Competition and Subsidies in the Deregulated U.S. Local Telephone Industry*

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March 5, 2013

Abstract

The 1996 Telecommunication Act introduces entry into an originally monopolistic U.S. local telephone industry. As competitors cherry-pick urban markets to enter, the Act calls for an explicit subsidy policy to narrow the divide in telecom infrastructure. To study relevant factors in designing such a subsidy, we estimate a dynamic oligopoly entry game using data on potential entrants' entry decisions into local markets. We find that subsidies to smaller markets or lower-cost potential entrants are more cost-effective in reducing monopoly markets, and subsidies in only early periods reduce the option value of waiting and speed up the arrival of competition.

Key Words: Entry, Dynamic Oligopoly Game, Option Value of Waiting, Telecommunications

JEL: L1, L96

*We thank Daniel Ackerberg, Steven Berry, Juan Esteban Carranza, Gautam Gowrisankaran, Paul Grieco, Philip Haile, Taylor Jaworski, Kai-Uwe Kühn, Francine Lafontaine, Ariel Pakes, Mark Roberts, Marc Rysman, Gustavo Vicentini, Jianjun Wu, Daniel Yi Xu, and participants of California Institute of Technology, the Federal Trade Commission, Harvard University, IIOC 2011, the Pennsylvanian State University, SED 2012, the University of Düsseldorf, the University of Michigan and Wayne State University for their constructive comments. We thank the NET Institute for financial support.

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1 Introduction

Many telecommunication services have been deregulated in the last few decades. Before the deregulation, services were provided by regulated monopolists, competitive entry was forbidden, and prices were set by cost-plus, rate-of-return regulation by federal and state authorities (Hausman and Taylor (2012)). After the deregulation, telecommunication markets opened to competition, and many of the pricing regulations were phased out. However, given the substantial sunk cost of entry into these services, how to ensure effective competition is critical in curbing the deregulated incumbent's market power. This issue is especially pressing in rural, sparsely-populated areas, where factors such as challenging terrain, long distance from existing networks and low population density greatly increase entry costs. Subsidizing competitors' entry costs, a widely adopted policy practice, seems to be a policy remedy to balance between deregulation and market power. This paper seeks to understand important factors for policy makers to consider in the design of subsidy policies. Specifically, we study the deregulated U.S. local telephone industry.

In the local telephone industry, the passage of the 1996 Telecommunications Act (henceforth the Act) dramatically changed the landscape of competition by opening the floodgate to Competitive Local Exchange Carriers (CLECs). Before 1996, local markets were monopolized by Incumbent Local Exchange Carriers (ILECs), mostly Baby Bell companies. Subject to state-law obligations to provide services to customers in high-cost areas, these ILECs redistributed profits from urban to rural areas to fulfill the "universal service" goal. This policy goal is to make basic telecom infrastructure such as local telephone, wireless telephone, and Internet available at affordable and relatively uniform rates throughout the United States. The Act reconfirms this policy goal, stressing on "quality services at just, reasonable, and affordable rates," especially with respect to "access to telecommunications services and information services for customers in rural, insular and high-cost areas" (47 U.S.C. 254(b)). As stated, "universal service" is not only about availability of telecom infrastructure, but also about affordable, competitive pricing. The deregulation, however, seems to be internally inconsistent with the goal. First, CLECs would selectively enter rich, urban markets and avoid rural, high-cost areas. Second, ILECs' profits in urban markets would become insufficient to cross subsidize rural markets as CLECs erode ILECs' market market in rich, urban markets. Anticipating these inconsistencies, the Act calls for an explicit subsidy policy to encourage entry into relatively rural,

sparsely-populated areas. The exact design of such explicit subsidies is left to open debate to this day.

We aim to provide input for the design of an explicit subsidy policy. The current policy practice is a *de facto* nondiscriminating subsidy to every CLEC entering a market, mainly in the form of mandating ILECs to offer free interconnections and leasing network at long-run average costs to CLECs. Under this policy, there was a surge of entry: around 40% of medium-sized markets experienced CLEC entry by the end of 1998. While a handful of medium-sized markets attract more than ten CLECs, over 30% of these markets did not have any CLEC operating by the end of 2002. If anything, the divide in telecommunications infrastructure between urban and rural communities seems to have widened. Looking back at the evolution of local market structures, we wonder whether there is potential to improve the efficiency of bringing competition into the marketplace. This is a high-stakes industry with substantial sunk costs of entry and significant firm-level heterogeneity; CLECs vary substantially in size, ownership and financial structure, and telecommunications experience. Perhaps a little additional subsidy to cover the entry cost were necessary, at least for rural markets? Or perhaps subsidies could have been offered to low entry cost CLECs as the same amount of subsidy might have different impacts on different CLECs? What about offering subsidies only in the early periods to speed up entry of potential entrants who are waiting indefinitely for better opportunities? More generally, what are the most important factors for policy makers to consider in the design of the subsidy policy? To answer these questions, we need a framework to capture the equilibrium effects of a subsidy, which may counteract each other. For example, a subsidy to reduce sunk costs of entry for every potential entrant, may lower the expected entry value of potential entrants because their competitors are also subsidized and thus more likely to enter. In turn the subsidy may not be effective when competition effect is large. Ultimately, this is an empirical question which depends on the subsidy's effect on the cost and value of entry.

We employ a rich panel data set which records all facilities-based CLECs' entry decisions into local telephone markets.[1] What is novel in our data is that we observe the identities of potential entrants into local markets. This is due to a key feature of the industry after the Act: a CLEC needs to obtain certification from a state in order to operate in cities within the state. After receiving state certification, a CLEC may

[1]Facilities-based CLECs, as the name suggests, provide service wholly or partly through equipment and facilities that the CLECs own or control. Facilities-based CLECs are deemed by the industry experts to represent true competition to ILECs.

wait years to commit actual entry. We define the set of potential entrants into a local market as the set of CLECs with certification from the state where the market is located. Knowing who the potential entrants are, we are able to observe a few crucial firm-level and firm-market-level attributes associated with sunk cost of entry.

To capture the unique feature of our data in a parsimonious way, we modify the theoretical framework of Pakes, Ostrovsky and Berry (2007) (henceforth POB) in two ways to incorporate the timing of entry and firm heterogeneity in a dynamic oligopoly entry game. First, a firm is a long-run player and decides on whether to enter or wait in each period. When making this decision, a firm compares the value of entry minus the entry cost with the value of waiting. This is in contrast with most entry studies in which a firm enters or perishes and the value of waiting is set to zero. Second, firms are heterogeneous, and this heterogeneity plays an important role in explaining the entry decisions and waiting time. For example, a better-funded firm may have smaller sunk costs of entry and hence may be more likely to enter in each period. Since our estimation strategy restricts the number of firm characteristics that can be incorporated,[2] we map multiple dimensions of firm-level heterogeneity into a single index by incorporating the decision of an established firm to become a potential entrant.

We have three main empirical findings. First, CLEC profit is increasing in market size, measured by the number of business establishments, once the CLEC becomes an incumbent. This is consistent with the conventional wisdom (e.g., Bresnahan and Reiss (1991)) that a larger market size is necessary to support more competitors. Second, we find a negative competition effect on profit. Third, firm-level heterogeneity in entry costs plays an important role in determining a firm's entry into a local market. We find that different types of CLECs draw their entry costs from different distributions and display asymmetric entry behavior.

With the estimated model parameters, we use counterfactual simulations to understand important factors in designing the subsidy policy to achieve the "universal service" goal. Note that "universal service" is to encourage more equal and affordable services across America, while in the short run such a goal may have

[2]To estimate this model, we follow the recent development in two-step estimation strategy of dynamic oligopoly entry games. In such a two-step procedure of estimation, the econometrician first obtains the conditional choice probability at any given state from data and then matches the empirical conditional choice probability with its counterpart predicted by the model. The first step is nonparametric, which puts a limit on the number of state variables in such a model. In our setting, this means a limit on the number of firms' heterogeneous characteristics that we can incorporate. On the contrary, in the reduced-form framework incorporating firm-level heterogeneity is typically not an issue. For example, Morton (1999) conducts regression analysis to study which attributes of potential entrants contribute to entry decision in the pharmaceutical industry. However, a reduced-form framework cannot allow us to properly address the policy question that we are interested in.

discrepancy with the goal of maximizing total social surplus as typically set by an economic welfare analysis. Through the counterfactual analysis, we find that a subsidy amounting to 5% of the average of the two types' entry cost mean reduces the fraction of monopoly markets from 52% to 32% by the end of 1998, and to 7% by the end of 2001. Doubling such a subsidy can further reduce this fraction to 14% by the end of 1998 and 1% by the end of 2001. However, such subsidies can be more effective in reducing monopoly if only offered in smaller markets or to lower-entry-cost CLECs. This suggests that subsidy policies should better exploit both market- and firm-level heterogeneity. More strikingly, we find that subsidies intended to reduce the option value of waiting change the timing of firms' entry behavior. A subsidy amounting to 10% of the average of the two types' entry cost mean, applied in *1998 only*, reduces the fraction of monopoly markets to 9% by the end of 1998. Compared to the effect of reducing the percentage of monopoly market to 14% by the end of 1998 when such a subsidy were to be applied to all years, we can see the importance of considering firms' strategic responses in a dynamic oligopolistic setting when designing an explicit subsidy policy.

"Universal service" has always been a policy goal since the start of the U.S. telecommunications industry. With these findings, we believe this study has shed new light on a critical policy area in one of the most fundamental infrastructure industries in the modern world. Furthermore, our findings have ramifications for public policy on other markets such as wireless telephone and Internet, where the same policy goal is in place. In these new telecommunication areas, the "universal service" policy goal is probably even more pertinent than in the local telephone markets as the discrepancies in the availability and quality of services between rural and urban communities are much steeper. As the New York Times put it, "digital age is slow to arrive in rural America" (February 17, 2011). Insufficient and unequal coverage of wireless or Internet is not just a matter of inconvenience to part of America, it is a matter of critical utility and infrastructure. The FCC voted unanimously in 2011 to modernize its universal service subsidy program, aiming to help the 18 million Americans who have no access to broadband where they live and work. The goal is that all Americans will have broadband access to Internet and telephone services by the end of 2020. To achieve this goal, the FCC may want to consider the lessons we learned from the local telephone market in the design of the new subsidy policy.

This paper is related to the literature on estimating dynamic entry games, which has been at the forefront

of research in empirical industrial organization over the last decade. The key in estimating entry games is to recover the distribution of sunk cost, which is usually not observed in the data but plays a pivotal role in determining market structure and competition intensity. The distribution of sunk cost is typically estimated using the observed probability of entry conditional on some market-level attributes determining post-entry payoffs. A handful of papers (Aguirregabiria and Mira (2007), Bajari, Benkard and Levin (2007), POB, Pesendorfer and Schmidt-Dengler (2008)) have made significant progress since Hotz and Miller (1993) proposed a two-step estimation strategy, in which it is unnecessary to solve for equilibrium in a complex dynamic model. However, due to lack of data there is an important limitation to applications utilizing this approach (Collard-Wexler (2012), Ryan (2012), Dunne, Klimek, Roberts and Xu (2009)). Researchers do not observe the identities of potential entrants and therefore have to assume that potential entrants are *ex ante* homogeneous and short-run players. Without considering the firm- and market- level heterogeneity reflected in the timing of entry, they may lose critical information in trying to recover the distribution of entry costs. Moreover, paradoxically the players in these dynamic games face a short-run decision of entering or perishing.[3] In fact, in most industries the decision facing a potential entrant is usually to enter or *wait*. This paper's contribution to this literature is to bridge the gap between dynamic entry game literature and the complex real entry game in which firms are often *ex ante* heterogeneous long-run players.

This project is also related to the literature on examining competition in the local telephone markets. Closest to this work is Greenstein and Mazzeo (2006), which studies CLEC entry decisions into differentiated categories using a "static" entry model, Economides, Seim and Viard (2008), which measures consumer welfare effects of the increase in local telephone competition after the Act, and Goldfarb and Xiao (2010), which emphasizes heterogeneity in managerial ability in the first year of this industry. Our paper complements these studies, emphasizing the importance of firm-level heterogeneity in understanding strategic interaction in the US local telephone market.[4]

This paper proceeds as follows. Section 2 briefly discusses industry background and telecommunications policies after the Act. Section 3 introduces the data we use. Sections 4 and 5 describe in detail our

[3]Fan (2006) makes the distinction between a short-run and long-run player in a dynamic entry game.

[4]Other papers on the US local telephone industry include Ackerberg et al (2009), Alexander and Feinberg (2004), Mini (2001), and Miravete (2002).

model and estimation strategy. Section 6 reports estimation results and Section 7 presents results from our counterfactual experiments. Section 8 concludes.

2 Industry Background

The Telecommunications Act of 1996 marked the end of a monopolistic era in the U.S. local telephone industry since the Kingsbury Commitment condoned a Bell system monopoly of telephone services in 1913. The Act opened up local telephone competition by barring state regulators from denying any eligible entrants the right to compete. More importantly, the Act actively solicited competition by forcing incumbents to interconnect with CLECs at no charge and to lease networks to CLECs at cost-based rates. To be consistent with these policy changes, the Act called for a reform of the complex, entrenched system of cross subsidies embedded in the monopolistic market structure. The replacement should be an explicit and pro-competitive subsidy policy to achieve the "universal service" goal.[5]

2.1 Policy Goal: Universal Service

In the modern world, access to telephone service is widely recognized to be a fundamental part of public infrastructure. Equal access to such infrastructure has been considered pivotal to narrow the developmental divide between urban and rural areas.[6] Moreover, increased access to telecommunication services creates positive network externalities for individual consumers and enhances democratic participation and public safety. In the United States, ubiquitous telephone subscribership is termed as "universal service" and a key part of the telecommunication policies both before and after the deregulation. Clearly, the goal is difficult to achieve because the cost of serving customers varies drastically across different geographic areas. Notably, customers in rural, sparsely populated areas are more costly to serve than customers in urban areas. Consider a 10-mile-long access line and a central office switch to serve a couple of farm families and the same length of line and the same switch to serve 10,000 urban households in a few city blocks (Kennedy (2001)). The average total costs per household are hugely different across the two scenarios.

[5]Economides(1999) provides an overview of the Telecommunications Act of 1996 and its impact.

[6]Equal access refers to "access to telecommunications services and information services for customers in rural, insular and high-cost areas that are reasonably comparable to those services provided in urban areas and that are available at rates that are reasonably comparable to rates charged for similar services in urban areas" (Kennedy (2001)).

Before 1996, local monopoly incumbents achieved the "universal services" policy goal by redistributing profit from urban areas to rural areas to cover the high cost of providing services to rural, sparsely-populated areas. Such practices are referred to as "implicit cross subsidy." Generally, the direction of cross subsidy is urban customers subsidizing rural customers, business customers subsidizing residential customers, long-distance services subsidizing local services, and upgraded services (for example, call waiting) subsidizing basic services (Kennedy (2001)).

This implicit subsidy mechanism has become increasingly unsustainable with deregulation and competition. Following the Act, CLECs eroded ILECs' market power, especially in rich, urban markets. In fact, CLECs have the ability to "cherry-pick" which markets to enter: unlike ILECS, CLECs are not subject to state-law carrier-of-last-resort obligations to provide services to high-cost customers at low rates. In turn, ILECs' profits in urban markets became insufficient to cross subsidize rural markets (Nuechterlein and Weiser (2005)). Anticipating this competition effect, the Act called for phasing out the implicit cross subsidy policy and replacing it with a "specific, predictable and sufficient" mechanism that would be funded by and available to "every telecommunications carrier that provides interstate telecommunications services" (Id. 254(d)). However, the exact design of such a mechanism falls under the jurisdiction of the Federal Communication Commission (FCC). It is up to the FCC to decide from whom funds supporting the subsidy system will be collected, how the funds will be calculated, and to whom the funds will be distributed. These questions were the subject of intense policy debate, which has continued long after the passage of the Act. To this day, no clear answers have emerged and current subsidies practices serve disparate purposes.[7] Motivated by the search for answers, our study combines economic theory and data to shed light on factors relevant in designing an explicit subsidy policy.

Specifically, we focus on the role of sunk cost of entry in shaping the CLECs' entry decisions. By definition, sunk costs are irreversible and unrecoverable investment costs for entrants to start businesses. In term of direct sunk costs, facilities-based CLECs must make substantial investments in building copper-wire networks and facilities such as the switching and distribution centers. On top of these direct sunk costs,

[7]The FCC's "universal service fund", in the amount of multiple billions of dollars, is composed of four programs: 1) the Lifeline and Link-up programs to provide need-based subsidies to low-income households; 2) the "high cost" program to keep telephone rates at high-cost areas affordable; 3) a program to fund broadband connections to the nation's schools and libraries; and 4) a similar program to fund broadband connections to rural health care facilities (Nuechterlein and Weiser (2005)).

there are indirect, "strategic" components of sunk costs (Pindyck (2005)). For example, the costs consumers face in switching from incumbents to the new entrant, which are especially important in telecommunication industries, may create disadvantages for later entrants. To overcome these disadvantages, the new entrants may need to incur huge costs of advertising and sign-up promotions. A measure of the total sunk cost does not exist in accounting books. However, firms' strategic entry decisions reflect the size and distribution of such costs and we can back them out combining a model of strategic entry and actual entry behaviors. With estimates of sunk costs, we then can evaluate the effects of different subsidy policies that directly reduce sunk cost of entry.

2.2 State Certification

A neat feature of the U.S. local telephone industry enables us to identify the set of potential entrants in a local market, that is, CLECs must first obtain certification from state regulators before they can operate in any city within the state. Before 1996, the states generally refused to license new telephone companies to compete with local monopoly incumbents in the market for local exchange service. After the 1996 Act became law, state and local governments could not prohibit "the ability of any entity to provide any interstate or intrastate telecommunications service."[8]

The requirements for obtaining and maintaining state certification are rather undemanding in all states. To satisfy the requirements, a CLEC applicant needs to submit paperwork such as specification of services to be offered, detailed construction plans and environmental impact statements. Furthermore, the applicant needs to show a certain degree of financial ability to serve. Some states require an applicant to show possession of a certain amount of cash or cash equivalent at the time of the application, while others follow more complex formulas.[9] With certification, a CLEC may "conduct its business without regulatory interference so long as it contributes to universal service and other funds, files state tariffs, and makes informational reports to regulators where required" (Kennedy (2001)). Overall, the consensus in the field is that state certification is reasonably easy to obtain and maintain for any CLEC with real intent to enter, but CLECs without real

[8] 47 U.S.C. 253(a): "In general No State or local statute or regulation, or other State or local legal requirement, may prohibit or have the effect of prohibiting the ability of any entity to provide any interstate or intrastate telecommunications service."

[9] Texas, for example, requires the applicant to show that 1) it has either $100,000 cash or sufficient cash for startup expenses for the first two years of operation; or 2) it is an established business entity and has shown a profit for two years preceding the application date (Kennedy (2001)).

intent to enter any city in a state will not apply for certification. Based on this consensus we think we can identify potential entrants in a local market as the set of CLECs with certification to operate in the state.[10] It is important to note that while regulatory approval is necessary for entry, it is not sufficient. After receiving state certification, a CLEC may wait indefinitely to commit actual entry. Some CLECs never enter any city in a state for which they are approved to enter during the years covered in this study (1998 to 2002).

3 Data

We combine information from CLECs' annual reports available from the New Paradigm Resources Group, Inc. (NPRG) and the US Census Bureau's Zip Code Business Patterns to create a panel data set of firms' entry decisions, firm-level characteristics, and market attributes.

3.1 The NPRG Annual Reports on CLECs

We acquired the 1998-2002 CLEC annual reports from NPRG, which contain information on the universe of facilities-based CLECs in the United States since the passage of the Act.[11] NPRG provides a detailed profile for every CLEC including history, management, ownership and organization, technology, state certification, and the location of its local voice networks. From these profiles, we know all local voice markets that a CLEC served and the exact year when the service started, which we treat as the year the CLEC *enters* the market. We also have firm attributes such as the year the company was founded, the zip code of the headquarters, whether the company is publicly or privately held, whether the company is venture capital funded, and whether the company is a wholly owned subsidiary of a larger telecommunications company.

[10] Although many states give CLEC applicants the authority of serving the entire state, a few states require these applicants to specify each local area to be served. We deal with this potential caveat to our definition of potential entrants by dropping small cities — those with fewer than 2,000 business establishments — from our analysis because these cities are less likely the target areas in the early years of the competitive U.S. local telephone industry.

[11] The NPRG CLEC annual reports cover 1996 to the present. However, 1998 is the year when NPRG started to report for the universe, instead of a selected sample, of facilities-based CLECs. In 2001, NPRG split facilities-based rural CLECs into another report series, which were only published for the year of 2001 and 2002. Therefore, we are only able to assemble information on the universe of facilities-based CLECs from 1998 to 2002.

3.2 Market Definition, Market Characteristics, and Sample Selection

To complement CLECs' voice network data, we obtain information on location characteristics in corresponding years. The locations in the NPRG reports, i.e., the cities a CLEC provides services to, are best interpreted as the Census "place", rather than the county or metropolitan statistical area. Therefore we choose a Census place as our market definition and use the popular name "city" henceforth.

As most of these CLECs' catered to small business clientele in the early years of this industry, we think the best proxy of market size is the number of business establishments in a city. We divide a city into a set of Zip Code Tabulation Areas (ZCTAs) and obtain the number of business establishments from the Zip Code Business Patterns.[12]

Lastly, we select medium-sized cities based on the number of business establishments. We only keep cities in which the number of business establishments in 1997 falls between 2,000 and 15,000. This amounts to dropping the largest 25 cities since CLECs may not directly compete with each other in these markets;[13] we also drop very small cities because in the early years CLECs may not have realistically considered entering these markets. That is, a CLEC holding a state certification in such a city may not actually be a potential entrant, making it difficult to identify the set of potential entrants for the city. After dropping all of the markets that do not fit our criteria we are left with 398 medium-sized cities for our analysis.

3.3 Summary Statistics

This combination of NPRG data and city-level business pattern data has several appealing features. Not only do we have information on all entry by all firms from the start of the industry, we can also match it to rich data on firm characteristics and market attributes affecting profitability in each market.

Tables 1 and 2 report descriptive statistics. Table 1 summarizes the data on firms. The firm attributes we use are what we think determine whether a firm is a high- or low-cost potential entrant. These attributes include the ownership, organizational and financial structure of the firm, as well as the age of the firm at the beginning of the CLEC industry. We also have two measures of the relationship between a firm and

[12]The Business Census only provides this information at the city level every five years while the Zip Code Business Patterns do this annually. We use a cross reference from ZCTAs to cities based on the 2000 Business Census to perform the decomposition.

[13]Atlanta is the cutoff city based on this threshold.

a market it can potentially enter. One is a dummy variable indicating whether the market is in the same state as the firm's headquarters. We think that there may be a home state advantage at the cost side; for example, a firm may have a lower cost in passing zoning requirements, dealing with local administration, advertising and public relations in the the state where it is headquartered. The other is a measure of the distance (in 1,000 kilometers) between a firm's headquarters zip code and the population centroid of a state, which naturally serves as a determinant of sunk cost of entry as well. We can see from Table 1 that these firms are generally privately held (on average 59% to 64% across years) and have high variances in age (the standard deviation is about twice the mean). A small proportion of these firms are subsidiaries to large corporations (on average 26% to 32% across years) and partially funded by venture capital (on average 17% to 22% across years). On average, these firms target regional or national markets, which is reflected by the large number of states from which they have certifications, the low rate of home state markets, as well as the long distance between a firm's headquarters and the local market it can potentially enter. The average number of cities where a CLEC has state certifications increased gradually from 1996 and peaked in 2000, right after which the market suffered a valuation crash. The variation in the number of firms over time also reflects the rapid boom and bust in the early years of telecommunications industry.

Table 2 describes the 398 medium-size cities that we use for our analysis. The number of business establishments is gradually increasing until year 2001, reflecting the ups and downs of the macro economy. There is only one incumbent for every market at the beginning of 1998 because only a single ILEC exists in each market at the time of the Act.[14] The number of incumbents, despite being a stock variable, fluctuates as exit is a frequent event.[15] A typical city has a large set of potential entrants but only a few incumbents (including the one ILEC in each market) and entrants. The number of new entrants has gone through a rapid increase and then a sharp drop, which again echoes the 2001 valuation crash.

[14]We treat 1997 (right after the Act) and 1998 (the first year of our data) as one period.

[15]We treat bankruptcy, being acquired by another firm, or simply going out of business as exit. In the few cases of mergers (less than 10 out of approximately 200 CLECs in our time period), we treat the smaller CLEC between the two as the firm exiting from business.

Table 1: Summary Statistics on Firm Attributes

	1998	1999	2000	2001	2002
Variables	Mean (Std. Dev.)				
Firm Attributes					
Privately held	0.639	0.595	0.576	0.598	0.640
	(0.483)	(0.493)	(0.496)	(0.493)	(0.483)
Subsidiary	0.320	0.284	0.288	0.268	0.302
	(0.469)	(0.453)	(0.455)	(0.445)	(0.462)
Financed by venture capital	0.175	0.190	0.220	0.206	0.221
	(0.382)	(0.394)	(0.416)	(0.407)	(0.417)
Firm age†	8.897	8.526	11.017	13.639	15.616
	(20.206)	(16.548)	(20.680)	(23.449)	(24.717)
# states with certification	9.237	10.500	13.217	13.135	12.917
	(11.438)	(11.978)	(13.019)	(12.484)	(12.646)
# cities with certification	100.381	111.138	128.102	122.196	123.209
	(108.026)	(112.298)	(116.251)	(114.220)	(117.659)
# observations (firm)	97	116	118	97	86
Firm-Market Attributes					
Home state dummy: if market is	0.124	0.110	0.107	0.096	0.102
in the same state as firm HQs	(0.327)	(0.313)	(0.309)	(0.295)	(0.303)
Distance from firm HQs to market	0.901	0.916	0.901	0.876	0.896
in 1000 km	(0.680)	(0.693)	(0.688)	(0.675)	(0.682)
# observations (firm-market)	9737	12892	15116	11853	10596

† The average firm age increases by more than 1 over the years. This is due to the entry into CLEC business by already established firms. For example, CTC Exchange Services, which is an ILEC with a history for over 100 years, started its CLEC services by starting a CLEC division in 2000.

Table 2: Summary Statistics on Market Attributes

	1998	1999	2000	2001	2002
Variables†	Mean (Std. Dev.)				
# business establishments	3999.565	4022.812	4021.528	4011.382	4091.894
	(2437.058)	(2439.516)	(2439.216)	(2427.654)	(2469.448)
# incumbents	1	1.819	2.661	3.015	3.231
	(0)	(1.429)	(2.269)	(2.696)	(2.787)
# potential entrants	24.465	31.573	36.319	27.766	24.392
	(7.481)	(9.616)	(10.575)	(10.031)	(8.578)
# entrants	0.960	1.523	1.638	0.746	0.327
	(1.618)	(1.798)	(2.306)	(1.066)	(0.597)
# observations (market)			398		

† At the beginning of each year.

4 Model

Our data set records CLECs' entry decisions into local markets right after the 1996 Act. Two key features stand out: first, we observe the identity of potential entrants and the waiting time between when a CLEC obtains state certification and actually enters a local market; second, summary statistics indicate that potential entrants are by no means homogeneous. To capture these key features of the data, we build a model based on Pakes, Ostrovsky and Berry (2007) with two main differences. First, we assume that potential entrants are long-run players. Under this assumption, in each period a potential entrant chooses to enter or to wait, and the value of waiting is non-negative. Second, we allow potential entrants to be heterogeneous. In particular, while POB assume that all potential entrants draw their entry costs from the same distribution, our model allows different types of potential entrants to face different distributions. We use firms' decisions on whether to become potential entrants to identify a firm's type. The key idea is that a firm decides to obtain state certification only if its expected value of being a potential entrant is sufficiently high. The expected value depends on the distribution of the entry costs, which is in turn determined by a firm's type. A firm's decision to obtain certification therefore reveals its type. The advantage of this approach is that a potential entrant's type is estimated from data instead of imposed on in an *ad hoc* fashion. We now explain this idea more in detail in Section 4.1.

4.1 The Decision to Become a Potential Entrant

When a firm decides whether to obtain certification from a state, and thereby become a potential entrant into that state's local markets, it considers the expected value of being a potential entrant.[16] This expected value, in turn, is determined by the expected payoff and the expected cost of future entry into cities located in the state. Note that we assume that a firm decides on whether to obtain a state certificate before its entry cost each year is realized. We write down a Logit model to account for various factors determining a firm's decision to become a potential entrant:

$$\Pr\left(certification_{fst}|\mathbf{z}_f, \mathbf{d}_{fs}\right) = \frac{\exp\left(\xi_{st} + \boldsymbol{\varphi}_1\mathbf{z}_f + \boldsymbol{\varphi}_2\mathbf{d}_{fs}\right)}{1+\exp\left(\xi_{st} + \boldsymbol{\varphi}_1\mathbf{z}_f + \boldsymbol{\varphi}_2\mathbf{d}_{fs}\right)}, \tag{1}$$

[16] As explained in Section 2.2, the cost of obtaining state certification to become a potential entrant does not vary much across firms.

where ξ_{st} is a state-year fixed effect that captures the expected value of entry in a given state in a given year, and $\mathbf{z}_f$ and $\mathbf{d}_{fs}$ are firm or firm-market characteristics affecting the entry cost. Specifically, $\mathbf{z}_f$ includes whether the firm is privately held, whether it is a subsidiary, whether it is financed by venture capital, and the age of the firm in 1998; $\mathbf{d}_{fs}$ includes whether the market is in the same state as firm headquarters (home state dummy), the distance between the headquarter of a firm and the population centroid of a state, and distance squared. We use these three firm-market characteristics to capture the idea that firms may face different entry costs in different geography.

Since the firm characteristics $\mathbf{z}_f$ and $\mathbf{d}_{fs}$ affect the entry cost, with equation (1) estimated, we use the estimated $\boldsymbol{\varphi}$ to represent multiple dimensions of firm-level heterogeneity that affect entry costs by a single index. In other words $\hat{\boldsymbol{\varphi}}_1\mathbf{z}_f + \hat{\boldsymbol{\varphi}}_2\mathbf{d}_{fs}$ is a scalar that we use to denote firm f's type in state s. To restrict the dimensionality of the state space. We also discretize firms' type. We let $\hat{\boldsymbol{\varphi}}_1\mathbf{z}_f + \hat{\boldsymbol{\varphi}}_2\mathbf{d}_{fs}$ determine whether a firm is one of two types: type 1 or type 2. We will explain the discretization in detail in Section 5.

4.2 The Decision to Enter a Local Market

After obtaining state certification, a firm decides whether to enter a city within the state in each period. As these CLECs offer rather homogenous services such as voice and internet access using standard technology, we think market size and competition are driving factors of post-entry profits. Therefore, we assume that post-entry profits are identical across firms, and only depend on the size of the market and the number of incumbents. Let m_{ct} be the market size and n_{ct} be the number of incumbents in city c and year t. We assume that the one-period profit function has the following parametric form:

$$\pi\left(m_{ct}, n_{ct}\right) = e^{\alpha m_{ct} + \gamma n_{ct}}, \tag{2}$$

where α (the market-size effect) and γ (the competition effect) are parameters to be estimated. The exponential function form ensures that the profit is positive.[17]

At the beginning of each period, a potential entrant observes its entry cost. The entry cost, which is

[17]This exponential functional form also allows nonlinear effects of the market size and the number of incumbents in the profit function. For example, as long as the competition effect is negative, this functional form allows the competition effect to decrease with the number of incumbents.

independently distributed across firms, markets and time, is a firm's private information. This distribution of the entry cost depends on a firm's type. Given that firm attributes are observed by all firms, the number of potential entrants of each type in a city is common knowledge. To summarize, at the beginning of each period, a potential entrant to a market observes the number of potential entrants of each type (T_{1ct}, T_{2ct}) as well as the market conditions (m_{ct}, n_{ct}). These are the relevant state variables for firms' decisions. The market size m_{ct} evolves exogenously according to a first-order Markov process, whereas the number of incumbents n_{ct} is endogenous. The transition of the number of potential entrants is determined by $T_{\tau ct+1} = T_{\tau ct} + (\#\ new\ potential\ entrants)_{\tau ct} - (\#\ exited\ potential\ entrants)_{_{\tau ct}} - (\#\ entrants_{\tau ct})$ for $\tau = 1, 2$. The transition of n_{ct} follows $n_{ct+1} = n_{ct} + (\#\ entrants_{1ct}) + (\#\ entrants_{2ct}) - (\#\ exited\ incumbents)_{ct}$. We assume that $(\#\ new\ potential\ entrants)_{\tau ct}$ is exogenous and i.i.d. across cities and years. As will be explained later, we also assume the exit rate to be exogenous and i.i.d. across cities and years. For notational simplicity, we suppress subscripts c, t for the remainder this section.[18]

If a potential entrant decides to enter the market, it will start to earn profits next period after paying an up-front cost of entry this period. The value of entry is therefore the expected value of being an incumbent next period. Let $V^I(m, n, T_1, T_2)$ be the value of an incumbent at state (m, n, T_1, T_2). Then,

$$V^I(m, n, T_1, T_2) = \pi(m, n) + \delta E_{\left(m', n', T_1', T_2'\right)|(m, n, T_1, T_2)} V^I(m', n', T_1', T_2'), \tag{3}$$

where δ is the discount factor and $E_{\left(m', n', T_1', T_2'\right)|(m, n, T_1, T_2)}$ is the expectation of the state in the next period (m', n', T_1', T_2') conditional on the current state (m, n, T_1, T_2).

Note that an incumbent in such a dynamic game typically also decides whether to continue operating at the end of each period. We choose not to endogenize this decision for the following two reasons. First, in our data an incumbent always stays in the local market until the firm exits as a whole, which is consistent with the observation that the variable cost of maintaining operation is very low. If exit is a firm-level decision, then we cannot treat the firm's entry decisions into local markets as independent decisions. This dramatically increases the state space of our dynamic problem (and hence our data requirements). Second, during the

[18] From now on whenever it is not obvious what we mean by "state", we use the phrase "geographic state" for a U.S. state such as California, and the word "state" for a state in this dynamic model.

time span covered in study, exiting is largely due to exogenous shocks related to the macro economy. We therefore assume that a firm exits exogenously and that all firms have the same expected probability of exit, denoted by p^x. At the end of every period, a firm exits exogenously with realized probability p_t^x, while p_t^x is centered at p^x. Note that p^x is common knowledge among all firms but p_t^x is unobserved *ex ante* by firms. Hence, δ in equation (3) is in fact the discount factor adjusted for the expected probability of exit: $\delta = \beta(1-p^x)$, where β is the standard discount factor.

A potential entrant's decision is based on the comparison of the value of waiting with the value of entry net of entry costs. As explained, the value of entry is the expected value of being an incumbent next period. The value of waiting is the expected value of being a potential entrant next period. Let $V^{PE}(m,n,T_1,T_2,\tau,\zeta)$ be the value of a potential entrant of type τ with entry costs ζ . Then,

$$\begin{aligned} V^{PE}(m,n,T_1,T_2,\tau,\zeta) &= \max\Big\{\delta E^{w}_{\left(m',n',T_1',T_2'\right)|(m,n,T_1,T_2,\tau)} E_{\zeta'|\tau} V^{PE}\left(m',n',T_1',T_2',\tau,\zeta'\right), \\ &\qquad \delta E^{e}_{\left(m',n',T_1',T_2'\right)|(m,n,T_1,T_2,\tau)} V^{I}(m',n',T_1',T_2') - \zeta\Big\}, \end{aligned} \tag{4}$$

where the two terms inside the max operator are, respectively, the value of waiting and the value of entering net of entry costs. For a long-run player, the payoff of waiting is the expected value of being a potential entrant next period. Hence we need to take two expectations in the first term: $E^{w}_{\left(m',n',T_1',T_2'\right)|(m,n,T_1,T_2,\tau)}$ is a type-τ potential entrant's expectation on future states *conditional* on itself *waiting* at state (m,n,T_1,T_2), and $E_{\zeta'|\tau}$ is the expectation of its entry cost next period. In the second term, $E^{e}_{\left(m',n',T_1',T_2'\right)|(m,n,T_1,T_2,\tau)}$ is a type-τ potential entrant's expectation on future states *conditional* on itself *entering*.[19] Note that after entering, the evolution of the states does not depend on a firm's own type; this is why the value of incumbent $V^I(m',n',T_1',T_2')$ is independent of τ. We assume that potential entrants' entry cost ζ follows a gamma distribution with mean μ_1 for type-1 firms and mean μ_2 for type-2 firms. The variance of the entry cost is normalized to be 1.[20]

[19]The expectation E^w (or E^e) is type-specific for two reasons: first, conditional on its own action, a type-1 potential entrant's perception on the number of incumbents next period depends on its belief on how many out of $(T1-1,T2)$ potential entrants will enter, while a type-2's perception hinges on how many out of $(T1,T2-1)$ potential entrants potential entrants will enter; second, the same argument about type dependency holds for a potential entrant's perception on the number of potential entrants next period.

[20]As in all discrete choice models, we can only identify model parameters up to a scale.

Following Hotz and Miller (1993), we define the value of entry for potential entrants at state (m, n, T_1, T_2) as

$$VE\left(m, n, T_1, T_2, \tau\right) = E^{e}_{\left(m', n', T_1', T_2'\right)|(m,n,T_1,T_2,\tau)} V^{I}\left(m', n', T_1', T_2'\right); \tag{5}$$

and the value of waiting as

$$VW\left(m, n, T_1, T_2, \tau\right) = E^{w}_{\left(m', n', T_1', T_2'\right)|(m,n,T_1,T_2,\tau)} E_{\zeta'|\tau} V^{PE}\left(m', n', T_1', T_2', \tau, \zeta'\right). \tag{6}$$

Combining equations (4), (5) and (6), we can write the value of waiting as

$$\begin{aligned} & VW\left(m, n, T_1, T_2, \tau\right) \\ = \; & E^{w}_{\left(m', n', T_1', T_2'\right)|(m,n,T_1,T_2,\tau)} E_{\zeta'|\tau} \max\left\{\delta VW\left(m', n', T_1^{'}, T_2^{'}, \tau\right), \delta VE\left(m', n', T_1^{'}, T_2^{'}, \tau\right) - \zeta'\right\}, \end{aligned} \tag{7}$$

which we can rewrite as[21]

$$\begin{aligned} & VW\left(m, n, T_1, T_2, \tau\right) = \\ & E^{w}_{\left(m', n', T_1', T_2'\right)|(m,n,T_1,T_2,\tau)} \left\{\left(1 - p^{e}\left(m', n', T_1', T_2', \tau\right)\right) \delta VW\left(m', n', T_1^{'}, T_2^{'}, \tau\right) + \right. \\ & \left. p^{e}\left(m', n', T_1', T_2', \tau\right)\left(\delta V\!E\left(m', n', T_1', T_2', \tau\right) - E\left[\zeta | \zeta < \delta V\!E\left(m', n', T_1', T_2', \tau\right) - \delta VW\left(m', n', T_1^{'}, T_2^{'}, \tau\right)\right]\right)\right\}, \end{aligned} \tag{8}$$

where $p^{e}\left(m', n', T_1', T_2', \tau\right)$ is a type-τ potential entrant's probability of entry at state (m', n', T_1', T_2'). A potential entrant enters if the value of entry net of entry costs is larger than the value of waiting, implying that the probability of entry for a type-τ potential entrant is

$$p^{e}\left(m, n, T_1, T_2, \tau\right) = \Pr_{\tau}\left(\zeta < \delta V\!E\left(m, n, T_1, T_2, \tau\right) - \delta VW\left(m, n, T_1, T_2, \tau\right)\right). \tag{9}$$

[21] Note that $E_x \max(a, b - x) = \left[1 - \Pr(x < b - a)\right] a + \Pr(x < b - a)\left[b - E\left(x | x < b - a\right)\right]$.

5 Estimation

Estimation is carried out in two main steps. In the first step, we "determine" the type of each potential entrant. To this end, we estimate $(\boldsymbol{\varphi}_1, \boldsymbol{\varphi}_2)$ in equation (1). We then compute $\hat{\boldsymbol{\varphi}}_1 \boldsymbol{z}_f + \hat{\boldsymbol{\varphi}}_2 \mathbf{d}_{fs}$ for each firm-state and divide them into two groups: a firm f is of type 1 in geographic state s if and only if $\hat{\boldsymbol{\varphi}}_1 \boldsymbol{z}_f + \hat{\boldsymbol{\varphi}}_2 \mathbf{d}_{fs}$ is below the overall median; otherwise, this firm is of type 2 in geographic state s. We expect that type-1 potential entrant to have a higher entry cost on average than type-2 potential entrants. But we do not impose this restriction (i.e., the mean of the entry cost for type-1 potential entrants (μ_1) is larger than the mean for type-2 (μ_2)) in our estimation.

In the second step, we estimate the parameters in the profit function (α, γ) and the parameters in the entry costs distributions (μ_1, μ_2). In the estimation, we set the discount factor β to be 0.95 according to the real interest rate, and the mean exit probability p^x to be the empirical average exit probability at the firm level, which is 23.9% from 1999 to 2002. The estimation of $(\alpha, \gamma, \mu_1, \mu_2)$ follows the procedure in POB with one modification: we need to consistently estimate the value of waiting as well as the value of entry.

To estimate these parameters, we rewrite equations (4), (5) and (8) in vector forms. The state in this model is a quadruple (m, n, T_1, T_2). Suppose there are J distinct states. We denote the ith state by $(m_i, n_i, T_{1i}, T_{2i})$. With a slight abuse of notation, let $V^I(\alpha, \gamma)$ be the vector with $V^I(m_i, n_i, T_{1i}, T_{2i})$ as its ith element. Here we add parameters as inputs of $V^I(\alpha, \gamma)$ explicitly. Similarly, the ith element of the vector $\pi(\alpha, \gamma)$ is $\pi(m_i, n_i)$. Using this notation, we can rewrite equation (4) in vector forms as

$$V^I(\alpha, \gamma) = \pi(\alpha, \gamma) + \delta M V^I(\alpha, \gamma), \tag{10}$$

where M is the transition probability matrix, i.e., its ij-element is the transition probability from state $(m_i, n_i, T_{1i}, T_{2i})$ to $(m_j, n_j, T_{1j}, T_{2j})$. This matrix M is estimated directly from data.

Similarly, we define vectors $VE_1(\alpha, \gamma)$ and $VE_2(\alpha, \gamma)$ as the values of entry for a type-1 and type-2 potential entrant. Their ith elements are, respectively, $VE(m_i, n_i, T_{1i}, T_{2i}, \tau = 1)$ and $VE(m_i, n_i, T_{1i}, T_{2i}, \tau = 2)$. Analogously, we define vector $VW_\tau(\alpha, \gamma, \mu_\tau)$ as the value of waiting for a type-τ potential entrants, and vector p^e_τ as the probability of entry for a type-τ potential entrant. Then, equations (5) and (8) for $\tau = 1, 2$

can be rewritten as

$$VE_\tau(\alpha,\gamma) = M_\tau^e V^I(\alpha,\gamma), \tag{11}$$

$$\begin{aligned} VW_\tau(\alpha,\gamma,\mu_\tau) = M_\tau^w \{ & (1-p_\tau^e)\,\delta VW_\tau(\alpha,\gamma,\mu_\tau) \\ & + p_\tau^e \left(\delta VE_\tau(\alpha,\gamma) - E\left[\zeta|\zeta < \delta VE_\tau(\alpha,\gamma) - \delta VW_\tau(\alpha,\gamma,\mu_\tau);\mu_\tau\right]\right)\}, \end{aligned} \tag{12}$$

where M_τ^e is a matrix whose ij-element is the transition probability from $(m_i, n_i, T_{1i}, T_{2i})$ to $(m_j, n_j, T_{1j}, T_{2j})$ conditional on a type-τ potential entrant *entering* and M_τ^w is the same matrix conditional on it *waiting*.

To estimate $VE_\tau(\alpha,\gamma)$ and $VW_\tau(\alpha,\gamma,\mu_\tau)$, we need consistent estimates of the transition probability matrices M, M_τ^e and M_τ^w. We use their empirical counterparts following POB. See Appendix A for the details on $\hat{M}$, $\hat{M}_1^e$, $\hat{M}_2^e$, $\hat{M}_1^w$, and $\hat{M}_2^w$.

With $\hat{M}$, $\hat{M}_1^e$, $\hat{M}_2^e$, $\hat{M}_1^w$, and $\hat{M}_2^w$ estimated, the estimate of the value of entry is given by

$$\hat{VE}_\tau(\alpha,\gamma) = \hat{M}_\tau^e \hat{V}_\tau^I(\alpha,\gamma) \tag{13}$$

where

$$\hat{V}_\tau^I(\alpha,\gamma) = \left(I - \delta\hat{M}\right)^{-1} \pi(\alpha,\gamma), \tag{14}$$

and I is an identity matrix. Meanwhile, $\hat{VW}_\tau(\alpha,\gamma,\mu_\tau)$ is the fixed point of (12) when $VE_\tau(\alpha,\gamma)$ and M_τ^w are replaced by their empirical counterparts. Note that the RHS of equation (12) is a contraction mapping of $VW_\tau(\alpha,\gamma,\mu_\tau)$ because ζ is assumed to be a log concave random variable (with gamma distribution) and it follows that $0 \leq \frac{\partial E(\zeta|\zeta<d)}{\partial d} \leq 1$ (see Proposition 1 of Heckman and Honoré (1990)).

Once we have consistent estimates of the values of entry and waiting, we can get consistent estimates of the probabilities of entry for given parameters. As explained in equation (9), the probability of entry at a state $(m_i, n_i, T_{1i}, T_{2i})$ is the probability that the entry costs are smaller than the difference between the discounted value of entry and the discounted value of waiting at this state.

The distribution parameters (μ_1, μ_2) and model parameters (α, γ) are estimated with the Generalized Methods of Moments. We observe the state of each year-market combination. The model prediction of the

probability of entry in this year-market is therefore determined by the element in $p_\tau^e\left(\alpha, \gamma, \mu_\tau\right)$ corresponding to this state. Its empirical counterpart is the fraction of type-τ potential entrants in this year-market that enter. The difference of the model prediction and the empirical probability of entry is the prediction error, which we compute for each type of firms and each year-market. We use a norm of the prediction errors and covariances between the prediction errors and the value of some state variables for each year-market as moment conditions. Specifically, we use the covariances between the prediction errors and market, the total number of potential entrants, the percentage of type 1 potential entrants, and a year 2001 dummy.

To summarize the estimation section, we discuss which data features and variation allow us to identify our structural parameters $\left(\alpha, \gamma, \mu_1, \mu_2\right)$. The market size coefficient α is identified by how much entry probabilities vary with market size. The competition coefficient γ is identified similarly, that is, by how entry probabilities change with different numbers of potential entrants in a local market, which affect the number of incumbents in this market. The variation in the number of potential entrants is largely driven the number of new potential entrants, which in turn is driven by the unpredictedness of the bureaucratic process of state certification. The year 2001 dummy, which is a macro economy crash indicator, also helps with the identification of our structural parameters. We argue that the macro economy crash was out of the control of the CLECs (or any single sector of the economy) and happened exogenously and unexpectedly. Lastly, the difference in the entry probabilities of type-1 and type-2 potential entrants identifies the difference in entry costs of these two types. Together with the levels of entry probabilities, these differences give us the distribution parameters $\left(\mu_1, \mu_2\right)$.

6 Results

6.1 State Certification Regression Results

Table 3 shows results from the regressions of CLECs' decisions to obtain state certification for the first time, as described in Section 4.1. The first two columns are OLS and Logit regressions and the last two are their counterparts with state-year fixed effects. Comparing results with and without state-year fixed effects, we can see that the inclusion of such fixed effects significantly improves the model's fit to the data, particularly

Table 3: Firms' Decisions to Obtain State Certification

	(1) OLS	(2) Logit	(3) OLS	(4) Logit
Dummy: =1 if the CLEC is privately held	-0.094	-1.154	-0.093	-1.229
	(0.004)***	(0.057)***	(0.004)***	(0.059)***
Dummy: =1 if the CLEC is a subsidiary of a firm	-0.054	-0.759	-0.056	-0.830
	(0.004)***	(0.062)***	(0.004)***	(0.064)***
Dummy: =1 if the CLEC is funded by venture capital	0.030	0.491	0.032	0.561
	(0.005)***	(0.070)***	(0.005)***	(0.073)***
Log of firm age in 1998	0.004	0.041	0.002	0.038
	(0.002)*	(0.023)*	(0.002)	(0.025)
Dummy: = 1 if home state	0.651	3.252	0.585	2.879
	(0.021)***	(0.218)***	(0.020)***	(0.233)***
Distance b/w headquarters zip code and state	-0.226	-2.407	-0.217	-2.500
	(0.012)***	(0.141)***	(0.013)***	(0.162)***
Distance squared	0.067	0.708	0.058	0.650
	(0.005)***	(0.057)***	(0.005)***	(0.065)***
Constant	0.297	-0.220	0.304	
	(0.008)***	(0.089)**	(0.009)***	
State-year fixed effects included?	No	No	Yes	Yes
R-squared	0.111		0.160	
Log Likelihood		-6137.563		-5106.745
Observations (firm-state-year)	21430	21430	21430	20681†

Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

† For 10 state-year combinations (corresponding 749 observations), no firm obtained state certification and therefore these groups are dropped from the Logit regressions with state-year fixed effects.

for the Logit model. This improvement suggests the importance of using state-year fixed effects to capture a general expectation of aggregate value of entry in a given geographic state s and year t. The results in the last two columns clearly indicate that observed firm attributes are key determinants of firms' decisions to obtain state certification. CLECs that are privately held or subsidiaries to firms are significantly less likely to obtain state certification. However, those funded by venture capital show the opposite pattern and the impact of firm age is insignificant. Furthermore, CLECs are significantly less likely to obtain state certification in states farther from their headquarters: the home state dummy has a significant positive impact on a CLEC's obtaining state certification; the distance between a CLEC's headquarters zip code and the population centroid of the state it obtains certification from has a significant negative impact, although such a negative impact is diminishing with the distance. Overall, it seems that CLECs may have a home state cost advantage and have higher entry costs into a more distant geography.

As described in Section 4.1 on firms' decisions to become potential entrants, we use results from certifi-

Table 4: Summary Statistics on Potential Entrants' Types

Variable	Mean	Std. Dev.	Min	Max
# potential entrants	28.903	10.365	5	56
# type-1 potential entrants	16.243	8.442	1	38
# type-2 potential entrants	12.660	6.794	1	34
Entry rate	0.040	0.067	0	0.5
Type 1's entry rate	0.029	0.066	0	0.6
Type 2' entry rate	0.055	0.100	0	1
# observations (market-year)		1990		

cation regression (Column 4, Table 3) to categorize firms into two types: type 1 and type 2 — CLECs with $\hat{\boldsymbol{\varphi}}_1 \mathbf{z}_f + \hat{\boldsymbol{\varphi}}_2 \mathbf{d}_{fs}$ smaller than the median are labeled as type 1 and those with this measure larger than the median are labeled type 2. Now any market-year combination can be characterized by four state variables: market size (log of the number of business establishments), number of incumbents (including a single ILEC and CLECs), number of type-1 potential entrants, and number of type-2 potential entrants. In addition to these four state variables, a potential entrant's decision on entry also depends on its own type. Table 4 reports summary statistics on the types of potential entrants. We can see that we have on average more type 1's than type 2's in a local market and there are substantial variations in the distributions of types.[22] In the data, entry rate for type-1 potential entrants is on average 0.029, while that for type-2 potential entrants is 0.055.[23] It is this difference in entry probabilities that helps us to identify the difference in entry costs for the two types.

6.2 Estimates of Structural Parameters

Table 5 reports estimation results on the four structural parameters in the model: two parameters in the profit function (market size effect α and competition effect γ) and two parameters describing the distribution of entry costs for each type of firms (mean μ_1 and μ_2). While the estimate of the competition effect parameter γ is not statistically significant, the other three parameters are estimated with statistical significance at 1%

[22]Note that the median cutoff we use in determining a firm's type in a geographic state is with respect to firm and geographic state while the local market is a city within a geographic state. Therefore it is possible that type 1 and type 2 are unevenly distributed in a local market. Moreover, a firm is no longer a potential entrant after entry. Given that type-1 firms on average have a lower entry rate (See Table 4), it is not surprising that there are more type-1 potential entrants on average across year-markets.

[23]Entry rate for type-τ potential entrants is defined as the number of type-τ entrants over the number of type-τ potential entrants in the local market.

Table 5: Estimation Results of Structural Parameters

Parameter	Estimate	Std. Error
α (market size effect)	0.150	0.023***
γ (competition effect)	-0.026	0.021
μ_1 (entry cost mean for type 1)	10.082	0.918***
μ_2 (entry cost mean for type 2)	9.671	0.917***
$\mu_1 - \mu_2$ (difference between entry cost means)	0.411	0.037***

*** significant at 1%

level.[24]

From these results we have three notable findings. First, market size, measured by the logarithm of the number of business establishments, affects the operating profit of an incumbent positively. This is in line with Bresenhan and Reiss (1991), who find that a larger market size is necessary to support more competitors. This also implies that smaller markets may get stuck with a monopolistic structure, as these markets do not have sufficient demand to attract entry.

Second, the number of incumbents negatively affects the operating profit of an incumbent. This result confirms the conventional wisdom that more incumbents in a market erodes average profitability. Looking at the market size effect and the competition effect together, we can see that a larger market attracts entrants; these entrants compete against each other, which lowers both current and expected future profits.

Lastly, firm-level heterogeneity in entry costs plays an important role in determining a firm's entry into a local market. The difference between type 1's and type 2's entry cost means are statistically significant at 1% level. Recall that we group potential entrants into two types based on their propensity to obtain state certification — type-1 potential entrants have lower such propensity than type-2 ones. We do not impose any restriction in estimation on the ranking of the entry cost mean for these two types, μ_1 and μ_2. We find that type-1 potential entrants indeed have higher costs on average than type-2 potential entrants. Therefore, type-2 potential enter are *ceteris paribus* more likely to enter. Put together, these results show that potential entrants who are more likely to obtain state certification also have lower entry costs, which supports the internal consistency of our model.

[24]To take into account the estimation error in the first-stage estimation on firms' decision to become a potential entrant, we use bootstrap to estimate the standard error.

6.3 Fit of Our Model

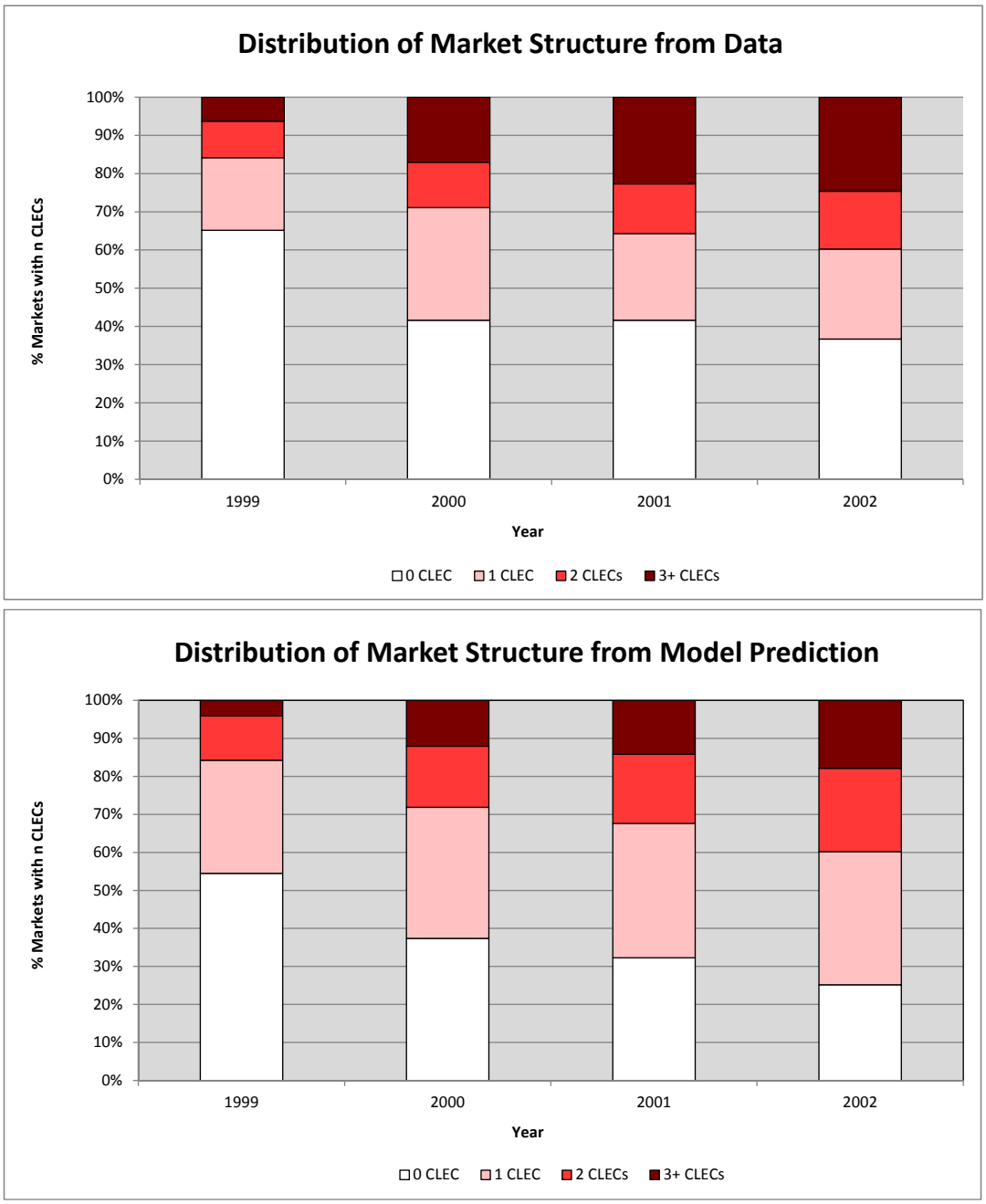
To ensure that our highly-stylized model is able to capture the dynamics of entry behavior in the industry, we compare the distribution of market structure from the observed data with that of model predictions. Figure 1 shows, in comparison, the percentage of markets with n CLECs from 1999 to 2002 for $n = 0, 1, 2$, and above. The observed data in the top panel shows that local markets have become increasingly competitive over time. However, monopoly markets (markets with no CLECs) continue to represent a significant proportion of all markets. From the comparison of the two panels, we can see that our estimated model, graphed on the bottom, fits the overall evolution of local market structures rather well. If anything, our model tends to slightly overestimate entry.

7 Counterfactuals

The goal of this research is to highlight factors that should be taken into account in an explicit subsidy mechanism, called for by the 1996 Act. The policy practice after the Act is a *de facto* non-discriminatory subsidy to every entrant, most notably in the form of forcing ILECs to interconnect with CLECs at no charge and to lease their networks and facilities to CLECs at rates based on long-run average-costs. Aided by these policies, CLECs are able to avoid negotiating interconnection agreements or building overlapping networks with ILECs. We consider these policies fundamental to telecommunications deregulation and do not intend to conduct counterfactual experiments to remove or alter these policies.[25] What we intent to do is to experiment with several explicit subsidy policies *on the top of* the existing policies, and study their effects on promoting competitiveness in local markets. Since we are dealing with an oligopolistic industry with substantial entry costs and significant market- and firm- level heterogeneity, our counterfactual experiments focus, respectively, on the level of an additional subsidy, market- and firm-level heterogeneity, and the oligopolistic nature of local competition. All policies studied subsidize the entry cost. Throughout the

[25]Moreover, the *de facto* subsidies imposed by the Act are difficult to quantify, which certainly does not facilitate any attempt to counterfactually reverse them. One may worry that these *de facto* subsidies, which lowers average variable costs by allowing CLECs to rent networks and facilities from ILECs, vary across markets and this unobserved market-level heterogeneity affects our estimation. However, the main component of CLECs' average variable cost is maintaining and servicing the networks and facilities. We can reasonably assume these subsidies are only a function of the size of the network, which only depends on market size. Therefore, most of the unobserved market-level policy heterogeneity is captured by market size, which is already included in the model.

Figure 1: Distribution of Market Structure: Data v.s. Model Prediction



analysis, we focus on different policies impact on reducing monopoly markets as this is the main goal of the "universal service" policy.

7.1 Subsidy to Every Entrant

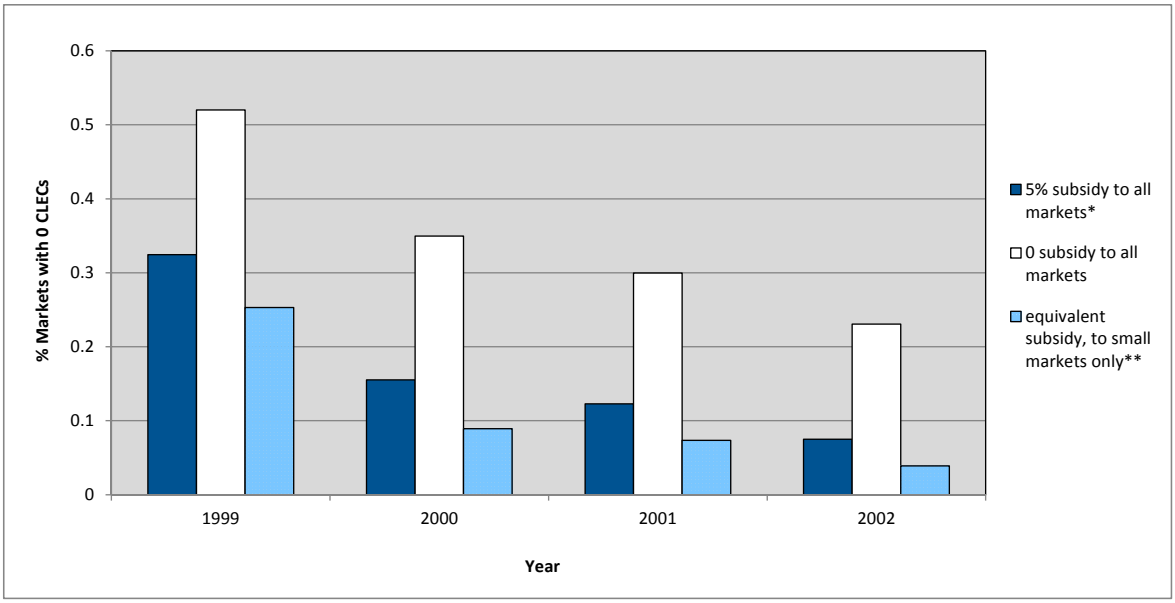
The top and bottom panels in Figure 2 show how applying a subsidy to every entrant could encourage entry into local markets. The white bars are the status quo — the model-simulated distribution of market structures with no subsidies.[26] The dark bars in the top and bottom panels show, respectively, the effect of a subsidy equaling 5% and 10% of the entry cost mean averaged across the two types (i.e. 5% and 10% of $(\mu_1 + \mu_2)/2$) to every entrant in every local market. The 5% subsidy can reduce the share of monopoly markets from 52% to 32% by the beginning of 1999, while the 10% subsidy can further reduces this share to 14% over the same period. By the beginning of 2002, the 5% subsidy reduces the percentage of monopoly markets from 23% to less than 10%, while the 10% subsidy nearly eliminates the existence of monopoly markets.

7.2 Subsidy in Small Markets Only

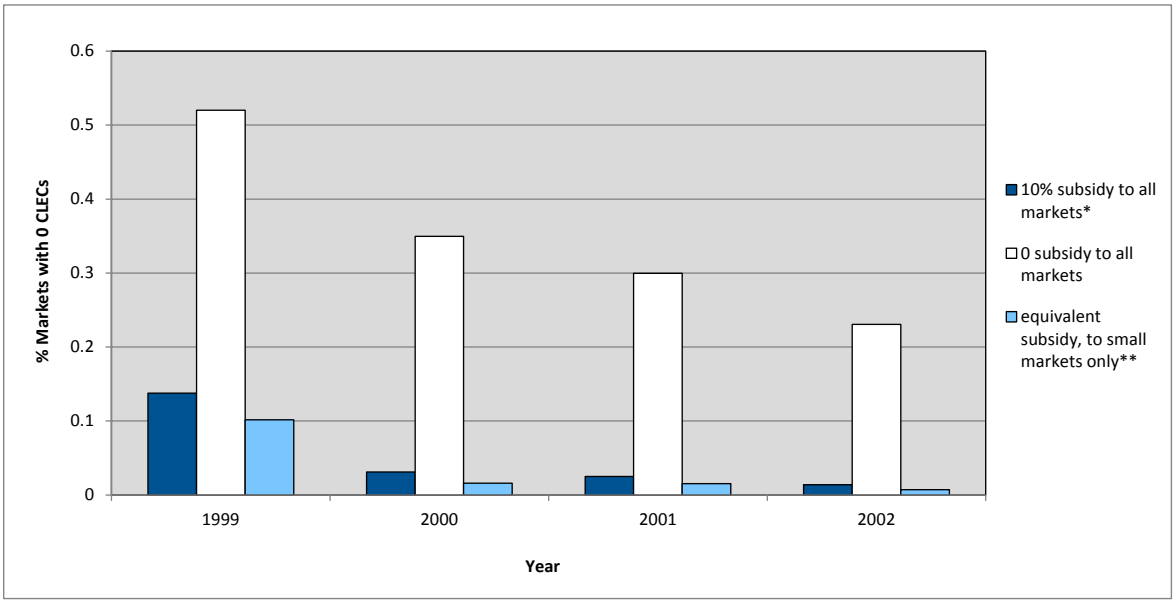
While applying a subsidy to every entrant in every market is effective, it may be quite costly. A subsidy equaling 5% to 10% of the average entry cost should be a substantial amount. In our model, this is equivalent to an increase in 5.1% to 10% of market size in every period. Another way to understand the magnitude of the subsidy is to use information on capital expenditure of the CLECs. In our data we observe annual capital expenditures for the majority of the CLECs. We divide the capital expenditure of a CLEC in a year by the number of cities the CLEC enters next year. The median for this measure of average sunk entry costs per market is approximately \$6.5 million. Therefore, we are looking at roughly \$325,000 for a 5% subsidy and \$650,000 for a 10% subsidy. Such high costs motivates us to look for alternative subsidies which target at selective markets or selective CLECs. We now study whether offering a subsidy in small markets only, that is, in cities with fewer than 5000 business establishments in 1998, is more effective at

[26] We use model-simulated market structure because we do not want realizations of unobservables in the data to affect the comparison between results with and without subsidies. Furthermore, we have shown that simulated market structure is rather close to observed market structure.

Figure 2: Percentage of Monopoly Markets: Subsidy to All Markets v.s. Small Markets Only



* 5% of the average of the two types' entry cost mean
** 5% subsidy to all markets is equivalent to 7.3% subsidy to small markets only.
Under these two subsidy schemes, the total amount of subsidy paid in these four years is the same.



* 10% of the average of the two types' entry cost mean
** 10% subsidy to all markets is equivalent to 12.6% subsidy to small markets only.
Under these two subsidy schemes, the total amount of subsidy paid in these four years is the same.

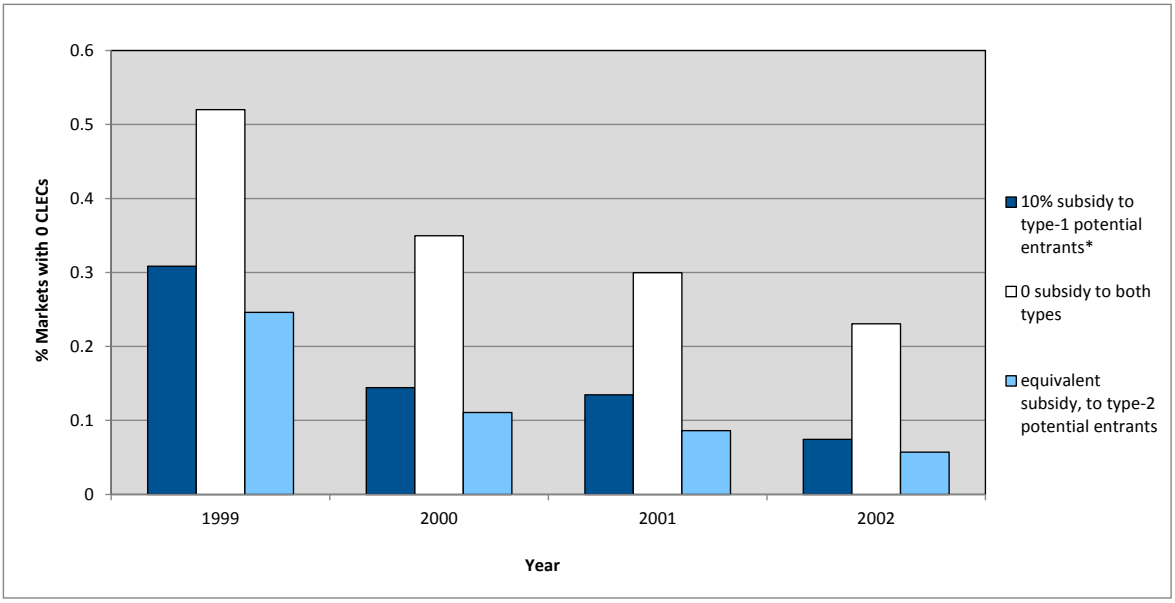
reducing monopoly markets.[27] The subsidy amount studied is still 5% and 10% of the entry cost mean averaged across the two types. A 5% subsidy in all markets is equivalent to a 7.3% subsidy in small markets only in terms of costs. In other words, under these two subsidy schemes, the total amount of subsidy paid in 1998 to 2001 is the same. Similarly, a 10% subsidy in all markets is equivalent to a 12.6% subsidy in small markets only. The lightly shaded bars in Figure 2 show the percentage of monopoly markets under the subsidy in small markets only. The comparison of the dark and light bars clearly shows that a subsidy in small markets is more effective than a subsidy in all markets: the same amount of money spent leads to a larger reduction in the share of monopoly markets. The reasoning is straightforward. Small markets are more likely to be monopoly markets before a subsidy. Therefore, a subsidy encouraging entry in a small market may immediately eliminate monopoly while a subsidy in relatively larger markets may only help to gain yet another competitor.

7.3 Subsidy to Low-Cost CLECs Only

A similar asymmetric subsidy can be applied to high-cost and low-cost potential entrants. We experiment with offering a subsidy only to one of the two types of potential entrants. The subsidy amount studied is 10% of the entry cost mean averaged across the two types. The 10% subsidy to type-1 potential entrants only is equivalent to a 9.1% subsidy to type-2 potential entrants only in terms of the total subsidy paid. Figure 3 compares the percentage of monopoly markets without a subsidy to either type (white bar), with a 10% subsidy to type 1 only (dark bar on the left), and with a 9.1% subsidy to type 2 only (light bar on the right). The comparison of dark and light bars shows clearly that a subsidy to type 2 only is more effective than a subsidy to type 1 only. Intuitively, this is because type-2 potential entrants have lower entry costs and a little push from the subsidy will generate more entry from this group. Combining results from Figure 2 and Figure 3, we reason that perhaps subsidizing only low-cost CLECs in only small markets is a more cost-effective way to eliminate monopoly markets.

[27] 310 of 398 cities fall into this category.

Figure 3: Percentage of Monopoly Markets: Subsidy to Type 1 v.s. to Type 2



* 10% of the average of the two types' entry cost mean

** 10% subsidy to type-1 potential entrants only is equivalent to 9.1% subsidy to type-2 potential entrants only. Under these two subsidy schemes, the total amount of subsidy paid in these four years is the same.

7.4 Subsidy in 1998 Only

Lastly, we consider changing the option value of waiting for potential entrants by offering a one-shot subsidy in 1998. There are two reasons why this modification might be effective. First, a potential entrant can only receive a subsidy if entering in 1998, not in subsequent years, which decreases the value of waiting in 1998. The second reason is indirect through the competition effect: any potential entrant knows their competitors will not be subsidized to enter other than in 1998. So there might be less competition in the future compared to when subsidized in all years. This increases the value of entry in 1998.

The subsidy amount studied is still 10% of the entry cost mean averaged across the two types. In the top panel of Figure 4 we compare applying a 10% subsidy to all years and applying 10% in 1998 only. The latter subsidy reduces the share of monopoly markets to 9%, compared with the former subsidy's 14%, by the beginning of 1999. This result suggests that the one-shot subsidy changes the option value of waiting and effectively speeds up the arrival of competition. This is indeed because of the two effects explained above. The average value of waiting (average over different values of the state variables) in 1998 for type-1 potential entrants decreases from 0.26 to 0.15 when a 10% subsidy is applied in 1998 only. Similarly, the average

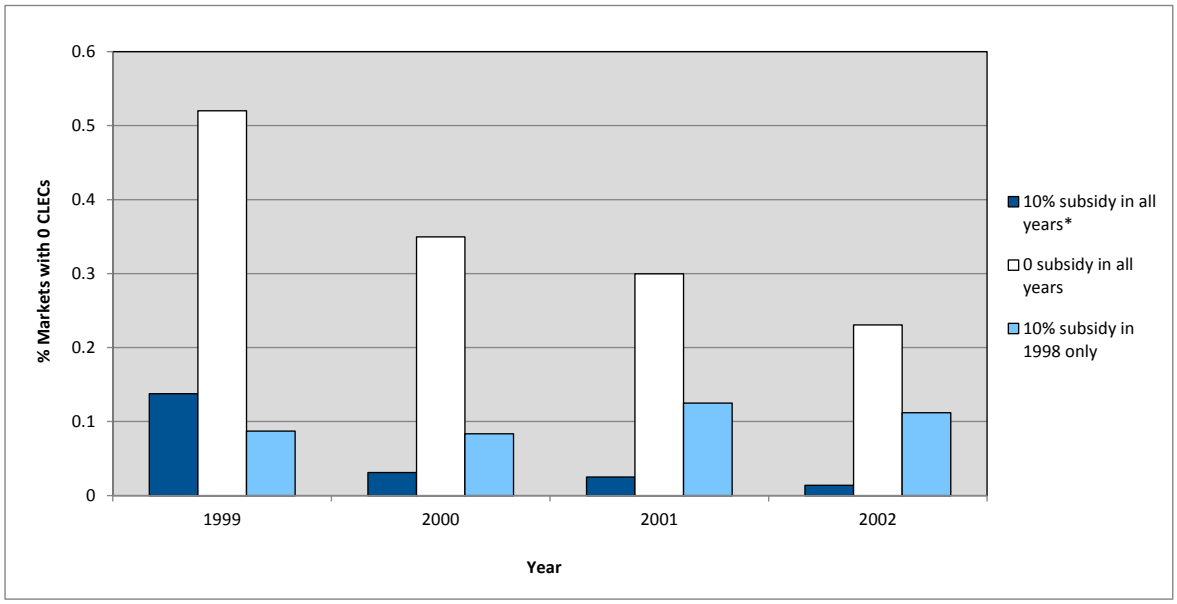
value of waiting for type-2 potential entrants decreases from 0.42 to 0.28 under the 1998-only subsidy. On the other hand, the average value of entry increases from 11.24 to 11.29. As in previous counterfactuals in which we keep the total amount of subsidy spent the same, we apply a 16.7% subsidy in 1998 only, which is equivalent to a 10% subsidy in all years. Again, under these two subsidy schemes the total amount of subsidy paid in these four years is the same. The bottom panel of Figure 4 indicates that this equivalent 1998-only subsidy drastically reduces the percentage of monopoly markets, nearly eliminating them by the beginning of 1999.[28]

8 Conclusion

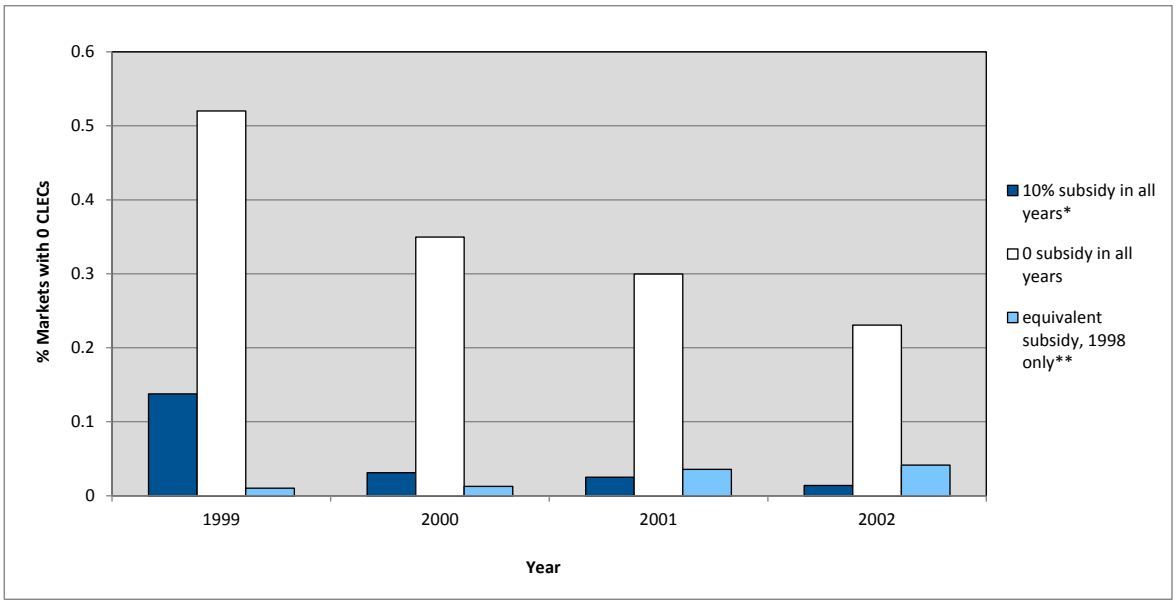
Before 1996, decades of regulation left the U.S. local telephone industry a monopolistic market structure. Under such a market structure, "universal service" was achieved through the implicit cross subsidy: ILECs could keep the rates in rural, sparsely-populated areas low and the resulting losses were recouped from monopoly profits in rich, urban areas. The Telecommunications Act of 1996 opened the telecom markets to competitive entrants, who had ample opportunities to target rich, urban areas and selective clientele. Recognizing the inconsistency between deregulated entry and the original implicit cross subsidy mechanism, the Act calls for an explicit subsidy policy to ensure competition in rural, high-cost areas. In this study we combine economic theory and data on the entry decisions of CLECs from 1998 to 2002 to provide input for designing of a new subsidy policy for the deregulated U.S. local telephone industry. We estimate a dynamic oligopolistic entry game, in which potential entrants are heterogeneous long-run players with the option value of waiting. We find that both market- and firm-level heterogeneity plays an important role in the entry decisions into local markets. Moreover, these entry decisions are significantly influenced by the consideration of both current and future competition. In the estimated game, there is not only the direct effect of any policy on the player itself, but also the indirect effect through the policy's impact on its competitors. Through counterfactual experiments, we find that subsidy policies should exploit the heterogeneity of markets and firms as well as the dynamic, oligopolistic nature of local competition. In

[28] In both panels in Figure 4, we see that the dark bars (subsidy in all four years) grow higher than the light bars (subsidy in 1998 only) over time. This is because this industry is highly volatile in early years and without a subsidy in all four years entry is not sufficient to replace exit.

Figure 4: Percentage of Monopoly Markets: Subsidy in All Years v.s. in 1998 Only



* 10% of the average of the two types' entry cost mean



* 10% of the average of the two types' entry cost mean
** 10% subsidy in all years is equivalent to 16.7% subsidy in 1998 only.
Under these two subsidy schemes, the total amount of subsidy paid in these four years is the same.

particular, we find that subsidies to smaller markets or lower-cost potential entrants are more cost-effective in reducing monopoly local markets, and subsidies in only early periods reduce the option value of waiting for potential entrants and speed up the arrival of competition.

Several limitations of our work need to be acknowledged. First, we are rather crude on capturing firm-level heterogeneity. If we had a longer panel and in turn more data points we might be able to discretize firms into more types so that we could learn more about firm-level heterogeneity. Second, our model does not incorporate post-entry firm-level heterogeneity. In the real world, CLECs may cater to different clientele and offer differentiated value-added services. Without data on post-entry competition, we are not able to provide insight on this issue. Despite these limitations, our model fits the data reasonably well. We believe that we have made an important first step that we hope will encourage future research in this understudied area.

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A Appendix: Estimation of the Transition Probability

We discretize the state space and estimate the transition probabilities directly from data. The estimate of the unconditional transition probability is

$$\hat{M}_{ij} = \frac{\sum_{k \in K(m_i, n_i, T_{1i}, T_{2i})} 1\left\{\left(n_{(k+1)}, m_{(k+1)}, T_{1(k+1)}, T_{2(k+1)}\right) = (m_j, n_j, T_{1j}, T_{2j})\right\}}{\#K\left(m_i, n_i, T_{1i}, T_{2i}\right)}, \tag{15}$$

where $K\left(m_i, n_i, T_{1i}, T_{2i}\right)$ is the collection of all market-years whose states are $(m_i, n_i, T_{1i}, T_{2i})$, k represents such a market-year and $k+1$ represent the same market one year later. The cardinality of the set $K\left(m_i, n_i, T_{1i}, T_{2i}\right)$ is $\#K\left(m_i, n_i, T_{1i}, T_{2i}\right)$.

The estimate of the transition probability conditional on a type-1 firm entering is

$$\hat{M}^e_{1ij} = \frac{\sum_{k \in K(m_i, n_i, T_{1i}, T_{2i})} e_{1(k)} 1\left\{\left(n_{(k+1)}, m_{(k+1)}, T_{1(k+1)}, T_{2(k+1)}\right) = (m_j, n_j, T_{1j}, T_{2j})\right\}}{\sum_{k \in K(m_i, n_i, T_{1i}, T_{2i})} e_{1(k)}}, \tag{16}$$

where $e_{1(k)}$ is the number of type-1 entrants in market-year k. Note that the transition of the states is weighted by the ratio of the probability that $(e_1 - 1)$ out of $T_1 - 1$ potential entrants enter over the probability that e_1 out of T_1 potential entrants enter. Similarly,

$$\hat{M}^e_{2ij} = \frac{\sum_{k \in K(m_i, n_i, T_{1i}, T_{2i})} e_{2(k)} 1\left\{\left(n_{(k+1)}, m_{(k+1)}, T_{1(k+1)}, T_{2(k+1)}\right) = (m_j, n_j, T_{1j}, T_{2j})\right\}}{\sum_{k \in K(m_i, n_i, T_{1i}, T_{2i})} e_{2(k)}}. \tag{17}$$

The same argument gives the estimate of the transition probability conditional on waiting. The transition of the states conditional on waiting for type-1 firms is weighted by the ratio of the probability that e_1 out of $T_1 - 1$ potential entrants enter over the probability that e_1 out of T_1 potential entrants enter. The transition for type-2 firms is analogously weighted. In other words, the estimates are

$$\hat{M}^w_{1ij} = \frac{\sum_{k \in K(m_i, n_i, T_{1i}, T_{2i})} \left(T_{1i} - e_{1(k)}\right) 1\left\{\left(n_{(k+1)}, m_{(k+1)}, T_{1(k+1)}, T_{2(k+1)}\right) = (m_j, n_j, T_{1j}, T_{2j})\right\}}{\sum_{k \in K(m_i, n_i, T_{1i}, T_{2i})} \left(T_{1i} - e_{1(k)}\right)}, \tag{18}$$

and

$$\hat{M}^w_{2ij} = \frac{\sum_{k \in K(m_i, n_i, T_{1i}, T_{2i})} \left(T_{2i} - e_{2(k)}\right) 1\left\{\left(n_{(k+1)}, m_{(k+1)}, T_{1(k+1)}, T_{2(k+1)}\right) = (m_j, n_j, T_{1j}, T_{2j})\right\}}{\sum_{k \in K(m_i, n_i, T_{1i}, T_{2i})} \left(T_{2i} - e_{2(k)}\right)}. \tag{19}$$