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Entry Barriers and Technological Innovation in Broadband^{*}

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Abstract

In this article, I present causal effects of institutional entry barriers to new firms on incumbents' technological innovation. In particular, I investigate the effect of entry barriers to municipal providers on incumbents' technology deployment in the U.S. broadband industry. I use a spatial regression discontinuity design for private incumbents' investment behavior and different entry regimes as sharp cutoffs for municipal entry threat. I collect and combine unique firm-level data on cable investment decisions and state-level data on legal entry barriers. I find that in markets with these entry barriers incumbents invest less in new technologies. Specifically, I find that the local entry barriers lead to a 20% lower technology adoption rate by cable incumbents because of reduced entry threat. These results imply that institutions that restrict entry of new firms can lead to significantly decreased technological innovation and lower internet quality across local markets, not only by deterring new firms but also by altering incumbents' strategic investment in broadband networks.

Keywords: Innovation, Entry Barriers, Broadband, Municipal, Spatial Discontinuity

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1 Introduction

In this article, I examine the effect of local entry barriers to new firms on technological innovation. Although there have been studies on the role of firms' entry and entry threat on incumbents' decision to innovate, there is no empirical evidence on the institutions that restrict entry for new firms and how they affect incumbents' strategic decision to innovate.

In the case of restricted entry for new firms, incumbents may enjoy increased profitability and choose to offer higher-quality products predominantly in markets in which these barriers are low and entry threat is credible (Bain, 1956; Porter, 1979). This paper aims to connect the literature on technological innovation, institutions that determine market efficiency, and the role of entry threat.

Methodologically, this paper uses a spatial discontinuity method that isolates the competitive effects of these exogenous local entry barriers and has not been used for identifying firms' strategic investment. I use the context of the U.S. broadband industry and cable incumbents' technological innovation to capture the effect of these local restrictions on technological innovation. These restrictions provide a direct and observable entry barrier that affects potential entry and determine entry threat. The industry is characterized by incumbents making innovation decisions for each local market capable of offering higher internet quality and by different entry regimes for municipal broadband providers across state borders.

Since the mid-1990s, private internet service providers (henceforth ISPs) in the U.S. have invested \$750 billion in their wireline broadband networks to provide high-speed internet¹. These investments involve expanding their broadband networks and adopting new broadband technologies (or improving existing ones).

¹USTelecom.

Despite these significant investments, in some markets in which private broadband infrastructure is inadequate, local communities and governments invest in broadband networks themselves in order to provide their residents with broadband service. Interestingly, there is anecdotal evidence that in markets where these municipal providers operate, private incumbent ISPs have responded by keeping their prices steady or upgrading their systems faster, compared to neighboring markets without the municipal entry threat. For instance, Time Warner Cable, a major cable incumbent, made significant improvements without raising its price in markets under municipal entry threat, while increasing price in neighboring markets in which the municipal entry threat was minimal².

There are arguments both in favor of and against municipal broadband. The supporters argue that these public firms can provide high-speed internet service and upgrades in markets that private providers do not find attractive; and that the increased competition drives the equilibrium product quality up and, thus, can promote local communities' economic development. The opponents of municipal broadband claim that public firms are ill-equipped to invest and operate broadband networks and that they should focus, instead, on basic infrastructure (e.g., electricity and roads).

This is a controversial policy issue, and 20 U.S. states currently restrict or ban municipal broadband³. Wilson, North Carolina and Chattanooga, Tennessee (two of the most successful cases of municipal broadband in the U.S.) asked the FCC⁴ to preempt these state law restrictions under federal law and allow municipal providers to enter into neighboring markets. In 2016, the 6th Circuit Court of Appeals ruled that the FCC had no authority to remove any state law restrictions and that this should be determined by the state authorities. In Congress, the debate continues on whether the state governments should impose these restrictions on local governments and communities⁵.

²Federal Communications Commission (FCC) about Time Warner Cable's strategy in Wilson, NC and neighboring markets.

³Congressional Research Service, 2016.

⁴Federal Communications Commission.

⁵Three bills were introduced in the 114th Congress (S. 240, S. 597 and H.R. 1106) about municipal broadband.

This article aims to contribute to the debate on the role of institutional entry barriers and municipal entry threat in technology diffusion. In particular, I quantify how these restrictions and the threat of municipal entry affect incumbents' strategic investment in new broadband technologies. Although there is a significant literature on the effect of the entry threat on incumbents' behavior, there is only a limited literature on how institutional entry barriers insulate incumbents from entry threat and alter their strategic behavior compared to that in markets with free entry. Porter (1979) has indicated that this form of entry barriers functions as a competitive force shaping an industry, but the empirical applications are limited.

Of course, state policies may or may not be the reason that private ISPs provide higher-quality products in response to municipal entry threat since broadband provision could be determined, instead, by unrelated unobserved characteristics. Specifically, there may be some state-specific market characteristics that affect broadband provision. I overcome this identification challenge by examining private ISPs across states with different entry regimes. In particular, I focus on cable incumbents that offer service in neighboring markets, but with different entry regimes for municipal providers. I use the spatial variation in state laws on municipal entry in the U.S. broadband industry and construct a spatial discontinuity design to isolate unobserved market characteristics and identify strategic effects. I find an abrupt change in investment in broadband technology adoption across the different entry regimes because of the municipal entry threat.

This spatial discontinuity approach has been used in other fields – to examine the role of minimum wage (Card and Krueger, 1994) and right to work laws (Holmes, 1998)⁶ but there is no empirical application to capture firms' strategic considerations. In the broadband industry setting, these local entry barriers reduce entry threat for cable incumbents.

⁶These papers also examine agents across the state borders.

The role of institutional entry barriers goes beyond broadband and is important for managers and public policy makers. For managers, it suggests that in secluded markets, incumbents may focus only on competition within the market and demand factors while for potential entrants, it defines which markets they can actually enter, conditional on demand and incumbents' investment strategy. From a public policy perspective, it contributes to the debate about local entry barriers and highlights the tradeoff between incumbents' innovation and new firms entering with new technologies. This paper shows that entry barriers may alter not only potential entrants' incentives, but also incumbents' innovation strategy. In addition, it provides insight into why some consumers may not have access to high speed internet.

I focus on the most important technological innovation in cable broadband (the switch to the DOCSIS 3.0 cable system) and examine where private cable incumbents decide to adopt it as a function of market characteristics and municipal entry threat. Municipal entry threat in this setting is determined by whether there are local entry barriers imposed on these public entities. Private ISPs adopt technology to offer higher speeds, and these local entry barriers provide geographical variation for the entry threat that they face.

I use cross sectional firm-level data from the U.S. Broadband Map project, which provides information on broadband deployment and technology used at the local market level. I also collect and combine data about municipal providers from states that impose restrictions or bans on municipal broadband and states that allow cities to expand to neighboring markets.

I show that markets with no entry barriers exhibit significant investment by cable incumbents, even when the distance from markets with municipal providers is large. In particular, I show that the cable adoption likelihood is 20% higher in markets with no entry barriers when considering providers that offer service in neighboring markets. These results indicate that municipal providers'

entry threat plays a significant role in cable firms' innovation process, and allowing them to enter neighboring markets may have strong innovation spillovers. In addition, the results show that not accounting for endogeneity can underestimate the role of these state entry barriers.

For robustness, I provide empirical tests in which I examine whether these results are uniform. For instance, I check whether the results hold only for radical innovation or also for marginal innovation. Also, I geographically expand the definition of a neighboring market. These exercises give similar results with the main specification, which implies that the results are robust and that these entry barriers create significant spatial variation in broadband technology deployment that managers and policy makers should take into account.

2 Related Literature and Theoretical Background

This paper is related and contributes to several streams of literature. First, to the best of my knowledge, this is the first paper to empirically examine and measure the role of local entry barriers in the innovation process of incumbents and, subsequently, spatial technology diffusion. In this setting, the question is how fast (or if) the cable incumbent adopts a new technology as a function of entry threat and what the role of local entry barriers. Although there is empirical literature on competition and innovation (Goettler and Gordon, 2011; Cornaggia et al., 2015) and on innovation and entry (Aghion et al., 2009), there is no literature on the specific institutions that restrict potential entrants.

A related literature is the effect of government entry barriers on firms' entry. Schivardi and Viviani (2010) and Sadun (2015) examine barriers in retail trade and Schaumans and Verboven (2008) in health professions. Dean and Brown (1995) find that pollution regulation creates a bar-

rier to new firm entry. Robinson and McDougall (2011) examine the role of entry barriers in new venture performance. Delmas et al. (2007) examine the role of deregulation in product differentiation in the electric utility industry, while Delmas and Tokat (2005) find that deregulation has a negative effect on firms' productive efficiency. The difference between these papers and mine is that I examine the effect of institutional barriers on technological innovation and that I focus on incumbents' strategic investment rather than entrants or product differentiation.

Second, there is a literature that investigates the role of firms' strategic behavior under the threat of entry. There is an extensive literature on firms' strategic behavior as it relates to limit pricing to pre-empt potential entry (Syverson and Goolsbee, 2008). A related paper is by Seamans (2012), who examines private cable TV networks' response to municipal providers' entry threat. The difference in this paper is that I consider innovation in broadband, I examine the role of entry barriers in incumbents' strategic behavior; and I use a quasi-experimental method based on state barrier discontinuities, which accounts for unobserved factors.

Third, an increasing number of studies examine competition in the broadband industry. Skiti (2016) provides evidence of strategic investment and entry deterrence in the U.S. broadband industry. In this article, however, I focus on the role of local entry barriers to municipal providers in strategic investment, while my identification method is based on the exogenous geographical variation in these institutional barriers. Xiao and Orazem (2013) focus on strategic entry in the broadband industry, while Xiao and Orazem (2011) examine the role of neighboring entry. Wilson (2016) examines the crowding effect of municipal investment in private ISPs' investment. Instead, I identify the strategic effects of entry barriers directly, using the spatial discontinuity across state borders. The difference from these papers is that I examine the effect of local entry barriers on technological innovation, and I use a spatial discontinuity design.

Fourth, some empirical studies use discontinuity regression designs to identify the effect of spatial policy variations. There is a large body of work in the labor and education literature that deploys quasi-experimental methods to identify the effect of various policies on employment (Card and Krueger (1994) among others) and education (Black, 1999) but the body of work that uses this approach to deduce the effect of a policy on firms' behavior is very limited. Holmes (1998) examines the effect of state policies on manufacturing and finds a significant effect of right-to-work on manufacturing employment. I use a similar identification method as these papers by examining incumbents' decision to innovate across the border of different entry regimes in neighboring markets. Snider and Williams (2011) use a multi-dimensional regression discontinuity approach to examine the effect of AIR-21 on airfares and product quality.

Again, my paper differs in that I use a spatial discontinuity design to identify firms' strategic behavior. To the best of my knowledge, this is the first paper to use a geographic regression discontinuity approach to identify firms' strategic incentives. The benefit of quasi-experimental methods is that we can remove the effect of unobserved market characteristics that may simultaneously determine market structure and firms' strategic investment behavior.

3 Industry Background

The U.S. wireline broadband industry has experienced significant investment in infrastructure by private ISPs wanting to upgrade their systems and offer higher internet speeds. In some markets (mostly rural), though, private ISPs have not made adequate investments, especially in the "last-mile," which connects consumers with the "backbone" cable or fiber broadband network.

In these markets, local governments started deploying broadband networks to serve their local

markets. These public firms are usually municipalities, communities, public utilities or just city departments, and the networks are owned either completely by the local government or by public-private ownerships. In addition, these public firms usually invest in optical fiber technology to offer broadband service to both residential and business customers.

Cable providers are the dominant firms in this industry and make switches to new cable systems to offer significantly higher internet speeds and bandwidth. DOCSIS 3.0 is the most important technological innovation in cable broadband, able to offer up to 20 times higher speeds compared to DOCSIS 2.0⁷. This technological innovation involves cable investment at the backbone network level and at the household level. Once the new DOCSIS, households access to the increased speeds.

As mentioned above, some states' legislation restricts or bans municipal broadband. Table 1 lists the states that impose restrictions or (practically) ban municipal broadband. There is a large variation in the regulations on municipal broadband. For instance, Texas and Missouri completely ban municipal firms from providing broadband; some states, such as Louisiana and Minnesota, require local referendums before municipal firms provide broadband service⁸; others, such as Arkansas and Nebraska, allow only power utilities to offer broadband, while Pennsylvania and Virginia allow municipal broadband only if there are no private ISPs willing to offer service.

4 Theoretical model

I present a model to provide intuition about the cable's incumbent's incentive to adopt a new technology when there are entry barriers to potential municipal entrants. Assume a sequential game between cable incumbent c and a potential fiber entrant f . In the first stage, the cable incumbent

⁷See Skiti (2016).

⁸Minnesota requires a majority of 65%.

makes the binary decision d_c of whether or not to adopt a new technology that offers higher product quality. In the second stage, the potential fiber entrant observes first-stage incumbent's decision and decides whether to enter.

Assume that cable incumbent c 's profits in market m are given by:

$$\Pi_{m0}^c = \theta_{00c}\alpha_m + \theta_{10c}Muni_m + \epsilon_{0c} \quad (1)$$

$$\Pi_{m1}^c = \theta_{01c}\alpha_m + \theta_{11c}Muni_m - C + \epsilon_{1c}, \quad (2)$$

where Π_{m0}^c and Π_{m1}^c are the profits when cable incumbent c decides not to and to adopt, respectively; α is a measure of demand in market m ; $Muni_m$ is whether there is a municipal provider in market m ; and C is the adoption cost of a new technology. ϵ_0 and ϵ_1 are random profit shocks⁹.

The cable incumbent adopts if:

$$\Pi^c = \theta_{0c}\alpha_m + \theta_{1c}Muni_m - C + \epsilon_c > 0, \quad (3)$$

where $\Pi^c = \Pi_{m1}^c - \Pi_{m0}^c$, $\theta_{0c} = \theta_{01c} - \theta_{00c}$, $\theta_{1c} = \theta_{11c} - \theta_{10c}$ is the difference of profits and coefficients because of the technology adoption¹⁰.

The potential fiber entrant's profits in the case of entry are given by

$$\Pi^f = \theta_{0f}\alpha_m + \theta_{1f} - \phi + \epsilon_f, \quad (4)$$

where α_m is defined as above; θ_{1f} is the effect of cable adoption on post-entry fiber profits; and ϕ is the entry cost for the potential entrant. Assume that the fiber firm's profits are 0 in the case of no

⁹Note that I do not make any assumption about the distribution of the error terms.

¹⁰This can be also interpreted as the marginal profit of the cable adoption.

entry. ϵ_f are the profit shocks.

Note that ϕ incorporates any local entry barriers that increase the entry cost and, thus, reduces the probability of fiber entry. In the case of a local market with restricted or prohibited fiber entry, this term will be large.

The potential fiber entrant will enter if

$$\Pi^f = \theta_{0f}\alpha_m + \theta_{1f} - \phi + \epsilon_f > 0, \quad (5)$$

The cable incumbent uses the expected profits $\bar{\Pi}^c$ to decide whether to adopt, taking into account the effect of the adoption on the likelihood of fiber entry:

$$\bar{\Pi}^c = \theta_{0c}\alpha_m + \theta_{1c}\Phi^f(a_m|d_c) - C + \epsilon_c, \quad (6)$$

where Φ^f is the conditional fiber entry probability that is a function of demand α_m and the cable incumbent's decision d_c . Note that Φ^f can be written as:

$$\Phi^f(a_m|d_c) = P(\theta_{0f}\alpha_m + \theta_{1f} - \phi|d_c) \quad (7)$$

and now (6) can be written as :

$$\bar{\Pi}^c = \theta_{0c}\alpha_m + \theta_{1c}P(\theta_{0f}\alpha_m + \theta_{1f} - \phi|d_c) - C + \epsilon_c > 0 \quad (8)$$

Then, the likelihood that the cable incumbent adopts is:

$$P(d_c = 1) = P(\bar{\Pi}^c > 0) = P(\theta_{0c}\alpha_m + \theta_{1c}P(\theta_{0f}\alpha_m + \theta_{1f} - \phi|d_c) - C + \epsilon_c > 0) \quad (9)$$

Note that ϕ will reduce entry by municipal providers since it is an entry cost. Assume that entry cost reduces the entry likelihood of municipal providers – that is, $\frac{\partial \Phi^f}{\partial \phi} < 0$. This assumption is consistent with sunk entry cost reducing the likelihood of new entry because it creates a cost advantage for incumbents (Bain, 1956; Porter, 1979; Karakaya and Stahl, 1989). The hypothesis is that entry threat by municipal providers increase technology adoption by cable incumbents, or $\theta_{1c} > 0$.

5 Data Description and Definitions

I collect and combine data about the universe of U.S. broadband providers from four main sources. First, I use firm-level data from the Broadband Map project compiled by the FCC and state agencies. The dataset provides information about wireline broadband ISPs' quality provision (e.g. download and upload speeds) and technology deployment (e.g., cable, optical fiber, DSL) at the census tract level.

I focus on cable incumbents since they are the dominant firms in the industry and offer the highest internet speeds¹¹. This dataset provides me with cable firms' technology adoption decisions across markets and the number of other firms and technologies¹² in the market.

Second, I use state-level data for 20 states with entry barriers on municipal broadband (either ban or restrictions) and states in which the city ISPs are allowed to offer service outside the city limits. In the data, I define municipal broadband as ISPs that belong to a town, city, community, municipality or public utility. In general, these state laws do not change often and, thus, do not have time variation. The dataset indicates which markets in the sample have entry restrictions or

¹¹FCC. The optical fiber ISPs may offer higher speeds but have considerably fewer subscribers, while DSL technology offers much lower speeds.

¹²DSL and fiber firms.

bans on municipal providers. In Table 1, I provide some information about these restrictions per state.

Third, I collect data on the identity and location of municipal providers. I compile these data from various sources: White House reports on the universe of municipal providers in the U.S.; Community Broadband Networks¹³; and, Broadband Communities Magazine¹⁴. Finally, I use market-level data on population, area and income from U.S. Census. These data provide population, population density and income, which i will be use in the estimation.

The geographical unit I use is the census tract. This is a local market definition that I use throughout the paper. In the spatial discontinuity design, I use neighboring census tracts that belong to different states.

I define the technological innovation as the cable switch from DOCSIS 2.0 to DOCSIS 3.0. The switch occurs when the cable incumbent offers DOCSIS 3.0 in 2013 but not in 2012 in a local market. Cable firms are the dominant firms in the wireline broadband industry and, in most cases, offer the highest internet speeds. In addition, the adoption of DOCSIS 3.0 has been the most important technological innovation in cable broadband. In the spatial discontinuity design, I examine whether incumbents that offer service to neighboring local markets, make different technology adoptions as a function of the credible entry threat.

The final sample has 347,056 observations for all private ISPs and municipal providers in the U.S. for the year 2013¹⁵. The level of observation is at the firm/market level. The final dataset provides information about technology deployment for all private ISPs and whether they decided to switch to DOCSIS 3.0; the number of other firms and technologies in each local market; and

¹³<https://muninetworks.org/>

¹⁴<http://www.bbpmag.com/>.

¹⁵As mentioned above, I focus on one year because the local entry barriers do not have time variation, and thus, I use spatial variation of these barriers.

market population, population density and income and whether a state imposes entry barriers. In Table 2, I provide the variable definitions. In Table 3, I provide some descriptive statistics. In almost half of the markets in the sample there is municipal entry threat, while in each market, there is, on average, one cable incumbent and one or two DSL firms. In Table 4, I provide the correlation matrix of all variables.

6 Empirical Model and Estimation

In this section, I discuss the estimation strategy and identification. First, I provide an analysis that uses various specifications to capture cable incumbents' strategic investment using the whole sample. I examine incumbents' investment behavior in states with and without entry threat from municipal providers.

Then, I describe and present the spatial discontinuity design in which I examine cable incumbents' investment behavior across state boundaries. The geographical boundary of state barriers provides a deterministic cutoff for entry barrier policies for municipal providers. In particular, I observe the same private cable incumbent's behavior in a state without entry barriers (which will be the control) and a state with entry barriers (which will be the treatment).

6.1 Entry threat and Technology Adoption

In this subsection, I examine how entry barriers affect technology diffusion and compare the likelihood of cable adoption in markets with and without entry barriers. I use the following linear probability specification:

$$y_{jm}^{3.0} = \beta X_m + \gamma Z_m + \alpha_1 \text{EntryThreat}_{state} + \epsilon_m \quad (10)$$

where j is a cable incumbent in market m ; $y_{jm}^{3.0}$ is a dummy variable for technology adoption by a cable provider j in market m ; ϵ_m is an error term following normal distribution with mean zero; X_m are market characteristics (logarithmic values of population density, aggregate income and population); Z_m include market structure variables (number of DSL and fiber ISPs), $\text{EntryThreat}_{state}$ is a dummy that indicates whether the incumbent is in a market with no entry barriers (or equivalently, free entry). In addition, note that which states have entry barriers is exogenous from the private ISP's perspective and there is no variation within a state. Then, the probability that the cable incumbent adopts is:

$$P(y_{jm}^{3.0} = 1|X) = \Phi(\beta X_m + \gamma Z_m + \alpha_1 \text{EntryThreat}_{state}), \quad (11)$$

where $\Phi(\cdot)$ is the cumulative distribution function of the normal distribution. The results of this exercise are shown in Table 5, column (1). I report marginal effects. The coefficient for municipal threat is 0.15, which means that in states with no entry barriers, cable incumbents are 15% more likely to adopt the new cable system. This is statistically significant.

In addition, I examine incumbents' behavior, viewing the within competition from a municipal ISP and the distance from neighboring markets in which a city offers service. With this approach, I assume that the closer a city provider is to the cable incumbent's market, the more credible the entry threat is. I define a neighboring market by whether it is in a different radius from a market with a municipal provider. The identification assumption is that if entry barriers are important, then, in markets with entry barriers, incumbents should adjust their behavior in markets in which

municipal entry is a credible threat. I use five radii from the city provider's market to make the neighboring market definition flexible.

Specifically, I estimate the following probit model:

$$y_{jm}^{3.0} = \beta X_m + \gamma Z_m + \delta_j + City_m + \sum_{k=1}^5 \alpha_k Q_{dist_{mm'}}^k \{Entry Threat\}_{State} + \epsilon_{jm} \quad (12)$$

where $y_{jm}^{3.0}$, X_m , Z_m , δ_j , ϵ_{jm} are as defined above; m' is a market with a municipal provider; $Entry Threat_{State}$ is a dummy variable that captures whether the city provider is in a market with no local entry barriers; and $City_m$ is a dummy for whether there is a municipal provider in market m . $dist_{mm'}$ is the distance (in km) of market m from market m' . I break distance from market m' into quantiles Q^k , using $k=5$. Note that the coefficients α_k capture the difference in cable adoption likelihood for markets without and with entry barriers when in a distance radius k .

The probability that the cable incumbent adopts the new system is:

$$P(y_{jm}^{3.0} = 1|X) = \Phi(\beta X_m + \gamma Z_m + City_m + \sum_{k=1}^5 \alpha_k Q_{dist_{mm'}}^k \{Entry Threat\}_{State}), \quad (13)$$

where $X=(X = (X_m, Z_m, Entry Threat_{State}, City_m, Q))$.

Table 5, columns (2)-(3) show the results of this specification. Column (3) indicates that in neighboring markets within 20km of markets with no entry barriers, the cable adoption likelihood is higher by 23%, compared to markets with local entry barriers. In addition, the effect of within market competition from municipal providers is positive and statistically significant when the distance radii are included (0.45) and when they are not (0.07).

6.2 Spatial Discontinuity

The above results can be biased if broadband deployment depends on state-specific characteristics that affect all firms within state the same way. If that is the case, then the states that have entry barriers may be the states that restrict broadband in general, so the reason that these markets exhibit lower innovation is not necessarily the entry barriers. Methodologically, the state borders provide an exogenous variation of entry regimes for firms' decisions.

I use a spatial regression discontinuity design to identify strategic effects of technology adoption on municipal entry threat in neighboring local markets. More specifically, I use variation of incumbents' investment across state boundaries to understand whether credible municipal entry threat affects market outcomes. Note that a difference from most regression discontinuity studies is that geographic boundaries in this setting allow me to examine the same agents' behavior (in this case, private cable ISPs) across the deterministic cutoff. This implies that I can recover individual treatment effects and do not need an assumption about local averages.

The probability of receiving treatment jumps to 1 for the treated private cable ISP and 0 for the non-treated in these neighboring markets. I focus on 4,174 local markets that neighbor to a local market in a state with a different entry regime and with the same private cable ISP offering service across the barrier. The variation of local entry barriers provides the identification of the effect of the treatment defining entry barriers.

I make the assumption that unobservable characteristics change smoothly across the state border. This implies that the only characteristic that changes abruptly when crossing the state border is the entry regime. To support the use of this assumption, I show in Table 6 that observable characteristics in neighboring markets across the state borders do not change significantly¹⁶.

¹⁶Of course, across state borders, there may be economic, political or other conditions that change. I make the assumption that

This design is similar to those of Black (1999) and Holmes (1998) but adjusted for firms' decision to adopt a new technology. The difference from the previous literature is that I can observe the same agent (in this setting, the cable incumbent) in neighboring markets but in states with different entry regimes. In other words, I observe an agent's decision across the cutoff. This implies that I difference out unobserved factors of similar markets.

I use the following specification:

$$\Delta y_{jmm'} = \beta \Delta X_m + \gamma \Delta Z_m + \delta_j + \alpha \Delta City_m + \Delta \xi + \epsilon_{jmm'}, \quad (14)$$

where m' is a market in which a municipal provider offers service. X_m and Z_m are as defined above; and δ_j are firm fixed effects to capture unobserved firms' characteristics that affect technology adoption. $\Delta \xi$ is the difference between any unobserved factor in the two neighboring markets that belong to two states with different entry regimes.

As mentioned above, I make the following assumption:

Assumption: ξ has the same distribution across the neighborhood of the state border with a mean 0.

This assumption implies that the part of error term $\Delta \xi$ equals 0. In addition, I assume that errors terms for provider j are iid across the state border. This implies that I assume that in the neighborhood of the state border, the same cable ISPs do not exhibit technological or other differences.

in the small neighborhood of the state border, these unobserved characteristics will remain the same; that is neighboring local markets belonging to different entry regimes will exhibit the same unobserved factors. In addition, this assumption implies that cable incumbents in neighboring markets have more technological and other similarities than incumbents that are distant from the state border cutoff.

The probability to adopt then:

$$\Delta y_{jmm'} = \Phi(\beta \Delta X_m + \gamma \Delta Z_m + \delta_j + \alpha \Delta City_m + \Delta \xi) \quad (15)$$

$\Delta y_{jmm'}$ is a dummy variable that measures a quality differential across the border. In particular, $\Delta y_{jmm'}$ is 1 if the cable ISP has adopted in market m but not m' . Similarly, ΔX_m and ΔZ_m are the differences of market characteristics while $\Delta City_m$ is the difference of the dummy of whether there is a municipal provider across the state border. The above assumption about the unobserved characteristics implies that $\Delta \xi$ equals zero.

The results of the regression discontinuity design are presented in Table 7. The results indicate that the incumbents will adopt with 20% higher likelihood than in markets which impose restrictions on municipal entry.

7 Robustness tests

I provide two tests to check whether the results are robust to alternative explanations. First, I use an alternative choice variable to examine whether the results are sensitive to the dependent variable definition. I find that the results remain robust. Second, I use an alternative spatial definition taking the distance from the state border.

7.1 Alternative Choice: Marginal Innovation

In this test, I use an alternative choice variable for cable incumbents' investment. Instead of using the technological switch to the new cable system DOCSIS 3.0 – which might be considered

a radical technological innovation since it significantly increases internet quality – I use as a dependent variable any type of upgrade (marginal or radical). Table 8, column (2), are similar to those in Table 7 but with only different magnitude. These results imply that there is variation in internet speeds across the cutoff because of the municipal entry threat and that the specification is not sensitive to the technology measure. Additionally, the results imply that the municipal entry threat is more likely to lead to radical innovation to marginal innovation.

7.2 Alternative Spatial Definition

In this robustness check, I examine incumbents' investment behavior using an alternative spatial definition. In particular, I examine investment behavior within 100km of a state border and the difference between the technology choice across the different entry regime. Table 9 shows that the results are robust to expanding the geographical range.

8 Discussion and Implications

In this paper, I provide evidence that entry barriers for municipal providers significantly affect private incumbent firms' incentive to invest in their networks. I use various empirical tests to measure the effect of these barriers. In particular, using the first measure, I analyze the distance from a municipal provider and how it affects cable incumbents' investment behavior. The main measure uses the spatial discontinuity of these entry regimes and also accounts for unobserved market characteristics that may simultaneously determine cable ISP and broadband city provision. I find that incumbents decrease their technological innovation significantly by 20% and, thus, offer a lower-quality product in the presence of local entry barriers.

This paper contributes to the literature on technological innovation and the role of entry barriers and entry threat. Although there is empirical evidence about the role of competition in innovation or the role of entry barriers in firms' entry, there is limited evidence on how incumbents respond to this institutional environment of restricted entry. In addition, the article introduces a spatial discontinuity approach to identify firms' strategic decision to innovate which has not been used to identify firm's strategic behavior.

The article also contributes to the policy debate on why institutional entry barriers and subsequently reduced entry threat may significantly reduce competition and equilibrium product quality in a local market. Importantly, it shows that entry threat can have significant innovation spillovers across local markets with entry barriers. These barriers lower technological innovation and, thus, significantly lower access to higher internet speeds for consumers since these innovations are crucial for quality improvements.

There are some extensions of this articles that may be considered. First, I do not include municipal providers' entry decisions since the focus has been on incumbents' innovation decision. Second, this paper considers only existing municipal providers but not a mechanism for generating new public firms. Third, future work could incorporate additional information on the local restrictions that affect potential entrants' decisions and increase entry cost. For instance, municipal firms may need to negotiate requirements with neighboring local governments that may affect entry cost. Finally, an extension of this paper would examine variation of financial constraints for municipal providers and how these would affect private ISPs' decisions.

Tables

State	Restrictions	Ban
Alabama	x	
Arkansas	x	
California	x	
Colorado	x	
Florida	x	
Louisiana	x	
Michigan	x	
Minnesota	x	
Missouri		x
Nebraska		x
Nevada	x	
North Carolina		x
Pennsylvania	x	
South Carolina	x	
Tennessee	x	
Texas		x
Utah	x	
Virginia	x	
Washington	x	
Wisconsin	x	

Table 1: States with ban or restrictions on municipal broadband (2016).

	Definition
$y_{jm}^{3.0}$	dummy, technology switch to DOCSIS 3.0
$\log(\text{pop. density})_m$	$\log(\text{population}/\text{km}^2)$
$\log(\text{income})_m$	$\log(\text{total income})$
$\log(\text{population})_m$	$\log(\text{number of residents})$
DSL firms_m	number of DSL ISPs
$\text{DOCSIS 3.0 firms}_m$	number of cable ISPs offering DOCSIS 3.0
Fiber firms_m	number of optical fiber ISPs
Entry Threat	In a state with no entry barriers
Distance	Incumbent's distance from a municipality
Local market m	Census tract

Table 2: Definitions.

	Mean	SD
$y_{jm}^{3.0}$	0.24	0.43
$\log(\text{pop. density})_m$	6.04	1.95
$\log(\text{income})_m$	7.30	0.49
$\log(\text{population})_m$	8.27	0.48
DSL firms_m	1.71	0.87
$\text{DOCSIS 3.0 firms}_m$	1.15	0.52
Fiber firms_m	0.65	0.83
Entry Threat_{jm}	0.49	0.49
Distance_{jm}	230.76	257.22

Table 3: Data description.

	1	2	3	4	5	6	7	8	9
1. $y_{jm}^{3.0}$	1.0000								
2. $\log(\text{pop. density})_m$	-0.0513	1.0000							
3. $\log(\text{income})_m$	-0.0097	0.0259	1.0000						
4. $\log(\text{population})_m$	0.0059	0.0522	0.8726	1.0000					
5. DSL firms $_m$	-0.0157	0.0604	0.0214	-0.0030	1.0000				
6. DOCSIS 3.0 firms $_m$	0.1160	0.0421	0.0943	0.0827	0.0296	1.0000			
7. Fiber firms $_m$	0.0119	0.0845	0.1174	0.0939	0.0930	0.1576	1.0000		
8. Entry Threat $_{jm}$	0.1709	0.0615	-0.0376	-0.0011	0.0435	0.0319	0.0627	1.0000	
9. Distance $_{jm}$	0.0614	0.0576	-0.0478	-0.0181	-0.0299	-0.0962	-0.0167	-0.0796	1.0000

Table 4: Variable correlation matrix

$y_{jm}^{3.0}$	(1)	(2)	(3)
$\log(\text{pop. density})_m$	-0.014*** (0.00)	-0.011*** (0.00)	-0.005* (0.00)
$\log(\text{income})_m$	-0.036*** (0.00)	-0.058*** (0.00)	-0.058*** (0.01)
$\log(\text{population})_m$	0.039*** (0.00)	0.059*** (0.00)	0.077*** (0.01)
DSL firms $_m$	-0.010*** (0.00)	-0.007*** (0.00)	-0.004 (0.00)
Fiber firms $_m$	0.005*** (0.00)	0.010*** (0.00)	-0.000 (0.00)
EntryThreat $_m$	0.150*** (0.00)		
City $_m$		0.072*** (0.01)	0.451*** (0.01)
$Q^1_{\text{dist}_{jm'} < 20\text{km}} * \text{EntryThreat}_m$			0.237*** (0.01)
$Q^2_{20\text{km} < \text{dist}_{jm'} < 40\text{km}} * \text{EntryThreat}_m$			0.145*** (0.01)
$Q^3_{40\text{km} < \text{dist}_{jm'} < 60\text{km}} * \text{EntryThreat}_m$			0.195*** (0.01)
$Q^4_{60\text{km} < \text{dist}_{jm'} < 80\text{km}} * \text{EntryThreat}_m$			0.158*** (0.01)
$Q^5_{80\text{km} < \text{dist}_{jm'} < 100\text{km}} * \text{EntryThreat}_m$			0.210*** (0.01)
Log-likelihood	-23,729	-24,685	-23,003
Number of obs.	347,056	347,056	53,179

p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Table 5: Probit model. Entry barriers and technology adoption (whole sample). Marginal effects are reported. Standard errors in parentheses.

	Mean	Median	Standard Deviation
$\log(\text{pop. density})_m$	0.007	0.06	1.683
$\log(\text{income})_m$	-0.004	0.01	0.556
$\log(\text{population})_m$	-0.003	0.01	0.567
DSL firms $_m$	-0.005	0	1.134
Fiber firms $_m$	-0.010	0	1.210

Table 6: Distribution of differences

$y_{jm}^{3.0}$	(1)	(2)
$\Delta(\log(\text{pop. density}))_{mm'}$	-0.001 (0.00)	-0.002 (0.00)
$\Delta(\log(\text{income}))_{mm'}$	0.060* (0.03)	0.117*** (0.03)
$\Delta(\log(\text{population}))_{mm'}$	0.010 (0.03)	-0.050 (0.03)
$\Delta(\text{DSL firms})_{mm'}$	-0.001 (0.00)	-0.015*** (0.00)
$\Delta(\text{Fiber firms})_{mm'}$	0.010** (0.00)	0.012** (0.00)
$\Delta(City_{mm'})$	0.106*** (0.01)	0.203*** (0.02)
Firm FE		Yes
Log-likelihood	-9,249	-6,607
Number of obs.	13,387	13,387

p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Table 7: Probit model. Entry barriers and technology adoption for the neighboring local markets. I focus on ISPs that offer service across state entry regimes with and without entry barriers. Marginal effects are reported. Standard errors in parentheses.

	(1)	(2)
$\Delta(\log(\text{pop. density}))_{mm'}$	-0.010*** (0.00)	0.001 (0.00)
$\Delta(\log(\text{income}))_{mm'}$	0.206*** (0.03)	0.079* (0.03)
$\Delta(\log(\text{population}))_{mm'}$	-0.218*** (0.03)	-0.118*** (0.03)
$\Delta(\text{DSL firms})_{mm'}$	0.017*** (0.00)	0.020*** (0.00)
$\Delta(\text{Fiber firms})_{mm'}$	0.028*** (0.00)	-0.011* (0.00)
$\Delta(City_{mm'})$	0.105*** (0.01)	0.030# (0.02)
Firm FE		Yes
Log-likelihood	-6,154	-4,790
Number of obs.	10,155	10,155

p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Table 8: Robustness Check: Marginal innovation. The alternative dependent variable definition is a marginal increase in internet speeds. Marginal effects are reported. Standard errors in parentheses.

	(1)	(2)
$\Delta(\log(\text{pop. density}))_{mm'}$	-0.001 (0.00)	-0.267*** (0.04)
$\Delta(\log(\text{income}))_{mm'}$	0.060* (0.03)	1.90*** (0.29)
$\Delta(\log(\text{population}))_{mm'}$	0.010 (0.03)	-1.609*** (0.30)
$\Delta(\text{DSL firms})_{mm'}$	-0.001 (0.00)	-0.103* (0.05)
$\Delta(\text{Fiber firms})_{mm'}$	0.010** (0.00)	-0.029 (0.04)
$\Delta(City_{mm'})$	0.106*** (0.01)	0.571*** (0.14)
Firm FE		Yes
Log-likelihood	-9,182	-598
Number of obs.	13,387	13,387

p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Table 9: Robustness Check: Alternative spatial definition. 100 km around the state border of state with different entry regimes. Marginal effects are reported. Standard errors in parentheses.

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