



# Invention, Innovation and Diffusion of Local Loop Unbundling in the UK

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## Abstract

A “reference offer” for Local Loop Unbundling was first published in the UK in December 2000, but by the end of 2005 just 2% of competitive copper access lines used LLU, compared with 56% in France. In 2005 Ofcom, introduced policy changes to commercialise LLU, which has increased to around 70% of competitive copper access lines. This paper measures the impact of Ofcom’s policy changes and concludes that these policy changes induced both the innovation and diffusion of LLU. The paper concludes that it is insufficient for regulators simply to mandate access: they must also ensure commercially attractive, non-discriminatory terms.

## 1 Introduction

An entrant in the telecoms market that does not own a local access network requires access to the incumbent’s local loop (the copper-based connection between a telephone exchange and the customer premises) to connect to customers. There are three primary forms of such access: Resale Access (RA), Bitstream Access (BA) and Local Loop Unbundling (LLU): collectively referred to in this paper as ‘Competitive Copper Access’ (CCA). An entrant using RA or BA faces low barriers to entry but has little opportunity to differentiate its product from the incumbent as it is dependent on the incumbent for its service parameters, in particular the access speed. An entrant using LLU faces higher barriers to entry, as it needs to invest in its own equipment to prepare the unbundled loop for broadband access, but does have the opportunity to differentiate its product. LLU can, therefore, be considered superior to RA or BA as the entrant can compete across more dimensions and pose a stronger competitive threat to the incumbent<sup>1</sup>.

Until 2005, the proportion of all forms of CCA in the UK accounted for by LLU lagged behind comparable EU countries, despite becoming available to Internet Service Providers (ISPs) at about the same time, in December 2000. By the second quarter of 2005 LLU accounted for just 2% of CCA (LLU:CCA) in the UK compared with 56% in France. In 2004/2005, the UK regulator for electronic communications markets (Ofcom) introduced a number of policy reforms, specifically “functional separation” along with LLU price cuts to try to increase the take-up of LLU. These policies appear to have been successful as by 2011 LLU had risen to 70% of CCA: a level

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<sup>1</sup> Opal Networks (2006) discusses in general terms the economics of entry via LLU and BA. They describe BA as needing “no capital investment” and having Opex of £18.90 per month per user. They state that the cost of installing an MSAN (“the main piece of infrastructure required to unbundle”) capable of supporting LLU 500 lines as £50,000, with a monthly Opex of £9.70 - £11.20 per user depending on the number of lines.

comparable to that found in France. Using the language of Schumpeter (see Section 2 below), whilst LLU may have been “invented”<sup>2</sup> prior to 2005, it was only after Ofcom forced its hand that BT “innovated” LLU and made it a commercially attractive offer.

Despite this increase in the take-up of LLU, there has been debate as to how effective Ofcom’s policy changes were, and which policy change had the stronger effect (Waveman and Dasgupta 2007, Amendola et al 2007, Whalley & Curwen 2008). Three broad assessment of the impact of Ofcom’s policies can be identified:

- i) That functional separation was essential to encouraging investment in LLU;
- ii) That the price reduction was the key policy; and
- iii) That the take-up of LLU would have happened regardless of policy initiatives by Ofcom.

This paper draws on Schumpeter’s (1942) distinction between invention, innovation and diffusion to explore whether Ofcom’s policy interventions induced the innovation of LLU in the UK, which then diffused through the market.

The paper is organised as follows: Section 2 introduces the concepts of innovation, diffusion and induced diffusion through a brief summary of some of the key literature. Section 3 presents some data on the diffusion of Local Loop Unbundling as a proportion of Competitive Copper Access in the UK and the other four of the five largest (pre-2004) EU Member States (EU5). Section 4 discusses the economic decision of an entrant to invest in either LLU or another form of CCA. Section 5 briefly summaries the policy responses to discrimination in the UK. Section 6 presents a model of induced diffusion of LLU in the UK and Section 7 concludes.

## **2 Literature Review: Innovation, Diffusion and Induced Diffusion**

Schumpeter (1942) distinguishes three stages in the process by which a new technology permeates the market.

- i) *Invention* is the initial development of a new product process
- ii) *Innovation* is accomplished only when the new product or process is commercialised and made available to the market
- iii) *Diffusion* is the adoption by firms or individuals of the new product or process.

In this Schumpeterian sense, innovation means the commercialisation of an invention and the cumulative economic impact of a new technology results from all three stages of the process (Jaffe et al 2002). Ruttan (1959) points out that Schumpeter emphasised that invention without innovation produces no economically relevant effect. Throughout this paper the term innovation will be used to mean the

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<sup>2</sup> LLU was not invented in any sense by BT, but was a regulatory requirement developed the European Union. The point here is that LLU existed in the UK before it was commercialised.

process of turning an invention into an economically relevant, commercial proposition.

Once the entrepreneur has innovated, i.e. commercialised an invention, the product diffuses through the market. The diffusion of innovations has been widely studied (Griliches 1957, Rogers 1962, Bass, 1969, and Davies 1979). The essence of diffusion is that an innovation is adopted by a market at a rate proportionate to the existing number of users and the maximum number of potential adopters of the technology. It can be simply expressed as:

$$Pen_t = \frac{Pen^*}{1 + e^{-(a_t + b_t t)}}$$

Where  $Pen_t$  is the penetration of an innovation at time  $t$  and  $Pen^*$  is the ceiling or equilibrium penetration of the innovation. The coefficient  $a$  shifts the diffusion curve forwards or backwards without changing its shape and  $b$  is the rate of change of the slope at a given time.

Geroski (2000) provides a particularly useful review of the literature and refers to four types of diffusion model: epidemic, probit, legitimation & competition and information cascades.

The basic premise of the epidemic model, the type most appropriate to this paper, is that information diffusion drives technology diffusion. A small group of early adopters of a new technology must first acquire their information from a central source before word of mouth spreads experience and knowledge of the new technology through the rest of the potential user population. At first there is a small proportion of the population who adopt the new technology but the number of users increases rapidly until information is nearly universal at which point further adoption slows. This pattern of knowledge diffusion leads to the 'S' shaped curve, and indeed to the asymmetric curve as the later stages of diffusion occur more slowly than would be predicted by a symmetric curve.

A distinction can be made between intra-firm and inter-firm diffusion (Mansfield 1963, Battisti and Stoneman 2003, 2005). *Inter-firm* diffusion refers to the adoption of a technology by different firms, whilst *intra-firm* diffusion refers to the intensity of use by individual firms. Assuming a profit driven model of diffusion, Battisti and Stoneman (2005) point out that technology use in any given period will only extend to the point where the marginal expected profit gain from the new technology equals the cost of adoption.

Gruber and Verboven (2001) were among the first to apply diffusion to the telecoms sector in a study of the mobile market and the impact of digital technologies on the diffusion of mobile, with a development of Griliches' (1957) logistic model. The Gruber and Verboven model has been adapted and developed by Li and Lyons (2011) to estimate the effect of competition, market entry and independent regulation on the diffusion of mobile telephony.

Denni and Gruber (2006) and Lee and Brown (2008) apply diffusion techniques to the broadband market: the former to explore the role of competition and the latter to examine the effects of different Local Loop Unbundling (LLU) policies on the diffusion of broadband.

Denni and Gruber find that inter-platform competition is more conducive to driving broadband diffusion than intra-platform competition, i.e. competition between, say, cable and copper is more important than competition on the copper platform. Lee and Brown apply Gruber and Verboven's (2001) logistic model of mobile penetration and use the OECD as their sample. The effects of policy variables, specifically the forms of LLU (fully unbundled loops, shared access, and bitstream access<sup>3</sup>) in each country, are included in their regression as dummy variables. They also include a broad range of non-policy variables. They find that all three types of LLU policy variables have a statistically significant effect on broadband penetration at the 1% level.

The theory of diffusion has been taken forward by the study of "induced diffusion" (Jaffe et al 2002). The principle behind induced diffusion is that policy makers wish to see either a higher ceiling, or equilibrium level, of adoption of a technology or a more rapid take-up of that technology. Diaz-Rainey (2009) defines induced diffusion as:

*Any intervention that aims to alter the speed and/or total level of adoption of an innovation by directly or indirectly internalising positive and/or negative externalities.*

Interventions aimed at inducing diffusion are usually mandated, or at least inspired, by government or independent regulators and, in the final analysis, all such interventions are aimed at incentivising individuals and businesses to alter their choices by altering the economic attractiveness of one option over another (Diaz-Rainey 2009).

Induced diffusion has particularly been widely researched in the energy sector where governments have sought to promote environmentally "friendly" technologies, such as wind energy. Jaffe et al (2002) set out two questions in relation to emission reduction technologies. First, what is the theoretical and empirical potential for induced diffusion? Specifically, how do policy instruments that increase the economic incentive to reduce emissions affect the diffusion rate of these technologies? Secondly, how have market failures in the energy and equipment market limited diffusion?

The second of Jaffe et al's questions has been addressed in relation to LLU elsewhere (Cadman 2010). This paper addresses their first question by examining the effects that policy instruments had on the innovation *and* diffusion of Local Loop

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<sup>3</sup> Bitstream access is not normally regarded as a form of Local Loop Unbundling. Although Lee and Brown regard it as one, bitstream is not considered a form of LLU for this paper, in line with normal usage.

Unbundling in the United Kingdom. The choice of broadband access via LLU or BA<sup>4</sup> is not made by the consumer but by the Internet Service Provider (ISP) who provides one or other (but not usually both) access method in a telephone exchange area, of which there are some 5,500 in the UK. ISPs have not changed-over all telephone exchanges at once from BA to LLU, but rather have done so over time, and so diffusion of LLU has the characteristics of intra-firm at least as much as inter-firm diffusion. The evidence of take-up in the early period of the market appears to suggest that first experience of the provision of LLU hindered its diffusion. This paper seeks to identify whether the policies adopted by Ofcom in 2004-2005 induced the innovation (in the Schumpeterian sense) of LLU as much as a change in the rate of the diffusion of LLU as a proportion of CCA.

### 3 Invention, Innovation and Diffusion of LLU

Local Loop Unbundling was not invented in the traditional sense: that is there was no private inventor that created a new idea with the hope of either commercialising it himself or having someone else commercialise it. Rather LLU was “invented” by policy makers as a means of introducing competition into the telecoms sector that was dominated by vertically integrated incumbents. In the European Union, LLU could be regarded as having been invented by the European Parliament and Council in the “LLU Directive”<sup>5</sup>. The Directive required “notified operators” (primarily incumbents) to “publish from 31 December 2000, and keep updated, a reference offer for unbundled access<sup>6</sup> to their local loops and related facilities” (Article 3). The intention of this Directive was to allow new entrants to access just the copper loop that connects customer premises to the local exchange. The entrant would then be able to install its own equipment in the exchange to provide broadband access with different product characteristics from those of the incumbent. Not all notified operators met the deadline for publishing a reference offer, however, and Table 1 shows the date of publication of a reference offer in the five largest EU Member States (EU5) along with the launch date of a retail DSL product.

**Table 1: LLU Reference Offer Implementation Dates**

	Full LLU*	Shared Access*	Retail DSL**
France	16 July 2001	16 July 2001	November 1999
Germany	11 April 2000	Not published	August 1999
Italy	5 January 2000	Not published	December 1999
Spain	21 January 2001	21 January 2001	1999
UK	31 December 2000	31 December 2000	July 2000

\*Source: European Commission 2001, Annex 2.1, Table 1

\*\*Source: OECD (2001) Table 1

<sup>4</sup> From hereon “BA” will be used to include both BA and RA.

<sup>5</sup> REGULATION (EC) No 2887/2000 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of on unbundled access to the local loop

<sup>6</sup> Sometimes referred to as a Reference Unbundled Offer (RUO), this is a standard set of terms and conditions under which regulated services are provided to competitive communications providers.

If LLU was invented, in the Schumpeterian sense, by the LLU Directive of December 2000, then the beginnings of its innovation occurred between December 2000 and July 2001 with the publications of reference offers. However, as Ruttan (1959) pointed out, Schumpeter considered that an economically relevant effect is necessary for an invention to become innovation.

An economically relevant effect can be measured in the share LLU has of all broadband access lines and as a proportion of CCA. Figure 1 compares the proportion of CCA and all retail Broadband Access (BBA) accounted for by LLU as at July 2005, across the EU5. It is clearly visible that the UK lagged behind the other major economies of the EU at that time on both measures of the economic relevance of LLU.

The situation in Germany was something of a special case as when Deutsche Telekom's network was first opened to competitive access there was no bitstream product, only LLU. Until the start of 2005, therefore, all competitive access lines based in DT's network used LLU. The remaining three countries (other than the UK) all started with both LLU and bitstream access.

**Figure 1: Proportion of LLU to CCA, EU5, 2005**

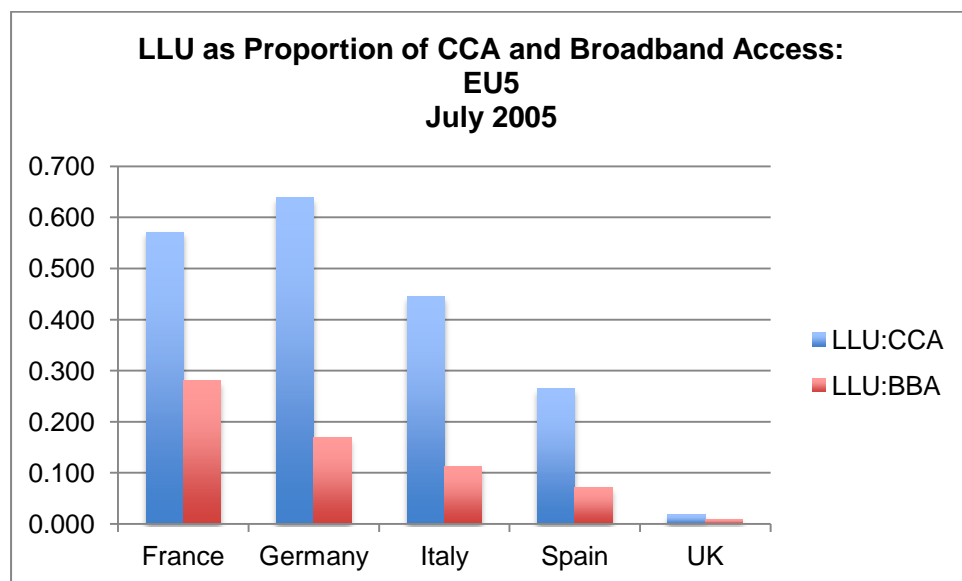
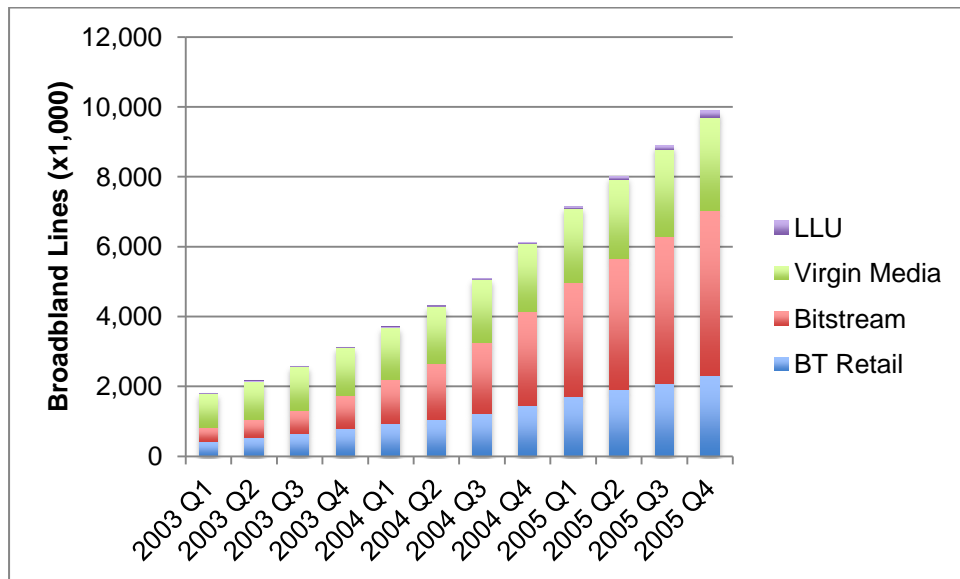


Figure 2 shows the growth in the number of broadband lines by technology in the UK from 2003 to the end of 2005. As can be seen, LLU had a very small share of the market.

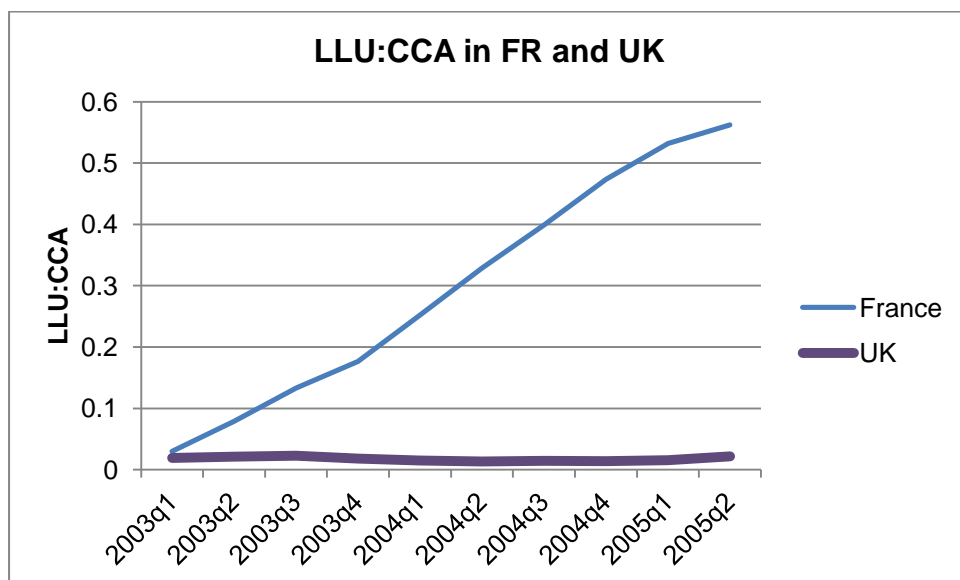
**Figure 2: UK Broadband Market Structure 2003 - 2005**



Source: Ofcom

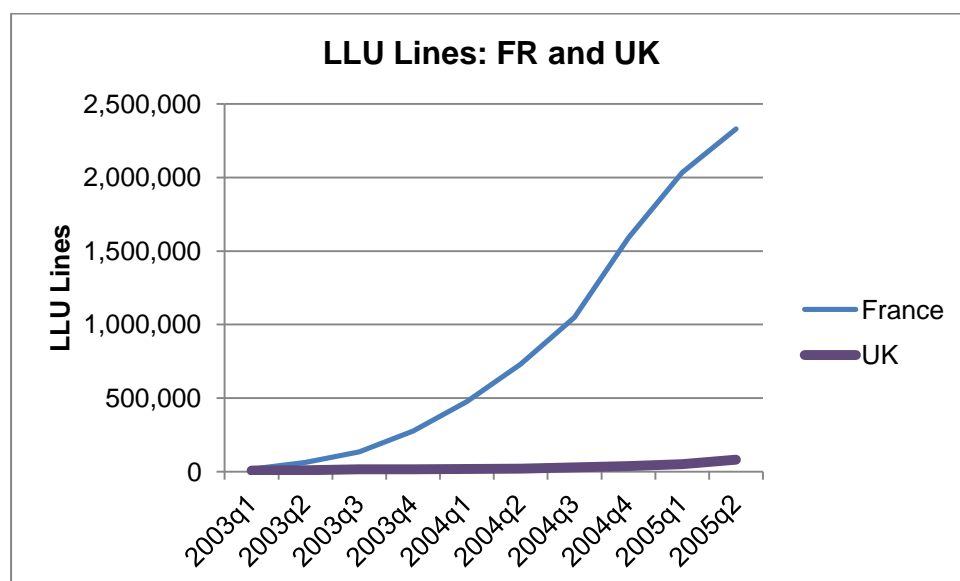
Figures 3 and 4 show a more detailed comparison between the rate of diffusion of LLU in France and UK over the period 2003 to 2005. Figure 3 shows the rate of diffusion of LLU:CCA in France and the UK and Figure 4 shows the absolute number of LLU lines in the two countries. It is quite clear from these graphs that LLU not only grew more rapidly as a proportion of CCA in France, but also in absolute numbers. By the middle of 2005 there were nearly 2.5 million LLU lines in France compared with fewer than 100,000 in the UK.

**Figure 3: LLU:CCA in France and UK**





**Figure 4: Total LLU Lines, FR and UK, 2003 - 2005**



Equations 1 and 2 below show the results of simple regressions of LLU:CCA against time and the square of time (denoted ' $T$ ' and ' $T^2$ ') in the two countries, with T-stats in brackets underneath the coefficients. Unsurprisingly, the coefficient on time in France is strong and significant (at 1%), and the  $R^2$  indicates that  $T$  and  $T^2$  explain nearly all of the change in LLU:CCA over the period. In the UK the coefficients on  $T$  and  $T^2$  are significant, but the low  $R^2$  suggests that this simple model does not have a strong explanatory effect over this period.

$$(1) \quad LLU:CCA_{FR} = -0.04 + 0.06T + 0.0004T^2$$

(-2.0) (7.0) (0.6)  $R^2 = 0.99$

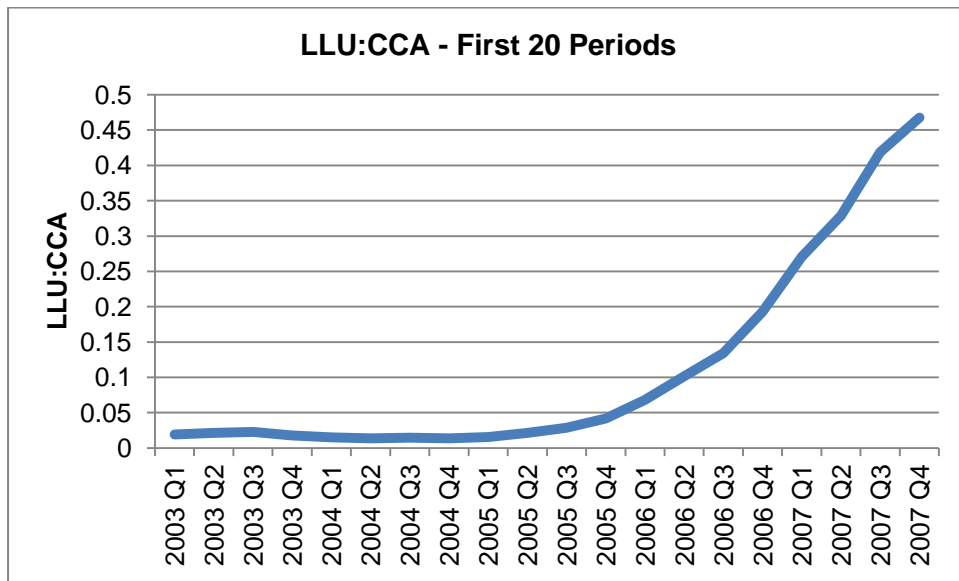
$$(2) \quad LLU:CCA_{UK} = 0.02 - 0.003T + 0.0003T^2$$

(7.8) (-2.45) (2.16)  $R^2 = 0.36$

If an economically relevant effect can be measured by the impact that LLU had on the structure of the broadband market, then quite clearly the UK lagged behind the other EU5 countries by some considerable distance by the end of 2005 despite LLU being available over the same time period.

Since 2005, however, the diffusion of LLU:CCA has grown rapidly in the UK and now stands at around 0.70: a proportion that is comparable with that in France. Figure 5 shows the diffusion of LLU:CCA in the UK over the five years since 2003. It can clearly be seen that the rate of diffusion changed significantly between the ten quarters before 2005 Q2 and the ten quarters after.

Figure 5: Comparative Diffusion of LLU:CCA, UK 2003 - 2005 vs. 2005 - 2007

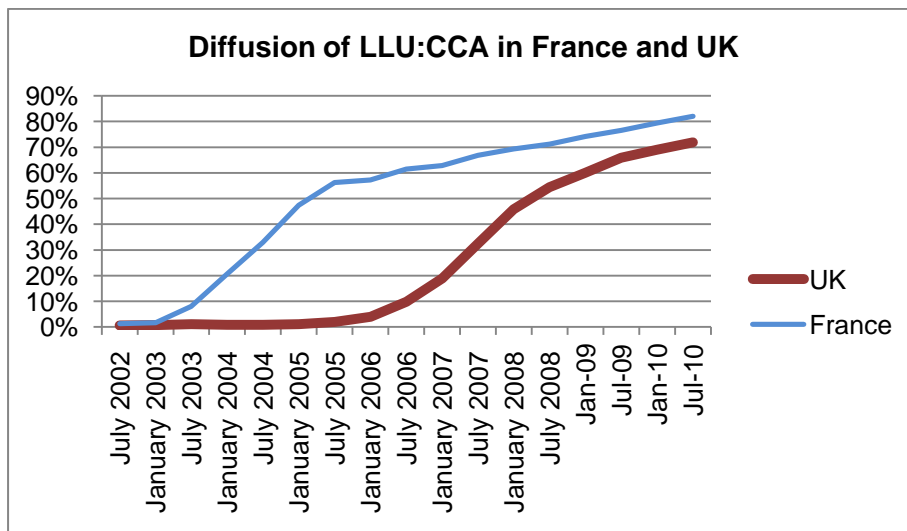


Equation 3 again regresses LLU:CCA against time, but for the period Q32005 to Q42007.

$$(3) \quad LLU:CCA_{UK} = 0.35 - 0.07T + 0.004T^2 \quad (2.88) \quad (-4.60) \quad (7.78) \quad R^2 = 0.99$$

Comparing equation 2 and 3 we see that the coefficients on  $T$  and  $T^2$  are much greater and that the  $R^2$  indicates that  $T$  and  $T^2$  have a very strong explanatory effect on the growth of LLU:CCA. Looking over the whole time series (Figure 6), we can see that LLU in France diffused rapidly whilst in the UK it did not begin to diffuse until 2005, and even now does not account for the same proportion of CCA as it does in France.

Figure 6: Diffusion of LLU:CCA in France and UK: 2003 - 2010



In the language of Schumpeter adopted earlier in this paper, it appears that LLU moved from an invention to an innovation in France in 2003 but not until 2005 in the UK. Once LLU was commercialised, it diffused rapidly in both countries, though it has not yet reached the same level in the UK as in France.

The remainder of this paper discusses the choice an entrant has between LLU and BA and then considers the effect of two specific policy changes in the UK that induced the innovation of LLU.

#### 4 The Choice between LLU and Bitsream

A firm entering the broadband market needs to decide whether to invest in its own access network - cable, fibre or wireless – or to buy one or other form of CCA from the incumbent. The decision can be examined both statically and dynamically.

Considered statically, it would be reasonable to assume that the decision is likely to be based on the expected profits from the alternative access methods. Baranes and Bourreau (2005) describe the decision between facilities based entry and services based entry formally as:

$$\pi^F - F \geq \pi^S(r) - f$$

Where  $\pi^F$  is the profit from facilities based competition,  $F$  is the fixed cost of the facility,  $\pi^S$  is profit from service competition,  $r$  is revenue and  $f$  is the variable cost of the bought-in wholesale service.

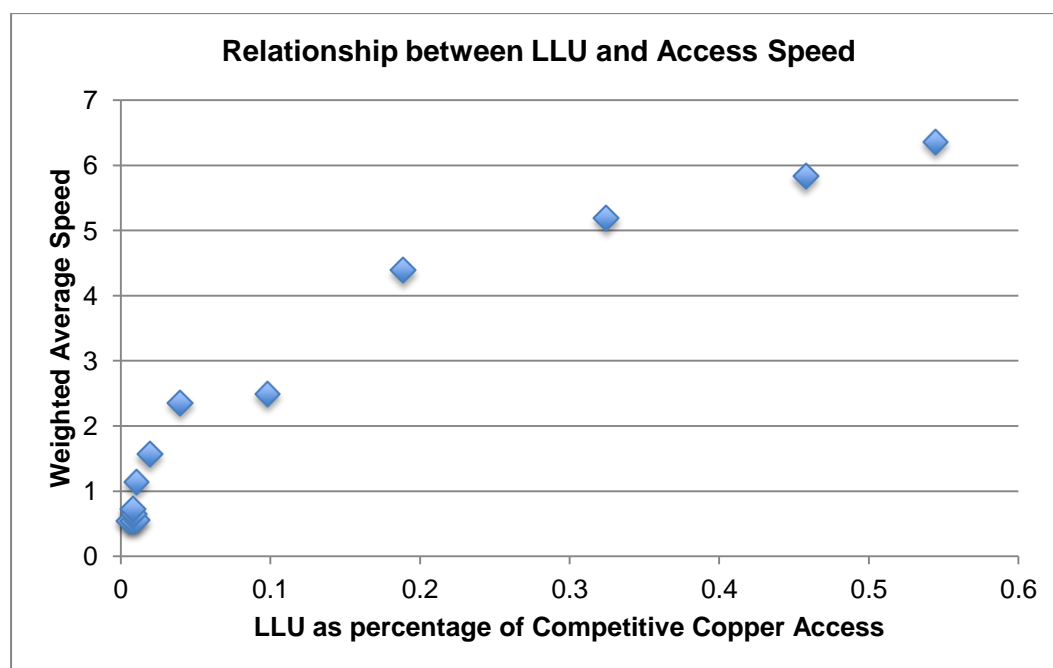
However, the decision about whether to enter the market via bitstream, unbundling or even building own facilities, is unlikely to be made on a nationwide basis in all but the smallest of countries. Rather the decision will be determined by population density in different areas of the country. Thus, in the UK, the cable networks, before they merged to form Virgin Media, passed around 55% of homes in the more urban areas. A firm choosing some form of CCA is likely to make the decision regarding which form of CCA at the telephone exchange area level. Generally speaking exchange areas that are more densely populated and so have more customer lines connected to that exchange will be unbundled (i.e. the entrant will buy LLU), whilst in less densely populated areas the entrant will purchase either RA or BA. Baranes and Bourreau's inequality can therefore be re-configured to illustrate the decision between LLU and BA on an exchange-by-exchange basis, as

$$\pi_i^{LLU} - (F_i + f_i^{LLU}) \geq \pi_i^{BA}(r) - f_i^{BA}$$

In words, the entrant will invest in LLU at exchange  $i$  when the profits from LLU less the fixed and variable costs of LLU are greater than the profits less the variable costs of BA (or RA). The marginal exchange, i.e. the exchange where the entrant is indifferent between LLU and BA, is located where the left hand side equals the right hand side.

The decision to use LLU rather than BA may also be dynamic as an ISP using LLU has scope to control product features, such as access speed and contention ratios, and can thus differentiate its own retail product from that of the incumbent and other competitors. Higher access speeds, for example, allows the ISP to offer product bundles including broadband, television and telephony known as “triple play”.

**Figure 7: LLU:CCA and Access Speed**



Data source: Ofcom. Author's analysis

Figure 7 plots the weighted average download speed in the UK against LLU:CCA. The plot shows how as LLU has increased as a proportion of CCA so too has the download speed available to broadband users over the time period 2002 - 2008. Over that period there were technical developments in broadband access technology that were exogenous to the rate of unbundling but which nevertheless affected the available access speeds. These developments are listed in Table 2 below. The point to note is that increase in access speeds in the UK substantially lagged behind the technical developments that made these increases possible. The diffusion of these versions of DSL and DOCSIS may therefore be affected by LLU:CCA.

**Table 2: Broadband Access Technology Development**

Physical Connection	Technology Version	ITU-T standard number	Date standard released	Maximum Speed of Standard	Weighted average access speed in UK at date
Copper	ADSL	G992.1	7/99	8 Mbps	<0.5 Mbps
	ADSL2	G992.3	7/02	12 Mbps	0.55 Mbps
	ADSL2+	G992.5	5/03	24 Mbps	0.55 Mbps
Cable	DOCSIS1	J.112	3/98	9 Mbps	<0.5 Mbps
	DOCSIS2	J.122	12/02	27 Mbps	0.55 Mbps
	DOCSIS3	J.222	12/07	123 Mbps	5.8Mbps

The paper now considers the policy changes introduced by Ofcom in 2004/2005 and their effects on the rate of diffusion. These policies, as shall be shown, were designed to change the location of the marginal exchange so that more exchanges would be unbundled.

## 5 UK LLU Policy Changes

An important policy change that occurred in 2005 was the implementation of a set of organisational and procedural changes at BT known as Equivalence of Input (EOI) and “Functional Separation”. These were implemented in a set of Undertakings (Ofcom 2005) agreed between BT and Ofcom following Ofcom’s Strategic Review of Telecoms (SRT) conducted in 2004/05. The primary objective of EOI and Functional Separation was to deter anti-competitive discrimination by BT against its rivals in retail markets, and in particular in the retail broadband market (Cadman 2010).

The problem of discriminatory behaviour by a vertically integrated firm that is dominant in the upstream market (as was the position of BT) is well understood in the literature (Salop & Scheffman 1983, Kandaurova and Weisman 2003, Sand 2004, Rey and Tirole 2006 and Bustos & Galetovic 2009 ). Economides (1998) finds that “a monopolist in the essential input market has an incentive to practice non-price discrimination against its downstream rivals. The monopolist raises the costs of its downstream rivals (or, equivalently, reduces the quality of the monopolised product to them) until they are driven out of business.”

Discrimination is not just a theoretical possibility. There is also empirical evidence of such behaviour, most recently in a case taken by the European Commission against the Polish telecoms incumbent, Telekomunikacja Polska (TP)<sup>7</sup>.

In June 2011 the European Commission adopted a decision under Article 102 TFEU against TP. The Commission found that TP had abused its dominant position in the

<sup>7</sup> Case COMP/39.525 - Telekomunikacja Polska. English language summary published in Official Journal 9<sup>th</sup> November 2011

markets for Local Loop Unbundling and Bitstream Access, in which it was the monopoly supplier, and specifically that TP was

- Proposing unreasonable conditions governing Alternative Operators' access to wholesale broadband products;
- Delaying the negotiation process;
- Limiting access to its network;
- Limiting access to subscriber lines;
- Refusing to provide.

The Commission concluded that TP's abusive conduct was capable of restricting competition in the retail market and was likely to reduce the rate of entry and expansion of competitors. The critical finding was that these differences in treatment were not objectively justifiable and therefore were discriminatory. TP was fined €127.6 million and ordered to bring an immediate end to the infringement. Had such different treatment been objectively justifiable, then this behaviour would not have been discriminatory. The Commission's decision is subject to an appeal by TP.

At the time of the SRT, BT was in a position where it had both the incentive and the means to discriminate against its downstream rivals. BT was a vertically integrated firm with market power in the upstream, physical local access market: an essential input for any entrant wishing to compete with BT that does not have its own access network. Although BT was never found to have discriminated, there was plenty of expectation by its rivals that it either was discriminating or would discriminate against them if they invested in LLU. Indeed, it is conceivable that the mere expectation by entrants that BT would discriminate against them was sufficient to change behaviour and to deter entry into the broadband market via LLU<sup>8</sup>.

Entrants' choice of entry methods (via LLU or some other form of CCA) may be affected by the expectation of discrimination, which is in effect a cost they need to recover through price. Although the incumbent may have the ability and incentive to discriminate against entrants on all CCA platforms, the cost of discrimination for the entrant on LLU would be greater than on RA or BA because the entrant faces higher fixed costs when using LLU as it has to invest in its own capital equipment at each exchange.

Baranes and Bourreau's inequality can therefore be adapted still further to incorporate the cost of discrimination ( $\Theta$ ) as shown below.

$$\pi_i^{LLU} - (F_i + f_i^{LLU} + \theta^{LLU}) \geq \pi_i^{BA}(r) - (f_i^{BA} + \theta^{BA})$$

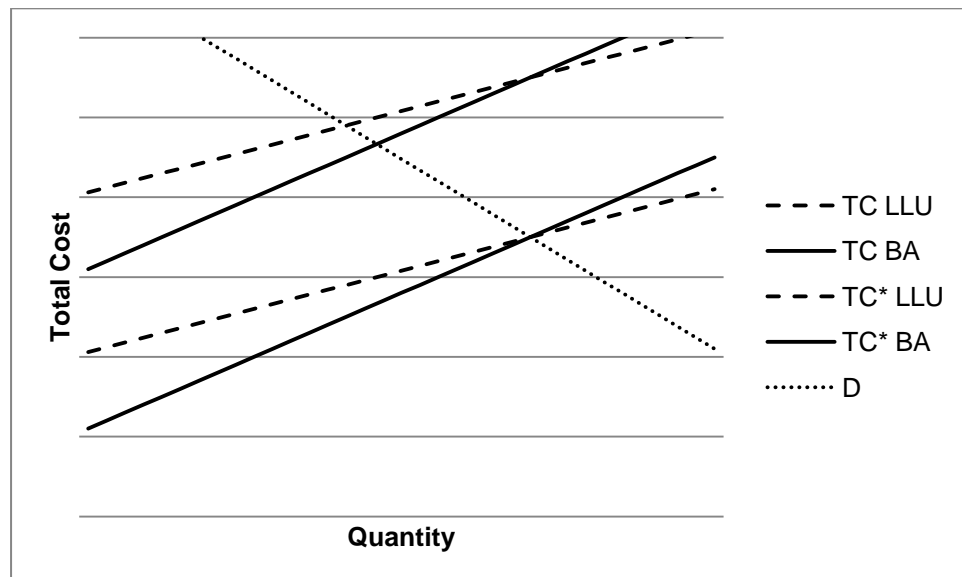
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<sup>8</sup> Whilst beyond the scope of this paper, a simple game theoretic model similar to that deployed by Gilbert and Newbery (1988, 1994) to describe the game between the regulator and the utility could demonstrate such behaviour. If the entrant could confidently predict that the incumbent would discriminate and that it would make a loss, it would not invest in the first place.

The effect of  $\Theta$  would be to raise the overall costs of each of LLU and BA but to leave the breakeven quantity the same. The fixed cost of market entry are economic barriers to entry<sup>9</sup>, whereas  $\Theta$  is an antitrust barrier to entry, defined by McAfee et al (2004) as “a cost that delays entry and thereby reduces social welfare relative to immediate but equally costly entry”.

In the presence of a downward sloping demand curve the incentive to remain with BA increases with  $\Theta$ . Further, the more elastic the demand, the greater the incentive to remain on BA. Figure 8 below simply presents the effect of discrimination on the incentive of the entrant to stay with BA. The solid lines represent the total cost of BA, where TC is the total cost without discrimination and TC\* is the total cost with discrimination. The dashed lines represent the total costs of LLU. In this representation  $\Theta$  affects the fixed costs of each product, so as  $\Theta$  rises the total costs of each wholesale option intersect the demand curve at an increasing distance from each other. Thus as  $\Theta$  decreases, and/or the demand curve shifts to the right, the incentive to invest in LLU increases.

**Figure 8: Effect of Discrimination on Total Costs**



For any given demand curve, the proportion of CCA accounted by LLU may therefore be taken as a measure of the effectiveness of non-discrimination policies by the regulator: the higher the proportion the more effective the regulator at deterring discrimination.

Concern amongst both BT’s rivals and Ofcom that BT had the incentive and ability to discriminate became a central issue in Ofcom’s SRT. Ofcom concluded that BT had weak incentives to comply with the “no undue discrimination” obligation placed on it in the Wholesale Network Infrastructure Access (WNIA) market and, in possibly the

<sup>9</sup> Defined in McAfee et al (2004) as “a cost that must be incurred by a new entrant and that incumbents do not or have not had to incur”.

most damning paragraph in the review, that those entrants who “rely on BT to provide access have experienced twenty years of:

- slow product development;
- inferior quality wholesale products;
- poor transactional processes; and
- a general lack of transparency.” (Ofcom 2004)

Ofcom concluded that, even though BT had not been found to have unduly discriminated, the “no undue discrimination” obligation, as then interpreted by Oftel, permitted differences between the treatment of BT’s wholesale customers and BT’s own retail activities which, while relatively insignificant in isolation, constituted significant disadvantage when taken in combination. Therefore a more rigorous form of non-discrimination obligation was required which would deliver “real equality of access”.

The result of the SRT was a set of Undertakings signed between BT and Ofcom in lieu of a reference to the Competition Commission under the Enterprise Act 2003 (Ofcom 2005). In these Undertakings BT agreed to provide certain wholesale products, including both fully unbundled and shared access local loops on exactly the same terms and conditions and using exactly the same processes to its own retail division and to external customers. BT also committed to certain organisational changes, which have become known as “functional separation” by which the access division was placed in a separate business unit with localised incentives (Cave 2006).

The objective of these changes was to reduce the fact or expectation of discrimination such that entrants would be prepared to invest in LLU, which was expected to have a positive impact on innovation in the market. In terms of the revised Baranes and Bourreau inequality:  $\theta^{LLU} = \theta^{BA} = 0$ . The choice between CCA type would then be made on economic grounds and not distorted by actual or expected anti-competitive behaviour by BT.

A second major regulatory change that occurred at around the same time was a significant reduction in the regulated price of LLU. The price of LLU, and in particular the comparative price of LLU and BA, obviously affect the relative profitability of the different forms of CCA and therefore the location of the marginal exchange. If the price of LLU compared with bitstream was much higher in the UK than the other five countries then this might account for the limited proportion of CCA based on LLU.

The price of LLU is readily available from the European Commission but bitstream access prices are not available and are highly complex. A comparison of LLU prices in the UK with the other of the five largest EU Member States shows that the UK was not more expensive in 2005, but that the UK had had a substantial price drop in the two years between 2003 and 2005. Table 3 shows the prices, in Euro per month, at October 2003 and 2005 for fully unbundled loops and shared access for the EU5. The data show that in 2003 the UK was 55% more expensive than the average for



fully unbundled loops and more than twice as high as the average for shared access. Indeed the price difference for shared access was so great in 2003 that the UK was the only EU5 country to be above average. By 2005, however, UK prices were about average for these countries. Given that it takes time for entrants to respond to prices to invest in LLU and roll out access to exchanges, then it may not be surprising, on the superficial evidence of these price differences, for the LLU:CCA ratio to be lower in the UK than the other countries.

The price of LLU may also provide information to entrants about the willingness and ability of the regulator to enforce its will on the incumbent. If the regulator allows the regulated firm to have prices substantially above equivalent firms in other comparable countries, this might signal to entrants that the regulator is not prepared to take tough action against potential anti-competitive behaviour. Thus when Ofcom enforced price cuts on BT for LLU, these cuts may have signalled a renewed willingness to enforce a more level playing field allowing competitors easier access to the market.

**Table 3: LLU Prices, EU5, 2003 & 2005**

		France	Germany	Italy	Spain	UK	Average
October 2003	Full LLU	17.10	16.50	11.00	14.00	25.50	16.22
	Shared Access	9.42	11.01	6.51	5.74	22.59	11.05
October 2005	Full LLU	10.90	11.80	9.30	12.00	11.20	11.04
	Shared Access	4.39	3.74	4.14	3.84	3.34	3.89

Source: European Commission Implementation Reports

The Undertakings and reduction in the regulated price of LLU can therefore be regarded as policies designed to induce innovation and diffusion of LLU as a proportion of CCA and/or to raise the equilibrium maximum level of LLU:CCA. The two policies served different functions. The purpose of the business process and organisation changes in the Undertakings was to provide reassurance to ISPs that BT would no longer be in a position where it had the incentive and ability to practice anti-competitive, non-price discrimination. This would give ISPs the confidence to invest in LLU. The purpose of the price reduction was to move the location of the marginal exchange so that ISPs would be prepared to roll-out LLU to more exchanges.

The next section of this paper reports on a diffusion model of LLU:CCA to determine how effective these policy changes were at inducing diffusion.

## **6 Induced Innovation and Diffusion in the**

Induced innovation and diffusion occur when some exogenous policy, normally some form of regulation, encourages the commercialisation of a regulated product and seeks either to increase the maximum level of diffusion or increase the rate of take up of a product. In relation to LLU in the UK, the regulator, Ofcom, took two specific actions in 2005 aimed at incentivising BT to commercialise LLU: the agreement of a

set of Undertakings with BT and a sharp reduction in price. Figures 5 and 6 above clearly demonstrate the affect that these decisions had on the diffusion of LLU and how it has taken over from BA as the principal form of wholesale broadband access. The remainder of this paper presents the results of a model to measure the determinants of the innovation and diffusion of LLU as a proportion of CCA in the UK.

The model is a regression model using the logistically transformed proportion of LLU:CCA as the dependent variable where:

$$y_t = \log \left( \frac{LLU:CCA_t}{LLU:CCA^* - LLU:CCA_t} \right)$$

The saturation penetration level (LLU:CCA\*) was set at 76.5%, which appears to be the level at which LLU:CCA reaches its maximum.

Dummy variables are used to indicate when the Undertakings were signed and when the price cut was introduced by Ofcom. The basic model has the equation:

$$y_t = \beta_0 + \delta U_t + \delta P_t + \beta_1 \log(GDP_t) + \beta_2 \log(BT_t) + \beta_3 \log(V_t) + \beta_4 T + \varepsilon$$

The variables used in the model are presented in Table 4 below, together with a brief description. Further explanation of some variables is provided after the table. Data are quarterly over the period Q1 2003 to Q4 2010.

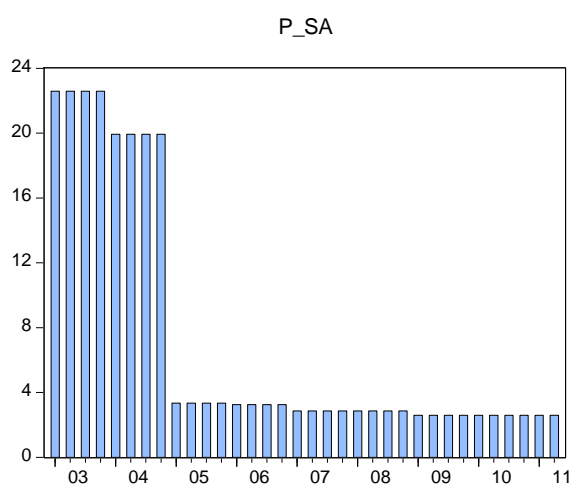
**Table 4: Model Variables**

	Name	Description	Source
Dependent Variable	$y_t$	Logistically transformed ratio of LLU to CCA	Ofcom
	C	Constant	
Regulatory Variables	U	Agreement of Undertakings between BT and Ofcom, having value 0 before and 1 after	Ofcom documents
	P	Period before and after major price cut of shared access lines by Ofcom, having value 0 before and 1 after	European Commission
Exogenous Control Variables	GDP	GDP – inflation adjusted	Office of National Statistics
	BT	BT's retail	Ofcom

		broadband market share	
V		Virgin Media's retail broadband market share	Ofcom
T		Time trend	

- *Price.* Price is set as a dummy rather than continuous variable primarily because there was a very large reduction in price of LLU in the UK in 2004 (see Table 1), in particular for “shared access” LLU, which until recently accounted for the majority of LLU lines in the UK<sup>10</sup>. There is very little variation in price either side of this reduction, as shown in Figure 9. The effect of the price reduction is therefore caught by a dummy variable.

**Figure 9: LLU Shared Access Price, UK, 2003 - 2011**



Source: European Commission

- *Share BT.* Sibley and Weisman (1998) argue that a vertically integrated firm with market power upstream is less likely to discriminate against its downstream rivals if it has a low share of the retail market itself. This is because it stands to lose more profits by harming its rivals if it derives more profit from its wholesale rather than its retail division. A higher market share for BT would therefore be correlated with a lower ratio of LLU:CCA.
- *Share Virgin.* As a broadband operator using its own infrastructure, Virgin Media has the ability to differentiate its product from BT. CCA based rivals of BT would need access to LLU to differentiate themselves from BT and Virgin Media to remain competitive. We would therefore expect a positive relationship between Virgin Media's market share and LLU:CCA.

<sup>10</sup> The ECTA Broadband Scorecard for 2009 (the most recent available) shows 70% of LLU lines in the UK are shared access – [www.ectaportal.com](http://www.ectaportal.com)

Six variations on the model have been calculated:

1	All right hand side variables contemporaneous with $y_t$
2	U & P lagged by two quarters
3	P excluded – all remaining variables contemporaneous with $y_t$
4	P excluded – U lagged by two quarters
5	U excluded – all remaining variables contemporaneous with $y_t$
6	U excluded – P lagged by two quarters

Models that interacted U and P and included the dummy variables individually returned “Near Singular Matrix” due to perfect correlation between the interacted dummy variables and the individual dummy variables.

Results of the six models are shown in Table 5

**Table 5: Model Results**

	1	2	3	4	5	6
	$\delta t$	$\delta t-2$	$\delta t$	$\delta t-2$	$\delta t$	$\delta t-2$
C	-146** (-2.42)	-98** (-2.15)	-142** (-2.41)	-130** (-2.87)	-237*** (-4.09)	-127** (-2.49)
U	0.87** (2.86)	0.62*** (2.92)	0.92*** (3.27)	0.78*** (3.77)		
P	0.17 (0.52)	0.46* (1.94)			0.48 (1.40)	0.73*** (2.91)
Log(GDP)	12.2** (2.61)	8.29** (2.34)	11.92** (2.6)	10.60*** (3.01)	19.2*** (4.25)	10.7** (2.70)
Log(BT)	6.52*** (3.05)	6.23*** (3.85)	6.42*** (3.05)	4.75*** (3.15)	3.98* (1.81)	7.06*** (3.86)
Log(V)	4.95*** (4.32)	3.38*** (4.03)	4.68*** (4.62)	3.53*** (3.99)	6.05*** (4.96)	3.33*** (3.46)
T	0.31*** (9.41)	0.28*** (11.18)	0.31*** (9.57)	0.29*** (12.03)	0.36*** (11.39)	0.28*** (10.08)
R2	0.986	0.992	0.986	0.991	0.982	0.989

\* Significant at 10%. \*\* Significant at 5%, \*\*\* Significant at 1%

The three models with lagged dummy variables (models 2, 4 & 6) were found to be better specified and had little or no problems of heteroskedasticity or autocorrelation, whereas the models with contemporaneous dummy variables had some autocorrelation problems and weak heteroskedasticity problems.

The models including the price dummy in the same time period as the dependent variable (Models 1 and 5) show P as not significant. However, in models 2 and 6, where the dummies were lagged by two periods, P was significant at 10% and 1% respectively.

In model 2, both U and P are significant, though U is somewhat more significant and has a stronger coefficient. The coefficient on both is positive, as expected.

In models 4 and 6 U and P have similar coefficients and are similarly significant. However, the timing of the price reduction in comparison with the implementation of the Undertakings means that it may be difficult to distinguish between the lagged price dummy in model 6 and the contemporaneous Undertakings dummy in model 3.

All the models show that the Undertakings and Ofcom's price cut had a significant effect on the adoption of LLU as a proportion of CCA. However, the timing of the two policies mean that it is not possible to draw a conclusion as to which had the most effect nor whether either would have had a significant effect without the other. The only sustainable conclusion is that both policy interventions induced the innovation of LLU in the UK.

From Sibley and Weisman (1998), we would expect the coefficient on BT to be negative if it is true that vertically integrated incumbents have less motive to discriminate when their market share is lower. However, the coefficient on BT is both positive and very significant in all models except 5 where it is only significant at 10%. The finding does not therefore support Sibley and Weisman's model. At the time that BT signed the Undertakings, its retail market share of copper based access was around 33%, but has steadily increased to 35% by the end of the period. At the same time, copper's market share has increased from 72% to 80%, in part as broadband availability has spread beyond Virgin Media's network footprint – the Virgin Media network covers about 55% of households. When the Undertakings were being negotiated, BT said at several public meetings that they were “up for it”, meaning they supported the idea of EOI and functional separation. The divergence of this result from what we would expect from Sibley and Weisman may be explained by the probability that at the beginning of the period BT was already in a position where it would earn more profit from wholesale activities and this position has hardly changed over the period, despite a small increase in market share.

The coefficient on V is positive and significant in all models as expected, suggesting that ISPs moved from BA to LLU to compete with Virgin Media.

## **7 Summary and Conclusion**

Local Loop Unbundling was introduced in Europe through regulation in 2000 and the EU5 all had Reference Offers for LLU in place by July 2001. This regulatory introduction is akin to invention in the Schumpeterian meaning. However, substantially fewer lines were unbundled by ISPs in the UK in the five years before December 2005 compared to the other EU5 countries. So whilst LLU had been “invented” in 2000, it was not “innovated” and had little, if any, economic impact in the UK. One specific concern of Ofcom expressed in its Telecoms Strategic Review was that BT was able to discriminate against competitive ISPs and thus deter the diffusion of LLU and the competitive pressure this might put on BT. Discrimination

raises the cost of rivals and thus for any given demand curve would result in competitors buying BA, with its lower fixed costs, rather than LLU.

An ISP does not make a choice between LLU and BA for the whole network, but rather on a per exchange basis. The location of the marginal exchange, where the competitor ISP is indifferent between BA and LLU, will be influenced both statically – where the profit from LLU is equal to the profit from BA – and dynamically – the additional profits available from more advanced services. The evidence from the early years of LLU in the UK is that marginal exchange was not far into the network.

Ofcom introduced two policy changes in 2004/2005 to encourage investment in LLU and thereby move the marginal exchange further into the network: a significant price reduction; and Equivalence of Input and Functional Separation. These policy changes were designed to commercialise LLU and to prevent non-price discrimination. Following the introduction of these policy changes LLU rapidly diffused through the market, as is clear from Figures 5 and 6.

Regression models, using the logistically transformed proportion of LLU:CCA as the dependent variable, support the graphical representation of the data and indicate that Ofcom's policies did have the intended effect of commercialising LLU and so starting the diffusion of LLU as a proportion of Competitive Copper Access. The results of the regression show strong and significant coefficients on the Undertakings and Price dummy variables. However, the models do not allow a firm conclusion to be drawn as to the relative importance of the Undertakings and the price reduction. The timing of the two policies are too close and there may be a lagged effect and even a leading effect if the policies were predicted and entrant behaviour changed in anticipation of the policies.

Two alternative explanations of these results could be considered. First, that the increased take-up of LLU simply reflected greater certainty about retail broadband demand making an investment in LLU less risky. ISPs may have been reluctant to incur the relatively high fixed costs of LLU until the level of demand for broadband became clearer. However, Figure 2 shows that retail demand was growing substantially in the period from 2003 to 2005, and by the time the Undertakings were signed there were already some eight million broadband subscribers, but fewer than 100,000 LLU lines. The comparison with France, where the retail market was growing at approximately the same rate, shows that ISPs there were not reluctant to invest in LLU. The rapid acceleration in the take-up of LLU after the policy changes suggests that there was strong pent-up demand and that reluctance was based on ISPs' concern that LLU was not commercialised and/or that they would be discriminated against.

Secondly, it might be that the technology ISPs needed to install in BT's exchanges was not available, or at least not available on suitable commercial terms. The relevant equipment<sup>11</sup>, however is not specific to the UK, but supplied by firms internationally. Again, the comparison with France demonstrates that this equipment

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<sup>11</sup> DSLAMs and MSANs

was available on commercial terms and that French ISPs were installing the equipment across France.

It therefore does not seem feasible that either demand or technological uncertainty can explain the late adoption of LLU in the UK compared with other EU countries. The key difference in the period before and after mid-2005 was the two policy changes adopted by Ofcom that had the specific intention of commercialising LLU and removing the incentive for discrimination. The overall conclusion, therefore, is that the policies adopted by Ofcom were successful and that the change in take-up cannot be explained by other factors.

The general conclusion from this paper is that it is not enough for regulators simply to mandate access to essential facilities. Vertically integrated firms with dominance upstream would not, in such circumstances, lose the incentive and the ability to offer non-commercial terms and to discriminate against their downstream rivals. They could still prevent an invention, over which they have market power, from having an economic impact and delivering welfare gains to consumers through either static or dynamic efficiency gains. Simply mandating access to essential facilities, therefore, still leaves in place the incentive and means for incumbents to raise antitrust barriers to entry.

Whilst this paper has concentrated on LLU, other regulated wholesale telecoms products have also been the subject of slow commercialisation in the UK. For example, in the Phase 2 SRT consultation document, Ofcom referred to a comment by Cable and Wireless in its response to the first SRT consultation document, in which C&W described LLU as "*prohibitively expensive, not industrialised and not fit-for-purpose*". Ofcom agreed with C&W and added: "We believe that similar stories could be told about carrier pre-selection, wholesale line rental, partial private circuits and indirect access in their early days" (Ofcom 2004 para. 6.3). Wholesale line rental went through three versions before a fit-for-purpose product was available to the industry. Thus, at least in UK telecoms, the problem of slow commercialisation of regulated products was a general problem, rather than one specific to LLU.

Section 2 above, referred to two questions asked by Jaffe et al (2002), the first of which is addressed in this paper in relation to LLU. That question was, what is the theoretical and empirical potential for induced diffusion? Specifically, how do policy instruments that increase the economic incentive to reduce emissions, or in this case induce the take up of LLU as a proportion of CCA, affect the diffusion rate of these technologies?

This paper has shown that to remove what McAfee et al (2004) refer to as antitrust entry barriers and thus incentivise the innovation *and* diffusion of welfare enhancing technologies, regulators cannot simply mandate access. They must also ensure that the terms under which those facilities are made available to customers are commercially acceptable to wholesale buyers, and that the vertically integrated incumbent has reduced incentives to discriminate against its competitors. This means, at the very least, that prices must be reasonable, and that conditions of supply do not allow the owner of the essential facility to favour its own downstream

affiliate. In Schumpeter's language: it is not enough for regulators to invent, they must also innovate.



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