

Econometric modelling of  
broadband penetration in the UK

2006-2010

Non-Confidential Version

Report

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Professor John Nankervis

University of Essex

## 1. Introduction

This report presents findings from an analysis of a large data set on broadband uptake since LLU unbundling occurred in the UK. The aim of the study is to obtain estimates of the effects on the growth rate of BT's penetration in the presence of competing Communication Providers (CPs). I estimate growth rates in the penetration rates for BT at the wholesale and retail level and for other CPs and evaluate the sensitivity of these rates to the number of providers in each exchange. These estimates are obtained for Ofcom's current designated Markets 2 and 3 over time.

## 2. Data

The data set considered covers all UK exchanges; for 5558 exchanges we have data on up to 37 monthly observations from July 2006 to March 2010 for all LLU Communication Providers (CPs). The observations are irregular in that data is not available for all months; data is available for July, November and December 2006, January 2007, March 2007 and then monthly until October 2007, December 2007, January 2008, and then monthly from March 2008 until March 2010. ✕

For July 2006 to September 2007 the monthly observations for BT are obtained by cubic spline interpolation using quarterly IPstream and Datastream data for June 2006 to September 2007 and the monthly LLU data from October 2007 till June 2008. Figures 1 to 6 give plots of the numbers of LLU circuits in the UK from July 2006 to March 2010. From Figure 1, we see that the total number of LLU circuits is still gradually increasing but that the rate of increase has slowed down since June 2008. The total number of BT LLU circuits has stayed at approximately 8 million since July 2006. From Figure 2 we see there is growth for ✕ and ✕ and from March 2008 for ✕. Figures 3-6 show these growth effects in Markets 2 and 3. Figures 7 and 8 give the average penetration rates, the number of LLU circuits for each provider relative to the number of premises, over exchanges where each CP has a presence.

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### 3. Modelling methodology

The models considered are (logistic) diffusion models which take the form:

$$y_{it} = \frac{y_i^*}{1 + \exp(-a_i - b_{it}t)} \quad (1)$$

where  $y_{it}$  is the number of ‘circuits’ at exchange  $i$  at time  $t$  and  $y_i^*$  is the ‘saturation’ level. In this exercise  $y_i^*$  is taken to be the “number of premises” associated with exchange  $i$  so that

$y_{it}/y_i^*$  represents a ‘penetration ratio’. The  $a_i$  are referred to as ‘level’ effects and the  $b_{it}$  as diffusion growth effects. The above nonlinear functional form allows for possible S-shaped growth.

From the above model it can be shown that the growth rate in the number of circuits (and penetration ratios) is given by:

$$\frac{dy_{it}}{dt} \frac{1}{y_{it}} = \frac{d(y_{it}/y_i^*)}{dt} \frac{1}{(y_{it}/y_i^*)} = b_{it} \frac{y_i^* - y_{it}}{y_i^*} \quad (2)$$

and that

$$b_{it} = \frac{dy_{it}}{dt} \frac{1}{y_{it}} \bigg/ \left( \frac{y_i^* - y_{it}}{y_i^*} \right) \quad (3)$$

i.e.  $b_{it}$  is the growth in the number (penetration) of circuits in exchange  $i$  relative to the proportion of those who have not ‘adopted’ broadband at exchange  $i$ . We report estimates of these relative growth effects, from (3), together with estimates of the growth rates given by (2) where these latter estimates are evaluated at the mean of  $(y_i^* - y_{it})/y_i^*$ .

Transforming (1) above we obtain the following form that will be used for estimation,

$$\log \left( \frac{P_{it}^K}{1 - P_{it}^K} \right) = a_{it} + b_{it}t + v_i + \varepsilon_{it} \quad (4)$$

where we have added a term for unobserved heterogeneity,  $v_i$ , and an error term,  $\varepsilon_{it}$

and where

$P_{it}^K = y_{it}^K / y_i^*$  denotes the penetration ratio in exchange  $i$  at time  $t$  by communications

provider  $K$ .

We consider both Random Effects and Fixed Effects panel data estimation for model (4). Fixed Effects estimators provide consistent estimators of the parameters even if unobserved heterogeneity (across exchanges) is correlated with explanatory variables; Random Effects estimators are consistent only when there is no such correlation and can also provide estimates of effects of time-invariant variables such as the Social Class variable we consider in our models below.

#### 4. Models estimated across Markets 2 and 3 using data from July 2006 to March 2010.

The first models estimated are specified as:

$$\log\left(\frac{P_{it}^K}{1-P_{it}^K}\right) = a_i + b_i TR_t + v_i + \varepsilon_{it}$$

$$a_i = \alpha_1 + \alpha_2 M3_i + \alpha_3 SC\_AB_i + \alpha_4 SH\_VM_i \quad (5)$$

$$b_i = \beta_1 + \beta_2 M3_i$$

where:

$$P_{it}^K = \frac{y_{it}^K}{y_i^*}, \text{ penetration in exchange } i \text{ at time } t \text{ by communications provider } K,$$

$y_{it}^K$  = number of LLU live circuits in exchange  $i$  at time  $t$  [combined MPF and SMPF data on LLU circuits, except for BT Wholesale for 25/07/2006 to 1/10/2007 where we use combined DS and IPS data]

$y_i^*$  = number of premises in exchange area  $i$ ,

$$K \in \{BT, CPW, O2, Sky, Org, CW\}$$

$TR$  = Time trend (in years)

$SC\_AB_i$  = proportion of residents in Social Class AB in exchange area  $i$  (Jun 2009),

$SH\_VM_i$  = penetration rate of number of Virgin Media cable subscribers (000s) in exchange area  $i$  (June 2009).

$M3_i = 1$  if exchange  $i$  is in Market 3, otherwise  $M3_i = 0$ .

The dummy variable  $M3$  is included in the models to allow for estimation of differential level and growth effects across markets 2 and 3. The model is estimated for cases where  $0 < P_{it}^K < 1$ .

Table 1 reports results for Model (5) above. A Random Effects estimator was used to enable estimation of the coefficients of the time-invariant  $SC\_AB$  and  $SH\_VM$  variables. Fixed effects estimation produced very similar results for the other coefficients. The coefficients of  $TR$ ,  $\hat{\beta}_1$ , (e.g.  $\Sigma$  for BT) give the relative growth effects in Market 2. The sum of the coefficients of  $TR$  and  $TR \times M3$ ,  $\hat{\beta}_1 + \hat{\beta}_2$ , ( $\Sigma$  for BT) give estimates of the relative growth effects in Market 3.

Growth rates given by equation (2) above are calculated by multiplying the relative growth effects by the mean of  $(y_i^* - y_{it}^K) / y_i^* = 1 - P_{it}^K$  and are reported in the last two lines of the table. We see that all estimated growth rates are positive, apart from BT in market 3 where there is an estimated decline of  $\Sigma\%$ . All other CPs have much higher growth rates than BT in both Markets. The largest growth rates are those for  $\Sigma$  – which has had steady growth from a very low base. Also note that the penetration rate of Virgin Media has a strongly significant negative effect on the level of customers for  $\Sigma$  and  $\Sigma$ . The proportion in Social Class AB has a positive effect on all CPs except for  $\Sigma$ .

In order to estimate the effect of the presence of the two largest LLU competitors on the growth rates in BT's number of circuits I have estimated the model:

$$\log\left(\frac{P_{it}^{BT}}{1 - P_{it}^{BT}}\right) = a_{it} + b_{it}TR_t + v_i + \varepsilon_{it}$$

$$a_{it} = \alpha_1 + \alpha_2 DSKY_{it} + \alpha_3 DCPW_{it} + \alpha_4 DSKY_{it} \times DCPW_{it} + \alpha_5 SC\_AB_i + \alpha_6 SH\_VM_i \quad (6)$$

$$b_{it} = \beta_1 + \beta_2 DSKY_{it} + \beta_3 DCPW_{it} + \beta_4 DSKY_{it} \times DCPW_{it}$$

where :

$DSKY_{it} = 1$  if SKY is operating in exchange  $i$  at time  $t$ , zero otherwise.

$DCPW_{it} = 1$  if CPW is operating in exchange  $i$  at time  $t$ , zero otherwise.

The effect of introducing these dummy variables is that, for example, when CPW has LLU circuits in exchange  $i$  at time  $t$  (but Sky does not), the relative growth effect on BTs number of circuits (and penetration) is given by  $b_{it} = \beta_1 + \beta_3$ . When both SKY and CPW are present

the relative growth effect is given by the sum of all four growth variables ( $b_{it} = \beta_1 + \beta_2 + \beta_3 + \beta_4$ ). Results are reported in Table 2 and show that the effect on BT's growth rate of having Sky as a competitor is to reduce the growth rate to  $\times$  and  $\times$  in Markets 2 and 3 respectively. With  $\times$  (only) as a competitor, there is a stronger effect. The growth rates for BT are reduced to  $\times$  and  $\times$  (negative growth rates). With both as competitors the growth rates become  $\times\%$  and  $\times\%$  in Markets 2 and 3.

**Table 1:** Estimated Penetration for all LLU CPs in Markets 2 and 3, July 2006 – March 2010

<i>Dependent Variable</i>	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$	$\log\left(\frac{P_{it}^{CPW}}{1-P_{it}^{CPW}}\right)$	$\log\left(\frac{P_{it}^{SKY}}{1-P_{it}^{SKY}}\right)$	$\log\left(\frac{P_{it}^{ORG}}{1-P_{it}^{ORG}}\right)$	$\log\left(\frac{P_{it}^{O2}}{1-P_{it}^{O2}}\right)$	$\log\left(\frac{P_{it}^{CW}}{1-P_{it}^{CW}}\right)$
<i>Location Variables</i>						



**Table 2:** Estimated Penetration for BT in Markets 2 and 3, July 2006 – March 2010

	Market 2	Market 3
<i>Dependent Variable</i>	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$
<b><i>Location Variables</i></b>		
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### 3. Estimation using data from October 2008 to March 2010.

Since September 2008 monthly data on a consistent basis is available for BT as well as the other CPs. For this period we also have data on BT Retail sales. I re-estimated the model set out in (6) above over this reduced sample period for both BT Retail and BT Wholesale. The results are given in Table 3.

The base growth rates are higher for BT Retail compared to the rates for BT Wholesale.

$\alpha$  no longer has a stronger effect on BT Wholesale's share than  $\beta$  does. For BT Retail the entry of either  $\alpha$  or  $\beta$  reduces BT's share by around  $\alpha$  % in Markets 2 and 3. If both  $\alpha$  and  $\beta$  are competitors, the overall growth rate for BT Wholesale is  $\alpha$  and  $-\beta$ ; very close to the  $\alpha$  and  $\beta$  estimates obtained using the whole data period from July 2006. This suggests that competition is not weakening in its impact over time.

**Table 3:** Estimated Penetration for BT Wholesale and BT Retail in Markets 2 and 3, October 2008 – March 2010

Dependent Variable	BT WHOLESALE		BT RETAIL	
	Market 2	Market 3	Market 2	Market 3
	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$

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### 3.2 Estimation of effects of number of competing CPs.

Rather than use current definitions of Markets 2 and 3, it is of interest to investigate the effect on the growth of BTs number of circuits (penetration) in both the Wholesale and Retail markets with respect to the number of competing CPs. I have estimated the model:

$$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right) = a_{it} + b_{it}TR_i + v_i + \varepsilon_{it}$$

$$a_{it} = \omega + \sum_{K=0}^5 \alpha_K SK_{it} + \alpha_6 SC\_AB_i + \alpha_7 SH\_VM_i \quad (7)$$

$$b_{it} = \sum_{K=0}^5 \beta_K SK_{it}$$

where

$SK_{it} = 1$  if there are  $K$  LLU competitors to BT in exchange  $i$  at time  $t$ , otherwise  $SK_{it} = 0$  ( $K = 0, 1, 2, 3, 4, 5$ ).

The coefficients  $\beta_K$  directly give the (relative) growth effect on BT's number of circuits (penetration) of there being  $K = 0, 1, \dots, 5$  competing LLU providers. I have also done separate estimations over exchanges where Virgin Media (VM) is present - VM presence is represented by the number of cable subscribers in exchange  $i$  in June 2009. Estimates for the latter case are given in columns 2 and 4 of Table 4. I also consider the effect on BT's penetration when model (7) is estimated over exchanges that either satisfy or do not satisfy Ofcom's 65% threshold for the presence of Virgin Media in an exchange area. Table 6 reports the growth rates for the estimation results reported for model (7) in Tables 4 and 5.

Note that Growth Rate Effects refers to the the coefficients  $\beta_K$  discussed above and the impact on the penetration rate (equivalent to volume growth) is shown below in the Table (Growth Rates).

**Table 4:** Estimated Penetration for BT in Exchanges with and without Virgin Media presence, October 2008 – March 2010

BT WHOLESALE		BT RETAIL	
with Virgin Media present		with Virgin Media present	
Dependent Variable	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$
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**Table 5:** Estimated Penetration for BT in Exchanges which either are all below or all above Ofcom's 65% Virgin Media presence threshold; October 2008 – March 2010

BT WHOLESALE		BT RETAIL	
All Exchanges Below VM 65% threshold	All Exchanges Above VM 65% threshold	All Exchanges Below VM 65% threshold	All Exchanges Above VM 65% threshold

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**Table 6:** Growth Effects of Virgin Media presence on BT Wholesale and BT Retail Penetration, October 2008 to March 2010

Number of LLU CPs competing with BT	BT Wholesale		BT Retail		BT Wholesale		BT Retail	
					All Exchanges Below VM 65% threshold	All Exchanges Above VM 65% threshold	All Exchanges Below VM 65% threshold	All Exchanges Above VM 65% threshold
	All Exchanges	with Virgin Media	All Exchanges	with Virgin Media				
Relative Growth Effects								

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From the results reported in column 2 of Table 6 we see that for BT Wholesale, the estimated growth rate of ✂ is reduced ✂ % when one CP enters market and the first entrant has the largest impact. The effect of a second entrant is to reduce the growth rate to ✂ Further entrants have minor effects on growth rates. For exchanges where Virgin Media is present the base level of the growth rate in BT Wholesale's share is %; with one entrant this reduces to %✂. With two entrants this reduces to ✂ The base growth rate of ✂ % for BT Retail over all exchanges is larger than that for BT Wholesale and this reduces to %✂ in exchanges where Virgin Media is present. Further entrants after the second again have a small effect on the growth rates. Similar results for BT Wholesale and BT Retail are obtained when I estimate the models in cases where exchanges are either all below or all above the VM 65% threshold.

Tables 7 and 8 report results obtained for BT Wholesale when the sample period used for estimation is the earlier period of July 2006 to September 2008.

**Table 7:** Estimated Penetration for BT Wholesale, July 2006 to September 2008 with effects of presence of Virgin Media in exchanges.

BT Wholesale				
Dependent Variable:	All Exchanges		All Exchanges	
	Below VM		Above VM	
	65% threshold		65% threshold	
	All exchanges	with Virgin Media	All exchanges	with Virgin Media
	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$	$\log\left(\frac{P_{it}^{BT}}{1-P_{it}^{BT}}\right)$

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**Table 8:** Growth Effects of Virgin Media's presence on BT Wholesale Penetration, July 2006 to September 2008.

Number of LLU CPs in exchanges	BT Wholesale		
	All exchanges	with Virgin Media	All Exchanges Below VM 65% threshold All Exchanges Above VM 65% threshold
Relative Growth Effects			

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Comparing the results in Table 8 with the first 4 columns of growth rates in Table 6, we see that, as expected, the base growth rate is higher in all cases and that the effect of more entrants on BT's penetration is more variable.