Investment in Broadband Infrastructure Under Local Deregulation: Evidence from the U.K. Broadband Market

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Abstract

This paper investigates telecommunication operator investment in broadband infrastructure after local deregulation of the wholesale broadband access market. Using a panel dataset covering all 5,598 exchange areas in the United Kingdom, we exploit regional differences in deregulation following a 2008 reform. Controlling for initial conditions, first-difference estimates show that local deregulation increases local investment in infrastructure by the incumbent and we find no negative effects on the incumbent's competitors.

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1. Introduction

Creating competition was a main concern in regulating European broadband sectors over the last decade. For this end, former incumbents' networks were opened for alternative providers by mandated access at regulated prices. Nowadays broadband markets in many countries have developed satisfactory levels of competition that are especially pronounced in urban areas where alternative providers find broadband deployment most profitable. With some regions enjoying more infrastructure-based competition than others, many observers argue that national regulators should focus their attention on areas in which competitive markets cannot be sustained (EC, 2008a; Weizsäcker, 2008). As a result, in recent years, a number of European countries have debated[1]—and in some cases introduced—the deregulation of competitive areas in a specific broadband wholesale market. The so-called Wholesale Broadband Access (WBA) market allows entrants with non-exhaustive own infrastructure to offer broadband services to the end-users via the incumbent's (or other providers') network.

In this study, we investigate how broadband providers change their investment behavior in response to a local deregulation. Infrastructure investments are of direct relevance to regulators. While in the past, regulators' focus was on creating competition on already existing networks, they need to take a more dynamic perspective nowadays and should rather focus on market outcomes such as investment and innovation (Vogelsang, 2013). According to the European Commission, substantial investments in telecommunication infrastructure are necessary in order to ensure European competitiveness and growth (EC, 2012).

It remains unresolved from a theoretical perspective, how deregulation of areas with well-developed competition affects future competitive development (see Stumpf, 2010). Entrants benefit from the WBA regulation since they are able to test local markets "risk-free" via the incumbent's network (Cave & Vogelsang, 2003). On the downside, this may in fact hamper entrants' incentives to invest in own infrastructure in the "make or buy" decision that every company faces (Nardotto et al., 2012). With some markets being deregulated, the entrant faces higher degrees of uncertainty about future access and price developments. Entrants may therefore have a higher incentive to invest in established markets with high demands for their services and gradually roll out their own infrastructure. A higher degree of infrastructure-based competition in turn is likely to influence the incumbent's investment behaviour. One way for the incumbent to escape competition would be to upgrade the local networks with optical fibre and to offer a higher quality, i.e. bandwidth, to the end-user.

[1] For an overview, see Tables A1 and A2 in the Appendix.

However, the ultimate effects of this new regulatory scheme on investment decisions and eventually the competitive environment are unknown (see e.g. Xavier and Ypsilanti, 2011). Policymakers are thus reluctant to institute deregulation (e.g., Bundesnetzagentur, 2010; EC, 2008c). We therefore empirically evaluate the effects of local deregulation in the WBA market on infrastructure investment by the incumbent telecommunication carrier and its competitors. To this end, we make use of a change in the regulatory scheme in the United Kingdom WBA market. In 2008, the U.K. regulator, Ofcom, divided the WBA market into three competition areas. In areas with sufficient infrastructure-based competition, the incumbent (British Telecom) was released from regulation in that specific market. Ofcom applied a set of rules that determine the deregulation of exchange areas, inter alia, based on the number of relevant competitors that are active in the respective markets, and the size of the local retail market.

We measure investment incentives on two dimensions. First, we investigate the number of infrastructure-based competitors - so called "local loop unbundlers" (LLU). LLU operators undertook large investments in installing and maintaining infrastructure. They provide end-users with broadband Internet with their own network. Second, we analyze the incumbent's infrastructure investments by its roll-out of optical fibre which enables higher transfer rates and allows the incumbent to differentiate itself from the competitors. We concentrate on these measures, since increasing infrastructure-based competition is the preferred goal of regulatory authorities. It is favored over service-based competition since it is sustainable and increases consumer choice while lowering consumer prices in the long run (Bourreau and Dogan, 2004; Woroch, 2002).

We quantity the effects of deregulation with a first-difference approach in which we compare the development of regulated and deregulated areas between 2007 and 2012. Since deregulation decisions are based on the competitive situation in an exchange area, deregulation is endogenous by design and regulated and deregulated areas must differ in their initial (i.e., prior to the reform) competitive situations and other local characteristics. In order to deal with the endogeneity, we control for the initial competitive situation and other local characteristics. In further specifications we present propensity score matching based on socio-demographic characteristics as well as subsample estimates based on very similar competition levels in 2007. One related concern is that our basic specification might capture a "self-fulfilling prophecy," which arises due to the fact that Ofcom's deregulation decision depends not only on actual, observed investment, but also on its forecast for local investments by large infrastructure-based competitors. A change in the deregulation rules allows us to distinguish similar exchange areas with and without forecasts.

Our data are from the Internet platform Samknows (Samknows, 2007, 2012), a not-for-profit website that provides detailed local features of the broadband market in the United Kingdom. We merge these exchange-level data with ward-level socio-demographic characteristics.

We find overall positive effects of deregulation on infrastructure-based competition. The number of LLU operators by tendency increases more in deregulated exchange areas than in regulated areas between 2007 and 2012. We are able to quantify the part of these investments that cannot stem from Ofcom forecasts and therefore capture the pure deregulation effect. Furthermore, deregulation increased British Telecom's investment in optical fiber infrastructure: in deregulated areas, British Telecom is significantly more likely to roll out optical fiber.

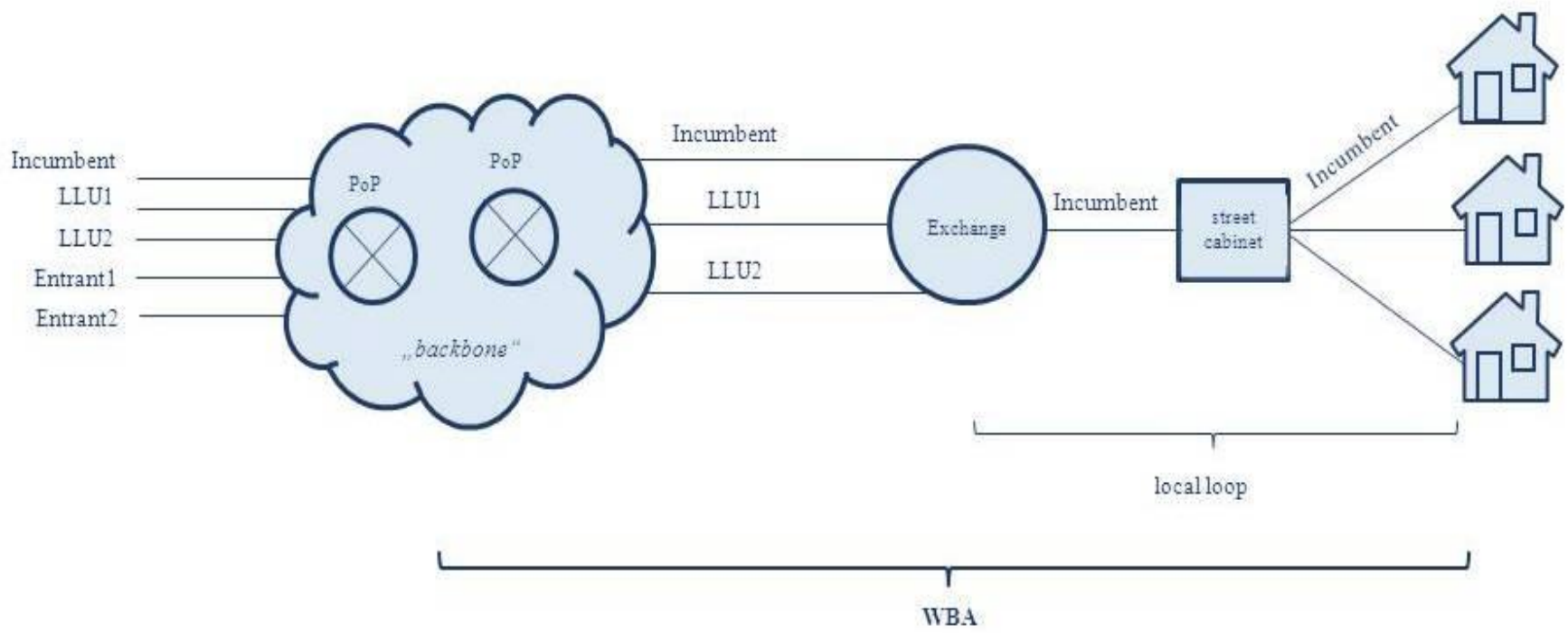
The remainder of the paper is organized as follows. Section 2 describes in more detail the WBA market and the deregulation process in the United Kingdom. Section 3 introduces our data. Section 4 presents our estimation strategy, basic results, and various robustness specifications. Section 5 concludes.

2. Institutional Setting

2.1. Wholesale Broadband Access

WBA refers to a wholesale market in which an entrant with limited own infrastructure buys transmission services from the incumbent with access to the end-users' premises. Figure 1 displays the structure of the WBA market. The entrants' own infrastructure only reaches certain points of presence in the backbone network. These points of presence are intersection points where entrants hand over data transmission to the incumbent. Mandated wholesale broadband access used to be considered to create competition in the broadband market since market entrants could offer products on the retail market without owning infrastructure that actually connects to end-users. Over the last several years, however, market entrants have increasingly begun to invest in their own infrastructure. Their own networks typically expand until the exchange where they connect to the copper-based local loops that link every premise to the exchange, a process known as local loop unbundling (LLU). The local loops are owned by the incumbent, who is required to grant access on regulated conditions. The infrastructure-based competitors thus can offer not only services to end-users, but also wholesale broadband access. Copper-based local loops are viewed as an essential facility and the regulation of access to them is not under debate. Deregulation of the WBA market, in contrast, has been widely discussed throughout Europe, at least for areas with increasing infrastructure-based competition (OECD, 2010; Kiesewetter, 2011).

Figure 1: The Structure of the WBA Market



Notes: WBA = wholesale broadband access; LLU = local loop unbundling operator; PoP = point of presence.

2.2. The Process of Local Deregulation in the United Kingdom

In the United Kingdom, the WBA market used to be regulated on a national basis, but in 2008, geographically differentiated regulation of the WBA market came into effect. The European Commission supported Ofcom's decision since ex ante regulation should be relaxed when infrastructure-based competition becomes sufficiently developed (EC, 2007).

British Telecom's local exchange areas were chosen as the relevant geographical unit. Broadband service providers make their supply and infrastructure investment decisions at the exchange level, since each exchange covers a certain geographical area and therefore defines the local customer base. Ofcom grouped all exchange areas into three categories based on their competitive situation.[2] Categories 1 and 2 remain regulated, but the incumbent British Telecom was released from regulation in Category 3 areas.

Category 1 is comprised of exchange areas where British Telecom is the only operator. Category 2 contains exchange areas in which some competition has developed. These are exchange areas with two or three relevant competitors – so called "Principal Operators" (POs) - actually present or forecast to be so. Also in Category 2 are exchange areas with four relevant competitors, which includes one forecast competitor (i.e., three are actually present), but that serve less than 10,000 premises. Besides British Telecom and Virgin Media (the cable operator), six LLUs with a national coverage of more than 45 percent of U.K. premises were considered to be relevant competitors.[3] Exchange areas with four or more relevant competitors and exchange areas with three relevant competitors and at least one more forecast, but that serve more than 10,000 premises, form Category 3. Table A3 in the Appendix summarizes the criteria underlying the deregulation decision in 2008.

In its 2010 revision of WBA market regulation, Ofcom considered the 10,000 premises rule redundant and introduced a new criterion for deregulation. In addition to the number of relevant competitors, British Telecom's market share had to be lower than 50 percent, the standard threshold at which significant market power can be assumed according to Commission guidelines (Ofcom, 2010). Table A4 in the Appendix summarizes the criteria underlying the 2010 market definitions. Figure 2 shows the geograph-

[2] In addition, a fourth market was defined in the Hull area, where KCOM, a local provider, was the only operator. This area contains 14 exchange servers and covers 0.7 percent of U.K. premises. Due to data limitations, exchanges owned by KCOM are excluded from this analysis.

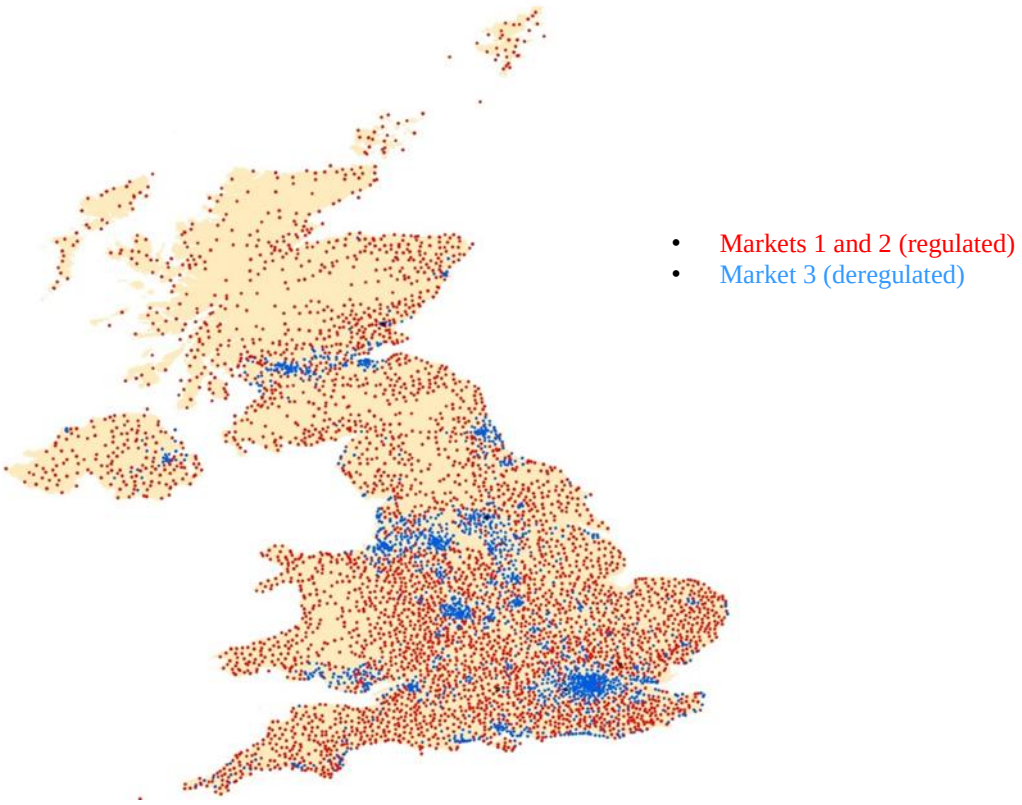
[3] These are Sky, O2, Orange, Cable&Wireless, Tiscali, and the TalkTalk group. Virgin Media counts as a relevant competitor if its coverage of premises in the respective market is at least 65 percent.

ical distribution of deregulated exchange areas in the United Kingdom as of 2010, mapping exchange areas that were deregulated in 2008 and 2010.

3. Exchange-Level Data and Regional Characteristics

Our data are from the Internet platform Samknows, a not-for-profit website that was originally founded to provide broadband speed tests to the general public. The website provides comprehensive information on the local competitive environment, such as the LLU operators present in an exchange, the enabled technologies that determine the broadband speed, and the number of premises served by an exchange. The website is continuously updated and we observe cross-sections or "snapshots" of all 5,598 exchange areas at two points in time, December 2007 and November 2012.

Figure 2: Geographic Distribution of Deregulated Exchange Areas in the United Kingdom



Source: own representation based on Samknows data

Our measure for infrastructure investment by the incumbent's competitors is the number of LLU operators present in an exchange. In order to become a LLU, a firm undertakes substantial investments in own network infrastructure. It still competes in the retail market based on wholesale services (the last mile is still rented from the incumbent) but

it competes on a higher level of vertical integration. We therefore consider the number of LLUs a good measure of infrastructure investment, even though they may not represent a form of sustainable infrastructure-based competition in the retail market Table A5 in the Appendix lists the LLU operators along with their national coverage in both years. The list of LLU operators in the U.K. market is not fully congruent over time due to the highly dynamic nature of the broadband market. The six largest firms in terms of infrastructure coverage were considered relevant competitors in 2007 and are relevant for the deregulation process. In 2012, there were in effect only four operators. In 2010, the relevant competitor Orange handed its LLU network back to BT. In the same year, the relevant competitors Tiscali and TalkTalk merged. Despite this fact, Samknows still reports the two firms separately and so we observe them as separate LLUs.

Our measure for the incumbent's infrastructure investment is a binary indicator that takes the value 1 when optical fiber (the "next generation access" or "FTTC" technology) has been enabled by the incumbent British Telecom or will be enabled in the exchange by 2013[4]. It should be noted, that this variable does not provide direct information on the number of homes passed with FTTC. Whether or not a household may receive FTTC services is determined at the level of the street cabinet (see Figure 1). Within an enabled exchange area, only the premises covered by fibre-enabled street cabinets will be able to receive FTTC services[5]. This typically covers an average of around 85% of homes and businesses within an enabled telephone exchange area (ISP review, 2013). As Table 1 shows, in 2007 none of the exchange areas had FTTC technology installed, since the technology had not yet been introduced to the broadband market. By 2012, 25 percent of exchange areas had this infrastructure or had it installed in the near future. Table 1 further reveals that the number of LLU operators present in an exchange area increased considerably from, on average, 1.24 LLU operators in 2007 to 1.80 LLU operators in 2012. The incumbent BT and the cable operator Virgin Media count as POs, but they are not considered as LLU operators and consequently are not included in these numbers.

Table 1: Descriptive statistics of exchange- and ward-level characteristics, by year

	2007	2012

[4] Technically, in 2006, the BT group formed a separate infrastructure division, Openreach, which is in charge of the maintenance and deployment of BT's local access network (the last mile). Since the separation took place before the time period considered in this analysis, and affected all exchange areas equally, this should have no influence on our estimates.

[5] According to the FTTH Council Europe, as of December 31st 2012, the FTTC take-up rate in the UK was around 8.9% at a total of 1.17 million FTTC subscribers and nearly 13 million homes passed (thinkbroadband, 2013).

	mean	std. dev.	mean	std. dev.
Exchange-level characteristics				
# of exchange areas	5,598		5,598	
# LLU operators	1.24	(2.27)	1.80	(2.57)
FTTC enabled	0	(0)	0.25	(0.44)
Deregulated	0	(0)	0.28	(0.45)
# of premises	4,852.03	(6,984.94)	4,852.03	(6,984.94)
Broadband via cable available	0.24	(0.42)	0.24	(0.42)
Ward-level characteristics				
Population share working age	0.60	(0.05)	0.62	(0.05)
Population density (per km²)	956.10	(1,997.30)	984.99	(2,064.33)
Claimant count share (working age)	0.02	(0.01)	0.03	(0.02)

Note: Standard deviations (std. dev.) in parentheses.

We also obtain our main explanatory variable—the WBA deregulation status—from Samknows.[6] Each exchange is assigned to one of the three regulatory markets. In 2008, 1,193 out of 5,598 exchange areas were deregulated. After Ofcom's 2010 revision, another 348 exchange servers were deregulated, while seven were reregulated. Overall, 28 percent of exchange areas were deregulated in 2012, which corresponds to 78.2 percent of U.K. premises.

We derive cable operator presence in the exchange area from Samknows in order to account for composition of the local infrastructure competition. Even though cable operators do not offer WBA services during the period of analysis, they exert indirect competitive pressure via the retail market. Broadband connections realized via cable infrastructure are in direct competition with FTTC lines since they offer similar broadband speeds. Lastly, we obtain from Samknows the size of the local market an exchange serves, reported as the number of premises connected to the exchange. The number of premises comprises all residential as well as commercial premises connected to an exchange.

Samknows reports the exchange areas' geographic locations via their postcodes. With this information we are able to geo-code the exchange areas and assign them to wards. We thus merge the exchange-level data with regional characteristics at the ward level. The information on ward boundaries in Great Britain is from Edina (2012); ward boundaries for Northern Ireland are made available from the Northern Ireland Statistics and Research Agency (2012a). As of 2011, the United Kingdom had 9,523 electoral wards with an average population of 5,500. The working-age population and the claim-

[6] Since we base our estimates on data from Samknows and not from Ofcom directly, small deviations from the figures published in Ofcom (2008, 2010) occur.

ant count serve as proxies for local income and demand for broadband, respectively. Population density is a measure for supply since it indicates the unit costs of providing broadband. In densely populated areas, a provider can reach a larger customer base with the same amount of infrastructure investment than it can in a sparsely populated area.

The working-age population is defined as the population share of the male inhabitants aged 16–64 and the female inhabitants aged 16–59. Population density is calculated as ward inhabitants per km². The population data are obtained from the U.K. national statistical offices: the Office for National Statistics (2012), which covers England and Wales, the Scottish Neighborhood Statistics (2012), and the Northern Ireland Statistics and Research Agency (2012b). The claimant count is obtained from NOMIS (2012), the Office for National Statistics' database on U.K.-wide labor market statistics. This measure is available at the ward-level and counts the unemployed people claiming Jobseeker's Allowances in a particular month. We construct the annual average, which is expressed as the share of claimant count in the working-age population. Descriptive statistics for these variables are reported in Table 1.

4. The Effect of Local Deregulation on Investment Behavior

4.1. Estimation Strategy and Sample Restriction

We estimate the effect of local deregulation of the British WBA market on the investment behavior of both the incumbent and its competitors in a first-difference model conditional on initial exchange and ward characteristics:

$$\Delta Y_{i,2007-12} = \alpha + \beta D_{i,2008/10} + X_{i,2007}\gamma' + \Delta X_{i,2007-12}\kappa' + \varepsilon_i \qquad (1)$$

ΔY is the change in the outcome of interest between 2007 (i.e., before deregulation) and 2012 (i.e., after deregulation). Our outcomes of interest are the development of the number of LLU operators in the exchange *i* and the incumbent's FFTC status, both of which serve as indicators of the intensity of infrastructure-based competition in the respective exchange areas. D is a dummy variable that equals unity if the exchange is no longer regulated in 2008 or 2010. X is a matrix of exchange characteristics (number of premises, number of LLU operators, and cable presence) and local characteristics at the ward-level (working-age population share, population density, claimant count population share, dummies for England, Wales, Scotland, and Northern Ireland) in 2007. We control for these initial values to account for the fact that regulated and deregulated exchange areas were already different before deregulation and thus might exhibit differing

trends even if deregulation had not taken place. For example, with the unbundling of the local loop in the United Kingdom in 2001, all exchange areas started without LLUs. By 2007, some areas had achieved a considerable level of competition and therefore were deregulated, whereas other areas experienced no competition. Therefore, the matrix X also contains the "number of LLU operators in 2007." ΔX is a matrix of all local characteristics at the ward level expressed in changes between 2007 and 2012. ε is an error term.

β is the coefficient of interest. It gives us the association between local deregulation and either the number of LLU operators present in the exchange or the FTTC status of the incumbent conditional on initial values of exchange and (changes in) ward characteristics. The effect of local deregulation is estimated consistently under the assumption that investments at regulated and deregulated exchange areas would have developed in parallel in the absence of deregulation given the initial structural differences. To ensure comparability between regulated and deregulated areas regarding their characteristics in 2007, we also estimate our model for subgroups of exchange areas that are very similar in their initial conditions.

Figure 3 shows the probability of an exchange being deregulated based on number of premises served. The figure indicates that if the exchange has less than 2,000 premises, its probability of being deregulated is practically zero, whereas if it serves more than 23,000 premises, the probably is unity. In contrast, we find strong variation in the probability of local deregulation of the WBA market for exchange areas having a number of premises served that falls between these two values. We thus restrict our analysis to those 2,276 exchange areas that serve between 2,000 and 23,000 premises.

Table 2 shows descriptive statistics for the exchange areas included in our analysis. Descriptive statistics are reported before deregulation took place in 2007, and by regulatory status in 2008/2010. Out of the 2,276 exchange areas, 928 (41 percent) are deregulated by 2008/2010. The table reveals that regulated and deregulated exchange areas are not directly comparable due to large structural differences between them that already existed before deregulation. Deregulated exchange areas serve on average about 8,000 premises more than regulated exchange areas. Initial competition is more pronounced in deregulated exchange areas than in regulated exchange areas as deregulated exchange areas initially have, on average, 4.17 LLU operators more than regulated areas and they are located in denser wards than are regulated exchange areas.

Figure 3: The Probability of Deregulation by Premises

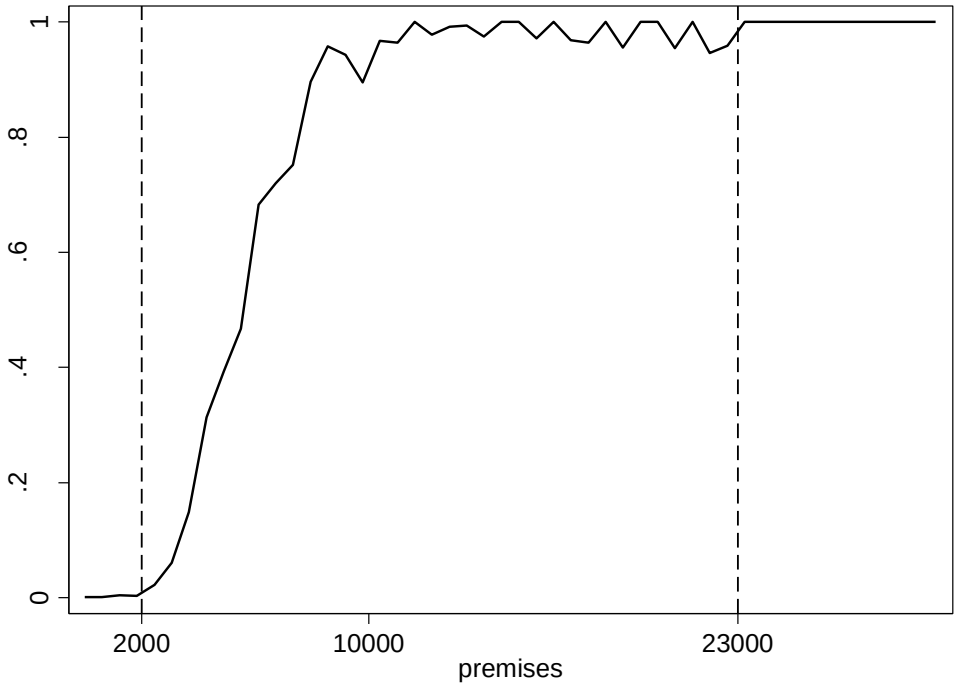


Table 2: Descriptive statistics in 2007, by regulatory status

	regulated	dereg.	|difference|
Exchange-level characteristics			
No. of exchange areas	928	1,348	
No. of LLU operators	0.09	4.26	4.17***
No. of principal operators	1.13	5.29	4.16***
FTTC enabled	0	0	
No. of premises	3,832.80	11,790.90	7,958.1***
Cable via broadband	0.16	0.70	0.54***
Ward-level characteristics			
Population share working age	0.59	0.62	0.03***
Population density (per km^2)	587.7	2,705.4	2,117.7***
Claimant count share (working age)	0.015	0.024	0.009***

Notes: Descriptive statistics for exchange areas with 2,000 to 23,000 premises. *** $p<0.01$.

4.2. The Effect of Local Deregulation on Investment

Table 3 shows the results for our first-difference specification. The first column reports results for changes in the number of LLU operators and the second column for the FTTC status of British Telecom. Both regressions include the initial number of LLU operators, the number of premises served by the exchange, and cable presence. This information is from the year 2007. We also include ward characteristics for the year 2007 and changes in ward characteristics from 2007 to 2012. Robust standard errors are reported in parentheses. The results suggest that, on average, deregulated exchange areas have 1.1 (rounded) LLU operators more than regulated exchange areas. FTTC rollout is on average 26.2 percentage points more likely in deregulated exchange areas.

The control variables have the expected signs and magnitudes. The initial value of LLU operators is negative in Column (1), which might indicate a saturation effect: with an increasing amount of initial infrastructure-based competition, it is less profitable for additional competitors to become LLUs. In contrast, the effect is positive in Column (2), which denotes the incumbent's reaction: in regions with a priori well-developed infrastructure competition, BT is more likely to invest in FTTC. This infrastructure upgrade might be a reaction to increased competition from the LLUs since BT can use FTTC to differentiate itself from its competitors by offering a higher quality product (in terms of bandwidth). As expected, the cable variable is negative in both estimations. In areas in which broadband is already available via cable, LLU operators and the incumbent find it less economically worthwhile to invest. In a sense, the cable variable could be interpreted as reflecting the cable operator's first-mover advantage. Finally, the premises variable clearly reveals that broadband provider investment is driven by local demand as they are more likely to invest in larger markets.

To this point, we have imposed a linear relationship between the outcome of interest and the initial exchange and ward characteristics. This assumption of linearity between the outcome of interest and the initial exchange and ward characteristics becomes especially hazardous when we estimate the effect on the change in the number of LLU operators and additionally control for the number of LLU operators in 2007. Our specification implies that an increase in the initial number of LLU operators from, e.g., one to two operators will have the same effect on changes in the number of LLU operators as would an increase from four to five initial LLU operators.

To see whether this may affect our results, we next relax the assumption of a linear relationship between the outcome of interest and the initial exchange characteristics. We do this by replacing the initial number of LLU operators in our basic regressions with a full

Table 3: Basic results

	(1) ΔLLU	(2) ΔFTTC	(3) ΔLLU	(4) ΔFTTC
Deregulated (in 2008 or 2010)	1.055***	0.262***	1.199***	0.199***
	(0.072)	(0.028)	(0.096)	(0.035)
# LLU (in 2007)	-0.476***	0.041***		
	(-0.023)	(0.007)		
LLU dummies (in 2007)			yes	yes
Broadband via cable (in 2007)	-0.168***	-0.117***	-0.191***	-0.102***
	(-0.051)	(-0.021)	(-0.053)	(-0.022)
Premises (in 1,000s)	0.079***	0.023***	0.079***	0.023***
	(0.009)	(0.003)	(0.009)	(0.003)
ΔRegional characteristics	yes	yes	yes	yes
Regional characteristics in 2007	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes
# of exchanges	2,276	2,276	2,276	2,276
R-squared	0.333	0.394	0.348	0.4

Notes: First-differences estimations on the exchange level. Exchange areas with 2,000 to 23,000 premises are included in the regressions. Columns (3) and (4) include a full set of dummies for every starting value of LLU operators. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

set of dummies for every starting value of LLU operators. The results are shown in Columns (3) and (4) of Table 3. Deregulated exchange areas, on average, now have 1.2 LLU operators more than regulated exchange areas. FTTC rollout is on average 19.9 percentage points more likely in deregulated exchange areas. The estimated effects of local deregulation are comparable to the effects found in the first specification, indicating that the functional form of the first specification does not compromise the validity of our results.

4.3. Ensuring Comparability Between Regulated and Deregulated Exchange Areas

To better compare regulated and deregulated areas regarding their initial situations, we now create subsamples of regulated and deregulated exchange areas, for each of which the two areas have very similar initial conditions. Our first subsample consists of regu-

lated and deregulated exchange areas that are "statistical twins" in terms of their ward characteristics. Statistical twins are matched, using the propensity score matching method, on working-age population share, population density, and claimant count population share. As a nonparametric estimation technique, propensity score matching allows us to impose a common support in the sample. With common support, only exchange areas with similar propensity scores, i.e., with similar probabilities of deregulation, are compared with each other. The results are shown in Table 4 and suggest that deregulated exchange areas have, on average, between 0.84 and 0.95 LLU operators more than regulated exchange areas, depending on the matching algorithm. FTTC rollout is on average between 14.3 and 23.3 percentage points more likely in deregulated exchange areas. Overall, the matching only slightly decreases the magnitude of the deregulation effects presented in Table 3, suggesting that differences in initial ward characteristics, which are the basis of our matching approach, do not distort our results.

Our second subsample approach concentrates on the 451 exchange areas with three or four POs present in 2007. These exchange areas are comparable in terms of their initial competitive situation but differ in the probability of being deregulated according to Ofcom's rules. Note that in 2008, Ofcom deregulated only those exchange areas with four POs or exchange areas with three POs if at least one more PO was forecast and the number of premises served by the exchange is greater than 10,000. The results of this subsample estimation are shown in Columns (1) and (2) of Table 5. On average, deregulated exchange areas have 0.61 LLU operators more than regulated exchange areas. FTTC rollout is on average 17.1 percentage points more likely in deregulated exchange areas.

Even though in the subsample of exchanges with three or four POs in 2007 deregulated and non-deregulated exchanges are comparable in terms of initial competitive situation, they might still differ in terms of market size. Deregulated exchange areas serve on average larger markets. Therefore, in a next step, we restrict the sample of exchanges with three or four POs in 2007 to exchange areas serving fewer than 10,000 premises so as to achieve better comparability between regulated and deregulated exchange areas. The results are shown in Columns (3) and (4) of Table 5. Again, deregulation shows a positive effect, and the coefficients are significant at the 5 and 10 percent level for the number of LLU operators and FTTC deployment, respectively. The effect on the number of LLU operators decreases to 0.42, while the effect on FTTC deployment remains relatively stable and decreases only slightly to 16.1 percentage points.

The results in Table 5 imply that controlling for the initial competitive situation in an exchange area is not sufficient to guarantee the validity of the common trend assump-

tion when considering the effect on BT's competitors. Restricting the subsample to ex ante more similar exchange areas thus provides more credible estimates of the deregulation effect.

Table 4: Propensity score matching

	1-to-1 w/out replacement		1-to-1 with replacement		5-n-n with replacement		Kernel (Epanechnikov)	
	(1) ΔLLU	(2) ΔFTTC	(3) ΔLLU	(4) ΔFTTC	(5) ΔLLU	(6) ΔFTTC	(7) ΔLLU	(8) ΔFTTC
Deregulated (in 2008 or 2010)	0.949***	0.233***	0.877***	0.154***	0.875***	0.143***	0.841***	0.144***
	(0.065)	(0.027)	(0.077)	(0.033)	(0.07)	(0.029)	(0.066)	(0.028)
# LLU (in 2007)	-0.466***	0.051***	-0.458***	0.051***	-0.439***	0.054***	-0.431***	0.050***
	(-0.017)	(0.007)	(-0.018)	(0.008)	(-0.016)	(0.007)	(-0.016)	(0.007)
Broadband via cable (in 2007)	-0.172***	-0.114***	-0.172***	-0.065**	-0.159***	-0.072***	-0.125**	-0.081***
	(-0.052)	(-0.022)	(-0.06)	(-0.025)	(-0.054)	(-0.023)	(-0.052)	(-0.022)
Premises (in 1,000s)	0.093***	0.017***	0.075***	0.012***	0.071***	0.012***	0.069***	0.013***
	(0.008)	(0.003)	(0.007)	(0.003)	(0.006)	(0.003)	(0.006)	(0.003)
ΔRegional characteristics	yes	yes	yes	yes	yes	yes	yes	yes
Regional characteristics (in 2007)	yes	yes	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes	yes	yes	yes
# of exchanges	1,854	1,854	1,581	1,581	1,932	1,932	2,148	2,148
R-squared	0.294	0.408	0.31	0.304	0.294	0.317	0.275	0.305

Notes: First-differences estimations at the exchange level. Columns (1) and (2) report results for one-to-one nearest neighbor matching without replacement. Columns (3) and (4) report results for one-to-one nearest neighbor matching with replacement. Columns (5) and (6) report results for five-nearest neighbor matching with replacement. Columns (7) and (8) report results for kernel matching with Epanechnikov kernel. Propensity score matching is based on ward characteristics in 2007. Only exchange areas with 2,000 to 23,000 premises are included in the regressions. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.

4.4. Removing Principal Operator Forecasts

The last subsample is interesting from another perspective, too: in its deregulation decisions, Ofcom considers unobserved forecasts of principal operators' future investments. Thus, our estimation results of the effect of deregulation on the number of LLU operators might simply reflect, to some extent, Ofcom's forecasts as a self-fulfilling prophecy: that is, an exchange area is expected to have a positive development in the future and is consequently deregulated. If the expected investments occur in the future, they will be attributed to deregulation in the results presented in the previous section, even though they would also have occurred in the absence of deregulation, giving rise to endogeneity bias of the deregulation coefficient.

To distinguish between the effect of deregulation and these forecast effects, we use the fact that Ofcom incorporated the criterion that exchange areas had to exceed 10,000 premises for deregulation in 2008, but then dispensed with this requirement in 2010. This change leads to the situation that in our subsample of exchanges areas with three or four POs and less than 10,000 premises, 120 premises were deregulated in 2008 because they had four POs. Out of the remaining 221 exchange areas that were not deregulated by 2008, 179 were deregulated in 2010. Since the 10,000 premises criterion was dropped, these areas could be deregulated in 2010 if they initially had three POs and at least one additional PO forecast. The remaining 42 exchange areas were not deregulated. These areas had three POs present and no PO forecast. To disentangle the forecast effect from the deregulation effect, we estimate separate effects for exchanges that were deregulated in 2008 and those deregulated in 2010. The binary variable for deregulation in 2008 captures the pure deregulation effect, whereas the indicator for deregulation in 2010 captures both effects. The difference between the two estimators is thus the forecast effect.

The estimates are shown in Column (5) of Table 5 and imply, as expected, that the pure deregulation effect from 2008 is considerably smaller than the estimate from 2010 that captures both effects. According to our point estimates, upon being deregulated, an exchange area gains 0.22 additional LLU operators, whereas the forecast effect is about 0.24 LLU operators, the difference between the two coefficients. At 340 observations, the sample is unfortunately small and therefore the point estimates of the deregulation effect as well as the forecast effect are not statistically significant on conventional levels. However, the estimate allows us to rule out large negative effects of a deregulation on competitors' investment behavior.

4.5. Validity of the results

The previous sections established a large positive and statistically significant relationship between local deregulation and the investment in optical fibre by the incumbent and a weakly positive effect on infrastructure investment by the incumbent. In this section we address several concerns that might arise when considering the validity of our results.

The first relates to the choice of our first outcome variable, the number of Local Loop Unbundlers. In order to become a LLU, a firm undertakes substantial investments in own infrastructure. Despite this fact, such firms cannot be considered sustainable infrastructure-based competitors as they still rely on the incumbent's last mile in order to provide services in the retail market. But nonetheless, they compete on a higher level of vertical integration, which reflects investments in network infrastructure. We therefore consider the number of Local Loop Unbundlers an indicator that allows for a dynamic perspective on developments in the broadband markets.

One concern on the estimated effects may relate to firms' behavior in anticipation of the new regulatory scheme. The partial deregulation of the WBA market has been subject to public consultations and discussion with the national regulator for some time before it was implemented. If firms adjusted their investment behavior accordingly before the actual deregulation took place, we would expect firms to start investing in areas in which they face high levels of competition (and which are likely to be deregulated). This early investment in later deregulated areas would lead to an underestimation of the effect of the deregulation.

In 2012, the UK government launched an umbrella scheme for the deployment of NGA networks, the Broadband Deployment UK (BDUK). Under this programme, around £530 million were made available as subsidies to broadband projects by 2015. The scheme targets predominantly so called "white areas", which are rural areas with little or no broadband infrastructure, which would remain unprovided under usual market conditions (European Commission, 2012). We have no detailed information on state funding within UK wards, but given that mostly rural areas receive subsidies, we conclude that if the broadband programme should interfere with our results, it would lead to an underestimation of the deregulation coefficient.

5. Conclusion and Outlook

This study provides first empirical evidence on the relationship between local deregulation and subsequent competitive development in the WBA market. Although to date

theoretical predictions about competition-related developments in deregulated local markets have been unclear, our findings shed some light on this "black box." Our estimates imply that local deregulation of the U.K. WBA market has a positive effect on infrastructure-based investment by the incumbent and we find no negative effects on competitors' investments.

We cannot observe counterfactual outcomes, i.e., we do not know with certainty how deregulated markets would have developed in the absence of deregulation. But given that our first-difference approach accounts for time-invariant exchange area characteristics, and that we also control for initial pretreatment conditions in 2007, we are confident that our results reflect the counterfactual effect very well. This is corroborated by the fact that we find positive effects of deregulation in all subsamples and for all alternative specifications. In addition, our LLU operator estimates are not confounded with forecast effects that would bias our results.

These findings have important policy implications. The data reveal no negative effects on infrastructure-based competition in response to deregulation of competitive areas. On the contrary, our study shows that deregulated areas exhibit even higher levels of competition after deregulation. This finding should mitigate, at least to some degree, regulators' concerns that competition will weaken when competitive exchange areas are deregulated.

Debate over the pros and cons of local deregulation of the WBA market is a recent development. We chose to study the effects of local deregulation of the British WBA market because the United Kingdom was the first country to take this step. This allows us to study the medium-term effects on the investment behavior of British Telecom and its competitors. We are confident, however, that the effects are generalizable to other countries. It is beyond the scope of our analysis to study longer-term effects such as how increased infrastructure-based competition will affect consumer prices and choice. Studying these effects provides a fruitful avenue of further research.

Table 5: Subsamples based on Ofcom's deregulation rule

	3 and 4 relevant competitors in 2007		3 and 4 relevant competitors in 2007 & premises < 10,000		
	(1) ΔLLU	(2) ΔFTTC	(3) ΔLLU	(4) ΔFTTC	(5) ΔLLU
Deregulated (in 2008 or 2010)	0.610***	0.171**	0.415**	0.161*	
	(0.191)	(0.077)	(0.196)	(0.084)	
Deregulated (in 2008)					0.216
					(0.253)
Deregulated (in 2010)					0.456**
					(0.193)
# LLU (in 2007)	-0.463***	0.059**	-0.386***	0.077**	-0.318***
	(-0.086)	(0.03)	(-0.085)	(0.037)	(-0.109)
Broadband via cable (in 2007)	-0.183	-0.156**	-0.122	-0.121*	-0.054
	(-0.169)	(-0.064)	(-0.181)	(-0.073)	(-0.19)
Premises (in 1,000s)	0.127***	0.027***	0.265***	0.029	0.273***
	(0.022)	(0.005)	(0.045)	(0.018)	(0.045)
ΔRegional characteristics	yes	yes	yes	yes	yes
Regional characteristics (in 2007)	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes
# of exchanges	451	451	340	340	340
R-squared	0.248	0.222	0.264	0.195	0.211

Notes: First-differences estimations at the exchange level. Columns (1) and (2) report results for the subsample of exchanges with three or four principal operators in 2007. Columns (3) to (5) report results for the subsample of exchanges with three or four principal operators in 2007 and less than 10,000 premises. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

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Appendix

Table A1: NRAs' requests for geographic differentiation of the WBA market

Criteria for deregulation	UK	PT	DE	AT	ES
Unit of (de)regulation	exchange areas	exchange areas	exchange areas	exchange areas	exchange areas
Market size (premises)	≥ 10,000 (in 2008 only)	-	> 4,000 households	> 2,500	≥ 10,000 households
Market share incumbent	≤ 50% (2010)	≤ 50%	< 50%	< 50%	≤ 50%
No. of relevant operators*	≥ 4	≥ 3 (min. 1 LLU, 1 cable)	> 4	≥ 4	≥ 4 (2 LLU + 1 cable or 3 LLU)
Cable	≥ 65 % cov.	≥ 60 % cov.	No	yes	≥ 60 % cov.
* incl. incumbent					
EC (or NRA) notification					
Status	approved (Feb. 2008)	approved (Jan. 2009)	rejected by NRA (2009)	rejected by Admin. Court (Dez. 2008)	rejected by EC "serious doubts" (Nov. 2008)
Reasons for rejection			national scope of market removal of exchanges (future development unknown)	national scope of market	national scope of market WBA < 30 Mbit LLUs' usage of own WBA is counted

Note: Apart from Germany and Austria, all countries' NRAs filed notifications for geographic segmentation with the EC, which were rejected or approved by the Commission. NRA= National Regulatory Authority; UK = United Kingdom, PT = Portugal, DE = Germany, AT = Austria, ES = Spain, FI = Finland, PL = Poland, RO = Romania, CZ = Czech Republic. Sources: Bundesnetzagentur (2010); EC (2008b, 2008c, 2008d); Ofcom (2008, 2010).

Table A2: NRAs' requests for geographic differentiation of the WBA market, continued

Criteria for deregulation	FI	PL	RO	CZ
Unit of (de)regulation	exchange areas	Municipalities		municipalities
Market size (premises)	-	-		-
Market share incumbent	< 50%	≤ 40%	*market traditionally unregulated*	≤ 40%
No. of relevant operators*	≥ 3 (or 2 +1 BWA)	≥ 3 (retail level)		≥ 3 (competing infrastructures)
Cable	yes	no		yes
* incl. incumbent				
EC (or NRA) notification				
Status	rejected by EC "serious doubts" (Jan. 2009)	rejected by EC "serious doubts" (Apr. 2012)	acknowledged by EU in 2010	rejected by EC "serious doubts" (Aug. 2012)
Reasons for rejection	national scope of market	national scope of market		municipalities do not reflect local markets
	"structural" indicators	"structural" indicators no cost orientation for FTTC		differing infrastructures not sufficient for competition

Note: Apart from Romania, all countries' NRAs filed notifications for geographic segmentation with the EC, which were rejected or approved by the Commission. NRA= National Regulatory Authority; UK = United Kingdom, PT = Portugal, DE = Germany, AT = Austria, ES = Spain, FI = Finland, PL = Poland, RO = Romania, CZ = Czech Republic. Sources: EC (2008e, 2010, 2012a, 2012b).

Table A3: Summary of the WBA market definitions by Ofcom in 2008

Market	Description	Exchanges	Coverage
Market 1	those geographic areas covered by exchange areas where BT is the only operator	3,658	16.4%
Market 2	those geographic areas covered by exchange areas where there are 2 or 3 principal operators present (actual or forecast) AND exchange areas where there are forecast to be 4 or more principal operators but where the exchange serves less than 10,000 premises	747	16.8%
Market 3	those geographic areas covered by exchange areas where there are currently 4 or more principal operators present AND exchange areas where there are forecast to be 4 or more principal operators but where the exchange serves 10,000 or more premises	1,193	66.8%

Source: Ofcom (2008, p. 29); own calculations based on Samknows data.

Table A4: Summary of the WBA market definitions by Ofcom in 2010

Market	Description	Exchanges	Coverage
Market 1	exchange areas where only BT is present or forecast to be present	3,396	11.2%
Market 2	exchange areas where two principal operators are present or forecast AND exchange areas where three principal operators are present or forecast but where BT's share is greater than or equal to 50 percent	661	9.9%
Market 3	exchange areas where four or more principal operators are present or forecast but where BT's share is less than 50 percent	1,541	78.9%

Source: Ofcom (2010, p. 14); own calculations based on Samknows data.

Table A5: Development of local loop unbundlers between 2007 and 2012

2007	exchanges enabled	premises covered (in 1,000s)	2012	exchanges enabled	premises covered (in 1,000s)
TalkTalk	1,515	19,913	(Orange no longer LLU)	n.a	n.a
Sky	1,146	17,683	TalkTalk	2,537	24,759
AOL	1,036	16,490	Sky	1,952	22,869
Orange	940	15,115	O2	1,265	18,283
O2	819	13,374	AOL	1,252	18,802
C&W	793	13,911	Tiscali	947	15,459
Tiscali	569	9,793	C&W	942	16,080
Pipex	99	2,113	Pipex	132	2,627
Node4	4	79	Edge	38	526
Zen	4	120	Digitalregion	36	504
Newnet	3	88	Entanet	20	306
Smallworld	3	45	Newnet	11	301
WBI	1	23	Lumison	5	56
Edge Telecom	1	1	Rutland	5	23
			Node4	4	79
			Zen	4	146
			Smallworld	3	45
			Kingston	2	8
			WB	1	23

Note: LLU = local loop unbundler; PO = principal operator. Source: Own calculations based on Samknows data. Premises covered describes the potential number of premises a LLU operator could serve given the market size of the local exchanges where the LLU operator is present.