INCUMBENT AND ENTRANT INCENTIVES WITH NETWORK INTERCONNECTION: THE CASE OF US TELECOMMUNICATIONS

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Abstract

I examine how incumbents and entrants respond to prices for network interconnection in telecommunications. I find that low prices for entrants to lease incumbents' facilities, exchange traffic, and buy incumbents' services for resale increase entry. However, if prices for leasing incumbents' facilities are low relative to incumbents' retail prices, then less entry occurs, presumably because incumbents hinder entry to protect profits. Higher prices for exchanging traffic increase entrants' market share, presumably because they target customers (such as Internet Service Providers) who receive more calls than they make. Low prices for reselling services do not cause entrants to choose reselling over other supply methods.

* This paper is a work in progress. Please do not cite or quote without permission of the author. I would like to thank David Sappington, Steve Slutsky, and Chunrong Ai for their comments on the model. I would also like to thank Melis Uygur, Eric Chiang, Eileen Pun, and Janice Hauge for their assistance in gathering data, Verizon, SBC, Sprint, and US West for providing data, and AT&T for funding data collection. All errors and omissions are my own.

1. Introduction

The situation often arises in which one firm sells an input to another firm and then competes against the other firm in the market for the final product. Examples include local exchange telephone companies selling access to long distance companies and then competing in the long distance business themselves (Willig, 1979), vertically integrated electricity companies or natural gas pipeline companies selling transport to their generating or gas supplier competitors (Economides and White, 1995), railroads providing trackage to other railroads (Baumol, 1983), Internet backbone providers competing with Internet Service Providers (Crmer et al., 2000; Kende, 2000) and incumbent local exchange telephone companies interconnecting their networks with and selling services to new entrants (Katz, 1997). The issue of how to price this input is often couched in the context of a regulated firm interconnecting its network with a new entrant, but the issue could also apply to an unregulated monopolist providing an essential facility to downstream competitors (Economides and White 1995).

An extensive theoretical literature has developed on pricing these inputs and, at least in the case of telecommunications, a number of case studies and manuals have been written to assist industry regulators in overseeing these prices. I know of two empirical studies (Ros and McDermott, 2000, and Rosston and Wimmer, 2000) that examine entrants' responses to prices for interconnecting telecommunications networks. Both find that low prices encourage entry. Missing from this literature is an empirical test of how incumbents respond to interconnection prices. This test is important because prices that encourage entry may also encourage incumbents to hinder entry in order to protect profits. In this paper, I take an initial step to fill

this empirical void by testing how interconnection pricing in US telecommunications has affected the early development of competition in local telephone networks.¹ My main findings are that low prices for entrants to lease incumbents' facilities, exchange traffic, and buy incumbents' services for resale increase entry. However, if prices for leasing incumbents' facilities are low relative to incumbents' retail prices, then less entry occurs, presumably because incumbents hinder entry to protect profits. Higher prices for exchanging traffic increase entrants' market share, presumably because they target customers who receive more calls than they make. Entrants appear to resell incumbent services as part of a strategy to gain customers while building networks.

The US Telecommunications Act of 1996 (1996 Act) made allowing competition in almost all telecommunications markets a national policy and provides three methods of entry for local telephone service (illustrated in Figure 1). Some entrants use more than one method. Entrants can build their own facility-based network, lease portions of an incumbent local exchange company's (incumbent) network, or buy an incumbent's services and resell them.² The 1996 Act requires incumbents and entrants to interconnect their networks to exchange calls. Exchanging calls between competing networks is necessary for customers of one company to be

¹ Telecommunications has traditionally been divided between long distance service and local exchange service. Local exchange service in the US consists of a telephone line and calling within a local calling area, which is typically a city or town. Long distance is calling between local exchange areas. This distinction between local and long distance was based on late 1800's technological limits and the original city-by-city franchising arrangements under which the US telephone system developed. These reasons lost their relevance long ago, but the distinction has remained for regulatory purposes.

² Traditional voice telecommunications networks consist of lines and switches. Lines either connect customers to the network or connect switches in the network. Switches route calls between customers. Switches are of two types: local switches (also called central offices) that customers connect to and that switch local calls, and long distance switches (also called tandem or toll offices) that route long distance calls from one local switch to another.

able to call customers of another company. Payment for exchanging calls is called reciprocal compensation in the US.³

Figure 1. Interconnection Arrangements

Leasing portions of an incumbent's network is called purchasing unbundled network elements (UNEs). Figure 1 shows how an entrant would lease a local telephone line from the incumbent. The line would connect to the incumbent's building. It could then connect to the incumbent's switch or the entrant's switch, depending on how the entrant wishes to use the incumbent's facilities. Entrants that have their own switches must interconnect their switches

³ "Reciprocal" means that both companies involved in an interconnection are obligated to make payments. "Symmetric" reciprocal compensation means the companies charge the same prices to each other. Reciprocal compensation prices are generally symmetric in the US, so I assume symmetry in my models.

with those of an incumbent and pay reciprocal compensation for terminating telephone calls on the incumbent's network. Figure 1 shows how lines, called trunks, would connect the incumbent and entrant central offices. Likewise, an incumbent must pay reciprocal compensation for terminating calls to an entrant. The 1996 Act states that prices for UNEs and for reciprocal compensation are to be cost-based, which regulators have generally concluded means that they should be based on incremental cost.⁴ Regarding resale, Figure 1 shows an entrant's customer using a resold service. In a sense, reselling is little more than rebranding the incumbent's service. The 1996 Act says that wholesale prices must be based upon retail prices minus the portion attributable to marketing, billing, collection, and other costs avoided by the incumbent when it does not provide the retail service.

Ros and McDermott (2000) and Rosston and Wimmer (2000) examine how removal of subsidies from long distance to local service, and from business customers to residential customers, affect entry by new competitors. Both find that entrants are more likely to enter local exchanges where incumbents' retail prices are above incremental cost. Ros and McDermott (2000) also examine how UNE and resale affect entrants' incentives to enter markets, but do not include reciprocal compensation in their study and do not examine how interconnection prices affect incumbents' incentives to hinder entry. I incorporate reciprocal compensation and the effects of interconnection prices on incumbents in this study and obtain findings that conflict with some conclusions of Ros and McDermott (2000) and Rosston and Wimmer (2000).

⁴ This is based on a review of state commission interconnection decisions located on the National Regulatory Research Institute's web site (NRRI, 1998) for 1998, the time period for my study, the FCC and all state regulators but Arkansas determined that incumbents' prices for UNEs should be based upon incremental cost. Arkansas chose an accounting cost allocation approach called fully distributed cost as its method. Twenty-nine percent of the states also chose to base reciprocal compensation prices on incremental cost and the rest chose bill and keep. The FCC's policies allow for bill and keep, but do not mandate it. Some states that adopted bill and keep applied the policy only as long as the traffic exchange is relatively balanced.

Before presenting my results, I summarize empirical research on the development of competition in telecommunications. One of the earliest contributions in this area is Crandall (1991), who finds that investment in private telecommunications networks increased from 1984 to 1989. Tomlinson (1995), Ai and Sappington (1998), and Woroch (2000) find that new entry prompts incumbents to increase investment. Greenstein et al. (1995) find that entry by competitive access providers has no measurable affect on incumbents' investment levels, but that removal of regulatory restrictions on entry encourages incumbents' investment in fiber optics. Ros (1999) finds that competition increases teledensity (telephone lines per 1000 population) and decreases investment in the sample countries with liberalization. Dekimpe et al. (1998), Gutierrez and Berg (2000), and Wallston (2000) also find that competition increases output. Blank et al. (1998) show that entry by long distance companies into Bell Operating Company intraLATA long distance markets lowers Bell Operating Company intraLATA long distance prices.⁵ Spiller and Cardilli (1997) conclude that the absence of clear rules on interconnection and parity for long distance competitors in terms of the how customers can use their services, causes delays in entry and disadvantages new competitors. They also find that limiting rights for entrants to use incumbents' networks encourages investment by entrants.

The rest of this paper is organized as follows. In section 2, I describe the theories that I am testing. Section 3 describes my data and methods. Section 4 presents my findings and Section 5 is the conclusion.

⁵ The AT&T divestiture agreement of 1982 restricted the Bell Operating Companies from providing long distance service, except in limited areas (called Local Access Transport Areas, or LATAs).

2. Theory

Shepherd (1997), Noll (1995), Katz (1997), and Gulati et al. (2000) describe competitive issues in network industries with an incumbent monopoly or a dominant firm. Shepherd (1997) explains that a dominant firm may be able to hinder competition by controlling key inputs or using strategic pricing, or by virtue of its information advantage relative to customers, regulators, and rivals. Noll (1995) explains that incumbents may hinder entrants by refusing or hindering interconnection and delaying regulatory proceedings on entry policies. Because retail prices are generally regulated in telecommunications, he concludes that an incumbent's ability to hinder entry may be the best available indicator of market power. Katz (1997) shows that a dominant firm has a greater incentive to hinder entry than an entrant has to successfully enter a market because the dominant firm receives monopoly profits if it succeeds while the entrant's profits are less than that if it succeeds. Gulati et al. (2000) explain that when firms form a network of companies, the dominant firm sets the boundaries of the firms in the network. The dominant firm sells inputs to rivals only if selling the inputs is more profitable for the dominant firm than using the inputs itself to provide downstream products.

An extensive literature has developed on pricing inputs sold to rivals. One of the first methods proposed was the Baumol-Willig Rule, which is now known as the Efficient Component Pricing Rule (ECPR). (Baumol and Sidak, 1994a, 1994b, and 1995; Kahn and Taylor, 1994; Hausman and Tardiff, 1995; Larson and Parsons, 1994; and Larson, 1997.) Developed by Willig (1979) and Baumol (1983), the ECPR emphasizes developing prices that ensure that the entrant survives only if it is more efficient than the incumbent is. The ECPR ensures that an incumbent makes the same profit from selling the input as it does from selling the final product, thus making the incumbent indifferent as to which it sells. Ordover et al. (1985)

explain that, if the incumbent's profits on the input are less than its profits on the final product, then the incumbent could be expected to protect its retail market. Examples of incumbents' efforts to protect markets might include providing poor quality to entrants, delaying collocation, delaying negotiations, and aggressive marketing.

The pricing method favored by regulators is to set the input price equal to the incumbent's incremental cost with only a small mark-up for covering common costs. The underlying theory is that entrants would have difficulty competing if input prices were set according to the ECPR because entrants would be denied the opportunity to take retail profits from the incumbent. Furthermore, the ECPR is efficient only under strict assumption, which do not apply in telecommunications. (Mitchell et al., 1995; Albon, 1994; Economides and White, 1995; Tye and Lapuerta, 1996; and Tye, 1994.)

A third method, which applies only to reciprocal compensation, is called bill and keep or sender keeps all. The underlying theory is that the number of calls exchanged between two networks should be about equal in both directions, so charging is unnecessary. (Brock 1995)

Laffont et al. (1998a, 1998b) show that reciprocal compensation can lead to collusive market results. When two firms interconnect for exchanging calls, each firm's reciprocal compensation price is a marginal cost to the other firm. Therefore, a higher reciprocal compensation price can both increase a firm's revenues and raise its rival's costs. An incumbent can preclude entry by fledgling rivals by increasing reciprocal compensation prices.

I test the effects of regulatory decisions on pricing interconnection by examining how market entry and entrant market shares are affected by (i) price levels for UNEs and reciprocal compensation, (ii) the relationship between an incumbent's price-cost margin on UNEs and its price-cost margin on retail services, and (iii) the relationships between an incumbent's price-cost

margin reciprocal compensation to its price-cost margin on retail services. Because reciprocal compensation prices can be zero (as in the case of bill and keep), I express the relationships between price-cost margins for inputs and retail services as the ratio of two ratios: (i) the ratio of the input's price to its cost and (ii) the ratio of local retail service prices to their costs. If incumbents are able to hinder entry, then higher values of this ratio of ratios should be associated with more entry.

Some observers expressed concern that entrants would take advantage of large wholesale discounts to simply resell services and not build networks. (Harris and Kraft, 1997) I test the impact of wholesale discounts chosen by regulators by examining how they affect the level of entry and entrants' market share. If entrants avoid building facilities when discounts are large, then large discounts should be associated with (i) a low market share for entrants using their own facilities or UNEs and (ii) higher levels of service resale. If incumbents are able to hinder entry and incumbents make less profit on resale than on retail services, then large discounts would be associated with less entry and fewer resold services.

The 1996 Act established other policies designed to facilitate entry into local telecommunications exchanges. It mandates collocation, the process by which entrants locate their equipment in incumbents' buildings. Collocation decreases entrants' costs of interconnection and using UNEs, relative to entrants placing their equipment some distance away from the incumbents' facilities. I control for the effects of the availability of collocation by including in my models the percent of the incumbent's telephone lines that can be accessed through collocation arrangements.

The 1996 Act also requires competitively neutral means for subsidizing local telephone service. Some regulators have chosen to implement this policy in part by rebalancing prices, the

process by which incumbents increase some prices and decrease other prices in order to remove implicit subsidies and align prices with incremental cost. Another common method for implementing this policy is for regulators to develop a "tax" on telephone services, the monies from which are distributed to companies based on their serving customers who the regulators determine should have subsidized prices. I test the effects of rebalancing by including in my model the ratio of the incumbent's revenues from local telephone services to its cost of providing a telephone line. Higher ratios indicate higher profits for local telephone services. Higher ratios would be associated with (i) more entry and higher market share for entrants if they are willing and able to respond to this incentive or (ii) less entry and lower market share for entrants if incumbents are able to hinder their rivals. Following Ros and McDermott (2000), I test for the effects of early reforms to the subsidy system by including in my models a dummy variable that indicates whether the state regulator for the market has begun reforming these subsidies.

4. Methods and Data

I consider three types of models. The first describes entry. The second describes how entrants expand their market share by constructing their own networks and using UNEs. The third describes how entrants expand their market share by reselling incumbents' services. I first describe the market entry models.

4.1. Entry Models

I analyze how regulatory policies affect entrants' entry decisions and incumbents' decisions to hinder entry by extending Bresnahan and Reiss's (1991) and Berry's (1992) ordered

probit models for entry, which apply a zero-profit equilibrium for entrants. Ordered probit models are used when dependent variables are discrete and represent ordered outcomes. Figure 2 shows the number of entrants by market for 1998. Because of data restrictions, I consider each incumbent's traditional local exchange areas in a state to be a market.⁶ The number of entrants ranges from 0 to 164. Over 130 entry levels in this range are not observed and many have only one observation. This poses a problem for using an ordered probit because multiple observations for each value of the dependent variable are necessary to estimate probabilities of observing a market with a particular level of entry. To address this problem, I create an ordinal dependent variable, with values from 0 to 8, and which represents ranges of entry levels. I give markets with 0 to 2 entrants a value of 0, markets with 3 to 4 entrants a value of 1, markets with 5 to 7 entrants a value of 2, and so on as shown in Figure 2.

More entry is expected in larger markets, in markets where regulatory policies are conducive to entry and in markets where incumbents do not hinder entry. The previous section explains the effects of UNE, reciprocal compensation, and wholesale prices. Further explanation is needed for the effects of reciprocal compensation prices. Entrants receive more reciprocal compensation payments than they pay (i.e., are net receivers) if they obtain customers who are net receivers of minutes of calling (which I simply refer to as minutes). An Internet Service Provider (ISP) is an example of a customer that receives more minutes than it sends. A

⁶ This causes distortions because for a given incumbent, an entrant may choose to enter some of the incumbent's local exchanges and not enter others, and may choose to supply only some areas of a local exchange. Because regulators generally require incumbents to average retail prices across exchanges and to charge lower retail prices in rural areas than in urban areas, and because per customer costs are generally lower in high density, urban areas than in rural areas, I expect entrants to serve urban areas first. Therefore, regions with higher than average proportions of urban areas should have more entry than areas that are below average. To control for this effect, I include in my models a measure of customer density. Higher customer density indicates markets with higher than average proportions of urban areas.

Figure 2. Entry Observations

residential customer who uses telephone lines to reach an ISP, and does so for several hours per month, is an example of a customer that makes more minutes than it receives. High reciprocal compensation price-cost margins encourage entry if entrants are generally better able than incumbents to attract customers who are net receivers of minutes. This effect of high reciprocal compensation price-cost margins decreases as additional entrants enter the market because the number of available net-receiver customers decreases. Low symmetric reciprocal compensation price-cost margins encourage entry for firms that net senders of minutes.

My dependent variable measures the number of entrants in a market, which includes those that use their own facilities, those that use UNEs, those that are pure resellers, and those that use some combination of the three entry methods. Because competition in local networks was new at the time of this study, it is unlikely that the data represent a long-run equilibrium. I

adjust for this disequilibrium by including as an explanatory variable the amount of time that has elapsed since entrants were allowed to enter each market.

Table 1 summarizes the explanatory variables that I include in my entry models.

Table 1. Descriptions of Explanatory Variables for Entry Models	
<i>Explanatory Variable</i>	<i>Description</i>
UNE Price	The price per month for leasing a 2-wire local line in urban areas. ⁷ I choose local line prices to represent UNE prices because the sunk nature of line investment and the need for right-of-way and conduit space make lines the most difficult facilities for entrants to build. Two-wire lines are the most common technology used for local telephone service. I choose urban prices because I expect most entrants to serve urban areas.
Reciprocal Compensation Price	The price per minute for symmetric reciprocal compensation.
Residential Resale Discount	The discount regulators give entrants for buying wholesale services for residential customers. In states where discounts vary by service, I use the smallest percentage discount.
Lines per Central Office	The total number of billable telephone lines that the incumbent has in the market divided by the incumbents' number of central offices. This represents density.
Local Service Revenue to Cost Ratio	The ratio of the incumbent's local service per-line revenue to the incumbent's cost of providing a telephone line. This represents the incumbent's local service profit margin.
Percent of Voice Lines Assessable through Collocation	The percent of incumbent's voice telephone lines that could be accessed by entrants through collocation arrangements. This represents the ease of collocation.
Number of Quarters	For each market, the number of quarters prior to 1996 that the first entrant was given telephone numbers. This represents the amount of time that entrants have had to enter the market and gain market share.
Service Complaints in 1997	The total number of customer complaints to state and federal regulators about the incumbent's service in 1997. This indicates the incumbent's service quality.
Total Revenue	The incumbent's total operating revenue for 1998. This indicates market size.
Price-Cost Ratio for UNEs versus Retail Services	The ratio of the incumbent's UNE price-cost ratio to the incumbent's average retail price-cost ratio. This relates the price-cost margins of the incumbent's UNEs to its price-cost margins for retail services.
Price-Cost Ratio for Reciprocal Compensation versus Retail Services	The ratio of the incumbent's reciprocal compensation price-cost ratio to the incumbent's average retail price-cost ratio. This relates the price-cost margins of the incumbent's reciprocal compensation prices to its price-cost margins for retail services.
Universal Service Reform	A dummy variable indicating whether a state has taken steps to develop competitively neutral methods for subsidizing local telephone service. A value of 1 indicates that the state has done so.
Incumbent Indicator	Dummy variables that associate markets with incumbents. Incumbent dummy variables may reveal differences in how incumbents respond to entry.

⁷A two-wire local line has two wires twisted together that are used to connect the customer to the telephone company central office.

4.2. Models for Entrant Market Share

Now consider the second and third types of models, those that describe how entrants expand their market share. I use ordinary least squares regression to examine entrants' market share. I consider two measures of entrant output. The first measure is the number of entrant interconnections to the incumbent. These interconnections, called trunks, are necessary for exchanging minutes between entrant and incumbent customers. Figure 1 illustrates how these trunks interconnect central offices. Higher numbers of trunks indicate higher amounts of entrant output for customers served by entrant facilities and UNEs. Trunks understate entrant supply if the entrants are large because, as an entrant grows, the number of minutes that stay on the entrant's network generally increase. This happens because the probability of a call originating on an entrant's network also terminating on that entrant's network generally increases as the entrant attracts more customers. Trunks overstate entrant supply if there are many small entrants, or entrants whose customers are dispersed geographically. This happens because these entrants' low traffic volumes keep them from making efficient use of their local interconnection trunks. Figure 1 also illustrates how entrants use a local loop UNE. The local loop UNE connects the entrant customer to the incumbent's building that houses the incumbent's central office. At the central office, the entrant can either connect the customer to its own central office or use switching UNEs to route customer traffic.

My second measure of entrant supply is the number of business resold lines, i.e., the number of units of local telephone service that entrants resell to businesses. Figure 1 shows how entrant customers of resold services use incumbent facilities in the same way that the incumbents' own customers do. For models of entrant market share, I divide the dependent

variables and certain explanatory variables by the number of incumbent telephone lines in the market. This indexes these variables according to market size.

The theory underlying for these models is similar to the underlying theory for the models for entry. Larger entrant market share is expected in markets where regulatory policies are conducive to entrants and in markets where incumbents respond less aggressively to entrants serving the market demand. Prices for UNEs, reciprocal compensation, and wholesale services, and price-cost ratios retail services relative to those for UNEs and reciprocal compensation should affect market share as described above for entry. Greater availability of collocation should increase entrants' market penetration and cause entrants to use less resale when collocation lowers entrants' costs of UNEs or facilities. Table 2 describes the explanatory variables in my market share models that are not also in my entry models.

Table 2. Descriptions of Explanatory Variables for Market Share Models	
<i>Explanatory Variable</i>	<i>Description</i>
Business Resale	The discount regulators give entrants for buying wholesale business services. In states where discounts vary by service, I use the smallest percentage discount.
Local Revenue Per Line	The incumbent's per-line revenue from local service.
Service Complaints in 1998 Per Line	The total number of customer complaints to state and federal regulators about the incumbent's service in 1998 divided by the number incumbent telephone lines.
Total Revenue Per Line	The incumbent's total operating revenue for 1998 divided by the number of incumbent telephone lines.
Total Plant in Service Per Line	The net book value of the incumbent's assets in the market divided by the number of incumbent telephone lines.
Minutes of Use Per Line	The number of telephone minutes of use for the incumbent in 1998.
Central Office Total Plant in Service Per Line	The net book value of the incumbent's central office assets divided by the number of incumbent telephone lines.

4.3. Data

Table 3 describes the data I use for my dependent variables, which are from the United States Telephone Association's (USTA) report to Congressman Thomas Bliley on December 9,

Table 3. Descriptions of Dependent Variables						
Variable	Name in Model	Mean	Minimum	Maximum	Standard Deviation	Observations
<i>Number of Entrants</i>	COMPT	26.15	0	164	30.10	59
<i>Number of Interconnection Trunks</i>	NA	30,536.4	0	289,299	50,946.3	58
<i>Interconnection Trunks Per Line</i>	TRNKPLN	0.0096	0	0.0243	0.0066	58
<i>Number of Business Resold Lines</i>	NA	27,474.7	0	183,594	42,918.38	58
<i>Fraction Business Lines Resold</i>	RSLBSPR	0.0336	0	0.3303	0.0524	58

1998 (USTA, 1998).⁸ Data are for 1998. There were no reported entrants in West Virginia in Bell Atlantic's territories in 1998, so I omit this market from the market share models. Table 4 describes the data for the explanatory variables for my entry models. Table 5 describes data for the market share model explanatory variables that are not also used in the entry models. The Appendix describes sources of data for explanatory variables.

5. Model Results

In this section I examine the results of my models. I examine the entry models first. I then investigate the models for entrant facilities and UNEs. Lastly, I examine models for resale. Tests of log linear models did not improve the overall fit, so I report only the linear results.

⁸ Observations include Ameritech (all states), Bell Atlantic (all states), BellSouth (all states), GTE (California, Florida, Hawaii, Illinois, Indiana, Kentucky, Michigan, North Carolina, Ohio, Oregon, Texas, Virginia, Washington, and Wisconsin), SBC (Arkansas, California, Oklahoma, and Texas), and US West (all states) for 1998.

Table 4. Descriptions of Explanatory Variables for Entry Models

Variable	Name in Model	Mean	Minimum	Maximum	Standard Deviation	Observations
<i>UNE Prices</i>	UNEPRC	\$16.82	\$3.72	\$32.00	\$6.16	59
<i>Prices for Reciprocal Compensation</i>	RCP	\$0.0057	\$0	\$0.0283	\$0.0067	59
<i>Residential Resale Discount</i>	RESRSL	0.1788	0.0700	0.2500	0.0405	59
<i>Incumbent Total Billable Lines</i>	NA	2,286,606	235,862	16,071,707	2,785,059	59
<i>Number of Incumbent Central Offices</i>	NA	230.1	29	752	174.2	59
<i>Lines Per Central Office</i>	LNSPRCO	10,424.9	881.1	29,786.8	6,851.7	59
<i>Incumbent Local Service Revenues (000)</i>	NA	\$749,773	\$71,863	\$4,731,829	\$902,587	59
<i>Incumbent Line Cost Level</i>	NA	\$265.72	\$65.68	\$408.81	\$57.71	59
<i>Local Service Revenue to Cost Ratio</i>	LCLPUSF	1.3290	0.7967	5.0431	0.5551	59
<i>Collocation Availability for Voice Lines</i>	COLCV98	23.66%	0%	72.62%	17.54	59
<i>Number of Quarters</i>	NUMQRT	10.75	0	18	15.44	59
<i>Service Quality Complaints in 1997</i>	SCMPAM-97	274.29	6	2,637	466.18	59
<i>Incumbent Total Revenue 1998 (000)</i>	REVT	\$1,511,887	\$170,463	\$8,460,236	\$1,721,406	59
<i>Price-Cost Ratio for UNEs vs. Retail Services</i>	PRCST-UNE	0.1969	0.0546	0.4460	0.0739	59
<i>Local Calling Minutes for Incumbent (000)</i>	NA	7,056,890	820,771	36,441,427	7,740,706	59
<i>Price-Cost Ratio for Reciprocal Compensation vs Retail</i>	PRCST-RCP	0.1601	0	0.8236	0.1919	59
<i>Presence of Universal Service Fund Reform</i>	USFFUND	0.2881	0	1	0.4568	59
<i>GTE</i>	GTE	0.2373	0	1	0.4291	59
<i>Bell Atlantic</i>	BA	0.2203	0	1	0.4180	59
<i>BellSouth</i>	BS	0.1525	0	1	0.3626	59
<i>SBC</i>	SBC	0.0678	0	1	0.2536	59
<i>US West</i>	USW	0.2373	0	1	0.4291	59
<i>Ameritech</i>	AM	0.0847	0	1	0.2809	59

Table 5. Descriptions of Explanatory Variables in Market Share Models and not in Entry Models

Variable	Name in Model	Mean	Minimum	Maximum	Standard Deviation	Observations
<i>Business Resale Discount</i>	BUSRSL	0.1792	0.0800	0.2601	0.0377	58
<i>Local Revenue Per Line</i>	LCLPRLN	\$329.98	\$228.47	\$458.84	\$49.69	58
<i>Service Complaints in 1998 Per Line</i>	SCMP98-PL	0.00016	9.03×10^{-6}	0.00097	0.00019	58
<i>Total Revenue Per Line</i> ⁹	REVTPL	\$678.02	\$502.90	\$955.18	\$98.80	58
<i>Incumbent Total Assets (000)</i>	NA	\$4,532,754	\$493,351	\$27,585,598	\$5,118,892	58
<i>Total Plant in Service Per Line</i>	TPISPL	\$206.07	\$140.24	\$305.62	\$37.87	58
<i>Minutes of Use Per Line</i>	MOUPL	3,288.7	2,188.4	4,592.0	599.3	58
<i>Central Office Total Plant in Service Per Line</i>	COTPILPL	\$364.44	\$225.44	\$639.74	\$89.82	58

5.1. Entry Model Results

Table 6 provides the coefficients and t-statistics for the entry models. One asterisk (*) indicates significance at the 0.10 level. Two asterisks (**) indicate significance at the 0.05 level. Three asterisks (***) indicate significance at the 0.01 level. I estimate three models. Model 1 examines how UNE prices, reciprocal compensation prices, resale discounts, customer density, local service price-cost margins, service quality, market size, and UNE price-cost margins affect entry. All coefficients are statistically significant. The signs of coefficients can be misleading in ordered probit models, so I calculate the marginal effects of these variables in Table 7. Before reviewing Table 7, I examine whether other explanatory variables should be included in entry models.

⁹ Total revenue per line, total plant in service per line, and central office total plant in service per lines are expressed as \$1000 per line in the model. Minutes of use per line is expressed as 1000s of minutes per line in the model.

Table 6. Regression Results for Entry (COMPT)		
Explanatory Variable	Model 1	Model 2
<i>UNE Prices</i>	** -0.1523 (-2.000)	** -0.1964 (-2.307)
<i>Prices for Reciprocal Compensation</i>	* -56.038 (-1.879)	-51.4000 (-0.501)
<i>Residential Resale Discount</i>	** 10.0708 (2.230)	** 10.7780 (2.288)
<i>Lines Per Central Office (customer density)</i>	*** 0.0001 (2.794)	0.0001 (1.409)
<i>Local Service Revenue to Cost Ratio</i>	*** -1.9855 (-2.939)	** -1.9342 (-2.509)
<i>Collocation Availability for Voice Lines</i>		0.0126 (0.901)
<i>Number of Quarters</i>		-0.0643 (-1.108)
<i>Service Quality Complaints in 1997</i>	* -0.0010 (-1.697)	-0.0010 (-1.509)
<i>Incumbent Total Revenue 1998 (000)</i>	*** 1.77e-06 (5.038)	*** 2.00e-06 (5.039)
<i>Price-Cost Ratio for UNEs vs. Retail Services</i>	*** 14.4117 (2.287)	** 16.7705 (2.360)
<i>Price-Cost Ratio for Reciprocal Compensation vs Retail</i>		-0.0792 (-0.021)
<i>Presence of Universal Service Fund Reform</i>		0.2489 (0.605)
<i>GTE dummy variable</i>		0.6403 (0.730)
<i>Bell Atlantic dummy variable</i>	** 1.1397 (2.065)	1.447 (1.867)
<i>BellSouth dummy variable</i>	*** 2.2862 (3.761)	*** 2.845 (3.121)
<i>SBC dummy variable</i>	*** 5.0165 (4.769)	*** 5.5051 (4.183)
<i>US West dummy variable</i>		0.8116 (0.939)
χ^2	113.70 d.f. = 11	116.97 d.f. = 17
Log Likelihood	-66.2809	-64.6450

Model 2 in Table 6 provides the results of adding the other variables to Model 1, namely variables for collocation availability, time for entry, the ratio of the price-cost margin for reciprocal compensation to the price-cost margin for incumbent retail services, and universal service subsidy reform, and the dummy variables for GTE and US West. Using a likelihood-

ratio test, I fail to reject at the 0.10 level the joint hypothesis that the coefficients for these variables are all zero ($\chi^2(6) = 3.27$). Lower price-cost margins for reciprocal compensation relative to those for incumbent retail services have neither stimulated entry nor led incumbents to hinder entry. This is probably because, as the market share models indicate, some entrants, but not all, are net receivers of reciprocal compensation. Therefore, higher reciprocal compensation prices benefit some entrants, but not all entrants. This diversity of effects of reciprocal compensation prices probably causes the coefficient for this variable to be ambiguous. Lastly, I do not find that subsidy reform has encouraged entry. It may be that in 1998 subsidy reform efforts were still preliminary and so firms had not responded. I conclude that Model 1 is the most appropriate model for examining how regulatory policies affect entry decisions.

Table 7 shows the marginal effects of explanatory variables from Model 1 for each value of the dependent variable. The first row shows the dependent variable. Rows 2 and 3 show, respectively, show the range of number of entrants associated with each dependent variable value and the number of markets that fall into that range. The remaining rows show how a marginal change in each explanatory variable affects the probability of a market being in a particular entry range.

Higher UNE, reciprocal compensation, and wholesale prices, and higher local service price-cost margins and incumbent service complaints decrease entry. The distribution of markets shown in Figure 2 would shift to the left, indicating less entry. Likewise, greater customer density and market size, and higher ratios of UNE price-cost margins to incumbent retail price-cost margins cause the distribution to shift to the right, indicating more entry.

The marginal effects in Table 7 indicate that incumbents' incentives and abilities to hinder entry dominate those of entrants to enter markets. Consider the net effect of lower UNE

Table 7. Marginal Effects for Entry (COMPT)									
Markets									
Dependent Variable	0	1	2	3	4	5	6	7	8
Entrants in Market	0 – 2	3 – 4	5 – 7	8 – 14	15 – 25	26 – 38	39 – 44	45 – 60	> 60
Number Markets	8	8	5	4	12	11	3	4	4
Marginal Effects									
<i>UNE Prices</i>	0.00013	0.00051	0.00687	0.01454	0.01889	-0.00169	-0.03841	-0.00075	-8.20e-05
<i>Prices for Reciprocal Compensation</i>	0.04838	0.18599	2.52867	5.34936	6.94956	-0.62294	-14.13170	-0.27727	-0.03001
<i>Residential Resale Discount</i>	-0.00870	-0.03342	-0.45444	-0.96135	-1.24893	0.11195	2.53967	0.04983	0.00539
<i>Lines Per Central Office</i>	-8.63e-08	-3.30e-07	-4.50e-06	-9.50e-06	-1.20e-05	1.11e-06	2.52e-05	4.95e-07	5.36e-08
<i>Local Service Revenue to Cost Ratio</i>	0.00171	0.00659	0.08959	0.18954	0.24623	-0.02207	-0.50071	-0.00982	-0.00106
<i>Service Quality Complaints in 1997</i>	8.63e-07	3.32e-06	4.51e-05	9.55e-05	0.00012	-1.10e-05	-0.00025	-4.90e-06	-5.40e-07
<i>Incumbent Total Revenue 1998</i>	-1.53e-09	-5.90e-09	-8.00e-08	-1.70e-07	-2.20e-07	1.97e-08	4.46e-07	8.76e-09	9.48e-10
<i>Price-Cost Ratio for UNEs vs. Retail</i>	-0.01244	-0.04783	-0.65032	-1.37573	-1.78727	0.16021	3.63436	0.07131	0.00772
<i>Bell Atlantic dummy</i>	-0.00048	-0.00208	-0.05143	-0.10880	-0.14134	0.01267	0.28741	0.00564	0.00061
<i>BellSouth dummy</i>	-7.13e-06	-5.90e-05	-0.10316	-0.21824	-0.28352	0.02541	0.57654	0.01131	0.00122
<i>SBC dummy</i>	-6.67e-13	-2.30e-11	-0.22637	-0.47887	-0.62212	0.05577	1.26507	0.02482	0.00269

prices. From the marginal effects of UNE prices on entry, one effect of a UNE price decrease is to increase the probability of entry. However, there is a second marginal effect of the UNE price decrease, that of lowering the UNE price-cost margin relative to the incumbent retail price-cost margin. This second effect dominates the first effect, resulting in less entry, not more entry. For example, summing the marginal effects of UNE prices and the price-cost ratio for UNEs versus retail services for markets with 26-38 entrants, 39-44 entrants, 45-60 entrants, and more than 60

entrants shows that a nationwide 1 percent decrease in UNE prices would decrease the probability of a market having 26 or more entrants by nearly 4 percentage points.

The marginal effects of the variable for profitability of incumbents' local services lead to a similar conclusion. Contrary to the findings of Rosston and Wimmer (2000) and Ros and McDermott (2000), I find that higher incumbent profits for local service are associated with less entry, perhaps indicating that incumbents act to protect these profits.

The marginal effects of reciprocal compensation prices show that lower prices are associated with more entry. This could imply that the lower prices directly improve entrant profits, which encourages them to enter markets. However, as I explain below, another explanation is that incumbents' profits are harmed less by entrants who are net senders of calls (whom low reciprocal compensation prices favor) than by entrants who are net receivers of calls (whom high reciprocal compensation prices favor).

Lastly, the marginal effects of discounts for resold services indicate that higher discounts are associated with more entry. Higher discounts increase entrant profit, which encourages entry, and that incumbents do not hinder this entry. Furthermore, the effect of customer density is positive, indicating that more entry occurs in densely populated markets. Poor incumbent service quality in the previous year appears to decrease entry. This may be because of the importance of resale to entry. If an incumbent's retail services have poor quality, then it could be true that the wholesale versions of these same services will have just as poor, or poorer, service quality. Market size and selected incumbents (Bell Atlantic, BellSouth, and SBC) all

have positive effects.¹⁰ The importance of market size indicates that there may be some economies of scale for entrants, or that price competition between entrants becomes more intense as the number of entrants increases in a market.

5.2. Entrant Market Share Model Results

Tables 8 and 9 provide the results for the entrant market share models. Model 3 in Table 8 shows the results of including all of the explanatory variables in a model for entrants using UNEs and entrant-owned facilities. This model forms the basis for testing the signs and significance of nonlinear combinations of explanatory variables. Using an F-test, I fail to reject the hypothesis at the 0.10 level that coefficients for price-cost margins for UNEs, reciprocal compensation, and local telephone services, resale discounts, subsidy reform, and for the incumbent dummy variables for GTE, BellSouth, and US West are equal to zero ($F(8, 41) = 1.32$). This indicates that incumbents either do not hinder this form of entrant output and that neither higher margins on local telephone services nor potential subsidy reform prompt entrants to increase their supply using UNEs or facilities. Indeed, the positive and significant coefficient for reciprocal compensation prices indicates that entrants are increasing UNE and facility-based supply primarily to customers such as ISPs that are net receivers of minutes.

Model 4 in Table 8 provides results after dropping variables that prove to be insignificant; namely, the resale discount, universal service reform, and the dummy variables for GTE, BellSouth, and US West. Higher UNE prices limit entrant output. Higher prices for local

¹⁰ The results could indicate that these incumbents have responded less aggressively to entry than have other incumbents. Consistent with this result, Bell Atlantic and SBC are the only Bell Operating Companies at the time of this writing to receive permission to enter interLATA long distance markets.

Table 8. Regression Results for Output Using UNEs and Facilities (TRNKPLN)		
<i>Explanatory Variable</i>	Model 3	Model 4
	** -0.0004	** -0.0003
<i>UNE Prices</i>	(-2.287)	(-2.049)
<i>Prices for Reciprocal Compensation</i>	* 0.2213	* 0.1880
	(1.824)	(1.729)
<i>Residential Resale Discount</i>	0.0119	
	(0.686)	
<i>Local Revenue Per Line</i>	* 0.00004	** 0.00003
	(2.006)	(2.391)
<i>Collocation Availability for Voice Lines</i>	*** 0.0002	*** 0.0004
	(3.594)	(3.624)
<i>Number of Quarters</i>	** 0.0005	*** 0.0005
	(2.571)	(3.047)
<i>Service Complaints in 1998 Per Line</i>	6.9654	** 9.5048
	(1.553)	(2.433)
<i>Total Revenue Per Line</i>	0.0241	0.0170
	(1.274)	(1.176)
<i>Total Plant in Service Per Line</i>	-0.0076	-0.0050
	(-1.649)	(-1.368)
<i>Minutes of Use Per Line</i>	0.0022	** 0.0032
	(1.321)	(2.181)
<i>Central Office Total Plant in Service Per Line</i>	0.0192	* 0.0245
	(1.097)	(1.870)
<i>Presence of Universal Service Fund Reform</i>	0.0014	
	(0.807)	
<i>GTE dummy variable</i>	0.0047	
	(0.972)	
<i>Bell Atlantic dummy variable</i>	-0.0015	*** -0.0051
	(-0.455)	(-2.674)
<i>BellSouth dummy variable</i>	0.0043	
	(1.161)	
<i>SBC dummy variable</i>	** 0.0077	* 0.0053
	(2.218)	(1.998)
<i>US West dummy variable</i>	0.0063	
	(1.591)	
<i>Constant</i>	*** -0.0315	*** -0.0297
	(-3.630)	(-3.700)
F	4.71	6.53
d.f.	17, 41	12, 46
R ²	0.6613	0.6300

telephone services encourage customers to buy more from entrants and incumbents do not hinder this loss of incumbent market share. The coefficient for ease of collocation is positive and highly significant, indicating that collocation is important for entrants that want to build their own facilities and that want to use UNEs. The coefficient for the number of quarters is positive

and highly significant, showing that that building facilities and assembling UNEs takes time. Incumbent service quality has a positive and significant coefficient in Model 4. This implies that entrants choose to use their own facilities and UNEs, and that customers choose entrant services, when incumbent service quality is poor. The positive and highly significant coefficient for number of minutes per line is consistent with the conclusion that entrants use their own facilities and UNEs to target customers based on calling patterns. The negative and highly significant coefficient for Bell Atlantic may indicate that this incumbent has the most aggressive response to entrants targeting ISPs as customers.

Table 9 shows the results for entrant market share using resold business services. Model 5 forms the basis for a joint hypothesis test of the significance of price-cost margins of UNEs and local telecommunications services, and of incumbent investment, minutes, central office investment, reciprocal compensation prices, and dummy variables for GTE, BellSouth, Bell Atlantic, and SBC. Using an F-statistic, I fail to reject at the 0.10 level the null hypothesis that the coefficients for all of these variables and combinations of variables are zero ($F(10, 41) = 1.67$). Consequently, I show the results for Model 6, which omits the insignificant variables. The variable for reciprocal compensation prices is in Model 6 because I fail to reject the joint hypothesis when the price-cost margin for reciprocal compensation is included.

Comparing the results of Models 5 and 6, it is apparent that higher UNE prices decrease resold business lines. Comparing this result with the coefficients for collocation and subsidy reform (which are negative and significant), it appears that entrants primarily use resale of business lines as part of an entry strategy whose main intent is to use UNEs and facilities, and that availability of collocation and universal service subsidies causes entrants to move away from reselling business lines more quickly than they otherwise would. The business resale discount

Table 9. Regression Results for Resold Business Lines (RSLDBPLN)		
<i>Explanatory Variable</i>	Model 5	Model 6
<i>UNE Prices</i>	** -0.0010 (-2.218)	*** -0.0010 (-2.820)
<i>Prices for Reciprocal Compensation</i>	0.4120 (1.182)	0.4650 (1.472)
<i>Business Resale Discount</i>	0.0340 (0.642)	0.0290 (0.578)
<i>Local Revenue Per Line</i>	0.00002 (0.329)	0.00007 (1.673)
<i>Collocation Availability for Voice Lines</i>	*** -0.0004 (-2.410)	** -0.0003 (-2.158)
<i>Number of Quarters</i>	** 0.0013 (2.218)	* 0.0009 (1.734)
<i>Service Complaints in 1998 Per Line</i>	-21.0655 (-1.629)	* -21.7191 (-1.720)
<i>Total Revenue Per Line</i>	-0.0748 (-1.394)	* -0.0621 (-1.727)
<i>Total Plant in Service Per Line</i>	0.0058 (0.455)	
<i>Minutes of Use Per Line</i>	0.0018 (0.379)	-0.0017 (-0.446)
<i>Central Office Total Plant in Service Per Line</i>	0.0601 (1.201)	0.0079 (0.219)
<i>Presence of Universal Service Fund Reform</i>	** -0.0110 (-2.198)	** -0.0084 (-2.024)
<i>GTE dummy variable</i>	-0.0219 (-1.585)	
<i>Bell Atlantic dummy variable</i>	-0.0047 (-1.589)	
<i>BellSouth dummy variable</i>	-0.0079 (-0.751)	
<i>SBC dummy variable</i>	-0.0016 (-0.160)	
<i>US West dummy variable</i>	0.0162 (1.425)	*** 0.0306 (4.831)
<i>Constant</i>	0.0301 (1.213)	0.0379 (1.609)
F	2.97	3.82
R ²	d.f. = 17, 41 0.5522	d.f. = 12, 46 0.4990

itself is insignificant, indicating that entrant market share using a pure resell strategy is either minor or effectively nonexistent. Consistent with Models 4 and 5, more time for entrants to expand their systems increases the amount of business line resale. Consistent with the conclusions from Model 1, poor incumbent service quality decreases entrant use of resale, for reasons stated above. The positive and highly significant coefficient for US West's dummy

variable indicates that this incumbent may be more cooperative with resellers than with facilities and UNE-based entrants, relative to other incumbents.

6. Conclusion

This paper shows that incumbents are able to hinder entry in newly opened markets when incumbents' profit margins for inputs sold to entrants are lower than incumbents' retail profit margins. This confirms the theories of Shepherd (1997), Noll (1995), Gulati et al. (2000), and Ordovery et al. (1985). Incumbents in local telephone markets have been unable to limit entrants from gaining market share for facilities-based and UNE-based entry. Much of this market share has been for customers who are net receivers of calls, such as ISPs. This may explain why incumbents have lobbied the US Congress and the FCC to exempt incumbents from paying reciprocal compensation for calls to ISPs, an effort that was recently successful.

This paper also shows that entrants for local telephone service use a mixture of entry and supply strategies, but that most entrant output is based on a strategy to use UNEs and entrant-owned facilities. Reselling incumbent services appears to primarily facilitate entry by firms that ultimately intend to use UNEs and their own facilities. Higher UNE and reciprocal compensation prices discourage entry, but higher reciprocal compensation prices also cause entrants to market to customers who are net receivers of minutes.

Additional work is needed. I was unable to test whether the interLATA restriction, which is to serve as a carrot for Bell Operating Companies to open markets to entry, is effective. Also, I was unable to test whether competition improves welfare. Lastly, international comparisons are lacking, as are more in-depth analyses of entrant strategies for data and voice services.

Appendix

Data for UNE and reciprocal compensation prices and wholesale discounts are from state commissions (NRRI, 1998; Alabama, 1998), X-Change (1998-1999), and interviews with incumbents. In cases where there are discrepancies, I employ the data provided in state commissions' decisions (NRRI, 1998) when available, and other public data when the commission data is not available. Some states have multipart prices for reciprocal compensation. There may be separate prices for terminating minutes at a central office or a tandem office and for different times of the day. To express these prices as a single price, I follow the convention of assuming 6.25% of the minutes terminate at local central offices and the remainder terminate in a tandem. Entrants often connect to the incumbent's network at a tandem office because it gives them access to numerous central offices. In states where residential service discounts are different from business service discounts, I use the residential discount for the models explaining entry and output using UNEs and entrant-owned facilities. Business and residential discounts are highly correlated ($R^2 = 0.88$). In tests of various models, business and residential discounts have similar results. To avoid multicollinearity, I use only the residential discount for these models.

Data for incumbent total billable lines, number of central offices, local service revenues, service quality complaints, total revenues, local calling minutes, and total plant in service are from FCC ARMIS reports.¹¹ I use the ratio of total revenues for basic local telephone services and total billable lines to indicate incumbents' price levels for local exchange services. Firms charge many prices, so using a single price is inappropriate. I use incumbents' Universal Service Fund costs per line to represent incumbents' costs for telephone lines. Universal Service Fund

¹¹ All ARMIS data are from <http://fcc.gov> and were downloaded between March 1999 and August 2000.

costs are the local line costs that incumbents report to the FCC for estimating subsidies that are given to small incumbents and rural incumbents for 1998. USF costs are based on incumbents' regulatory accounting records and provide an average cost for all of an incumbent's operations in a state.¹² I use total numbers of customer complaints to state and federal regulators for 1997 and 1998 in metropolitan statistical areas as my measure of incumbent service quality. Low incumbent service quality should encourage customers to buy from facilities-based entrants. I use 1997 data to examine entry because it represents *ex ante* entry information. I use 1998 data per line in models for entrant market share because this represents the quality that customers and entrants experienced at the time supply and purchasing decisions were put into effect. I use the incumbent's total operating revenues for 1998 for the market, to indicate market size.

I use the percent of incumbent voice telephone lines accessible by entrants through collocation in 1998 to represent the ease of collocation. Data are from Tables 3.6 and 3.7 of the FCC's 1998 *Local Competition* report. (FCC, 1998) There is a risk of endogeneity because higher entrant interest in a market should increase entrant demand for collocation. Higher demand for collocation should increase the incidence of collocation, which could cause a higher percentage incumbent lines to be in central offices with collocation. However, differences between markets should also reflect the ease of obtaining collocation.

I use the number of quarters in a state from the time the first entrant was given telephone numbers until the 1996 Act took affect to represent the amount of time that entrants have been

¹² Regulatory costs are an imperfect measure of economic costs. The accounting processes (Gabel, 1967) and distortive efficiency incentives caused by methods of regulation (Sappington and Weisman, 1996) cause these regulatory costs to deviate from economic costs.

operating in a state. Data are from Table 4.8 of the FCC's December 1998 *Local Competition* report (FCC, 1998).

For the entry models, I include two price-cost ratios, PRCSTUNE and PRCSTRCP, as explanatory variables. PRCSTUNE is the ratio of the incumbent's UNE price-cost ratio and the incumbent's average retail price-cost ratio. The incumbent's average retail price-cost ratio is the ratio of the incumbent's 1998 total operating revenues and total plant in service. PRCSTRCP is the ratio of the incumbent's reciprocal compensation price-cost ratio and the incumbent's average retail price cost ratio.¹³ These ratios reflect the relationships between the price-cost ratios for inputs incumbents sell to entrants and the price-cost ratios for the incumbent's retail services that the entrants displace. Low values of PRCSTUNE and PRCSTRCP indicate that UNE and reciprocal compensation price-cost ratios are low relative to incumbents' retail price-cost ratios.¹⁴

I use dummy variables to indicate state efforts to reform universal service subsidies and to identify incumbents. According to a National Regulatory Research Institute survey (Rosenberg and Wilhelm, 1998), fourteen states had revised or were revising their subsidy policies in 1998. I have a dummy variable for each incumbent, but omit the Ameritech dummy

¹³ The UNE price-cost ratio is the ratio of UNEPRC to USFCOST. The reciprocal compensation price-cost ratio is the ratio of RCP and the incumbent's total investment in central office switches in 1998 divided by the total number of local exchange minutes in 1998. I use UNEPRC/REVTPL to test UNE price-cost margins because the actual ratio of interest, $(\text{UNEPRC}/\text{USF})/(\text{REVTPL}/\text{USF})$ solves to UNEPRC/REVTPL. Similarly, the reciprocal compensation ratio of interest, $(\text{RCP}/(\text{COTPISPL}/\text{MOUPL}))/(\text{REVTPL}/\text{COTPISPL})$ solves to RCP/(REVTPL/MOUPLN).

¹⁴ Including the variables PRCSTUNE and PRCSTRCP creates multicollinearity because the variables are constructed from other variables. Therefore, I exclude these variables from the entrant output models and test hypotheses of nonlinear combinations of UNE prices, reciprocal compensation prices, and incumbent revenues, costs, and quantities supplied. That is to say, I test incumbent responses to UNE price-cost margins by testing the significance of the combination UNEPRC/REVTPL, and I test incumbents' responses to RCP price-cost margins by testing the significance of the combination RCP/(REVTPL/MOUPLN).

from models to avoid multicollinearity. Incumbent dummy variables may reveal differences in how incumbents processed entrant requests interconnection from 1996 through 1998. Soon after the passage of the Act, incumbents differed in how they processed these entrant requests. One incumbent required entrants to fax their requests for telephone numbers or local lines. Another required entrants to call with their requests, but assigned only one employee to the task of taking entrant orders. Other incumbents worked on electronic methods of taking entrant orders. These differences, as well as differences in regulatory scrutiny and enforcement, could cause incumbent dummy variables to be significant.

To examine potential multicollinearity, I regress all explanatory variables on each other. I also examine the linear correlation of each pair of explanatory variables. Multicollinearity problems occur between the reciprocal compensation variables RCP and PRCSTRCP ($R^2 = 0.97$), between the service complaint variables SCMPAM97 and SCMPAM98 ($R^2 = 0.92$), between the resale discounts for business and residential services (BUSRSL and RESRSL, $R^2 = 0.88$), among variables that indicate market size (for example, REVT and TPIS), and between PRCSTUNE and the variables that are included in it. To avoid multicollinearity in the entry models, I include no more than one variable from each of the collinear groups, with the exception of collinear groups involving PRCSTUNE and PRCSTRCP. I need these variables in some entry analyses to perform likelihood ratio tests of entrant and incumbent incentives. Regarding multicollinearity in the entrant output models, dividing market size indicators such as REVT by LINES resolves much of the multicollinearity. Otherwise, I include in each model no more than one variable from each collinear group.

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