Net Neutrality, Foreclosure and the Fast Lane
An empirical study of the UK *

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Abstract

Consumers buy internet access from Internet Service Providers (ISPs) to reach online content providers. Under net neutrality, an ISP is not allowed to discriminate between content providers, even though it might have an incentive to do so. An ISP might want to sell a "fast lane" to content providers or use quality degradation to foreclose content providers that compete with the ISP's own content. Discarding net neutrality will have two effects on consumers: (i) consumers will reoptimize their choice of online content, at constant ISP choices; and (ii) consumers will reoptimize their choice of ISP. I empirically investigate whether an ISP has an incentive to break net neutrality, taking into account both channels of consumer response. I combine a novel data set on UK household content and ISP choices with data on ISP presence in local markets, as well as speeds and prices. Preliminary results indicate that a fast lane increases consumers' surplus, industry revenues and advertising revenues. In contrast, foreclosure seems an unlikely scenario since it reduces the foreclosing ISP's revenues from selling broadband by more than it can recuperate through advertising on online content.

Keywords: Net neutrality, Foreclosure, Telecommunications
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1 Introduction

Consumers buy internet access from Internet Service Providers (ISPs) to reach online content providers. Currently, ISPs must treat all data packets from content providers equally, a requirement that is known as "net neutrality". Whether or not it needs to be upheld is a question that has been part of the public debate for years.

An ISP might have an incentive to break net neutrality for several reasons. It might want to sell a fast lane to content providers for prioritized access to end users. This would allow the content provider to improve their consumers' online experience and would allow the ISP to extract some of those gains. Furthermore, a dominant ISP could have an incentive to foreclose online content providers that compete with its own offline telephony or TV services.

Advocates of net neutrality stress the importance of keeping the net neutral to stimulate independent content innovation. They also warn that ISPs who are vertically integrated with online content providers might behave anticompetitively towards competing content providers. Opponents of net neutrality claim that prioritizing certain data packages is necessary for good management of ever-increasing traffic on the network. Opponents also claim that being able to charge content providers for the last mile would stimulate investment in the network and thus benefit consumers in the long run.

Even though the internet is currently considered neutral, some ISPs have already experimented with discrimination on their network. For example, in its report of December 2010, the Federal Communications Commission (FCC) states that "*As early as 2005, a broadband provider that was a subsidiary of a telephone company paid $15,000 to settle a Commission investigation into whether it had blocked Internet ports used for competitive VoIP applications.*"(FCC10-201, §35.) In 2008 Google was reported to have approached major cable and phone companies to negotiate a fast lane for its content (WSJ 2008-12-15). Finally, as recent as April 2012, Comcast, the US' largest cable operator, has been accused of giving its own video content, Xfinity, preferential treatment on its network compared to competing video services such as Netflix (WSJ 2012-06-13).

Regulators worldwide have responded to these practices in different ways. In the USA, the FCC has adopted a set of rules that should "*preserve the Internet's openness and broadband providers' ability to manage and expand their networks.*" (FCC10-201, §43) The four core principles are: transparency, no blocking of content, no unreasonable discrimination, and reasonable network management. In Europe, no such rules have been adopted so far. Even though the European Commission is committed to "*preserving the open and neutral character of the internet*", it believes that the existing rules on transparency, consumer switching and quality of service are sufficient to ensure competitive outcomes. The EC will keep monitoring the market and assess the need for more stringent measures in the future.(COM(2011) 222, 04-19-2011)

In this paper, I investigate the incentives for ISPs to break net neutrality empirically. I combine a new data set on consumption of online content by British households, with detailed data on ISP presence in local markets, as well as information on speeds and prices. I develop and estimate a two-stage consumer demand model of differentiated online content providers and downstream ISPs. In a second stage, consumers' choices between online content providers depend on their demographics as well as on the speed of their connection. In the first stage, when choosing between ISPs, consumers take into account the utility from online content through each ISPs' connection. I find that consumers indeed care about connection speed in the consumption of online content and that consumers take this into account when choosing between ISPs.

Then I use the demand estimates to explore two counterfactual simulations of breaking net neutrality. I focus on YouTube in particular, since its owner, Google, is a dominant content provider and is known to be interested in a fast lane. Calculations show that YouTube would pay up to $8 million per year for a fast lane to British consumers at the incumbent ISP in 2009. Consumers would value the faster connection to YouTube and would watch more online videos. The incumbent ISP's broadband offering would also become more attractive, which would increase its market share and bring more consumers to the market. All in all, selling a fast lane seems beneficial both to the buyer and the seller of the fast lane as well as to consumers, while it would hurt content providers and ISPs left out of the agreement.

Foreclosure through quality degradation however, seems an unlikely scenario. I consider an agreement between YouTube and the incumbent ISP to foreclose competing providers of online video, specifically the popular category of catch-up TV. The results indicate that YouTube is not a good substitute for catch-up TV and would therefore only gain a fraction of the viewers who substitute away from catch-up TV. At the same time, broadband subscribers would move away from the incumbent ISP, making the overall agreement is unprofitable.

This paper contributes to the literature on net neutrality as it is, to my knowledge, the first to investigate the issue empirically. Theoretical research[1] has focused on two main rules that follow from equal treatment of data packets. The first is known as a *zero-price rule*, which states that a consumer's ISP cannot charge content providers for the last mile to consumers. This literature primarily makes use of a two-sided market framework and has found that the zero price rule generally benefits welfare, and is thus in favor of keeping the net neutral (Lee and Wu, 2009; Economides and Tåg, 2008). The second rule is a *non-discrimination rule*, which states that an ISP cannot discriminate between data packets

[1]For an overview of the literature, see Schuett (2010).

with respect to quality of transmission. First of all, this means that an ISP cannot offer a menu of speeds at different prices to content providers, i.e. it cannot offer a *fast lane* or engage in *price discrimination*. Choi and Kim (2010) show that price discrimination would not necessarily increase ISP's investments in the network, while Economides and Hermalin (Forthcoming) argue the opposite. Hermalin and Katz (2007) show that restricting price discrimination could increase or decrease total surplus, although they consider harm to welfare likely. Finally, the non-discrimination rule also implies that an ISP cannot slow down certain types of data packets for anticompetitive reasons, i.e. it cannot engage in *foreclosure through quality degradation*. Chen and Nalebuff (2006) show that, theoretically, a monopolist ISP does indeed have an incentive to foreclose the rival content provider by offering its own content for free and charging a higher price for internet access downstream.

Modelwise, this paper relates to papers modelling the uptake of content through networks or bundles, such as Crawford and Yurukoglu (2012) who model consumption of TV channels through TV bundles offered by distributors. In their paper, consumers choose a TV bundle, taking into account the utility they will get from watching individual TV channels. In this paper, consumers choose an ISP, taking into account the utility they will get from consuming online content through this ISP. This paper is also related to papers estimating complementarity or substitutability between products, specifically Gentzkow (2007)'s model of print and online newspapers. Finally, this paper relates to the literature on leveraging market power from one market to a related market, such as Genakos et al. (2011) who investigate Microsoft's incentives to leverage market power from personal computer to server operating systems. This paper investigates a similar incentive of an incumbent ISP to leverage market power from the market for broadband to the market for online content.

The remainder of this paper is organized as follows. Section 2 describes the data sets used in this paper. Section 3 presents the model of consumer demand for upstream content and downstream ISPs. Section 4 describes the estimation strategy and section 5 presents the results of the demand estimation. Section 6 presents the counterfactual simulations and section 7 concludes.

2 Data

I combine three data sets on internet usage in the UK in 2009. The main data set contains survey data on household demographics, ISP choices and online content choices. I supplement this survey data with market level data on ISP availability by zip code. Finally, I add prices and other product characteristics using advertisments from 2009. Before presenting the main data set, I present the market level data set for a better understaning of the industry background.

2.1 Market level data on choice sets by zip code

I use a market level data set on broadband penetration rates from the British regulator, Ofcom, which lists the number of subscribers by ISP for each Local Exchange (LE). This data set also registers the zip code of each LE, which allows me to match survey respondents from the survey data to LEs. This data set was collected by Nardotto et al. (2012) and I refer to their paper for more information on this data set.

The telephony network and local loop unbundling The incumbent telephone company, British Telecom (BT), owns the telephony network consisting of 5,587 local exchanges. BT used to be state-owned, but was privatized in 1984. Since then, the telecom regulator has regulated acces to the local exchanges. Entrants wishing to serve households using BT's network currently have two options: they can either rebrand BT's connection (*Bitstream*) or lease the connection itself (*Local Loop Unbundling (LLU)*). In the latter case, entrants have full control of the connection, allowing them to upgrade the connection in order to provide a better service to their customers.

The cable network Besides the telephony network, the UK also has an extensive cable network, owned by Virgin Media. The network is made out of fibre optic cables and connects 330 Ethernet nodes. In contrast to the telephony network, Virgin Media is not required to allow entrants on its network. Only a few cable companies remain that are not owned by Virgin Media, such as Smallworld and WightCable, but these only serve a small number of households.

National market shares The UK had about 26.5 million households in 2009, all of whom are connected to the telephony network. Almost half of them also have access to the cable network. Table 1 lists market shares of the seven biggest players. In 2009 about two thirds of British households had an internet subscription. British Telecom served 45% of them, either directly or through Bitstream re-branding. The second biggest ISP was Virgin, offering broadband on the cable network, with a marketshare of 21%. The Carphone Warehouse group, which housed the brands TalkTalk, AOL and Opal in 2009, provided broadband to 16% of the market. Sky, owned by the British Sky Broadcasting Group, had a market share of 11 %. Finally, the remaining smaller players, O2 (including BE), Orange and Tiscali (including Pipex), each had a few percentages of the market. These groups account for 94% of the LLU entrants' market.

Table 1: The players

ISP	Subscribers	Market share (%)
BT	7,809,332	45
Virgin	3,696,082	21
Carphone Warehouse	2,803,290	16
Sky	1,994,664	11
O2	452,482	3
Orange	403,853	2
Tiscali	308,958	2
Total internet subscribers	17,468,661	
N^o of phone lines	26,512,178	
N^o of cable lines	12,941,022	

Note: The table reports the number of residential subscribers in the UK in 2009, as well as the number of residential phone lines and cable lines. The number for BT includes Bitstream subscribers.

Local competition Competition takes place at the level of the Local Exchange. The assignment of a house to a LE effectively limits a consumer's choice set, since each household is only served by one LE. Therefore, the LEs also define the relevant markets. Table 2 illustrates the level of competition at the LE's. The telephony network consists of a total of 5,587 LEs. Only about 2,000 (36%) of those are LLU enabled, but they serve 85% of the population. 15% of the population lives in a LE that only has one player, which is always BT. 6% of the population lives in a LE that is a duopoly, either with BT and Virgin as players or with BT and an LLU entrant. 43% of the population lives in a LE where all seven players are present. The remaing 36% live in a LE where three, four, five or six players are present.

2.2 Consumer level data on ISP choices and online content choices

I make use of a new, extensive, consumer level data set on the British internet market, called "Ofcom Telecommunications Tracking Survey". The data is collected by Ofcom, the regulator and competition authority for the UK telecommunications markets. Each quarter, Ofcom surveys about 6000 consumer regarding their mobile and fixed internet, TV, telephone and mobile phone usage. Interestingly for this paper, the survey asks consumers about their internet connection (type, ISP, price, speed,...) as well as the content they consume

Table 2: Competition in the Local Exchanges (LE)

	Number	**% of LE**	**% of HH**
Total LEs	5,587	-	-
LLU enabled	2,032	36	85
By number of players			
Monopoly	3,570	64	15
Duopoly	445	8	6
Triopoly	211	4	5
4 players	206	4	6
5 players	248	4	10
6 players	295	5	14
7 players	612	11	43

Note: The table reports the number of Local Exchanges by LLU (Local Loop Unbundled) status and by the number of players.

online (email, browsing, downloading,...). Finally, the survey collects detailed information on demographics.

Household demographics I use one cross-section of the survey, namely Q1 2009. This cross-section contains 6090 individuals of whom 3858 have internet access. About half of the respondents are male and respondents have on average 0.7 children currently living under their roof. Table 3 summarizes some of the main household characteristics. Only 1714 respondents report the speed of their internet connection and I use all of these to assess the effect of speed on the uptake of online activities. About 300 of those report choosing an ISP in the last 12 months and I use most of those to predict market shares.

Download speed and consumtion of online content The data exhibit a positive correlation between a faster internet connection and consumption of more online content. Table 4 shows the share of households that consume each of the online contents, for households with a dowload speed lower than 8Mb/s and housholds with a download speed equal to or higher than that. For most of the online contents, uptake is higher among the households with a download speed of 8Mb/s or more. Households with a slower connection speed instead have a higher uptake for less speed sensitive content, such as general browsing and looking for information for personal reasons. Interestingly for this research is the uptake of YouTube and other video content, which could be considered as competitors of certain vertically integrated ISPs. All video contents see a higher uptake among households with a high speed connection, but especially downloading benefits from a faster connection.

Table 3: Summary statistics on households

Variable	Mean	Std. Dev.	Min.	Max.
sex	0.481	0.5	0	1
kids	0.673	1.054	0	8
married	0.560	0.496	0	1
employed	0.436	0.496	0	1
home owner	0.593	0.491	0	1
Number of hh	6090			
Number of hh with internet access	3858			
Number of hh who report speed	1714			

Note: The table reports summary statistics on households' demographics in Ofcom's Telecommunications Tracking Survey.

Other correlations show that households with kids have a higher uptake of most online content, but especially of finding information for school, online gaming, social networking sites, downloading, uploading, YouTube and IM/chat. Households in higher social groups also engage in more online content, most notably in online banking and looking for work-related information. Finally, connected households in England consume on average more online content than those in Wales and Northern Ireland, while households in Scotland consume the least amount of online content.

2.3 Data on product characteristics

I add prices and other product characteristics of each broadband option using the Internet Archive's "Way Back Machine", available at `http://archive.org/`. This archive stores copies of each webpage on the internet at different moments in time and currently holds over a 150 billion pages. This service allows me to retrieve ISP's websites from 2009 to search for the prices of each package offered. Table 14 in appendix lists each option offered by the main ISPs in 2009. Most ISPs offer two to four different broadband options in LEs where the ISP is already present. Some also offer one or more non-LLU options for consumers located in LEs where the ISP has not yet entered. These non-LLU options are Bistream offerings, i.e. rebranded BT packages. Most ISPs offer differentiation along the speed dimension and/or the data cap dimension. Table 5 summarizes the main product characteristics of the packages offered in 2009.

Table 4: Share of households that consume type of online content, by speed

Online content	**Speed $<$ 8Mb/s**	**Speed $\geq$ 8Mb/s**
Playing games	0.39	0.45
Purchasing goods/services	0.73	0.78
Banking	0.58	0.62
Gambling/trading/auctions	0.19	0.24
E-mail	0.85	0.88
IM, chat, voice calls	0.38	0.44
General surfing/browsing	0.84	0.83
Information for work/business	0.44	0.46
Information for school	0.34	0.37
Information for personal reasons	0.59	0.55
Download music or movies	0.39	0.46
Watch live TV programmes	0.19	0.21
Watch catch-up TV (Skyplayer)	0.26	0.27
Listen to radio	0.22	0.21
Watch news programmes	0.16	0.17
Watch video clips (YouTube)	0.37	0.39
Social networking sites	0.44	0.51
Upload content	0.19	0.26
None of these	0.02	0.01
Average number of chosen contents	7.6	8.1
Number of households	710	1004

Note: The table reports the share of houdeholds that consume each type of online content, both for households with a slow connection ($<$ 8Mb/s) and for households with a fast connection ($\geq$ 8Mb/s).

Table 5: Product characteristics

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
Speed (Mb/s)	10.19	7.19	2	50
Price (£/month)	19.84	7.61	5	51
Data cap (Gb/month)	66.13	40.43	1	100
Number of packages	36			

Note: The table reports summary statistics of broadband packages offered in 2009. The full list of broadband packages is available in table14 in appendix.

3 Model

3.1 A two-stage model of consumer choice for content and ISP

I model demand for online content on the one hand, and access to the internet on the other hand, as a two-stage game. In the first stage, consumers choose the broadband package that gives them the highest utility, taking into account broadband prices and speeds associated with content providers. In the second stage, consumers choose among a number of online contents, depending on the speed allocated to each content provider and other personal preferences. Figure 1 depicts the set-up of the model with two upstream content choices ("YouTube" and "MyTube") and two downstream ISP choices (ISP 1 and ISP 2). Both content providers can be reached through both ISPs, but each ISP can independently set the speed s_{jk} for each content provider. Each ISP also sets a price p_j to consumers for access to the internet. Depending on the speeds, consumers can achieve different utilities from content through each ISP. Consumers take this content utility into account when choosing between ISP 1 and ISP 2, as they do with prices p_j and other characteristics set by ISPs. Finally, one content provider might contract with, collude with or be vertically integrated with one ISP (e.g. MyTube and ISP 1).

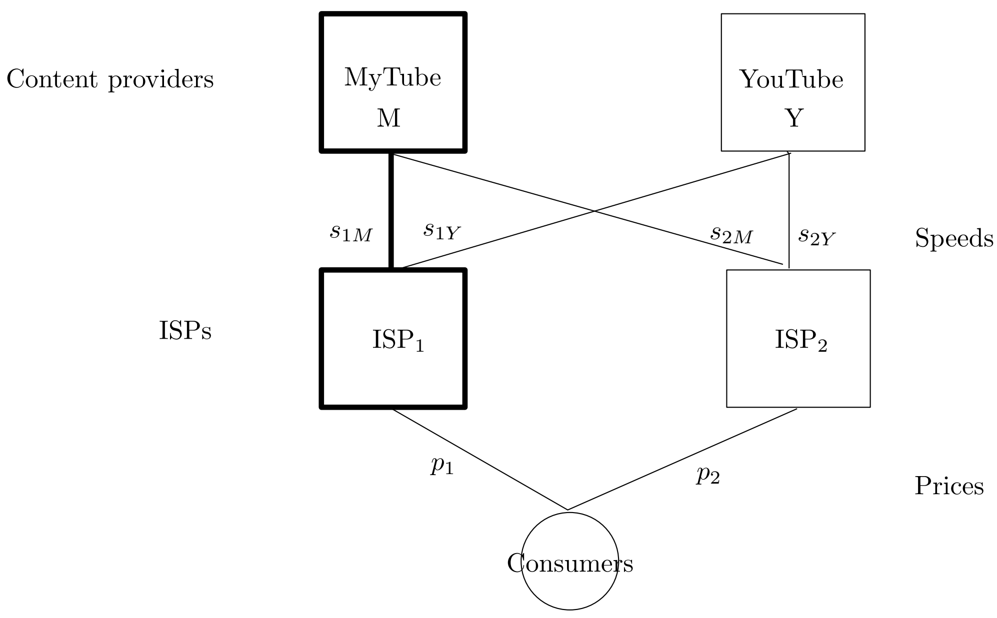

Figure 1: Example of the model with 2 content providers and 2 ISP's. Each content provider sets prices p_j to consumers and speeds s_{jk} to content providers. Utility from content depends on the speeds with which each content provider can be reached through each ISP. Consumers take into account content utility when choosing between ISP's. One ISP j could be vertically integrated, contract or collude with one of the content providers.

3.2 Content choice

Consumers with an internet connection can choose to consume a number of online contents. Individual i gets utility u_{ijk} from consuming content k through ISP j, given by

$$u_{ijk} = \gamma_k^0 + \gamma_k^1 s_j + \boldsymbol{\gamma_k^2 D_i} \tag{1}$$

where γ_k^0 is a content specific constant for content k, s_j is the speed at which ISP j offers online content k and $\mathbf{D_i}$ is a vector of demographics. Speed and demographics are allowed to enter the utility of each content k differently. This allows speed to matter more for content such as online gaming and video.

Choosing multiple alternatives Out of N possible alternatives, each consumer chooses a limited number of contents, K_i. Given that a consumer has chosen K_i contents, I define a consumer's choice set as the set S_i that contains all combinations of K_i from N contents. For example, if a consumer has chosen 2 contents out of 19 alternatives, her choice set containts all duo's of content that can be taken from the total of 19 alternatives, such as (1,2), (1,3), (1,4) etc. Formally, the number of choices is given by the binomial coefficient $\binom{N}{K_i}$. [2]

Complementarities In this new choice set S_i, I introduce notation c for a combination of Ki activities. Let d_c equal 1 if combination c has been chosen and 0 otherwise. Each combination c has a utility u_{ijc}, which depends on the characteristics of each content, but also on the interactions between the contents. This way, I allow certain contents to be complements or substitutes (such as watching online TV and downloading movies). Specifically, consumer i get utility u_{ijc} for a combination of contents c through its broadband package j, given by

$$u_{ijc} = \sum_{k \in c} u_{ijk} + \boldsymbol{\Gamma_c} + \epsilon^U \tag{2}$$

where u_{ijk} are the utilities of contents k in combination c, $\boldsymbol{\Gamma_c}$ is a series of interaction terms between each content k in combination c and ϵ^U is an i.i.d. random variable from a Type I extreme value distribution. As Gentzkow (2007) argues, observing that consumers often choose two contents jointly, could either mean that the two contents are complements, or that preferences for these two contents are correlated. $\boldsymbol{\Gamma_c}$ will take up any complementarities and the coefficients on the observed and unobserved demographics will take up correlated preferences over contents among consumers.

[2] $\binom{N}{K_i} = \frac{N!}{K_i!(N-K_i)!}$

Sample subset of choice set With 19 different online acitvities to choose from, the set of all possible combinations S_i becomes unmanagably large[3]. To deal with this, I sample a subset of all possible combinations as in McFadden (1978) and Train et al. (1987). If the subset is randomly sampled, the estimates are unbiased. Then, the probability that consumer i chooses combination of contents c, given her choice of speed in broadband package j, is given by

$$P_{ijc} = \frac{\exp(u_{ijc})}{\sum_{d \in S_i} \exp(u_{ijd})} \tag{3}$$

A consumer's total utility at the optimal choice of content among the N alternatives is denoted by u^*_{ijc}. It is given by $\sum_{c \in S_i} d_{ijc} u_{ijc}$ and predicted by $\sum_{c \in S_i} P_{ijc} u_{ijc}$ with S_i denoting consumer i's choice set of combinations of contet.

3.3 ISP choice

Given the expected utilities of consuming online content, consumers choose between a number of broadband packages offered by ISP's. The utility v_{ij} that consumer i gets from choosing broadband package j is given by

$$v_{ij} = u^*_{ijc} + \alpha p_j + X'_j \beta + \delta_j + \epsilon_{ij} \tag{4}$$

where u^*_{ijc} is the utility from the optimally chosen contents for consumer i, p_j is the price of broadband package j, X_j are the other observed characteristics of the broadband package, such as the connection speed, type (cable vs. telephone line), monthly data cap and upload speed and δ_j is an ISP specific component in utility. ϵ_{ijm} is a consumer-package idiosyncratic shock, which is assumed to be an i.i.d. draw from an Extreme Value Type I distribution.

I include ISP dummies to take up any unobservables at the ISP level. These could include national advertising and bundle characteristics. In the data, I observe that bundle characteristics are usually constant within ISPs. Certain ISPs always bundle with phone or TV. Other ISPs offer fixed discounts for broadband (e.g. £5) when a consumer also takes phone or TV. By including ISP dummies, I only look at the variation in prices and speeds within an ISP, thus avoiding complications with bundle characteristics. I don't include an additional unobserved product characteristic at the level of the package for several reasons. For one, a broadband pack is a simple product with few product characteristics (price, speed, data cap) which are all observable and which I all include in the estimation. Also, advertising is mostly ISP specific and not package specific.

[3]For example, the number of combinations of 5 elements out of 19 alternatives equals $\binom{19}{5}$=2,116,296

The probability that consumer i chooses broadband package j is given by

$$P_{ij} = \frac{\exp(u^*_{ijc} + \alpha p_j + X'_j\beta + \delta_j)}{1 + \sum_l \exp(u^*_{ilc} + \alpha p_l + X'_l\beta + \delta_l)} \tag{5}$$

where the utility of the outside good is normalized to zero, $v_{i0m} = 0$.

Finally, package j's market share is given by

$$s_j = \frac{1}{M}\sum_i^M P_{ij} \tag{6}$$

where M is the number of consumers in the market.

4 Estimation

One obvious approach is to estimate both content choice and ISP choice using maximum likelihood estimation. I choose to transform the both likelihood functions into moments and estimate the parameters using method of moments as in Berry and Waldfogel (1999). This is done by zeroing the first-order conditions of the loglikelihood to zero. I do this because MOM allows for easy joint estimation of the content choice and ISP choice, by stacking the moments conditions, even when using different data sets for the content choice and the ISP choice. Train (2009) shows that the MLE estimator is equal to the MOM estimator in which the moments require the residuals $(d_{ij} - P_{ij})$ to be orthogonal to instruments z_{ic}, when the instruments are the scores $z_{ij} = \partial P_{ij}(\theta)/\partial\theta$. In the simple Logit the ideal instrumens are the explanatory variables themselves.

Moments relating to content choice Let γ be the set of parameters to be estimated in the content choice $\gamma = \{\gamma^0_k, \gamma^1_k, \gamma^2_k, \Gamma\}$. The moments relating to the content choice require the difference between the observed choice of content and the predicted choice of content to be orthogonal to the explanatory variables.

$$\sum_i \sum_c \left[d_{ijc} - P_{ijc}(\gamma)\right] X_{ijc} = 0 \tag{7}$$

Moments relating to ISP choice Let θ be the set of parameters estimated in the ISP choice $\theta = \{\alpha^0, \alpha^1, \beta\}$. The moments relating to the ISP choice require the difference between the observed package choice and the predicted package choice to be orthogonal to the explanatory variables.

$$\sum_i \sum_j \left[d_{ij} - P_{ij}(\theta)\right] X_{ij} = 0 \tag{8}$$

Identification The vector of parameters in the content choice $\gamma = \{\gamma_k^0, \gamma_k^1, \gamma_k^2, \Gamma\}$ is identified from the observed covariance between content choice, connection speed and consumer demographics as well as the observed covariance between content choices themselves. These parameters are important to predict consumers' substitution patterns among online content, should one content become available at a lower or faster speed.

The other parameters $\theta = \{\alpha^0, \alpha^1, \beta\}$ are identified from the observed covariance between ISP choice, broadband characteristics and consumer demographics as well as from exogeneous variation in choice sets. Depending on a consumer's location, his choice set may include high speed internet through the cable or through LLU players. These parameters are important to predict consumers' substitution patterns among ISP's, should an ISP change the speed for certain content.

5 Estimation results

[I present here a simple version of the model without interactions that capture complementarities or substitutability. Future versions of this paper will contain more realistic and flexible modelling.]

5.1 Content choice results

Table 6 presents the parameters relating to the content choice. Consumers can choose between 19 different contents. Even though all 19 content dummies are estimated, I omit most of them from the table for expositional purposes. I am specifically interested in the 6 contents related to online video and I therefore aggregate the other 13 contents into 5 categories to create interactions with demographics. The category 'Trade' includes online shopping, banking, gambling, trading and auctioning. The category 'Communication' includes email, chat, IM, VOIP and social networks. The category 'Information' includes general browsing as well as finding information related to school, work or personal issues. Finally, the categories 'Games' and 'Upload' each only contain that content.

Activity dummies All activity dummies are positive and significant. For expositional purposes I report only the dummies for content related to video consumption. The other 13 content dummies are also positively and significantly estimated, but omitted from the

Table 6: Results content choice

	Mean	Interactions with demographics				
		Speed	Age	Kids	Married	Employed
Video content						
Download	4.57		-0.56	0.05	-0.02	0.11
	(0.40)		(0.03)	(0.03)	(0.04)	(0.04)
Live TV	2.27		-0.10	0.05	-0.04	0.11
	(0.40)		(0.03)	(0.04)	(0.05)	(0.04)
Video clips	4.32		-0.55	0.29	-0.45	0.19
	(0.41)		(0.03)	(0.03)	(0.04)	(0.04)
Catch-up TV	2.96		0.01	-0.25	-0.08	-0.25
	(0.41)		(0.03)	(0.04)	(0.04)	(0.04)
Radio	1.61		0.32	-0.23	-0.40	0.60
	(0.41)		(0.04)	(0.04)	(0.04)	(0.04)
News clips	1.33		0.35	-0.64	0.06	0.23
	(0.41)		(0.04)	(0.05)	(0.05)	(0.05)
All video		1.62				
		(0.60)				
Non-video content						
12 content dummies	[yes]					
Games		1.86	-0.60			
		(0.61)	(0.03)			
Comm		1.76	-0.53			
		(0.61)	(0.02)			
Upload		1.42	-0.23			
		(0.61)	(0.04)			
Trade		1.68				0.43
		(0.61)				(0.03)
Info		1.59				0.39
		(0.61)				(0.02)

Note: The table reports estimated coefficients related to the content choice. Out of 19 content choices, 6 are related to video consumption. These six are reported in detail. For the other 13 content choices, I estimate a content dummy. For demographic interactiosn, I group the content choices into 5 categories. Standard errors are between brackets.

table. Regarding the video content, the contents which give consumers the highest utility are downloading movies and music and watching video clips on websites such as YouTube. The outside option is to engage in no activities at all.

Demographics and speed Speed has either a positive effect on all content. Speed has the largest effect on playing online games and on communications (which includes VOIP and chat). Regarding the 6 video categories, 2 broad demographic trends are distinguishable. First, households with kids and younger households engage more often in downloading movies, watching clips on YouTube and watching live TV, but they less often watch catch-up TV, news clips and online radio. Secondly, households active in the work force and singles engage more often in almost all of the video categories than their unemployed or married counterparts. For the non-video content, I include less interactions, both for expositional and computational reasons, but some intuitive results surface nonetheless. Younger households engage more in games, communication and uploading than older households. Households active in the workforce engage more in online trading and searching for information than their unemployed counterparts.

5.2 ISP choice results

Table 7 presents the parameters relating to the ISP choice.

Utility derived from content As expected, utility derived from online content contributes in a positive and significant way to utility of broadband. This means that consumers take into account the utility they will get from using their internet connection to access content providers, when choosing a broadband offering. Therefore, individuals that consume more online content, have a higher utility for broadband.

Product characteristics The coefficient on price is significantly estimated and negative. Price elasticity is estimated to be on average -3.3. The coefficient on data cap is not significant. The ISP dummies are estimated to be either significantly negative or not distinguishable from the default category, which is BT. This confirms that BT, as the incumbent, still has a strong brand presence in the UK.

Table 7: Results ISP choice

	Coef.	**Std. Err.**
Content utility	0.24	0.01
Price	-0.93	0.02
Data cap	-0.27	0.11
ISP 1	-1.85	0.17
ISP 2	-1.70	0.15
ISP 3	-0.32	0.05
ISP 4	0.21	0.07
ISP 5	0.05	0.13
ISP 6	0.14	0.11

Note: The table reports estimated coefficients related to the ISP choice. Content utility is the utility a consumer obtains from consuming online content through the internet connection. The omitted ISP dummy is BT.

6 Counterfactuals

I compute two counterfactual simulations in which the non-discrimination rule is abandoned. The first counterfactual allows the sale of a "fast lane" to content providers. In the second counterfactual I allow an ISP to foreclose competitors of its own vertically integrated content by slowing down the speed with which these competitors can be reached. Competition authorities consider both of these scenarios to be realistic and worthy of investigation.

Driving forces The driving forces in both counterfactuals will be consumers' preference for speed as well as substitution patterns between content providers on the one hand and between ISPs on the other hand. When an ISP changes the speed with which a content provider can be reached, it changes consumers' utility for that content and this will induce consumers to make different content choices. However, this change of speed also influences the overall utility a consumer can obtain from content consumption through that ISP, so consumers will also reoptimize their ISP choice. Finally, these new ISP choices will also have a secondary effect on content choices. Especially substitution from the outside good will drive this secondary effect, since this brings new consumers to the market for online content.

6.1 Selling a fast lane

An ISP with substantial market power might be interested in selling a fast lane to one or more content providers. In this counterfactual, I calculate how much YouTube would be willing to pay BT for a faster connection to British consumers. I also calculate the effect on market shares and consumer surplus. YouTube's maximum willingness-to-pay for the fast lane equals the increase in revenue it would gain from additional viewers. Since YouTube does not charge viewers to watch its hosted videos, revenue comes solely from advertising.

Advertising on YouTube Currently YouTube does not show ads on its homepage, but it does show several types of advertising on the individual video pages. Some video pages display a 30 second advertisment clip before the actual video starts. Other pages display a text link on top of the video 10 seconds into the video. At the end of the video, several more text links can be displayed in the video window. Some pages display a non-video ad on the right side of the page. Finally, some pages show no ads at all. Which ads you see, depends on your location and how much Google (YouTube's owner) knows about your demographics or interests. Google knows your location through your computer's IP address and it might know your age and gender if you have provided this information in your user account. Also, Google can keep track of your search history, video history, email conversations, etc to get an idea of what type of person you are. Advertisers can then target their ads to certain demographic groups.

Ads per viewer and revenue per 1000 impressions (RPM) The model will predict how many additional households will watch online videos, but I need a few more paramaters to calculate YouTube's revenue. First, I transform households to individuals, by weighing the content choice probabilities by household size.

Second, I get an estimate on the number of ads each visitor views from comScore, a marketing research company that gathers data on a.o. online audiences, advertising and video. In 2009 comScore reported that YouTube reached 23.5 million unique visitors per month, who viewed 2.4 billion videos per month (comScore, 2009). This means that on average, each unique visitor viewed 103 videos per month or 1232 videos per year. Since some video pages show more than one add, while others show none, I take an average of 1 ad per video page.

Third, I need an indication of the average RPM (revenue per 1000 impressions) of an ad on YouTube. RPM is the publisher's revenue from displaying ads after all the fees and commissions are paid. Online RPM varies wildly and ranges from $0.1 to over $50. One way to get a sense of Google's RPM for ads shown to UK viewers in 2009, is through the following back-of-the-envelope calculation. Google's annual report lists $22.9 billion avertising revenue and they state that 12% of revenue was generated in the UK, which amounts to $2.7 billion (Google, 2009). Analysts at Forbes estimate that 3% of revenues are generated by YouTube, which leaves \$81 million (Forbes, 2010). Dividing this number by the 1232 adds per unique visitors and the 23.5 million unique UK visitors, gives an RPM of about \$2.8. Similarly to this number, analysts at Forbes estimated an RPM for YouTube at about \$ 2.4 in 2009 (Forbes, 2010). I will show results for RPMs between these two estimates, namely for \$2.4, \$2.6 and \$2.8.

Table 8: New content choices

Content	Original prob. (%)	Δ at const. ISP choices	Δ at new ISP choices
	Video content		
Download	25.67	-0.13	-0.08
Live TV	17.11	-0.02	0.00
Catch-up TV	19.43	-0.03	-0.00
Radio	17.41	-0.22	-0.20
News clips	14.88	-0.07	-0.05
Video clips	**22.77**	**3.39**	**3.52**
	Non-video content		
Games	25.95	-0.35	-0.30
Shopping	36.53	-0.28	-0.21
Banking	29.49	-0.13	-0.08
Gambl/trad/auct	17.27	-0.21	-0.19
E-mail	47.72	-0.41	-0.33
IM/chat/voice	24.12	-0.12	-0.08
Surfing	43.94	-0.42	-0.34
Info work	27.38	-0.22	-0.17
Info school	22.16	-0.05	-0.01
Info personal	28.81	-0.33	-0.28
Social networks	27.31	-0.36	-0.32
Upload	16.53	-0.06	-0.02
None	39.70	-0.04	-0.07

Note: The table shows substitution from other content to YouTube when YouTube's connection is increased from 8 Mb/s to 20 Mb/s at British Telecom. The first column shows the original probabilities, while the second and third show the absolute change at constant and new ISP choices.

New content choices When consumers are confronted with a faster connection from BT to YouTube, they will reoptimize their content choice as well as their ISP choice. Table

8 shows new content choices both before and after consumers reoptimize the choice of ISP. Utility from consuming YouTube videos through BT increases, so more households choose to consume videos from YouTube. At constant ISP choices, YouTube's market share increases by 3.4 percentage points, from 23% of households consuming YouTube to 26%, while all other categories lose market share. At new ISP choices, more consumers will choose to buy broadband through BT, so YouTube's market share increases even more. In fact, at new ISP choices, all categories except 'none' [4] gain market share compared to constant ISP choices, because of the additional broadband subscribers substituting from the outside good.

Advertising revenue Table 9 reports the changes in YouTube visitors and advertising revenue in the UK. Under net neutrality the model predicts 19 million unique visitors, which seems to underestimate the 23.5 million estimated by comScore. When BT sells a fast lane of 20Mb/s to YouTube, YouTube will gain an additional 2.4 million unique UK visitors. At an average RPM of $2.4 YouTube's UK ad revenues would increase by $7 million. At a higher average RPM of $2.8, YouTube's current ad revenues from the UK would increase by $8 million. The model therefore predicts that YouTube would be willing to pay between $7 and $8 million to BT for a fast lane of 20Mb/s, up from 2009's 8Mb/s.

Table 9: YouTube advertising revenue in UK

	Current (million)	Δ (million)
Unique viewers	19.16	2.39
Revenues		
At RPM=$2.4	56.66	7.08
At RPM=$2.6	61.39	7.67
At RPM=$2.8	66.11	8.26

Note: The table shows YouTube's increase in unique viewers and advertising revenue at different levels of Revenue per 1000 impressions (RPM) when YouTube's connection is increased from 8 Mb/s to 20 Mb/s at British Telecom.

New ISP choices Consumers take into account the changed speed for YouTube at BT, when choosing an ISP, both directly (through the product characteristics of the broadband

[4] The category 'none' includes consumers who are not connected to the internet (35%) as well as consumers who are connected, but don't report any content choices (5%).

package) and indirectly (through the utility from content). Consumers who prefer YouTube over other content (such as young employed singles and households with kids) will get increased utility from content when they get broadband from BT and they will be more likely to choose BT than before. Table 10 shows the current and predicted ISP market shares. BT gains 0.3 percentage point of market share, which is 0.5 percentage points in terms of the inside goods and which adds up to around 73,000 additional subscribers. BT mostly steals customers from other ISPs, but also some from the outside good. A similar pattern is visible in the revenues. BT gains £26 million in revenues, while other ISPs lose £14 million so that total industry revenue increases by £12 million. Finally, total consumer surplus also goes up by £12 million per year.

Table 10: Welfare effects of a fast lane

	Current	Δ
Market shares (%)		
OG	38	-0.11
BT	15	0.27
Others	48	-0.16
Revenue (mil £)		
BT	1394	26
Others	3917	-14
Total	5311	12
Consumer surplus (mil £)		
Total	-	+12

Note: The table shows the effects on market shares, revenue and consumer surplus when YouTube's connection is increased from 8 Mb/s to 20 Mb/s at British Telecom.

Conclusion The model predicts that YouTube would have been willing to pay BT a maximum of $7 to $8 million for a fast lane to British consumers in 2009. Consumers would value the faster connection to YouTube and would consume more online videos. Additionally, this increase in quality brings new broadband consumers to the market, which further increases consumption of online videos. BT's broadband offering would also become more attractive to consumers, increasing BT's market share and revenues. All in all, selling a fast lane seems beneficial both for the buyer and the seller of the fast lane as well as for consumers, while it would hurt content providers and ISP left out of the agreement.

6.2 Vertical foreclosure of content

A second scenario that involves breaking net neutrality, is the foreclosure of a content provider by a dominant ISP. A popular question among policy makers is whether an ISP would have an incentive to slow down access to video websites such as YouTube to promote their own video content or video content from an associated content provider. BT, the dominant ISP in the UK, however does not provide own online content. I therefore construct a scenario in which a dominant content provider, such as YouTube, colludes with a dominant ISP to foreclose a competing content provider. In the UK, the second biggest legal provider of online videos is catch-up TV. So in this scenario, I allow BT to decrease the speed for all catch-up TV providers from the current 8Mb/s to a much slower 2Mb/s in order to increase traffic to YouTube.

Catch-up TV Catch-up TV are videos of programs that have previously aired on national television and that are made available by broadcasters for (re-)viewing online. comScore reports that almost 100 million catch-up videos were watched per month in the UK in january 2009. 54 million of those were watched at BBC.co.uk. Other players are Channel4, iTV and Sky. comScore also reports that BBC.co.uk had almost 7 million unique video viewers in January 2009, up by 18% from January 2008 (comScore, 2009). This means that each unique visitor watched around 8 catch-up TV videos per month. Extrapolating this number to all 100 million catch-up TV videos watched per month, and extending the increasing trend from January 2008 to January 2009 over the whole of 2009, this leads to around 13.5 million unique catch-up TV viewers.

New content choices When catch-up TV is slowed down, it becomes less enjoyable so content consumers will switch away to other types of content. As before table 11 shows the changed household probabilities before and after consumers reoptimize their choice of ISP. At constant ISP choices, the model predicts a decrease of 1.25 percentage points for catch-up TV, but only a small increase for YouTube of 0.04 percentage points. As the demand results show, YouTube is a poor substitute for catch-up TV, since households with kids and younger households prefer YouTube, while older households without kids prefer catch-up TV. When consumers are allowed to reoptimize their choice of ISP, some consumers substitute away to the outside good, thus decreasing uptake of all online content compared to constant ISP choices.

Table 11: New content choices

Content	Original prob.	Δ at const. ISP choices	Δ at new ISP choices
	Video content		
Download	25.67	0.08	0.07
Live TV	17.11	0.11	0.10
Catch-up TV	**19.43**	**-1.25**	**-1.26**
Radio	17.41	0.17	0.16
News clips	14.88	0.09	0.08
Video clips	**22.77**	**0.04**	**0.04**
	Non-video content		
Games	25.95	0.05	0.04
Shopping	36.53	0.10	0.08
Banking	29.49	0.03	0.02
Gambl/trad/auct	17.27	0.10	0.09
E-mail	47.72	0.00	-0.01
IM/chat/voice	24.12	0.02	0.01
Surfing	43.94	0.04	0.02
Info work	27.38	0.14	0.13
Info school	22.16	0.00	-0.02
Info personal	28.81	0.12	0.11
Social networks	27.31	0.04	0.03
Upload	16.53	0.07	0.06
None	39.70	0.09	0.10

Note: The table shows substitution from other Catch-up TV to YouTube when Catch-up TV's connection is decreased from 8 Mb/s to 2 Mb/s at British Telecom. The first column shows the original probabilities, while the second and third show the absolute change at constant and new ISP choices.

Viewers and advertising revenue Table 12 reports the changes in YouTube visitors and advertising revenue in the UK. The model predicts a 2009 viewership for catch-up TV of 15.8 million unique viewers, which is somewhat higher than the 13.5 million estimated by comScore. About 900,000 people would stop watching catch-up TV due to the foreclosure. YouTube would gain only about 30,000 viewers, since it is not a good substitute for catch-up TV. For different levels of RPM, YouTube would gain between \$70,000 and \$90,000 in advertising revenue.

Table 12: Viewers and advertising revenue in UK

	Current	Δ
Unique viewers (mil.)		
YouTube	19.16	0.03
Catch-up TV	15.81	-0.9
YouTube revenues (\$mil.)		
At RPM=\$2.4	56.66	0.07
At RPM=\$2.6	61.39	0.08
At RPM=\$2.8	66.11	0.09

Note: The table shows YouTube's increase in unique viewers and advertising revenue at different levels of Revenue per 1000 impressions (RPM) when Catch-up TV is foreclosed by is decreasing its connection speed from 8 Mb/s to 2 Mb/s at British Telecom.

New ISP choices Table 13 shows the current and predicted ISP market shares. BT loses 0.06 percentage points of market share, which amounts to around 16,000 subscribers. Customers mainly substitute away other ISPs, but some also cease to buy broadband at all. A similar pattern is visible in the revenues. BT loses £6 million in revenues, while other ISPs gain £4 million so that total industry revenue decreases by £2 million. Finally, total consumer surplus goes down by £3 million per year.

Conclusion An agreement between BT and YouTube to foreclose online providers of catch-up TV seems like an unlikely scenario. YouTube is not a good substitute for catch-up TV and would therefore only gain a fraction of the viewers who substitute away from catch-up TV. Also, since BT's broadband offerings become less attractive, a small but substantial number of internet consumers cease to buy broadband at all, decreasing overall uptake of online content. YouTube's gain in advertising revenue be several times smaller then BT's loss in

Table 13: Welfare effects of foreclosure

	Current	Δ
Market shares (%)		
OG	38	0.02
BT	15	-0.06
Others	48	0.04
Revenue (mil £)		
BT	1394	-6
Others	3917	+4
Total	5311	-2
Consumer surplus (mil £)		
Total	-	-3

Note: The table shows the effects on market shares, revenue and consumer surplus when Catch-up TV is foreclosed by is decreasing its connection speed from 8 Mb/s to 2 Mb/s at British Telecom.

subscription revenue, so that the overall agreement is not profitable. A better substitute for YouTube seems to be (illegal) downloading of movies and music, since both content providers attract the same audience of young households, households with kids and employed singles. However, hindering access to illegal dowloading sites is much more difficult, since they easliy move to new locations.

7 Conclusions

Net neutrality regulation requires Internet Service Providers (ISPs) to treat all content providers equally. Specifically, ISPs must carry all data packets at the same speed. If consumers care about connection speed when consuming online content, discrimination with respect to speed would be a tool for ISPs to influence traffic to content. First, ISPs might be interested in selling a fast lane to extract some of the additional rents to content providers. Second, a dominant ISP might want to foreclose a content provider that competes with its own online content. Whether both scenarios are likely and desirable has been extensively debated by policy makers, media and theoretical economists.

I develop a model of broadband consumption on the one hand and online content consumption on the other and I apply it to a novel data set on content and ISP choices among

UK households. The results from the empirical model show that consumers indeed care about connection speed in the consumption of online content.

Then I use the estimates to explore two counterfactual simulations of breaking net neutrality. I focus on YouTube in particular, since its owner, Google, is a dominant content provider and is known to be interested in a fast lane. Calculations show that YouTube would pay up to $8 million per year for a fast lane to British consumers at the incumbent ISP in 2009. Consumers would value the faster connection to YouTube and would watch more online videos. The incumbent ISP's broadband offering would also become more attractive, which would increase its market share and bring more consumers to the market. All in all, selling a fast lane seems beneficial both for the buyer and the seller of the fast lane as well as for consumers, while it would hurt content providers and ISPs left out of the agreement.

Foreclosure through quality degradation however, seems an unlikely scenario. I consider an agreement between YouTube and the incumbent ISP to foreclose competing providers of online video, specifically the popular category of catch-up TV. The results indicate that YouTube is not a good substitute for catch-up TV and would therefore only gain a fraction of the viewers who substitute away from catch-up TV. At the same time, broadband subscribers would move away from the incumbent ISP, making the overall agreement is unprofitable.

I conclude, based on these preliminary results, that net neutrality regulation does not seem necessary at the moment. However, I will still expand the model to allow for more realistic substitution patterns as well as estimate complementarity or substitutability between content providers. Finally, future empirical research must look at the long run effects of net neutrality regulation on investment in the broadband network as well as on innovation among content providers.

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Appendix

Table 14: ISP offerings and product characteristics in 2009

ISP	Option	Bit-stream	Price (£)	Line rental (£)	Downl. speed (Mb/s)	Upload speed (Mb/s)	Data cap (GB)	Tech	Set up cost
AOL	Wireless	0	14.99	10.27	7.15	0.398	10	ADSL	0
AOL	Wireless Plus	0	19.99	10.27	7.15	0.398	40	ADSL	0
AOL	non-LLU Wireless	1	19.99	10.27	7.15	0.398	10	ADSL	0
AOL	non-LLU Wireless Plus	1	24.99	10.27	7.15	0.398	40	ADSL	0
BE	Be Value	0	13.5	10.27	8.192	1.331	40	ADSL	24
BE	Be Unlimited	0	17.5	10.27	21.381	1.331	Unlimited	ADSL	24
BE	Be Pro	0	21.5	10.27	21.381	2.56	Unlimited	ADSL	24
BT	Option 1	0	15.65	10.27	7.15	0.398	10	ADSL	0
BT	Option 2	0	20.54	10.27	7.15	0.398	15	ADSL	0
BT	Option 3	0	24.46	10.27	7.15	0.398	Unlimited	ADSL	0
O2	Standard	0	12.23	10.27	8.192	1.331	Unlimited	ADSL	0
O2	Premium	0	14.68	10.27	20.48	1.331	Unlimited	ADSL	0
O2	Pro	0	22.02	10.27	20.48	2.56	Unlimited	ADSL	0
O2	Home Access	1	22.02	10.27	7.15	1.331	Unlimited	ADSL	0
Orange	Home Starter	0	10	10.27	7.15	0.398	10	ADSL	0
Orange	Home Select	0	20	10.27	7.15	0.398	Unlimited	ADSL	0
Orange	non-LLU Home Starter	1	17.83	10.27	7.15	0.398	10	ADSL	0
Orange	non-LLU Home Select	1	27.83	10.27	7.15	0.398	Unlimited	ADSL	0
PlusNet	Value	0	5.99	10.27	7.15	0.398	10	ADSL	0
PlusNet	Extra	0	15.99	10.27	7.15	0.398	Unlimited	ADSL	0
PlusNet	non-LLU Value	1	11.99	10.27	7.15	0.398	10	ADSL	0
PlusNet	non-LLU Extra	1	19.99	10.27	7.15	0.398	Unlimited	ADSL	0
Sky	Base	0	5	10.27	2.048	0.256	2	ADSL	75
Sky	Everyday	0	10	10.27	7.15	0.398	40	ADSL	50
Sky	Unlimited	0	15	10.27	16.384	0.768	Unlimited	ADSL	25
Sky	Connect	1	17	10.27	7.15	0.398	40	ADSL	50
TalkTalk	Essentials	0	16.99	10.27	7.15	0.398	40	ADSL	29.99
TalkTalk	Plus	0	22.32	10.27	13.312	0.398	80	ADSL	29.99
TalkTalk	non-LLU	1	28.15	10.27	7.15	0.398	40	ADSL	29.99
Tiscali	Broadband Only	0	14.99	10.27	7.15	0.398	Unlimited	ADSL	0
Tiscali	non-LLU Broadband Only	1	19.99	10.27	7.15	0.398	Unlimited	ADSL	0
Virgin	Size M Cable	0	17	0	2.048	0.2	Unlimited	Cable	15
Virgin	Size L Cable	0	24	0	10.24	0.512	Unlimited	Cable	15
Virgin	Size XL Cable	0	36	0	20.48	0.768	Unlimited	Cable	15
Virgin	Size XXL Cable	0	51	0	51.2	1.536	Unlimited	Cable	80
Virgin	Broadband - ADSL	1	18	10.27	7.15	0.398	Unlimited	ADSL	15