Entry under Subsidy: the Competitive U.S. Local Telephone Industry*

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Abstract

The 1996 Telecommunication Act introduces entry into an originally monopolistic U.S. local telephone industry. As competitors cherry pick rich, urban markets to enter, the Act calls for an explicit and pro-competitive subsidy policy to narrow the potential divide in telecom infrastructure. To study relevant economic factors in the design of such a policy, we estimate a dynamic oligopoly entry game using data on the competitors' entry decisions into local markets. As we observe the identities of potential entrants and their waiting time before actual entry, we allow these firms to be heterogeneous long-run players who have the option value of waiting. We find that both market- and firm-level heterogeneity plays an important role in a potential entrant's local entry decisions. Moreover, these entry decisions are significantly influenced by the consideration of both current and future competition. Using structural estimates, we evaluate the effectiveness of different subsidy policies.

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

JEL: L1, L96

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1 Introduction

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. 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.[1] 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. The "universal service" goal was fulfilled as a result of these practices, which are referred to as "implicit cross subsidy". The passage of the 1996 Telecommunications Act (henceforth the Act) dramatically changed the landscape of the U.S. local telephone by opening the floodgate to Competitive Local Exchange Carriers (CLECs). Anticipating that these CLECs would selectively enter rich, urban markets, 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.

This paper aims 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. However, only a handful of medium-sized markets attract more than ten CLECs and 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-stake industry with substantial sunk cost of entry and significant firm-level heterogeneity; CLECs varying substantially in size, ownership and financial

[1] Equal access refers to "access to telecommunications services and information services for customers in rural, insular and high-cost areas that are reasonable 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).

structure, and telecommunications experience. Perhaps a little additional subsidy were necessary, at least for rural markets? Or perhaps subsidies could have been offered to low-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 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 such a subsidy may not be effective when competition effect is large. Ultimately, this is an empirical question which depends on subsidy's effect on the cost and value of entry.

We employ a rich panel data set which records all CLECs' entry decisions into local telephone markets. 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. Knowing these identities, we are able to observe a few crucial firm-level attributes and a firm's waiting time at each local market.

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. This allows us to incorporate the timing of entry and firm heterogeneity into 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 in each period. Since our estimation strategy restricts the number of firm characteristics that can be incorporated,[2] we map

[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

multiple dimensions of firm-level heterogeneity into a single dimension by incorporating the decision of an established firm to become a potential entrant. This decision reflects a firm's expectation of future payoff against its expectation of entry costs. The former is assumed homogenous in a given state and year, while the latter depends on multiple firm characteristics. An estimated model of a firm's decision to become a potential entrant therefore gives us a linear combination of firm characteristics that determines the firm's expectation of entry costs. We then categorize potential entrants into two types based on this single dimension of firm heterogeneity. The advantage of our approach is that a potential entrant's type is estimated from data instead of imposed on in an *ad hoc* fashion.

There are 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 significantly negative competition effect on profit. Third, firm-level heterogeneity in entry costs plays a significant 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 subsidy policy. We find that a subsidy equivalent 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 8% by the end of 2002. Doubling such a subsidy can further reduce this fraction to 14% by the end of 1998 and 1% by the end of 2002. 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 equivalent 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 an effect of 14% if 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

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.

explicit 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 & Mira, 2007; Bajari, Benkard & Levin, 2007; POB; Pesendorfer & Schmidt-Dengler, 2008) have made significant progress since Hotz & Miller (1993) proposes 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, 2008; Ryan, 2009; Dunne, Klimek, Roberts & 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 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, 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. In Section 2 we briefly discuss industry background and telecommunica-

[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 telecommunication industry include Economides, Seim, and Viard (2008), Ackerberg et al (2009), Mini (2001), and Alexander and Feinberg (2004).

tions policies after the Act. In Section 3 we introduce the data we use. Sections4 and 5 describe in detail our 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

"Universal service" has always been a policy goal since the start of the U.S. telecommunications industry. The goal is to make basic telephone service available at affordable and relatively uniform rates throughout the United states. The Act reconfirms this policy goal, which is about "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)). 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 costs per household are hugely different across the two scenarios.

Before 1996, local monopoly incumbents achieved the "universal services" policy goal by redistributing

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

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.[6] 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.

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 a given city within the state. Before 1996, the states generally refused to license new telephone companies

[6] 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).

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."[7]

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.[8] 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, and 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.[9] 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 months or years 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'

[7]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."

[8]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).

[9]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.

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[10] 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 public or private, whether the company is venture capital funded, and whether the company is a wholly owned subsidiary of a larger telecommunications company.

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

[10]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.

[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.

[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.

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 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, 2, and 3 report descriptive statistics. Table 1 shows that these firms are generally privately owned (59% to 64% across years) and have high variances in age (the standard deviation is about twice the mean for all years). A small proportion of these firms are subsidiaries to large corporations (26% to 32% across years) and partially funded by venture capital (17% to 22% across years). On average, these firms target regional or national markets, which is reflected in the large number of states from which they have certifications. The average number of cities a CLEC can potentially enter 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. 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.

[13]Atlanta is the cutoff city based on this threshold. Our results are robust to different cutoffs.

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

Table 3 summarizes the data at the firm-market level to give the readers a sense of the exogenous and endogenous variables we use in our structural model. The firm attributes we use are what we think determines 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 a measure of the distance (in kilometers) between a firm's headquarter zip code and the centroid of a state, which serves as a determinant of sunk cost of entry as well. The endogenous variable in this study is whether a potential entrant chooses to enter a local market in a given year. Note that once a potential entrant enters a local market the data indicate that the firm remains in the market until it exits the industry entirely. This is why we do not treat a firm's exit from a local market as an endogenous variable. We will discuss the exit of firms in more detail in the next section.

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: (1) 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 option value of waiting is non-negative. (2) 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. We now explain this idea in more 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.[15] This expected value, in turn, is determined by the expected payoff and the expected cost of future entry into cities located in the state. We write down a Logit model to account for various factors determining a firm's decision to become a potential entrant:

$$\Pr\left(certification_{fst}|z_f, d_{fs}\right) = \frac{\exp\left(\xi_{st} + \varphi_1 z_f + \varphi_2 d_{fs}\right)}{1 + \exp\left(\xi_{st} + \varphi_1 z_f + \varphi_2 d_{fs}\right)}, \tag{1}$$

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 z_f and d_{fs} are firm characteristics affecting the entry cost. Specifically, z_f includes whether the firm is privately owned, whether it is a subsidiary, whether it is financed by venture capital, and the age of the firm when the Act was passed. We also consider the distance between the headquarter of a firm and the centroid of a state, denoted by d_{fs}, to capture the idea that firms may face higher entry costs in more distant geography.

Since the firm characteristics z_f and d_{fs} affect the entry cost, with equation (1) estimated, we use the estimated φ to represent multiple dimensions of firm-level heterogeneity that affect entry costs in a single dimension. In other words $\hat{\varphi}_1 z_f + \hat{\varphi}_2 d_{fs}$ is a scalar that we use to denote firm f's type in state s. To restrict the dimensionality of the state space, we let $\hat{\varphi}_1 z_f + \hat{\varphi}_2 d_{fs}$ 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. 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} the number of incumbents in city c and year t. The market size m_{ct} evolves exogenously according to a first-order Markov process, whereas the number of incumbents n_{ct} is endogenous. We assume that the one-period profit function has the following parametric

[15] The cost of obtaining state certification to become a potential entrant is trivial, as documented in section 2.2.

form:

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

where α (the market size effect) and γ (the competition effect) are parameters to be estimated. The exponential function form ensures that the profits are positive.[16]

At the beginning of each period, a potential entrant observes its entry cost. The entry cost, which is 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.[17] 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 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. Second, during the time

[16] 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.

[17] The transition of the number of potential entrants is determined by $T_{\tau ct+1} = T_{\tau ct} + (\#\ \textit{new potential entrants})_{\tau ct} - (\#\ \textit{exited potential entrants})_{\tau ct} - (\#\ \textit{entrants}_{\tau ct})$ for $\tau = 1, 2$. The transition of n_{ct} follows $n_{ct+1} = n_{ct} + (\#\ \textit{entrants}_{1ct}) + (\#\ \textit{entrants}_{2ct}) - (\#\ \textit{exited incumbents})_{ct}$. We assume that $(\#\ \textit{new potential entrants})_{\tau ct}$ is exogenous and i.i.d. across cities and years. As explained later, we also assume the exit rate to be exogenous and i.i.d across cities and years. Thus, $(m_{ct}, n_{ct}, T_{1ct}, T_{2ct})$ is the state for a Markov strategy.

[18] From now on when what we mean by the phase "state" is not conspicuous, 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.

span covered in study, large-scale exiting is largely due to exogenous shocks related to the macro economy. We therefore assume that a firm exits exogenously with probability p_t^x in year t. All firms face the same probability of exit, although in line with the data this probability varies across years. We denote the mean of p_t^x as p^x. We assume p^x is common knowledge among all firms but p_t^x are realized in each year and unobserved *ex ante* by firms. Because of the possibility of exiting, δ in equation (3) is in fact the discount factor adjusted for the 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,

$$\begin{aligned} V^{PE}(m,n,T_1,T_2,\tau,\zeta) \quad = \quad & \max\Big\{\delta E^w_{(m',n',T_1',T_2')|(m,n,T_1,T_2,\tau)} E_{\zeta'|\tau} V^{PE}(m',n',T_1',T_2',\tau,\zeta'), \\ & \delta E^e_{(m',n',T_1',T_2')|(m,n,T_1,T_2,\tau)} V^I(m',n',T_1',T_2') - \zeta\Big\}, \end{aligned} \tag{4}$$

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: $E^w_{(m',n',T_1',T_2')|(m,n,T_1,T_2,\tau)}$ 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, $E^e_{(m',n',T_1',T_2')|(m,n,T_1,T_2,\tau)}$ 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]

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

[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 agrement 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.

before they observe their entry costs 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:

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

which we can rewrite as:[21]

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

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').

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 (φ_1,φ_2) in equation (1). We then compute $\hat{\varphi}_1 z_f+\hat{\varphi}_2 d_{fs}$ 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 $\hat{\varphi}_1 z_f+\hat{\varphi}_2 d_{fs}$ is below the median; otherwise, this firm is of type 2 in geographic state s. Our results are robust to alternative cutoffs used to determine firm type.

In the second step, we estimate the parameters in the profit function (α,γ) and the parameters in the entry costs functions (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

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

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 form. 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 $V^I(\alpha, \gamma, \delta)$ 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 $V^I(\alpha, \gamma, \delta)$ 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

$$V^I(\alpha, \gamma, \delta) = \pi(\alpha, \gamma) + \delta M V^I(\alpha, \gamma, \delta), \tag{9}$$

where M is the transition probability matrix, i.e., the 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 $VE_1(\alpha, \gamma, \delta)$ and $VE_2(\alpha, \gamma, \delta)$ 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 $VW_\tau(\alpha, \gamma, \delta, \mu_\tau)$ 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

$$\begin{aligned} VE_\tau(\alpha, \gamma, \delta) &= M^e_\tau V^I(\alpha, \gamma, \delta), && (10) \\ VW_\tau\left(\alpha, \gamma, \delta, \mu_\tau\right) &= M^w_\tau \left\{(1 - p^e_\tau)\, \delta VW_\tau\left(\alpha, \gamma, \delta, \mu_\tau\right)\right. && (11) \\ &\quad \left. + p^e_\tau\left(\delta VE_\tau(\alpha, \gamma, \delta) - E\left[\zeta | \zeta < \delta VE_\tau(\alpha, \gamma, \delta) - \delta VW_\tau\left(\alpha, \gamma, \delta, \mu_\tau\right); \mu_\tau\right]\right)\right\}, \end{aligned}$$

where M^e_τ 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^w_τ is the same matrix conditional on it *waiting*.

To estimate $VE_\tau(\alpha, \gamma, \delta)$ and $VW_\tau\left(\alpha, \gamma, \delta, \mu_\tau\right)$, we need consistent estimates of the transition probability matrices M, M^e_τ and M^w_τ. We use their empirical counterparts following POB. See Appendix A for the details on $\hat{M}$, $\hat{M}^e_1$, $\hat{M}^e_2$, $\hat{M}^w_1$, and $\hat{M}^w_2$.

With $\hat{M}$, $\hat{M}^e_1$, $\hat{M}^e_2$, $\hat{M}^w_1$, and $\hat{M}^w_2$ estimated, the estimate of the value of entry is given by

$$V\hat{E}_\tau(\alpha, \gamma, \delta) = \hat{M}^e_\tau \hat{V}^I_\tau(\alpha, \gamma, \delta) \tag{12}$$

where

$$\hat{V}_\tau^I(\alpha,\gamma,\delta) = \left(I - \delta\hat{M}\right)^{-1}\pi(\alpha,\gamma), \tag{13}$$

and I is an identity matrix. Meanwhile, $V\hat{W}_\tau\left(\alpha,\gamma,\delta,\mu_\tau\right)$ is the fixed point of (11) when $VE_\tau(\alpha,\gamma,\delta)$, M_τ^w and p_τ^e are replaced by their empirical counterparts. Note that the RHS of equation (11) is a contraction mapping of $VW_\tau\left(\alpha,\gamma,\delta,\mu_\tau\right)$ 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. The probability of entry at 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 $\left(\mu_1, \mu_2\right)$ and model parameters (α,γ) are estimated with the Generalized Methods of Moments. We use moment conditions which posit that prediction errors are uncorrelated with the exogenous explanatory variables. Specifically, 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 $p_\tau^e\left(\alpha,\gamma,\delta,\mu_\tau\right)$ corresponding to this state. Its empirical counterpart is the fraction of 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. This prediction error is uncorrelated with any exogenous variable describing the market structure of a year-market. Specifically, we choose market size, the total number of potential entrants, the percentage of type 1 potential entrants and a constant 1. Additionally, we include as instruments a year 2001 dummy, i.e., an Internet crash dummy, which negatively affects the number of incumbents as many firms exited in the crash.

6 Results

6.1 State Certification Regression Results

Table 4 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, particular 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 owned or subsidiaries to firms are significantly less likely to obtain state certification. However, those funded by venture capital or having a longer operating history show the opposite pattern. Furthermore, CLECs are significantly less likely to obtain state certification in states farther from their headquarters, suggesting that CLECs may 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 certification regression (Column 4, Table 4) to categorize firms into two types: type 1 and type 2 — CLECs with $\hat{\varphi}_1 z_f + \hat{\varphi}_2 d_{fs}$ 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 5 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[22] and there are substantial variations in the distributions of types. In the data, the entry probability for a type-1 potential entrant is 0.026, while that for a type-2 potential entrant is 0.051. 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 6 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

[22] Note that the median cutoff we use here 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.

of entry costs for each type of firms — mean μ_1 and μ_2. All four structural parameters are estimated with statistical significance.

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 a CLEC positively once it becomes an incumbent. 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 a CLEC. 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 a significant role in determining a firm's entry into a local market. 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 do 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 indicate that potential entrants who are more likely to obtain state certification also have lower entry costs, which supports the internal consistency of our model.

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.[23] 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 three counterfactual experiments focus, respectively, on the level of subsidy, market- and firm-level heterogeneity, and the oligopolistic nature of local competition.

7.1 Subsidy to Every Entrant

The top and bottom panels in Figure 2 show how applying 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.[24] 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 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

[23]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 vary across markets and this unobservable market-level heterogeneity affects our estimation. However, as long as average costs depend only on market size, this heterogeneity is captured by market size, which is included in the model.

[24]We use model-simulated market structure because we do not want estimation errors 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.

1999, while the 10% subsidy can further reduces this share to 14% over the same period. By the beginning of 2002, the 5% subsidy leads to less than 10% monopoly markets, while the 10% subsidy nearly eliminates the existence of monopoly markets.

7.2 Subsidy in Small Markets Only

While applying subsidy to every entrant in every market is effective, it may be quite costly. We do not have dollar figures on subsidies, but 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. We now study whether offering subsidy in small markets only, that is, in cities with fewer than 5000 business establishments in 1998, is more efficient.[25] 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 7.3% subsidy in small markets only. Under these two subsidy schemes, the total amount of subsidy paid in these four years is the same. Similarly, a 10% subsidy in all markets is equivalent to a 12.4% 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 subsidy. Therefore, subsidy encouraging entry in a small market may immediately eliminate monopoly while subsidy in relatively larger markets may only help to gain yet another competitor. The welfare gain from entry into a monopoly market is typically larger than from entry into a more competitive market.

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 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 9.7% subsidy to type-2 potential entrants only in terms of the total subsidy paid. Figure

[25] 310 of 398 cities fall into this category.

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 9.7% 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 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.

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 directly affects the option value of waiting. 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. Both effects reduce the option value of waiting.

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 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. As in previous counterfactuals in which we keep the total amount of subsidy spent the same, we apply a 16.5% subsidy in 1998 only, which is equivalent to 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.[26]

[26]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 subsidy in all four years entry is not sufficient to replace exit.

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 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 floodgate 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 and pro-competitive subsidy policy to achieve the "universal service" goal. 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 competitive 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 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.

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. Still, we are humbled by the limitations of our work. 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 any data on post-entry competition, we are not able to provide insight on this issue. Lastly, the model we have developed is highly stylized and may not capture other important elements of the early competitive U.S. local telephone industry. This industry is the product of 100 years' technological evolution, federal and state regulation, and a major deregulatory overhaul. It is an extremely complex and entrenched system, where every institutional detail may reflect a struggle between regulators and industry interests groups. Despite these limitations, we believe 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

The estimate of the unconditional transition probability is

$$\hat{M}_{ij} = \frac{\sum_{k \in K(m_i,n_i,T_{1i},T_{2i})} 1\left\{\left(n_{(k+1)}, m_{(k+1)}, T_{1(k+1)}, T_{2(k+1)}\right) = (m_j, n_j, T_{1j}, T_{2j})\right\}}{\#K\left(m_i, n_i, T_{1i}, T_{2i}\right)}, \tag{14}$$

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 represent such a market-year and $k+1$ represent the same market one year later. The cardinality of the set K 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

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

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,

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

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

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

and

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

B Appendix: Tables and Figures

Table 1: Summary Statistics by Firm-Year

	1998	1999	2000	2001	2002
Variables			Mean (Std. Dev.)		
Privately owned	0.639	0.595	0.581	0.598	0.640
	(0.483)	(0.493)	(0.495)	(0.493)	(0.483)
Subsidiary	0.320	0.284	0.282	0.268	0.302
	(0.469)	(0.453)	(0.452)	(0.445)	(0.462)
Financed by venture capital	0.176	0.190	0.222	0.206	0.221
	(0.383)	(0.394)	(0.418)	(0.407)	(0.417)
Firm age	8.897	8.526	11.020	13.330	15.267
	(20.207)	(16.548)	(20.769)	(23.416)	(24.695)
# states with certification	9.021	10.810	12.872	13.134	12.814
	(10.941)	(11.859)	(12.103)	(12.271)	(12.326)
# cities to potentially enter	100.381	111.138	127.111	122.196	123.209
	(108.026)	(112.298)	(116.250)	(114.220)	(117.659)
# observations (firm)	97	116	117	97	86

Table 2: Summary Statistics by Market-Year

	1998	1999	2000	2001	2002
Variables†			Mean (Std. Dev.)		
# business establishments	3999.083	4022.314	4020.987	4010.884	4091.384
	(2435.669)	(2438.102)	(2437.705)	(2426.277)	(2468.029)
# incumbents	1	1.819	2.598	2.960	2.224
	(0)	(1.429)	(2.185)	(2.603)	(2.776)
# potential entrants	24.465	31.573	35.769	27.822	24.400
	(7.481)	(9.616)	(10.493)	(10.000)	(8.577)
# entrants	0.960	1.523	1.613	0.802	0.334
	(1.618)	(1.798)	(2.268)	(1.150)	(0.599)
# observations (market)			398		

† At the beginning of each year.

Table 3: Summary Statistics by Firm-Market-Year

Variable	Mean	Std. Dev.	Min	Max
Firm attributes				
Privately owned	0.417	0.493	0	1
Subsidiary	0.184	0.387	0	1
Funded by venture capital	0.197	0.398	0	1
Firm age in 1998	10.443	22.000	0	114
Firm-market attribute				
Distance from firm headquarter to market (in 1000 kms)	1.470	1.107	0.0002	4.390
Market-level state variables				
# business establishments (in 1000s)	3.998	2.383	1.648	14.136
# incumbents	2.4	2.305	1	18
# potential entrants	32.217	10.171	5	55
Firm-market endogenous decision				
Entry	0.035	0.183	0	1
# observations (firm-market-year)		59950		

Table 4: Firms' Decisions to Obtain State Certification

	(1) OLS	(2) Logit	(3) OLS	(4) Logit
dummy: =1 if the CLEC is privately owned	-0.123	-1.326	-0.117	-1.365
	(0.005)***	(0.056)***	(0.005)***	(0.059)***
dummy: =1 if the CLEC is a subsidiary of a firm	-0.085	-1.077	-0.084	-1.128
	(0.005)***	(0.060)***	(0.004)***	(0.063)***
dummy: =1 if the CLEC is funded by venture capital	-0.005	0.195	0.011	0.302
	-0.006	(0.068)***	(0.005)**	(0.071)***
log of firm age in 1998	0.001	0.003	0.006	0.080
	(0.003)	(0.026)	(0.002)***	(0.027)***
distance b/w headquarter zip code and state	-0.052	-0.696	-0.066	-0.884
	(0.002)***	(0.030)***	(0.002)***	(0.036)***
Constant	0.303	-1.105		
	(0.007)***	(0.080)		
State-year fixed effects included?	No	No	Yes	Yes
R-squared	0.07		0.08	
Log Likelihood		-6050.482		-4972.045
Observations (firm-state-year)	20531	20531	20531	19933†

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

† For 8 state-year combinations (corresponding 598 observations), no firm obtained state certification and therefore we drop these groups from the Logit regressions with state-year fixed effects.

Table 5: Summary Statistics on Potential Entrants' Types

Variable	Mean	Std. Dev.	Min	Max
# type 1 potential entrants	16.361	8.455	1	37
# type 2 potential entrants	12.444	6.334	0	31
# observations (market-year)		1990		

Table 6: Estimation Results of Structural Parameters

Structural parameter	Estimate	Std. Error
α (market size effect)	0.151	0.014***
γ (competition effect)	-0.027	0.013*
μ_1 (entry cost mean for type 1)	10.083	5.538*
μ_2 (entry cost mean for type 2)	9.727	5.223*

* significant at 10%; ** significant at 5%; *** significant at 1%

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

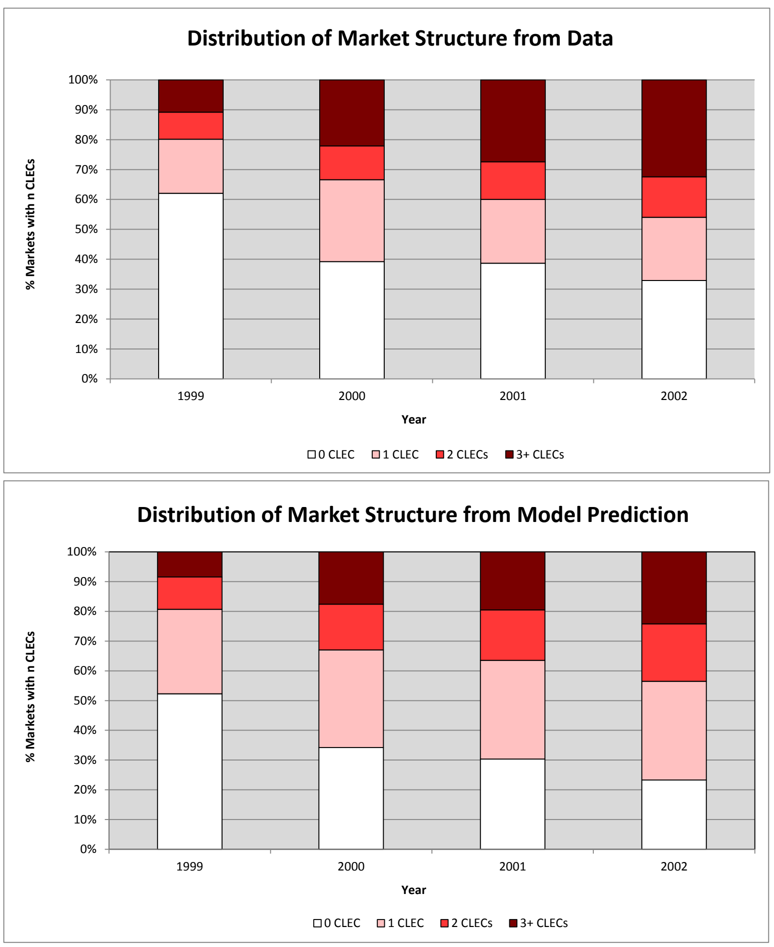
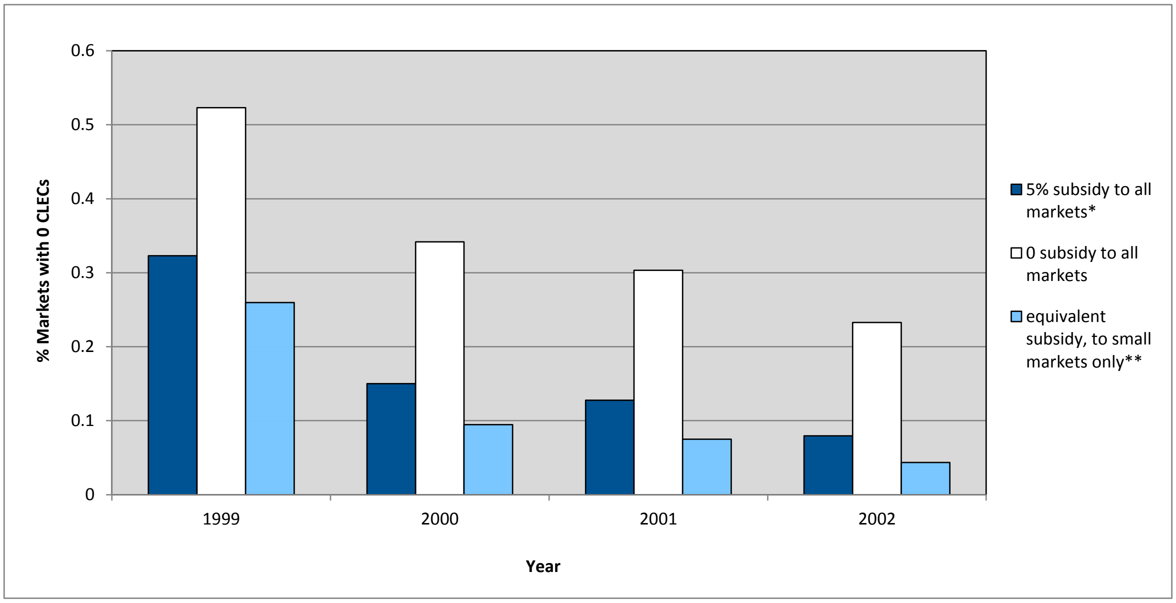


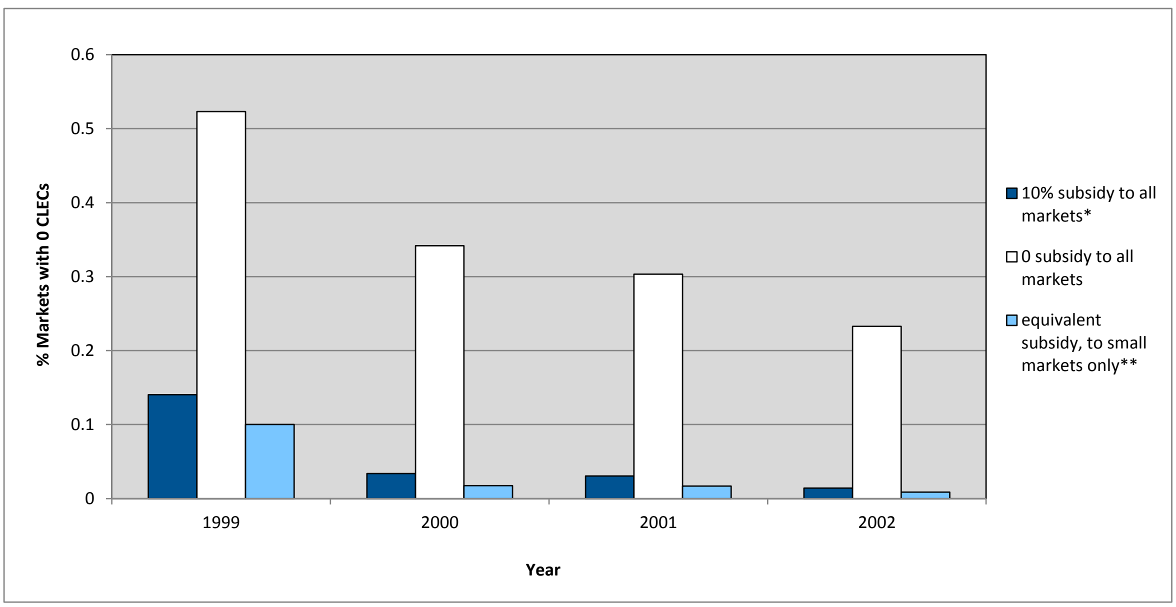
Figure 2: Percentage of Monopoly Markets: Subsidy to All Markets v.s. Small Markets Only



* 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.

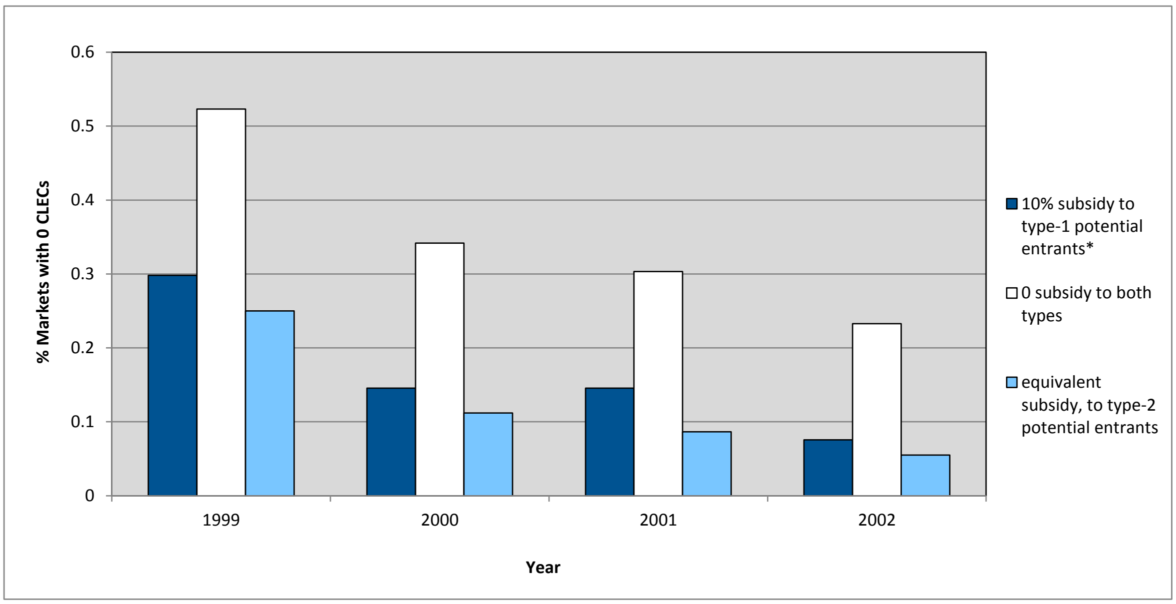


* 10% of the average of the two types' entry cost mean

** 10% subsidy to all markets is equivalent to 12.4% subsidy to small markets only.

Under these two subsidy schemes, the total amount of subsidy paid in these four years is the same.

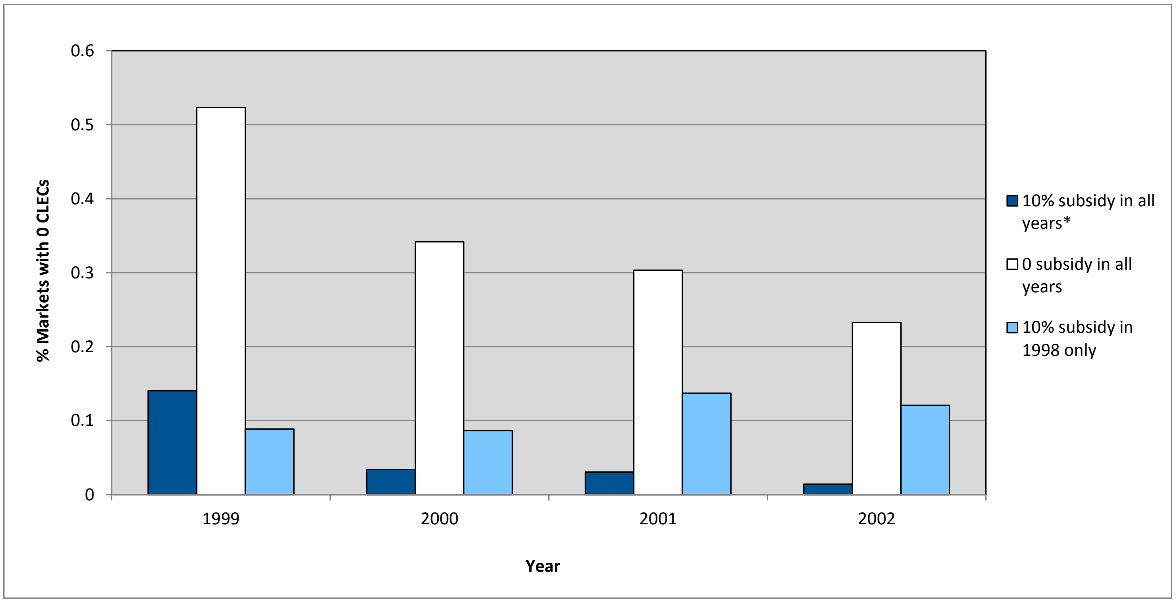
Figure 3: Percentage of Monopoly Markets: Subsidy to Type 1 v.s. to Type 2



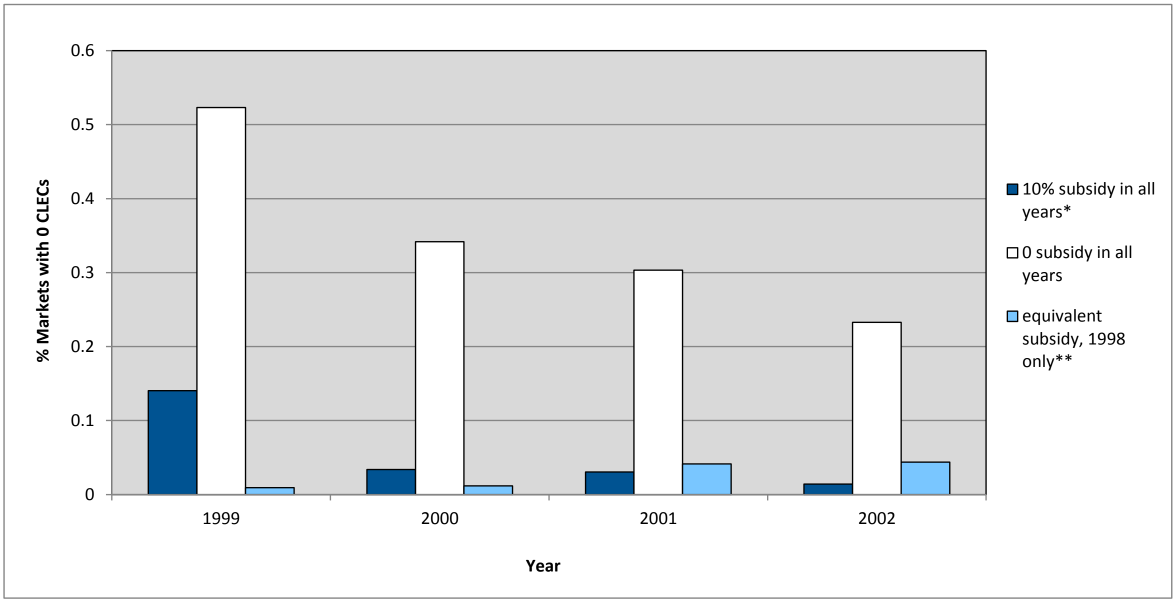
* 10% of the average of the two types' entry cost mean

** 10% subsidy to type-1 potential entrants only is equivalent to 9.7% 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.

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 16.5% subsidy in 1998 only.
Under these two subsidy schemes, the total amount of subsidy paid in these four years is the same.