutes walking each way) to get a signal to make or receive calls.
	There are parts of your local area that do not have a mobile phone signal. On average, you and others in the area need to travel 1/4 mile (around 8 minutes walking each way) to get a signal to make or receive calls.
	There are parts of your local area that do not have a mobile phone signal. On average, you and others in the area have to go outside the building, approximately 2 minutes walking, to get a signal to make or receive calls.
	There is a mobile phone signal in your local area, and people can make and receive phone calls and texts anywhere in the local area.
Quality	Weak signal, with occasional loss of service
	Strong signal
Services	You can make and receive calls and send texts, but do not have access to Internet services (voice-only 2G)
	You can make and receive calls and send texts, and get Internet access (Voice and data – 2G and 3G)
	You can make and receive calls and texts, and have access to FAST Internet access, allowing you to watch TV, films, etc. (Voice and high-speed data – 2G and 4G)
Prices	Price/month (residents, visitors (and home-run businesses who are visitors)): £50, £30, £20, £10, £5, £0
	Price/month (small businesses/resident home-run businesses): £80, £50, £35, £20, £10, £0
	Price/month (large businesses): £150, £80, £50, £25, £10, £0
	Price/day (tourists): £10, £7, £5, £2, £1, £0

Service quality has been reflected in three aspects presented in the first three rows in Table 1.

Ease of getting a signal: The value of having a signal within a home or business premise could depend on the ease of getting that service. In the SPDCE this is described by the distance (with travel time used as a proxy for this measure) that an individual would have to travel to get the signal. Respondents were asked to consider the average distance that individuals in the 'local area' would have to travel to get a signal.

Type of services that would be provided: It was judged that it would be informative to investigate the extent to which WTP for service provision is contingent upon the level of services provided. We therefore included an explicit attribute to describe the type of services that would be obtained, whether voice and basic data only (2G), voice and data (3G), or voice and high-speed data (4G).

Strength of the signal: Signal quality is explicitly incorporated in the experiments, described by a signal quality attribute including two levels: a weak signal, with occasional loss of service, and a strong signal.

The inclusion of price in the experiments was to facilitate computation of WTP (noting that it would be impractical for Mobile Network Operators to charge more in rural not-spot areas).

We followed the WTP calculation assumptions in the business case for the MIP which were based on the additional monthly price that individuals would be willing to pay for mobile services. These were approximated by the additional travel costs individuals would have to incur to access mobile phone services, or more specifically the average time spent walking per month multiplied by assumed values of time (£5/hour; the value of leisure time from the Transport Projects Guidance Webtag⁴). For consistency, we measured WTP in terms of an additional monthly price on top of current subscription fees. For residents who did not have a mobile phone, we provided information on the average subscription prices for having a mobile phone (£15/month⁵). For tourists, we presented the price on the basis of an additional cost per day, which is likely to be more realistic to tourists, and is conceptually similar to the idea of paying roaming charges for a short period when travelling.

Price levels were tested and refined through the pilot survey to ensure that we covered a wide range of possible values of WTP, ie that the range was high enough to mean that people were not always choosing the option with the best quality. A zero price level was also included to provide scenarios where individuals could indicate that they were not willing to pay.

3.2 Experiment design and presentation

Attribute levels were combined using an orthogonal experiment design⁶, resulting in 72 different combinations of attribute levels being considered across the sample⁷. Orthogonal blocking was then

⁴ See HM Government (2013d).

⁵ The real price of a basket of mobile phone services, based on average use in 2012 (in 2012 prices), was £14.10 (Ofcom 2013b).

⁶ Orthogonal refers to fact that the difference in levels of each attribute varies independently over choice sets, indicating that the levels of the attributes are independent of each other. For more details, refer to Louviere et al. (2000).

⁷ The same design was used for residents, businesses, local tourists and visitors. However, the levels of attributes for each segment are different.

used to split the scenarios into blocks for presentation to respondents. Each respondent was asked to consider eight different choice scenarios: nine different blocks were used. The blocking ensured that each respondent was presented with choices with variation in each of the attributes.

The SPDCE presented two ‘unlabelled’ alternatives, each described by the varying quality and price levels. A ‘neither’ option was included to allow consumers to indicate when neither option was acceptable. An example of a choice is shown in Figure 1 below.

Figure 1 Example of the choice scenario

	Option A	Option B
Mobile phone coverage	There is a mobile phone signal in the parts of the local area that you are visiting or travelling through, and people can make and receive phone calls and texts anywhere in the local area.	There are parts of the local area you are visiting or travelling through that do not have a mobile phone signal. On average, you and others in the area need to travel 1/2 mile (around 15 minutes walking each way) to get a signal to make or receive calls.
Service Quality where signal is available	Strong signal	Weak signal, with occasional loss of service
Mobile phone Service where signal is available	You can make and receive calls and texts, and get internet access (Voice and data - 2G and 3G)	You can make and receive calls and send texts , but do not have access to internet services (voice only 2G)
Payment for mobile phone services (on top of the mobile phone service charges)	extra £50 per month	No extra cost
<p>I would choose:</p> <ul style="list-style-type: none"> - Option A - Option B - Neither 		

In our survey we ask respondents to consider which hypothetical service they would prefer in their local area for their own general needs. As part of the background questions we investigated the most important reasons for needing a mobile phone (discussed in Section 4.2). As part of the In the introduction to the experiments we noted that provision of services would impact both making and receiving calls in the local area, but it was emphasised that they should concentrate on the value of the mobile phone service for themselves or their business only, and not to include the value others in the local area might put on it (to avoid double-counting).

4. Data collection and sample description

4.1 Data collection

The SPDCE was tested and refined by a pilot survey, undertaken in October 2013. The main survey was undertaken between November 2013 and January 2014. A total of 712 interviews were conducted amongst the four population groups of interest, as shown in Table 2.

Table 2 Number of interviews, by population segment

Segment	Target number of interviews	Achieved interviews
Residents in not-spot areas	300	302
Businesses in not-spot areas	100	102
Local visitors to not-spot areas	150	153
Tourists and out-of-area visitors to not-spot areas	150	155
Total	700	712

A database⁸ of areas for which no mobile phone signal was predicted was used to identify not-spot areas. The not-spots locations were converted into postcodes and phone numbers were attached to addresses using a database from ADMAR, a company providing telephone information. At the start of the survey, screening questions were also asked to determine whether the household was unable to obtain a mobile signal inside their home (residents) or able to receive a mobile signal inside their home but regularly/occasionally travel through or visit places in their local area where there is no mobile phone signal (local visitors).

Quotas were not applied to the sample due to lack of information regarding the demographic characteristics of those residing in or near not-spot areas. Instead, random sampling was adopted to obtain a sample of households representative of the demographic characteristics of people found within not-spot areas. To do this we selected households at random from the sample list, and then selected an adult within each household by asking to speak to the adult in the household whose birthday was next. By this means we aimed to randomly select the respondent in each household.

Businesses were randomly selected from the ADMAR list and, once contacted, screened to ensure they were within the scope of the research. The targeted respondent was the person within the company or organisation responsible for making decisions about procurement of telecommunications for the company – in this case the critical factor being purchase of mobile phone services.

Residents who ran businesses from home were incorporated in the resident and local visitor samples, a change made after the pilot survey, to ensure that these samples appropriately reflected employment levels in rural areas⁹.

The survey was undertaken by computer-assisted telephone interviewing (CATI) for the target households, businesses and local visitors. Respondents were contacted by phone, recruited and assigned to the appropriate segment, and then sent the show material for the choice exercise by post or email. Respondents were then re-contacted by phone to continue with the survey. Efforts were made to reduce sampling bias potentially caused by the telephone interviewing method (which

⁸ The database detailed coordinates that marked the bottom-left hand corner of 200 x 200-m squares across the UK where there are premises but none of the 2G operators predicts a signal strength of -86dBm or more.

⁹ A recent Office for National Statistics (ONS) report provides evidence of this, indicating that nearly 20% of people in employment in rural areas work from home or run a business from home, rising to 25% for both categories amongst people who live in sparsely populated areas (Pateman, 2011).

might over-represent older and unemployed residents), by calling during evenings and weekends as well as during the day and undertaking multiple call-backs to maximise the response from households where no answer was received at first contact.

An online survey was used to target tourists who in the past year had made a leisure and/or business trip outside their local area to a not-spot area. These respondents completed and submitted the questionnaire online.

4.2 Current mobile phone usage by survey segment

As part of the survey, respondents were asked about the communication devices they currently had access to, for personal or business use, and their usage. Table 3 summarises the findings for the different segments.

Table 3 Self-reported access and usage of communication devices, by segment

	Residents (n=302)		Local visitors (n=153)		Businesses (n=102)		Tourists (n=155)
	Residents (236)	Home-run business (66)	Local visitors -120	Home-run business (33)	Small* (56)	Large* (46)	
Access to the device							
Landline	99%	98%	99%	100%	96%	100%	90%
Mobile (personal use)	97%	92%	99%	85%	54%	54%	97%
Mobile (business)	14%	45%	18%	58%	34%	41%	19%
Computer broadband for VoIP service	52%	52%	50%	42%	32%	28%	57%
Average usage per day (minutes)							
Landline	28.1	40.8	25.4	37.5	n/a	n/a	14.5
Mobile (personal use)	14.8	14.3	20.7	24.3	n/a	n/a	29.7
Mobile (business)	22.5	25.1	33.3	42.1	n/a	n/a	54.8
Computer broadband for VoIP service	34.4	32.2	24.4	16.6	n/a	n/a	32.6
Monthly payment (£/month)							
Mobile (personal use)	13.5	20.1	16.6	23.6	28.9	27.6	18.7
Mobile (business)					39.7	77.7	

* Small businesses reflect those with less than 5 employees, large ones with 5 or more employees.

From the background questions, the most important reason cited by resident and local visitor survey participants for owning a mobile phone was dealing with potential emergencies – with almost 80 per cent of residents stating this to be the case, alongside over 60 per cent of local visitors. This was also one of the most important factors cited by businesses, with over 60 per cent of large businesses and 50 per cent of small businesses reporting that ownership of mobile phones was important to manage the safety of staff.

4.3 Socio-economic characteristics of the residents and local visitors segments

Statistics of the population in not-spot regions are not available for comparison with our survey sample. Therefore, the sample characteristics have been compared to 2011 census data¹⁰ in 'rural areas' and 'rural hamlet, sparse setting' locations. Table 4 shows the distribution of age and employment status for the sample of residents and local visitors compared to 2011 Census figures. The local visitors have an age profile only slightly older than the 2011 Census data for England; however, residents have a higher proportion of 60–74 year olds and lower number of young people. We note that qualitative work undertaken in conjunction with the survey suggested that young people are reluctant to live in not-spot areas and tend to move away when they can; this appears to be reflected in the age profile of the sample (Lu et al, 2015).

Table 4 Resident's and local visitor's age distribution and employment status

	Sample (%)		2011 Census (%)	
	Residents	Local visitors	All rural areas	Rural hamlet, sparse setting
Age distribution				
18–24	0	3	8	7
25–44	9	18	27	22
45–59	31	33	28	31
60–74	50	35	24	29
75+	9	11	12	11
Working status				
In employment/self-employed	51	63	64.7	65.9
Self-employed	22	22	13.9	25.2
Retired	43	30	18.1	19.6
Other	6	9	17.1	14.5

Although the sample contains a higher proportion of retired people than expected from census figures for rural areas, it is not clear that this is a result of under-sampling working people. In the local visitors segment, where the same sampling methodology was used, the proportion of employed people is very close to the 2011 Census data for rural areas. In addition, the proportion of self-employed people sampled in both residents and local visitors segments is close to that expected for remote areas. We conclude that there are two possible explanations for the proportion of older people in the sample. The first is that older people were more likely to participate in the survey and that older people are therefore over-represented in the sample. The second is that more elderly people may live in the particular not-spot locations that were sampled for the survey than in rural locations in general, and that this is accurately reflected in the sample. With regard to the first possibility we note that substantial effort was made to reduce the sampling bias potentially caused by the telephone interviewing method by calling during evenings and weekends as well as during the day, and undertaking multiple call-backs to try to maximise response from households where no answer was received at first contact. Moreover, the fact that both the resident and local visitor samples were obtained in the same way and that the same characteristic is not present in the local visitors sample suggests that older people may well be more likely to live in not-spot areas. However, if the sample *is* biased towards older people then the resulting average valuations will be underestimated (because we find that older people provide lower valuations for getting a signal in

¹⁰ Office for National Statistics 2011 Census.

their home if they currently can get a signal outside their house). But this impact will not be large (because we do not find differences in valuations for other distances to be travelled to get a signal).

4.4 Characteristics of the businesses segment

As noted earlier, business interviewees were recruited from a list of businesses in relevant postcodes. For the purpose of this study, businesses with five or more staff are categorised as large businesses, and the rest are categorised as small businesses. In terms of staff numbers, 25% of small businesses are sole traders (with only one member of staff) and 75% have two to four staff members. 48% of the large businesses have five to nine staff members; whilst 43% have between 10 and 49 staff members. The remaining large businesses (9%) have 50 or more staff.

Also, as noted earlier, respondents in the residents and local visitor segments who ran businesses from home were included in those segments in order to better represent their employment profile. Nearly 40% of respondents with home-run businesses in these segments had an annual turnover of less than £49,000. Also, nearly 40% are in an agriculture-related industry, and 15% of local visitor businesses operate in the area of wholesale, retail and repair of motor vehicles. The rest are scattered across various types of industries.

In summary, the businesses sampled in not-spot areas are relatively small in scale and mostly in the agriculture and accommodation industries. Their mobile phone access (as shown in Table 3) is relatively low compared to residents, although this is not the case when it comes to reliance on fixed telephony. For those who have access to a mobile phone, however, their usage and monthly payments also appear to be higher than those of other segments.

4.5 Characteristics of the tourists segment

Some 90% of the tourists in the sample stated they travelled for leisure. Most of them had a short stay in the not-spot regions: 35% stayed for less than one day; whilst another 35% stayed for one to three days. Some 64% were not aware that they were travelling to a not-spot area, prior to making their journey. Only 1% actively sought to find a place without a mobile phone signal.

5. Model estimation and results

5.1 Discrete choice models

Discrete choice models were developed from the experimental data. Discrete choice modelling provides an analytical framework to analyse and predict how consumers' choices are influenced by the characteristics of the alternatives and the characteristics of the people making the choices. The basic tenet of discrete choice modelling is utility maximization; that is, given a set of alternatives, people choose the alternative which brings them most utility.

Functions describing the utility of each choice alternative available to a consumer are therefore constructed, incorporating explanatory variables like price and service quality, multiplied by coefficients (β) that reflect the relative value of the terms, for example for a specific alternative (labelled j):

$$U_j = \beta x_j + \varepsilon_j. \tag{1}$$

where x is a vector of measured variables influencing the SPDCE decision task; β is a vector of unknown parameters (to be estimated); ε is the unmeasured error. In this study, the utility equations for the service alternatives reflect the characteristics of the specific hypothetical mobile services as presented in the choice experiment. The utility equation for the ‘neither’ alternative is described by a constant only.

Epsilon (ε) is the model error, which is assumed to follow a type I extreme value distribution, with errors distributed identically and independently (iid) for all alternatives and observations. The distributional assumptions of ε permit the derivation of a closed form expression for the choice probability, the multinomial logit model (Train, 2003), i.e.

$$P_{ni} = \frac{e^{\beta x_{ni}}}{\sum_j e^{\beta x_{nj}}}. \quad (2)$$

It is the model coefficients (β) that are estimated in the model estimation procedure, which assumes that each respondent chooses the alternative with the highest utility. The estimation can therefore be conducted within the framework of random utility theory, i.e. accounting for the fact that the analyst has only imperfect insight into the utility functions of the responding households and businesses. The standard statistical criterion of Maximum Likelihood is used. Both the values of the coefficients (in utility terms) and the significance of the coefficients are output (Ben-Akiva and Lerman, 1985).

5.2 Model estimation

In the study, multinomial logit (MNL) models have been developed. To ensure that the differences in errors are appropriately accounted between sub-segments within any population group (for instance, residents and home-run businesses in the residents segment), scale parameters are introduced (Daly & Bradley 1991). This approach best utilises all the choice data available. A scale parameter of 1 indicates equal level of errors, a value less than 1 for the segment indicates higher error in the segment and greater than 1 lower levels of error in the segment.

The model results for each segment are presented in Table 5 . Coefficients for categorical attributes, ie mobile searching distance, quality of service and level of service provided, are measured relative to a base level (explicitly shown in the tables, with estimate 0.000 and t-ratio ‘n/a’). Negative coefficients reflect attribute levels that are valued negatively relative to the base level; positive coefficients reflect attribute levels that are valued positively relative to the base level. Cost is included as a continuous variable and the coefficients reflect the (negative) utility for each cost increment. Each model also includes a constant on the ‘neither’ alternative.

In the choice experiments, the levels of mobile phone coverage varied from having a signal in the respondents’ house or business (‘with signal’) to having to travel ‘5 miles or more’ to obtain a signal. The best model formulation that described the impact of travel distance on the resulting WTP valuations reflects a combination of categorical and continuous variables to describe the impact of distance:

- The base level of service is the ‘with signal’ level, which reflects the presence of a signal in the respondent’s home or business (residents and businesses) or the local area they are visiting or the places they have travelled to (local visitors and tourists).

- The level of having to 'go outside' was coded as a categorical variable, reflecting the disutility of having to go outside to make or check for calls, measured relative to the 'with signal' level.
- A constant to reflect cases where respondents 'have to travel for signal' – which was applied to all levels with distances from 0.25 miles. This measures the disutility of having to travel at all, independent of the distance. A negative value for this constant reflects an aversion to travelling or willingness to pay to avoid travel.
- In addition to the constant, a continuous variable describes the additional disutility of having to travel longer distances to get a mobile signal, which is a function of the distance. A negative coefficient for this term reflects an aversion to travel further distances and determines the amount respondents are willing to pay to avoid travelling further distances to get a signal (the marginal rate per distance saved).

A key part of the model analysis was to investigate how choices and preferences regarding mobile phone services were influenced by the demographic characteristics of the respondents. Tests were undertaken to examine the impact of socio-demographic and other factors on the importance of service characteristics in the stated choices. However, the relatively small sample size in each population segment prevented us from being able to identify many significant effects. The characteristics that were examined in this investigation included: respondent's age, car ownership, gender, household size and structure, tourist's length of stay and size of business.

We also examined variations in price sensitivity. We found that residents and local visitors who ran home businesses were less sensitive to cost changes compared to others. However, the variation in cost sensitivity became less significant when age was included in the models, implying that the variation in cost sensitivity was largely explained by age.

Table 5 Discrete choice model results for each segment

	Residents		Local visitors		Business ¹¹		Tourists	
Mobile signal searching distance	Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio
With signal at home (reference)	0	n/a	0	n/a	0	n/a	0	n/a
Go out of building (under 65s)	-0.260	-1.9	0	n/a	0	n/a	0	n/a
Go out of building (over 65s)	0	n/a	0	n/a	0	n/a	0	n/a
Penalty for have to travel for signal (constant)	-0.444	-4.1	-0.272	-2.1	-0.344	-2.2	0	n/a
- Searching distance (per mile)								
- Under 65s	-0.087	-4.1	-0.101	-2.4	-0.114	-2.1	-0.058	-1.7
- Over 65s							-0.156	-1.8
Quality of service								
Strong signal	0.496	5.5	0.538	4.7	0.078	0.4	0.790	6.1
Weak signal (reference)	0	n/a	0	n/a	0	n/a	0	n/a
Level of service provided								
2G (reference)	0	n/a	0	n/a	0	n/a	0	n/a
2G + 3G (under 45)			0.424	2.2			0.531	2.5
2G + 3G (over 45)	0.060	1.0	0	n/a	0.1875	1.4	0	n/a
2G + 4G (under 45)			0	n/a			0.673	2.7
2G + 4G (over 45)			0	n/a			0	n/a
Cost (on top of monthly mobile cost)								
Cost ⁺	-0.044	-8.1	-0.061	-8.3	-0.022	-5.9	-0.311	-7.2
Other model parameters								
Neither constant (under 45s)	-0.697	-4	-1.885	-3.2				
Neither constant (over 45s)	-0.532	-3.1	-0.670	-3.5			0.246	1.8
Neither constant (pilot survey)					-0.224	-0.3		
Neither constant (main survey)					-1.090	-3.2		
Scale (home run business)	0.733	4.7	0.599	3.1				
Scale (large business, pilot survey)					0.464	2.6		
Scale(reference)	1	n/a	1	n/a	1	n/a		

+ For residents, local visitors and business, it is the monthly cost; for tourists it is daily cost.

In order to take account of the repeated nature of the SP data, a 'bootstrap' re-sampling procedure was applied to ensure that the standard errors and t-ratios produced by the models in Table 5 are a realistic statement of the true errors of the model parameters (Efron & Tibshirani 1993).

5.3 Willingness to pay for the mobile service

The ratio of the model coefficients quantifies the marginal rate of substitution between attributes. Moreover, the ratios of the service and price coefficients estimate consumers' WTP for service improvements, measured in £/month for residents, local visitors and businesses and £/day for tourists. Hence WTP can be estimated for each of the three service attributes: decreased distance to signal, improved signal strength and type of service.

The model results indicate that respondents in all segments were willing to pay to avoid travelling for mobile phone services, and the further they had to travel to get a signal, the greater their willingness to pay for local services. Residents and businesses in not-spot areas were willing to pay the highest amounts for having a signal at their house or business premises. Perhaps this is not be

¹¹ Due to the small sample size, the pilot survey data of the business segment is incorporated into the model development with a separate scale parameter allowing the different level of error variances across different data sets.

surprising, since people actually living or working on a daily basis within not-spots may be most affected by not having mobile phone coverage. Our analysis suggested that local visitors and tourists were willing to pay less to receive a mobile phone signal. This is summarised in Table 6.

Table 6: WTP for a mobile phone signal at home/business, by distance saved, for all segments

Mobile phone coverage	Residents (£/month)	Local visitors (£/month)	Businesses (£/month)	Tourists (£/day)
Coded as categorical variables				
With signal (reference)				
Go outside	6.00			
Have to travel constant	10.20	4.40	16.00	
Coded as continuous variables				
Searching distance (/mile)	2.00	1.60	5.30	0.20
				0.50

Respondents were also willing to pay for what they perceived to be a good-quality signal (measured relative to a 'weak' signal), and the provision of a high-quality signal is valuable to residents, businesses, local visitors and tourists. Residents show the highest WTP for mobile phone signal improvement at £11.40/month, followed by local visitors at £8.80/month, and business at £3.60/month. Tourists also show a substantial willingness to pay for a strong signal and are willing to pay £2.50/day for local mobile services at their destination with a strong signal

Respondents were willing to pay more for 3G and 4G services as shown in Table 7, but this was less important than access to a mobile phone signal *per se* and the quality of the signal. In general, 3G services were preferred to 2G services, although not by local visitors or tourists aged 45 years or older. Somewhat unexpectedly, we did not find 4G services to be valued more highly than 3G services, except among tourists aged less than 45 years. This may be because most people have not yet experienced 4G services and have yet to see the value of them. Thus we would expect these valuations to change in the future.

Table 7: WTP for service type, by segment (£/period)

Type of service provided	Age	Residents (£/month)	Local visitors (£/month)	Businesses (£/month)	Tourists (£/day)
2G (reference)					
3G	<45 years	1.40	6.90	8.70	1.70
	>=45 years		(same as 2G)		(same as 2G)
4G	<45 years	1.40	(same as 2G)	8.70	2.20
	>=45 years		(same as 2G)		(same as 2G)

In the following table we bring together the information across the different attributes for use in application to quantify the value of improving services in local not-spot areas. Table 8 summarises the WTP valuations for 2G services and their 90% confidence intervals. Valuations for 3G and 4G services are presented in the report (Lu et al, 2015). The WTP values depend on how far people currently have to travel to obtain a signal and the quality of signal at that location. Average

valuations are presented reflecting the average reported distanced travelled by respondents in our survey to get a signal.

The average WTP for residents in not-spot areas for local 2G services of the same quality of those available nearby is £12/month (+/- £4.10). It is emphasised that this is in addition to the amount that they would pay for a service contract. If the quality of signal is improved, relative to a weak signal nearby, residents would be willing to pay £23.40/month (+/- £5.10). The value of mobile phone services for local visitors to not-spot areas is £6.30/month (+/- £3.80), for the same quality of service, and £15.10/month (+/- £4.10), for improved services. The values for businesses are £20.90/phone/month (+/- £11.50) and £24.50/phone/month (+/- £14.00), for the same or improved services, respectively. We found that the values for tourists over 65 years old are higher than for those under 65, with tourists over 65 being willing to pay 40 pence per day (+/- £0.35) and those under 65 being willing to pay 20 pence per day (+/- £0.10) for mobile services of the same quality at their tourist destination, and £3.00/day (+/- £0.80) and £2.70 per day (+/- £0.70) for improved services, by age category respectively.

Table 8: WTP for local services by distance saved for travelling to get current services, by segment (£/period)

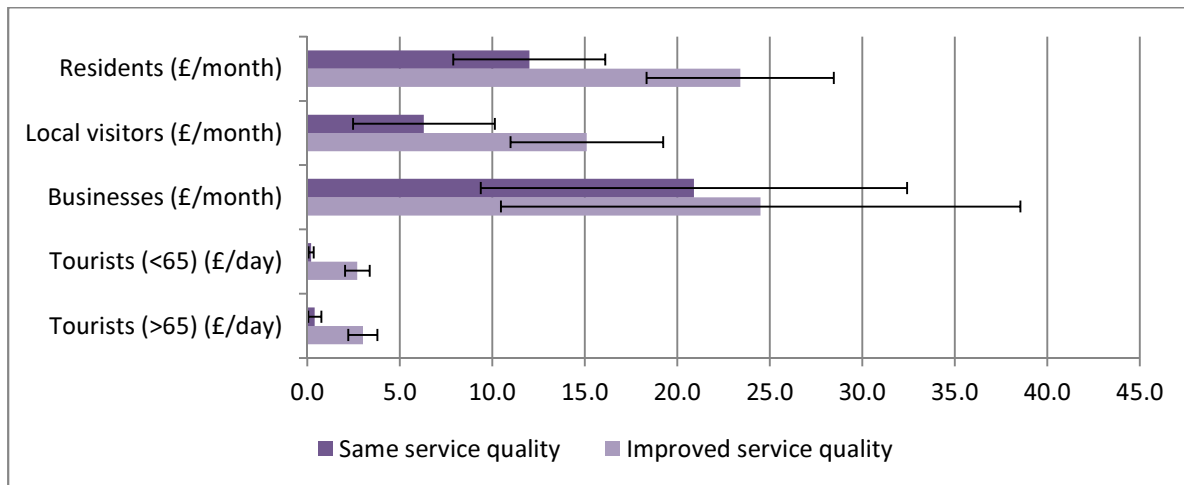
Segment (Observed distance to signal, miles)	2G (<65 years)		2G (>65 years)	
	Same signal quality	Better signal quality	Same signal quality	Better signal quality
Residents (d=0.92)	12.00	23.40	12.00	23.40
90% Conf. Interval	+/-4.10	+/-5.10	+/-4.10	+/-5.10
Local visitors (d=1.16)	6.30	15.10	6.30	15.10
90% Conf. Interval	+/-3.80	+/-4.10	+/-3.80	+/-4.10
Business (d=0.94)	21.00	24.50	21.00	24.50
90% Conf. Interval	+/-11.50	+/-14.00	+/-11.50	+/-14.00
Tourist (d=0.85)	0.20	2.70	0.50	3.00
90% Conf. Interval	+/-0.10	+/-0.70	+/-0.40	+/-0.80

* All valuations have been rounded to the nearest 10p

** The unit for residents, local visitors and business segments are £/month, whilst for tourists, the unit is £/day

The average valuations for each population segment and their 90% confidence intervals are summarised in the figure below.

Figure 2 Average WTP for local 2G services, for same quality and improved quality services, by population segment (with 90% confidence intervals)



We see higher levels of uncertainty in the WTP valuations for businesses, which reflect the lower sample sizes in the survey for these population segments relative to the resident and local visitors. There may also be more heterogeneity in the valuations for businesses. We also see a relatively large confidence interval for the tourist valuations for provision of values with similar service quality, particularly relative to the WTP valuation, which is small compared to the valuation for improved service quality.

6. Discussion and policy implications

The WTP valuations obtained from this study help us to understand the average value that residents and businesses located in not-spot areas, and local visitors and tourists to these areas place on being able to access a mobile service locally. We emphasize that the values obtained from this study reflect average values to individuals living, working or visiting not-spot areas to improve the mobile phone coverage in that area. They can be used to help quantify the social benefits of programmes aimed at providing or improving signal strength (quality) in not-spot areas. These benefits can then be compared to the costs of these investments to provide an assessment of the overall value of these investments. Environmental costs, including the visual impact of masts, should also be taken into account. These were not quantified in our research; however, evidence from the small in-depth samples of this study suggest that the visual impact of phone masts was not a major concern to local residents in not-spot areas and local visitors, this is an area where further research is required.

The WTP valuations for residents should be applied to the resident population of not-spots areas. Valuations for local visitors and tourists should be applied to those people making local or longer journeys to not-spot areas. WTP valuations for businesses provide estimates of the benefits of provision of mobile phone services to businesses and the local economy. These can also be compared with estimates of productivity loss, provided by businesses participating in this research.

Our research shows that the WTP for service improvements is influenced by a number of factors that will vary between different not-spot areas (as may the costs of providing new infrastructure).

One key factor influencing WTP is proximity of access to a mobile signal. We found that consumers are willing to pay to reduce the distance they have to travel to get mobile phone services. If we apply

these models to distances people currently travel to get signals, this implies that people in more remote or cut-off areas would be willing to pay more to save travelling these large distances for the provision of mobile services. However, if information on distances to current signal alternatives is not available, the average valuations from our sample can be used (on the basis that our survey is considered to be representative of not-spot areas in the country).

The WTP valuations also depend on the quality of the signal that individuals get at these (distant) locations compared to what is proposed for their local area. It is suggested that higher value can be placed on providing connectivity with high signal quality compared to low signal quality. Again, if information on the quality of signal for current mobile phone alternatives is not known when applying the valuations to quantify benefits, then we recommend that sensitivity tests using both valuations for similar service quality and improved service quality be undertaken.

We find WTP valuations to be influenced by the type of service available, with some respondents willing to pay more for 3G and 4G services. These results allow investigation of whether provision of high quality 3G and 4G services is economically justified. Interestingly, we did not find 4G services to be valued more highly than 3G services, except for tourists aged less than 45 years. This may be because when the survey was conducted most people would have not yet experienced 4G services and had not yet seen the value of such services. Thus we would expect these valuations to change if people start to experience the benefits of 4G, and perhaps 3G services, and would recommend that the WTP valuations be revisited periodically.

We present 90% confidence intervals for the estimates, and we recommend that sensitivity tests are undertaken when comparing the WTP benefits with costs, using the lower-bound estimates.

Finally, we also found some evidence, albeit from small samples, that young people find rural areas without a mobile phone signal less desirable to live in. This might suggest that the provision of mobile phone coverage may influence the future structure and sustainability of communities affected by not-spots. The impact of availability of mobile services on the structure of the economy may also be an important factor. This study found that even though local businesses had lower mobile phone ownership than not-spot residents, they too were willing to pay for local mobile phone services (£20.90/phone/month for 2G services of the same quality as current services and £24.50/phone/month for 2G services with improved signal quality). The study has not directly examined the extent to which availability of mobile services might affect both business performance and the types of businesses which can operate in remote and rural areas. However, this is potentially significant, and it is proposed that the availability of mobile services could be an important factor in ensuring diverse rural economies, and long-term sustainability of rural communities. This is an area that could both be further investigated in future research, and be monitored as a possible impact of new and improved mobile infrastructure services (such as 4G deployment).

7. Conclusions

The objective of the paper was to estimate the value associated with eliminating mobile not-spot areas. This arose from a concern that, despite measures to widen coverage, it is likely that complete not-spots will persist in isolated rural areas. Given the increasing use of mobile phones throughout the population and particularly by businesses, it was considered important to understand the range of costs and benefits to different groups, and society as a whole, from provision of mobile coverage in complete not-spot areas in rural locations within England.

A research approach was designed to address these issues using a mix of qualitative and quantitative methods to provide an estimate of the value of mobile telephony in mobile network not-spots. The specific questions that were examined quantitatively were the value to residents and businesses of obtaining coverage on existing networks, and the benefits to tourists and other local visitors who visit current not-spot areas. We found that the majority of people living in not-spot areas owned a mobile phone, the key reason being to deal with emergencies, both for residents and businesses. Businesses also cited communication with business partners, customers and colleagues as important reasons for using a mobile phone and also the main impact of not being able to use one. About half of the respondents from our survey, both from large and small businesses, indicated that being in a not-spot area had a negative impact on their profit, turnover and productivity. Although many found it difficult to estimate the size of this impact, there did seem to be a relationship between the size of the impact and the size of the business.

The stated preference discrete choice experiment that was carried out enabled the average willingness to pay for an improved mobile phone service to be calculated for the four different groups of interest: residents (including those with run home-run businesses, businesses, local visitors, and tourists). Three different service attributes were considered and it was found that all groups were willing to pay to avoid having to travel to obtain a signal. They were also prepared to pay a similar amount to have a strong signal but were less interested in having a better type of mobile phone service (3G/4G instead of 2G). In general businesses were willing to pay the most and tourists the least. Overall, using the average distance currently travelled by respondents in this survey, it was possible to calculate average willingness to pay for a set of combined improvements (for example a strong signal at home with 2G service). These values could then be used more generally to determine the benefits to not-spot users of a particular policy intervention.

Overall, qualitative research conducted in tandem supported the quantitative results, as well as informing opinion on the social and economic benefits resulting from improved connectivity. We found that the lack of a mobile phone signal may affect the long-term sustainability of rural communities by limiting employment opportunities. There was also limited evidence that, for some younger people, rural areas without a mobile signal were less desirable to live in. The visual impact of mobile phone masts was not found to be unimportant.

We emphasise several caveats to the study findings. Firstly, stated preference experiments may over-estimate willingness-to-pay valuations, and this should be recognised when using these values to quantify the benefits of proposed schemes. We would recommend that a range of values be quantified, using the 90% confidence intervals. Secondly, the valuations are relevant for those who live, work and travel to not-spot areas and cannot be used to calculate the value to society as whole of elimination all not-spot areas.

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