

**Structural Simulation of Facility Sharing: Unbundling Policies and
Investment Strategy in Local Exchange Markets**

William P. Zarakas*
Glenn A. Woroch**
Lisa V. Wood*
Daniel L. McFadden**
Nauman Ilias*
Paul C. Liu*

Revised
July 15, 2005

**The Brattle Group*

**University of California at Berkeley and *The Brattle Group*

The authors gratefully acknowledge the excellent research and modelling support provided by David Bledin and Kenneth Martinian and the comments provided by Rosa Matzkin.

ABSTRACT

We develop a dynamic oligopoly model of competition in local exchange markets to analyze the impacts that mandatory sharing of incumbent facilities has upon investment in telecommunications infrastructure. Our model is distinguished from other treatments of the relationship between unbundling and investment by capturing the microeconomic structure underlying strategic interaction of the various providers competing in these markets. We calibrate the structural parameters using market data and then use those values to simulate investment outcomes under alternative unbundling policies.

In the model, three types of providers supply both voice and data services in each geographic market using their own network facilities: an incumbent local exchange carrier (“ILEC”), a cable television company (“CATV”), and a facilities-based competitive local exchange carrier (“CLEC-F”). A fourth type of carrier, the “CLEC-L,” provides these services by leasing facilities from the ILEC at regulated wholesale rates. Each of the three facilities-based carriers chooses a level of capital investment to maximize the net present value of its cash flows. Capital obeys the conventional accumulation rule that assumes geometric depreciation. All four carriers compete in mass-market retail services by setting prices for their differentiated voice and data services.¹ We employ the concept of a Markov-perfect equilibrium (MPE) to select the outcome of investment and price competition in discrete time over a finite horizon.

To estimate the impact of changes in regulated lease rates on industry investment, we calibrate a linear-quadratic version of the model using publicly-available data from 2000-2003 for selected states. Using data on investment and capital stocks, capital and operating expenditures, and rates for unbundled local loops (UNE-Ls) and platforms (UNE-Ps), we calibrate the structural parameters by matching predicted and actual capital investment levels over time. Using these fitted values, we simulate equilibrium investment and output paths for all carriers under alternative scenarios for UNE prices. We can then compare investment levels for combined voice and data service lines, and for data lines alone. We compare but-for and actual levels in

¹ In this paper, the CLEC-L provider of voice services relies 100% on the ILEC’s network.

terms of average investment over the sample period and also the investment levels at the end of the sample period.

We find that higher UNE prices result in greater investment by each of the three facilities-based carriers – and hence, greater aggregate industry investment for each market – and also reduced levels of CLEC-L leased lines. This suggests that mandatory network sharing at historical UNE prices tends to drive competitors to favor service-based (*i.e.*, non-facilities) supply, while higher UNE prices tend to support higher levels of facilities-based competition, specifically inter-modal competition.

Importantly, the impact of higher UNE prices is much greater for high-speed data lines than for voice services. CATV and CLEC-F carriers register significantly greater increases in data lines than the ILEC. The increased levels of investment are typically accompanied by increased average revenue per line (“ARPL”). This increase can be caused by an increase in service quality as well as by an increase in retail prices.

Several policy conclusions regarding facility sharing follow directly from our simulation results. First and foremost, policies attempting to stimulate local exchange investment by facilitating entry of service-based competitors – such as lowering UNE prices – can backfire. In particular, we conclude that keeping UNE prices at current levels (or decreasing them further) is likely to have a notable dampening effect on future investment in the data services market. Second, while mandatory sharing of incumbent facilities may have been effective at facilitating entry by service-based carriers and driving down retail prices over the short run, it blunts incentives to make durable investments, diminishing aggregate investment in local exchange infrastructure generally, and in critical broadband facilities in particular. We do not resolve the welfare trade-off that arises between lower retail prices and increased investment, but we can conclude that if increasing investment in telecommunications infrastructure in the U.S. is a primary policy goal, then reducing UNE rates below their current levels is not an effective regulatory strategy. Our model and the simulation results offer guidance if and when the 1996 Telecom Act is rewritten, and when policy makers consider whether to open up other infrastructure facilities such as cable television networks.

I. INTRODUCTION

Rapid, widespread deployment of advanced telecommunications technology has long been a policy goal of federal and state governments. Deployment of broadband is often identified as a critical building block for the country's economic development, and a requirement to compete in international markets. This view has led certain nations to adopt industrial policies with the chief objective of promoting broadband deployment. Some of those countries – notably Korea and Japan – have achieved remarkable success in terms of availability and bandwidth.¹ In the U.S., the Telecommunications Act of 1996 (“Telecom Act”) took the bold move of embracing competition as the preferred means to reach this goal. On each anniversary of its enactment, however, commentators call into question the Telecom Act's effectiveness in promoting investment in advanced networks, as well as stimulating local exchange competition. The low ranking of the U.S. on various scales of international broadband deployment has re-focused policy makers on the issue of how to best promote broadband deployment.²

The core of the Telecom Act's strategy to encourage investment and competition is to force incumbent local exchange carriers (“ILECs”) to share their networks with competitors. Many countries in Europe and Asia have followed suit, imposing facility sharing for this purpose.³ The reasoning behind this policy is that such sharing will enable entry by reducing the capital requirements associated with entering local exchange markets. As emerging competitors solidify a customer base and gain operating experience, the framers of the Telecom Act reasoned, they will invest in technology and deploy their own networks capable – in full or in part – of providing next generation communications services. In response, incumbent providers will

¹ See C. Lee and S. Chan-Olmsted, 2004, ITU, 2003, 2004.

² The Organisation for Economic Co-operation and Development ranked the U.S. as 11th among its member countries in terms of broadband penetration. See OECD, 2004. Based on fixed-line broadband penetration, the International Telecommunication Union (ITU) ranked the U.S. as 13th. See ITU, 2004.

³ For example, in *Working Party on Telecommunication and Information Services Policies, The Development of Broadband Access in OECD Countries* (OECD, October 29, 2001), the OECD states that “the most fundamental policy available to OECD governments to boost broadband access is infrastructure competition.” Despite this conclusion, it goes on to promote service-based competition as an attractive alternative: “... policies in unbundling and line sharing are key regulatory tools available to create the right incentives in new investment in broadband access. The evidence states that opening access networks, and network elements, to competitive forces increases investment and the pace of development.” See also S. Ismail and I. Wu, 2003.

invest in their own networks in order to provide comparable competitive services. This creates a virtuous cycle of competition and investment.

Our concern is that the reasoning underlying the policy of facility sharing is flawed, or at least incomplete. While requiring access to an incumbent's networks makes it easier for new competitors to enter a market, the sharing of ILEC networks (especially at artificially low prices) may distort the incentives to invest in networks. Requiring ILECs to share facilities needed to deliver these services is likely to result in greater downward pressure on retail prices than might otherwise be the case, and reduces the ILEC's return on investment in its own network facilities. Further, access to ILEC facilities on attractive terms will also discourage competitive local exchange carriers ("CLECs") from building their own facilities, thereby reducing an alternative source of local exchange infrastructure. Incentives to invest are driven, in part, by pressure on firms to adopt cost-efficient technologies and deploy innovative services, or risk losing customers to more resourceful rivals. If competitors rely solely on ILEC networks to deliver services to customers, then both ILECs and CLECs face little competitive pressure to invest in cost reductions or advanced services.⁴

The price for access to unbundled network elements ("UNEs") is subject to considerable debate. Competing theories abound concerning the impact of UNE prices on investment in local exchange infrastructure and next generation technologies. While we do not endorse telecommunications policies whose sole purpose is to win an international broadband race, we do believe that UNE pricing has an impact on the U.S. broadband penetration. Because of these opposing tendencies, how UNE prices affect investment in local exchange infrastructure is ultimately an empirical question. In this paper, we explore the empirical relationship between UNE prices and investment levels.

Telecommunications infrastructure is composed of several distinct components, including transport and trunking as well as the "last mile" of customer connections. The extent of investment varies widely across these components, and also varies with respect to the types of customers served. Examining dollars invested at an aggregate level can mask these distinctions.

Some CLECs have made investments in facilities to provide transport services to other carriers. Others have invested in facilities in metropolitan areas and in campus settings to serve medium and large business customers. It appears, however, that few CLECs have invested in facilities to serve the “mass market” (*i.e.*, residential and small business customers). Data compiled by the Federal Communications Commission (“FCC”) indicate that the CLEC share of access lines to mass market customers using their own facilities is low and, in the case of voice lines, has declined over the period December 2000 through December 2003. During this period, however, the number of access lines leased by CLECs to serve mass market customers grew considerably,⁵ while average prices for UNEs declined.⁶ Based on these observations, it appears that the current UNE pricing regime has failed to promote CLEC investment in the mass market – the customer segment that accounts for the majority of access lines in the U.S.

While there have been several attempts to empirically establish the relationship between facility sharing and investment, to date, analyses of telecommunications investment have failed to capture the full extent of the investment dynamics in the telecommunications industry. Willig, *et al.* adopted a reduced-form approach to study the relationship between ILEC investment and UNE rates.⁷ Their approach ignores the underlying strategic nature of interaction among the various participants in the local exchange market.⁸ A more recent paper by Clarke, *et al.*, introduces dynamics in the form of CLEC entry decisions.⁹ However, by using CLEC entry as a proxy for investment, this study fails to show the full range of competitive responses by ILECs, CLECs, and others. It also fails to recognize that leasing of ILEC facilities is not the same as investment in infrastructure as a means of deploying advanced telecommunications services.

⁴ Incumbents do have incentives to be cost efficient under some regulatory regimes, such as price caps. We do not model the regulation of retail rates in this paper, however.

⁵ See L. Wood, W. Zarakas, and D. M. Sappington, 2004. Also see Table 3 in FCC, 2004a.

⁶ Between January 2002 and January 2004, average UNE-P rates declined 17.1% from \$18.95 per month to \$15.71 per month and average UNE-loop rates declined 6.7%. See Appendix 4 in B. Gregg, January 2004.

⁷ See R. Willig, W. Lehr, J. Bigelow, and S. Levinson, 2002.

⁸ In addition, their work has been criticized for temporal inconsistency across data sources, as well as incorrectly interpreting causality of the results. See D. Aron, 2004.

⁹ See R. Clarke, K. Hassett, Z. Ivanova, L. Kotlikoff, 2004.

We develop a dynamic oligopoly model of competition in local exchange markets to analyze the impacts that mandatory sharing of incumbent facilities has upon investment in telecommunications infrastructure. Our model is distinguished from other treatments of the relationship between unbundling and investment by capturing the strategic behavior in the choice of durable investment among rivals over time. We then investigate the impact that UNE pricing has on investment in local exchange facilities that serve mass market customers.

In the model, three types of providers supply both voice and data services in each geographic market using their own network facilities: an incumbent local exchange carrier (“ILEC”), a cable television company (“CATV”), and a facilities-based competitive local exchange carrier (“CLEC-F”). A fourth type of carrier, the CLEC-L, provides these services by leasing facilities from the ILEC at regulated wholesale rates. Each of the three facilities-based carriers chooses a level of capital investment to maximize the net present value of its cash flows (“NPV”). Capital obeys the conventional accumulation rule that assumes geometric depreciation. All four carriers compete in mass-market retail services by setting prices for their differentiated voice and data services.¹⁰ We employ the concept of a Markov-perfect equilibrium (MPE) to select the outcome of investment and price competition in discrete time over a finite horizon.

To estimate the impact of changes in regulated lease rates on industry investment, we calibrate a linear-quadratic version of the model using publicly-available data from 2000-2003 for selected states. Using data on investment and capital stocks, capital and operating expenditures, and rates for unbundled local loops (UNE-Ls) and platforms (UNE-Ps), we calibrate the structural parameters by matching predicted and actual capital investment levels over time. Using these fitted values, we simulate equilibrium investment and output paths for all carriers under alternative scenarios for UNE prices. We can then compare investment levels for combined voice and data service lines, and for data lines alone. We compare but-for and actual levels in terms of average investment over the sample period and also the investment levels at the end of the sample period.

¹⁰ In this paper, the CLEC-L provider of voice services relies 100% on the ILEC’s network.

We find that higher UNE prices result in greater investment by each of the three facilities-based carriers, and hence, greater aggregate industry investment for each market. As expected, the number of CLEC-L leased lines falls confirming that mandatory sharing at historical UNE prices tends to drive competitors to favor service-based supply, and that higher UNE prices will support platform competition.

We organize this paper in six sections. Section II describes dynamic strategic models and their applicability to the debate concerning stimulation of investment in the local exchange. In Section III we specify the MPE model that we use in this analysis, and describe the process that we used to calibrate the model. In Section IV we present the data that we used in the model. Section V provides results for the local exchange markets in two states, New York and Texas. In Section VI, we provide conclusions.

II. DYNAMIC STRATEGIC MODELS

Network industries operate under enormous scale and scope economies which are realized by substantial outlays on durable capital. Telecommunications is further distinguished from other network industries, such as electric power and water distribution, by its rapid pace of technological change, and innovations in communications services traditionally have been embodied in the capital itself. In such industries, durable investment decisions not only affect a firm's cash flows in the short run and the long run, but have strategic implications for its rivals as well. The durability of telecom capital creates a natural linkage across time, causing current investments to impact a provider's future capital spending by reducing the variable cost of production or by increasing the quality of the service supplied. Capital stock likely will also influence competing carriers' investment decisions, indirectly as they anticipate rivals' lower costs and higher service quality. For these reasons we summarize the "state" of the industry by the capital stocks of the facilities-based providers. We adopt the standard accumulation rule in which changes in a firm's capital stock equals its gross investment in the current period less

(geometric) depreciation of the stock.¹¹ Then each provider selects a strategy that maps from its current capital stock, as well as that of each of its rivals, into a level of investment. Only current stocks are taken into account, a property associated with the name of “Markov.” This simplification rules out more complicated strategies in which firms condition their investments on part or all of the history of past investments.¹²

Setting aside for the moment strategic motives for capital investment, a provider chooses to invest so as to balance the benefits of greater capital stock against the increased per-unit cost of growing the stock. Adding to capital stock involves the construction of facilities and the installation of equipment. The more rapidly that capacity expands, the most costly it is per unit: as we all have been told, Rome was not built in a day, but if it was, it would have been infinitely more costly.

Before addressing the impact of facilities sharing and different wholesale lease rates, however, we need to carefully model the interaction among all types of service providers – those who own network facilities and those who lease them. In its simplest form, all service providers compete in retail markets for residential and service customers with price, quantity, and quality, and facilities-based carriers also make durable capital investment decisions. When making all such decisions we assume providers seek to maximize the present value of their cash flows net of all costs (NPV) in their pursuit of the greatest shareholder value.¹³ For the current array of capital stocks, each provider chooses an investment strategy that maximizes its NPV given the investment strategies adopted by all of its rivals. This property must hold true at each point in time and regardless of the state of the industry, *i.e.*, array of capital stocks. When a collection of investment (and production) strategies exists, this solution concept is called a “Markov perfect equilibrium” or simply MPE.

¹¹ This convenient formulation has its limitations. For instance, it makes no distinction among different vintages of capital investment as they are entirely fungible across time. Also, in markets that exhibit rapid innovation, technological, obsolescence is likely to be more important determinant of changes in capital stock than physical depreciation.

¹² A history-dependent strategy would arise if a provider were to follow a rule that retires plant and equipment depending on their vintages. Expanding strategies to depend on past history would also enable certain collusive outcomes which we wish to disregard.

The MPE equilibrium concept has the power of taking full account of the strategic implications of long-lived investments with the reasonable simplification of restricting strategies to depend on current capital stocks. MPE has been used to study the properties of concentrated industries over time when oligopolists make durable capital investments.¹⁴ To our knowledge this class of models has never allowed for the possibility of facility sharing.

III. MODEL SPECIFICATION, CALIBRATION AND SIMULATION

We develop and apply our model in three steps: model specification, parameter calibration, and simulation under alternative parameter values.

MODEL SPECIFICATION

The specification of the dynamic game modeling competition in the local exchange industry consists of: 1) the players; 2) their objective functions; 3) the demand and cost equations that influence the objective function; 4) the strategic decision variables for each player; 5) the state variables for each player; and 6) the laws of motion that govern how the state variables change over time.

We allow for four key strategic players operating in local exchange markets:

- (1) an ILEC ($j = I$) that builds facilities that it uses to provide its own retail services, as well as to lease to the CLEC-L carrier.

¹³ In our simulations of the industry equilibrium below, we will assume providers discount cash flows over a finite number of periods, but in principle an infinite horizon is possible.

¹⁴ The theory of Markov perfect equilibrium grew out of the extensive literature on closed-loop solutions to dynamic control problems. It was adapted to describe concentrated industries by E. Maskin and J. Tirole, 1988a, 1988b. It was applied as an analytic tool by R. Ericson and A. Pakes, 1995, and A. Pakes and McGuire, 1994. Earlier, MPE was used to solve for dynamic oligopoly equilibrium when firms's strategic variables included durable capital. See, for example, S. Reynolds, 1987, 1991. For a discussion of MPE models and a summary of how these models may be applied to estimating damages, see M. Jenkins, P. Liu, R. Matzkin, and D. McFadden, 2004. For an application of a strategic timing model that employs the MPE concept to the broadband race between telephone and cable companies, see G. Woroch, 2004.

- (2) a CATV ($j = V$) that builds facilities that it uses exclusively to deliver retail voice and data services in addition to multichannel video.
- (3) a CLEC-F ($j = C$) that builds its own facilities for provision of its own services, similar to the cable franchisee. In our model, we assume this player owns all of the facilities used to provide voice and data service to mass market customers.
- (4) a CLEC-L ($j = L$) that leases facilities (*i.e.*, UNEs) from the ILEC. In this model, we define this player as leasing 100% of the facilities used to provide voice service to mass market customers, and/or leasing the loops required to provide data service while investing in additional equipment.

In fact, there may be multiple CLECs of both kinds and multiple cable operators selling voice and data services in a given market.¹⁵ To simplify, we represent the multiple carriers of each type by two representative service providers and the multiple cable systems by one representative service provider. In the process we ignore the presence of wireless providers of both voice and data services.

We focus exclusively on mass market customers in our model and exclude large business and enterprise customers. Each provider offers two services to mass market customers:

- Data services that include high speed Internet access over digital subscriber line (DSL), cable modem, and/or fiber optic or other high capacity lines.
- Combined voice and data services that include the above data services together with standard voice communications.

We rule out the possibility that any firm would build a fixed network to provide voice services only since that option would not make economic sense. The services offered by the four providers display some degree of product differentiation. This is certainly reasonable when alternative network infrastructures differ in physical properties, such as bandwidth and

¹⁵ In some cases CLECs may both lease ILEC facilities and build facilities of their own for voice service. These CLECs are not specifically defined in the model.

reliability. Differentiation likely also derives from different “brand images” that service providers have with current and potential customers.¹⁶

In our model, each carrier chooses a level of capital investment in each period that will maximize the NPV of its current and future cash flows. Current period cash flows are defined as revenues less operating costs and capital costs. The cash flows for the ILEC involve one additional revenue stream, payments for the leasing of facilities to the CLEC-L.

Each of the four players makes an investment decision in each period so as to maximize their NPV. The ILEC, the CATV and the CLEC-F choose the level of investment I_t^I , I_t^V , and I_t^C , respectively, in period t , where I is measured by the incremental change in service lines in period t . The CLEC-L behaves somewhat differently than the other three players, in that it selects the number of lines to lease. It does not make investments in lines and does not own any of these types of facilities. Capital investments (except those associated with the CLEC-L player) accumulate over time.¹⁷ Capital investment associated with leased lines (*i.e.*, leased to the CLEC-L) accumulate to the ILEC.

The investments made by each provider in any given period result in additions to the total level of capital stock for that provider. In our model, the ILEC capital stock includes investment in facilities that it uses to provide its own retail services as well as the facilities that it leases to the CLEC-L. The capital stock for each carrier obeys the standard accumulation equation that allows for geometric depreciation:

$$\text{ILEC:} \quad (K_t^I + K_t^U) = (1 - \delta_I) \times (K_{t-1}^I + K_{t-1}^U) + I_t^I$$

$$\text{CATV:} \quad K_t^V = (1 - \delta_V) \times (K_{t-1}^V) + I_t^V$$

$$\text{CLEC-F:} \quad K_t^C = (1 - \delta_C) \times (K_{t-1}^C) + I_t^C$$

¹⁶ For example, an ILEC such as Verizon is perceived as different from a CLEC such as AT&T which, in turn, is different from a cable company such as Comcast. The reasons for these perceived differences include differences in the products offered historically, differences in the current portfolios of products offered, differences in customer service, etc.

¹⁷ Estimates of accumulated capital investment must also take depreciation into account. We discuss our treatment of depreciation in Section IV. We include depreciation as a variable in the laws of motion governing capital accumulation in this section.

where $t = 1, \dots, 7$ and where δ_l , δ_c and δ_v are per-period depreciation rates for the three facilities-based providers. The depreciation rates may differ across providers but they are constant over time.

OBJECTIVE FUNCTIONS

The objective, or “value,” function for each player is effectively a representation of the player’s net present value. The NPV for an ILEC in each period, then, is the revenue associated with its retail business and the wholesale revenue derived from its leased line business, minus the variable costs of operating and maintaining all of its access lines, minus capital costs for the investment made in that period, plus the discounted present value of future cash flows beginning with the next period forward. The NPV equations for CATV and CLEC-F are similar, except that there are no revenues associated with leasing since they are not obliged to share their facilities, and they choose not to do so. Finally, the NPV for CLEC-L is the revenue from the service lines that it serves, minus leasing costs and other variable costs associated with using the leased lines, plus the discounted present value of future cash flows.

The objective function for each player in each period $t = 1, \dots, 7$ is shown below.

$$\text{ILEC: } V_t^I = P_t^I(K_t) \times K_t^I + p_t^U \times K_t^U - m_t^I \times (K_t^I + K_t^U) - C^I(I_t^I) + d^I \times V_{t+1}^I(K_t)$$

$$\text{CATV: } V_t^V = P_t^V(K_t) * K_t^V - m_t^V * K_t^V - C^V(I_t^V) + d^V * V_{t+1}^V(K_t)$$

$$\text{CLEC-F: } V_t^C = P_t^C(K_t) * K_t^C - m_t^C * K_t^C - C^C(I_t^C) + d^C * V_{t+1}^C(K_t)$$

$$\text{CLEC-L: } V_t^U = P_t^U(K_t) \times K_t^U - (m_t^U + p_t^U) \times K_t^U + d^U \times V_{t+1}^U(K_t)$$

Where $K_t = (K_t^I, K_t^V, K_t^C, K_t^U)$ is the vector of capital stocks, m_t^j is the variable cost per line for player j in period t , $C^j(I_t^j)$ is the incremental capital cost associated with building an additional last mile facility for firm j (assumed to be constant over time), and p_t^U are the UNE rates set by the state regulatory commissions for UNE-L and UNE-P in period t . d^j is the discount factor for player j (assumed to be constant over time), and V_{t+1}^j is the maximal NPV of

future cash flows for firm j from period $t+1$ forward. The *state* of the industry is represented by the three capital stock variables K_t . We discuss the data used in this model in detail in Section IV.

The revenue terms in the above value functions, $P(K) \times K$, represent the total revenue during the period. $P_t^j(K_t)$ is the inverse demand for carrier j 's product in period t ; $P_t^j(\bullet)$ is a function of capital stock because we measure the quantity of service by the number of service lines. This inverse demand provides the average revenue per line (“ARPL”) for carrier j in period t . We assume that ARPL is a linear function of the carriers’ output levels in period t ,

$$P_t^j(K_t) = A_t^j - B_t^I \times K_t^I - B_t^V \times K_t^V - B_t^C \times K_t^C - B_t^U \times K_t^U .$$

where A_t^j is the intercept term and B_t^j is the slope term in the inverse demand function. Both terms differ across players and so capture the degree of product differentiation among the services. The slope terms for CLEC-F and CLEC-L are assumed to be equal because their services are likely to be perceived as similar by consumers.

THE MPE SOLUTION

In a dynamic strategic model, players make their decisions considering the long-term consequences of their actions, conditional on the choices made by other players and on the values of the state variables. Each player chooses a rule that determines its investment for each possible current state so as to maximize its NPV given the rules chosen by its rivals and the laws of motion governing capital accumulation. An MPE consists of a strategy for each player such that no player has an incentive to deviate from their choice assuming all others will not change.

When the time horizon is finite, a Markov perfect equilibrium can be constructed recursively. In the final period, each player will choose an investment so as to maximize its NPV given the capital stock with which it begins the period. The NPV at that point in time is just the net cash flow during the final period, plus a “terminal value” which is the market value of the capital stock that remains after the final period. The equilibrium investments can then be plugged back

in to find the NPV of each player going into the final period. With these values each player will then select an investment level for the next-to-the-last period just as it did in the final period given the capital stocks entering that period, but now take the terminal value as the value derived in that period. This procedure is then repeated until it works its way back to the initial period, and matches with the initial capital stocks.

This recursive solution for finite-horizon games will ensure a unique MPE solution provided that the value functions we use are linear-quadratic in the state variables (K_t^j, p_t^U) and the control variables (I_t^j) .¹⁸ In addition to being tractable, the linear-quadratic specification can be shown to be an acceptable approximation to more general functional forms.

CALIBRATION AND SIMULATION

Our model is calibrated for the mass market in a particular state over seven time periods.^{19,20} Specifically, we calibrated the model for New York (where Verizon is the primary ILEC) and for Texas (where SBC is the primary ILEC). State-dependent investment strategies require the estimation of a function that takes capital stock levels and lease rates as inputs (rather than a fixed dollar amount for a terminal value). To achieve this, we calculate the present value of cash flows for each player that would result from an additional line, and we calculate the impact of a

¹⁸ This is similar to the approach taken by Kydland, 1975. Kydland finds an MPE for a discrete time, finite horizon game in which players have linear-quadratic objective functions and the law of motion is linear in the control. He confirms a general result for linear-quadratic dynamic games: the value function is quadratic in the state variable and the equilibrium control rule is linear in this state. These properties ensure a closed-form solution for the MPE. We did not use this closed-form solution because our terminal value was state dependent. See also A. Pakes and P. McGuire, 2001 and A. Pakes and P. McGuire, 1994.

¹⁹ The model time horizon is December 2000 through December 2003 and the periods are roughly six-month intervals, corresponding to the semi-annual releases of access line data provided by the Federal Communications Commission. Discussion of data is provided in Section IV of this paper.

²⁰ For voice services, mass market is defined as switched access lines in service to end-user residential and small business customers. According to the FCC's definition, this includes lines that connect to customer locations with fewer than four voice grade equivalent lines used for local exchange service. The total local exchange market in any state also includes services provided to medium and large business and enterprise customers through high-capacity facilities. On an access line equivalent basis, therefore, the local exchange market in any state could be higher than the access lines reported by the FCC in its various reports.

marginal increase in the lease rate on both ILEC and CLEC-L cash flows. These results are then combined to form our terminal value function.

After calibrating the free parameters of our model to real world data, we can use the model for prediction under a “but-for” scenario. In a “but-for” analysis, one or more parameters are altered to determine the effect of that change upon state and control variables. Specifically, we change UNE prices to determine the effect on investment (*i.e.*, number of lines) and on ARPL.

We include seven time periods in our game. In the final period, the players choose the level of investment (or leased lines) that will maximize their NPVs as of period 7, conditional on the beginning-of-period capital stock. NPVs in period 7 consist of the present value of cash flows in period 7 plus the discounted terminal value.²¹ We determine the MPE levels of investment and then recalculate the MPE (and corresponding NPV) in period 7 for values of initial capital stock to have a future value to use in period 6. In period 6, the players again choose their equilibrium levels of investment and leased lines that will maximize NPV as of period 6. We determine the MPE levels of investment in period 6. We then recalculate the MPE (and the corresponding NPVs) in period 6 for values of initial capital stock to have a future value for use in period 5. This procedure continues back to the first period. Thus the maximization of NPV in period t for each firm is determined by considering the maximization of its discounted cash flows over all periods $t + 1, \dots, 7$ and the terminal value of the firm.

Using fitted values for the parameters, we “roll forward” the model to predict players’ investments and ARPLs over the sample period. To do the roll-forward, we begin in period 2 using period 1 for initial values, and calculate the MPE solution implied by the parameters. In period 3, we use the MPE solution found in period 2 as the initial values, and calculate an MPE solution for period 4. Doing this through period 7 provides a predicted trajectory.

Taken together, the value functions for the four players in our model have seven unknown parameters in each period: the four demand intercepts $(A_t^I, A_t^V, A_t^C, A_t^U)$ and the three demand

²¹ The terminal value of a line is computed using revenue, operating cost, and leasing cost of that line from period 7.

slopes (B_t^I, B_t^V, B_t^C) .²² To calibrate the seven unknown parameters in each period, we fit the model to actual data on investment and ARPL. In particular, we find the parameter values that minimize the sum of squared differences between the investment and ARPL generated by the model and the actual investment and ARPL observed in the market data. Thus, the backward recursion establishes period-specific parameter values which constitute a “best fit” to the actual data.

Then, varying UNE prices and re-running the roll forward allows us to compare the predicted trajectories that would have occurred if UNE prices had been different than their actual levels. In our base case, we use historical UNE prices over the period December 2000 through December 2003. For the “but for” scenario, we estimate the effects on investment levels and ARPL that would have occurred if UNE prices had been 15 percent and 30 percent higher than these levels.

IV. DATA AND ASSUMPTIONS

To estimate the structural parameters of our model, we require specific data for each of the providers in each time period. This includes the number of lines (K_t^j); the capital expenditures associated with adding lines (C^j); the variable costs associated with network operations (m_t^j); the prices of unbundled network elements (p_t^U); the average retail prices as approximated by average revenue per line ($P_t^j(K_t)$); and the discount rates (d^j). The specific data required are discussed below and included in Tables A-1 through A-5 of Appendix A.

VOICE AND DATA LINES

Our primary unit of measurement is the number of service lines. This is composed of the mass market voice and data lines, where the mass market is defined by the FCC to include residential

²² As noted above and discussed in Section IV, we estimate the other parameters in the value function by using market data.

and small business customers. Capital stock is denominated in the number of service lines, and (net) investment is the incremental number of service lines from one period to the next.

We would prefer to measure capital investment in dollar amounts but such data are not available for all carriers in each market and for each class of service. It is not possible to simply use aggregate capital expenditures because investment figures for telecommunications carriers represent a mix of expenditures and not necessarily capital investment in networks, *per se*. Two types of data are more readily available: 1) the number of access lines and 2) the number of voice lines and data lines served.

In practice, there is not a one-to-one relationship between access lines and investment. It is possible that a service provider may make significant dollar investments in the form of network upgrades, but these investments may not result in the addition of new access lines. This occurs, for example, when a facilities-based carrier replaces copper loops with fiber-optic lines. This investment enables additional services (*e.g.*, DSL or fiber-to-the-home (FTTH)) and improves the quality of existing services, but the carrier might not report any change in the number of access lines. Gross investment includes expenditures needed to provide these new services as well as expenditures required to replace existing lines due to depreciation.

We define “service” lines as the number of voice and/or data services that are provided to customers over an access line. For example, a single access line which provides both basic voice telephony and high-speed Internet access is counted as *two* service lines. Service lines and capital expenditures move in the same direction, though they may not be strictly proportional to one another.²³ In a two product model, increases in investment may be approximated by increases in data service lines. This holds true in practice. For ILECs, in many states in the U.S. the number of access lines has declined in recent years. Specifically, for ILECs, voice service lines are decreasing while data service lines are increasing over our study period. The combined

²³ Returning to the example of a carrier that replaces copper loops with fiber optic loops, it is probable that such investments are being made to enable provision of high speed data and/or video services and to increase customer subscriptions to these services. Consequently change in the number of service lines is a reasonable directional proxy for changes in levels of investment.

number of data and voice service lines in the telecommunications market across all carriers has actually increased over this same time span.

The measure of investment that we use in our model likely represents a lower bound because it may not pick up discretionary types of investment that improve quality of services or enhance network efficiency but do not result in additional service lines. A significant example of such discretionary investment, which may not result in the addition of incremental voice or data lines is the current expenditure on fiber optics. As a result, the investment levels predicted by our model are likely to be conservative estimates.

The capital stocks held by the three facilities-based carriers, the ILEC, the CATV and the CLEC-F, are: $\bar{K}_t^I = K_t^I + K_t^U$, K_t^V , and K_t^C . Two characteristics of this system are important to note. First, the ILEC owns facilities that it currently uses to serve its own retail customers (K^I) and it also owns and has invested in facilities that it leases to the CLEC-L provider (K^U). Second, among the CLECs, only the CLEC-F owns the plant and equipment that it operates (K^C). The capital stock in a local exchange market is then given by: $\bar{K}_t^I = \bar{K}_t^I + K_t^C + K_t^V = K_t^I + K_t^U + K_t^C + K_t^V$. We summarize this as a vector of the three capacities: $\vec{K}_t = (\bar{K}_t^I, K_t^C, K_t^V)$.

We make an additional assumption concerning investment in our model. We assume that the three facilities-based providers have some network facilities in place and add customers by deploying new service lines. That is, we do not require that each carrier deploy a ubiquitous network and begin providing service with low utilization rates, gradually achieving economies of scale over a long period of time. Hence, we assume that capacity is equal to output, and that there is no unused capacity.

Gross investment made in any period is the difference between the capital stock in that period and the prior depreciated capital:²⁴

$$\begin{aligned} \text{ILEC:} & \quad I_t^I = (K_t^I + K_t^U) - (1 - \delta_I) \times (K_{t-1}^I + K_{t-1}^U) \\ \text{CATV:} & \quad I_t^V = K_t^V - (1 - \delta_V) \times K_{t-1}^V \\ \text{CLEC-F:} & \quad I_t^C = K_t^C - (1 - \delta_C) \times K_{t-1}^C \end{aligned}$$

Voice and data line counts for each state in the U.S. are reported biannually by the FCC.²⁵ We include seven data points in our analysis—semi-annual data beginning in December 2000 and ending in December 2003.

For voice lines, the FCC identifies whether the access lines are served by the ILEC or CLECs. For CLEC lines, the FCC distinguishes between access lines that are owned by CLECs and those that are leased by CLECs as UNE Platforms, resold lines or unbundled loops.²⁶ The FCC also reports the percentage of mass market lines by RBOC and CLEC in each state.²⁷

For data lines, the FCC reports high speed lines (over 200 kbps in at least one direction) by the following technology categories: asynchronous digital subscriber line (ADSL), other wireline, coaxial cable, and other. In terms of ownership, the FCC reports high speed lines by RBOC, other ILEC, and non-ILEC. For this paper, we assume that all coaxial cable lines are owned by the CATV provider and that all RBOC and other ILEC lines (*i.e.*, DSL and other wireline) are owned by the ILEC provider. For the remaining non-ILEC lines (ADSL, other wireline, and

²⁴ There are cases in which the capital stock for a firm decreases from one year to the next. Such cases are treated as divestment, whereby it is assumed that the firm sells a portion of its capital stock. In reality, the firm rarely divests its lines. Rather, it may lose customers. We do not distinguish between a divested line and a lost customer. Since the magnitude of divestments is not very large in relation to the capital stock of a firm, this assumption does not materially impact our results.

²⁵ Voice access line counts are based on the FCC’s “Local Telephone Competition” status report (see FCC, 2004a, 2003a, 2003b, 2002a, 2002b, 2002c, 2001a) and data line counts are based on the FCC’s “High-Speed Services for Internet Access” status report (see FCC, 2004b, 2003c, 2003d, 2002d, 2002e, 2002f, 2001b).

²⁶ As defined earlier, the model assumes two CLEC players participate in the voice market. CLEC-Fs own 100% of their own facilities and CLEC-Ls lease 100% of network elements from the ILEC (*i.e.*, a UNE-P or resale CLEC). Voice lines defined as UNE-L indicate that the CLEC leases the line but owns a switch. These lines do not fall into either category of CLEC player in the model. Hence, UNE-L lines are excluded from the model in the case of voice service.

²⁷ See, for example, FCC, 2004a, Table 11.

other), we assign a specific percentage to the CLEC-F provider and the remaining lines to the CLEC-L provider. For the results presented in this paper, we assumed that 5% of the high speed access lines in this category are owned by the CLEC-F provider and that 95% are leased by the CLEC-L provider. To determine the number of mass market high speed access lines, we use the FCC's estimate of residential and small business high speed access lines by state.²⁸

The voice and data lines counts that we included in our model for the states of Texas and New York are shown in Table A-1 of Appendix A.

CAPITAL EXPENDITURES

The value functions for the facilities-based providers include the capital expenditures (“capex”) incurred in deploying new lines. For this model, the relevant capex is the incremental expenditure required for each carrier to provide an additional local exchange voice or data line over its own last-mile facilities. We developed a capex estimate for each of the three facilities-based providers—the ILEC, the facilities-based CLEC, and the CATV.

There are a several ways to estimate the investment required for a telecommunications firm to construct an incremental line, including estimates by financial analysts and engineering-based estimates.²⁹ Capex is a function of the business model that an individual provider is pursuing.³⁰ Some models are characterized by low capex per line (*e.g.*, metropolitan area networks or MANs) and others are characterized by higher capex per line (*e.g.*, low density suburban areas). Hence, it is not appropriate to select a single business model and use its associated capex; a cross section of industry players is more appropriate. For this paper, we used publicly available historical industry data across a portfolio of providers to estimate capex. Specifically, we

²⁸ See, for example, FCC, 2004b, Tables 5, 7, and 11.

²⁹ See, for example, Banc of America, 2003a and 2003b, which provides estimates of capex associated with the provision of DSL.

³⁰ A review of literature and reports by financial analysts indicates that many categories of business models have been pursued. Various strategies include: FTTH overlay, WLL, UNE-L, EEL, UNE-P, BLEC, DLEC, RLEC Edge-Out, Cable HFC Overbuild, VoIP, WiFi, and DSL, among others. For example, SBC and Verizon have recently announced they will pursue a FTTH strategy in several areas in contrast to their existing copper line networks. RBOCs also have CLEC business units and other business units to target niche markets (*e.g.*, Verizon Avenue).

estimated the capex for ILECs from data reported in the FCC's ARMIS database,³¹ and we estimated the capex for CLECs and CATV from annual data reported in *The CLEC Report*.³² We used a panel of firms in each of these categories to statistically estimate capex per line.

We estimated capex per line for each of the three types of facilities-based providers using a pooled cross-section time-series regression model. For the ILEC, over the period 2000 through 2003, we regressed incremental capex in each year on 1) the incremental lines served and the actual lines served, 2) the incremental number of switches and the actual number of switches, and 3) the incremental fiber miles and the actual fiber miles.³³ This allowed us to estimate the specific amount of capex used to provision a line. Our dataset consists of 80 ILECs (*i.e.*, state-specific RBOCs and other ILECs across the U.S.) over the 4 year period. We excluded five outliers.³⁴ After accounting for these cases, we had 315 observations in the ILEC regression.

For the CLEC-F, CATV, and CLEC-L providers, we specified the regression model as incremental capex as a function of incremental lines. For the CLEC-F, our dataset consists of 10 facilities-based CLECs operating in the U.S. over 4 years. After accounting for outliers, we had 38 observations in the regression. For CATV, our dataset consists of 10 cable companies operating in the U.S. over 4 years. After accounting for outliers, we had 39 observations in the regression.³⁵

Regression results for each provider are reported in Table A-2 of Appendix A. The coefficient on the "incremental access lines" variable is an estimate of the capex per access line (in thousands) for each provider. Based on these results, for the ILEC, the estimated capex per line is \$821. For the CATV provider, the estimated capex per line is \$678. For the CLEC-F, the

³¹ See FCC Automated Reporting Management Information System, ARMIS, 2004.

³² See New Paradigm Research Group reports, 2001, 2002, 2003, and 2004.

³³ For example, in the first period we use the incremental number of lines, switches, and fiber miles between 1999 and 2000.

³⁴ We defined outliers as observations where the incremental switches fell by 25,000 or more assuming that a decline in switches of 25,000 or more represents a significant divestiture that would not be captured by capex.

³⁵ For the CLEC-F, CATV, and CLEC-L providers, we defined an outlier as any observation where the incremental lines fell by 100,000 or more in a given period.

estimated capex per line is \$765. Based on these estimates, we used an average capex estimate of \$800 for the ILEC, the CLEC-F, and the CATV provider in the MPE model.³⁶

The capex requirements for the CLEC-L are different from the facilities-based players because the CLEC-L provider avoids the cost of building last-mile facilities. In the case of voice services, we assume the CLEC-L provider leases the entire network platform required to provide the service from the ILEC so no capex is incurred.³⁷ In the case of data services, we assume the CLEC-L provider is leasing a loop to provide DSL service. Thus, it incurs capex related to customer premise equipment, line reconditioning, and the addition of a digital subscriber line access modem (DSLAM). To estimate this capex amount, we used the results of a simple linear regression model where incremental capex is a function of incremental lines. For the CLEC-L, our dataset consists of a panel of 15 UNE-L CLECs operating in the U.S. over 4 years. After accounting for outliers, we had 58 observations in the regression. The estimated capex per line for the CLEC-L player is \$334 (see Table A-2 of Appendix A). We used an estimate of \$300 in our model.³⁸

An additional consideration for estimating capital expenditures is depreciation. Facilities-based providers incur maintenance capex to address the physical deterioration of their networks. This capex does not result in the addition of new lines. Our model focuses on the addition of new lines and we do not include the replacement of lines as incremental investment. Thus, we do not include this depreciation effect. However, maintenance capex is a cash expenditure that affects the NPV of the players and their investment decisions. In practice, the actual replacement of a

³⁶ Note that the capex estimates do not vary over time. Additionally, to examine the sensitivity of the MPE model results to our capex estimates, we used an alternative estimate of capex per line of \$1,000 for each facilities-based provider. The findings show that the MPE model results (in terms of investment levels and ARPL) are not highly sensitive to this change.

³⁷ CLECs may also use UNE-L to provide voice services, thus incurring a capex requirement for non-loop-related network infrastructure. However, as discussed earlier, since these CLECs are neither purely facilities-based nor purely lease-based, UNE-L voice lines are not included in our model.

³⁸ In the model, the capex estimate of \$300 is part of the operating expense incurred for a CLEC-L provider that leases a loop to provide data services. For the CLEC-L provider, capex, per se, is assumed to be zero.

physical line occurs so infrequently that the capitalized maintenance cost is a small percentage of total capex. This amount is included in our capex regressions described earlier.³⁹

VARIABLE COST

In the objective function, variable cost m_t^j is the operating cost per line for each of the four firms. This operating expenditure (“opex”) includes the cost of goods sold (COGS) and the costs associated with sales, general, and administrative functions (SG&A), excluding extraordinary items. Our model treats these costs as variable since the next line added will have the same opex as the previous line. In practice, telecommunications providers realize economies of scale on the fixed components of opex (*i.e.*, shared and common costs).

For ILECs, we estimated the opex based on data reported to the FCC and included in annual ARMIS reports for over 100 RBOC-state specific operating companies and other ILECs for the years 2000 through 2003.⁴⁰ For the CATV provider, we calculated the average opex for the years 2000 through 2003 based on company-specific 10-Ks filed with the Securities and Exchange Commission (SEC) for a panel of eight publicly traded CATV multi-system operators (MSOs).⁴¹

For the CLEC-F and CLEC-L providers, we estimated opex for the years 2000 through 2003 as the average COGS for a panel of providers plus an assumed level of SG&A based on company-specific 10-Ks filed with the SEC. We limited our dataset to CLECs with positive EBITDA in 2003.⁴² For the CLEC-F provider, we calculated the average COGS for five CLECs that had last

³⁹ In the capex regressions, replacement lines are not included. Since capex includes all capital expenditures (including maintenance), maintenance capex is captured by the coefficient on total lines in the ILEC regression.

⁴⁰ To calculate COGS and SG&A using ARMIS data, we add back Uncollectibles to Total Operating Revenues to be comparable to publicly reported data on CLECs and CATVs. COGS includes Plant Specific, Plant Non-Specific, and Access costs. SG&A includes Uncollectibles, Customer Operation Services, Customer Operations Marketing, and General & Administrative. FCC ARMIS data are reported annually, so the mid-year values are interpolated values. See FCC ARMIS.

⁴¹ The eight Cable MSOs used to estimate opex are: Cablevision, Charter Communications, Comcast Corporation, Cox Communications, General Communication, Insight Communications, LodgeNet Entertainment, and Mediacom Communications.

⁴² This excludes CLECs with exceptionally high levels of expenses (*i.e.*, exceeding revenues) that do not represent sustainable business models.

mile facilities.⁴³ For the CLEC-L provider, we calculated the average COGS for five CLECs employing UNE-P strategies for the voice estimate and five CLECs employing UNE-L strategies for the data estimate.⁴⁴ We then adjusted the average COGS for the CLEC-L provider by subtracting out the state-specific UNE component. For both the CLEC-F and CLEC-L providers, we added an additional cost for SG&A of 25% to the (adjusted) COGS to arrive at the total opex.⁴⁵

A summary of opex for the four players is provided in Table A-3 of Appendix A.

UNBUNDLED NETWORK ELEMENT (UNE) PRICES

The rates for UNEs are the prices paid by CLECs to ILECs for leasing components of the ILEC's network. Each state regulatory commission sets the lease prices for UNEs in its state. Such prices are set for numerous network components including loops, switching, and network interface devices (NIDs).⁴⁶ In our model, we use two UNE prices: the UNE-P price which is the price that the CLEC-L provider pays to lease all of the network elements required to provide voice service, and the UNE-L price which is the price that the CLEC-L provider pays to lease the loop required to provide data service.

In our model, UNEs are a variable cost for the CLEC-L provider and are treated as a component of COGS. In the objective function of the CLEC-L provider, p^U is the unit cost associated with leasing UNEs. For voice service, we use the UNE-P rate. For data service, we use the UNE-L rate because, when providing data service, a CLEC will lease the loop from the ILEC and then

⁴³ Since most CLECs that own last-mile facilities also provision some customers over leased last-mile facilities, a panel of purely last-mile CLECs is unavailable. We selected CLECs that provision a majority of their customers using their own last-mile facilities. The five facilities CLECs used to estimate opex are: CLEC Subsidiary of Centennial Communications, CLEC Subsidiary of Commonwealth Telephone, ICG Communications, Time Warner Telecom, and Level 3 Communications.

⁴⁴ The five UNE-P CLECs used to estimate voice opex are: Covista Communications, Talk America Holdings, Z-Tel Technologies, EPICUS Communications Group, and ATX Communications. We define a UNE-L CLEC as one that has data revenues between 25% and 50% of total revenues. The five UNE-L CLECs used to estimate data opex are: Pac-West Telecomm, Choice One, ITC^DeltaCom, McLeod, and US LEC. Ideally, we would include only DLECs, but data from such firms are unavailable.

⁴⁵ This SG&A cost is based on the average of the most efficient CLECs in the panel (*i.e.*, top third).

⁴⁶ As a result of the recent FCC Order on Remand (2005), the availability of switching as a UNE (and therefore UNE-P) will be phased out over the next few years.

make additional expenditures required to upgrade the line to provide DSL service. For combined voice and data services, we use a weighted average of UNE-L and UNE-P rates based on the proportion of CLEC-L lines that provide voice and data service to customers.

Current and historic UNE prices are available from the state regulatory commissions and other sources. In this paper, we use the UNE price data collected by the National Regulatory Research Institute (NRRI).⁴⁷ The UNE prices for the states of Texas and New York used in the model are provided in Table A-4 of Appendix A.

AVERAGE REVENUE PER LINE (ARPL)

The average revenue per line (ARPL) is determined in the model endogenously. However, as discussed earlier, we calibrate the parameters determining ARPL by minimizing the sum of the squared differences between the implied ARPL generated by the model and the actual ARPL. The ARPL values by provider by state are included in Table A-5 of Appendix A.

ARPL is the revenue per line (per month) that each provider can expect to receive, or the total amount spent by the end user on a per-line basis. Several different estimates of ARPL are available. As with the UNE price data, to estimate the ILEC's voice service ARPL, we use the average revenue per line per month reported by the NRRI for voice services.⁴⁸ To estimate the ILEC's data service ARPL, we use financial analyst reports.⁴⁹ We estimated the combined voice and data ARPL for the ILEC by calculating an average of the voice and data ARPLs weighted by the actual number of voice and data lines.

For the CLEC-F and the CLEC-L providers, we assume the ARPLs for voice and data services are equal to the ILEC's. For the CATV provider, we assume that the ARPL for voice service is

⁴⁷ Gregg, January 2004, July 2003, January 2003, July 2002, January 2002, July 2001, April 2001. Data for July 2004 is now available but we lack corresponding data for market shares by provider.

⁴⁸ See Table 2 in Gregg, January 2004; July 2003; January 2003; July 2002; January 2002; July 2001; and April 2001.

⁴⁹ Credit Suisse First Boston, 2004.

equal to the ILEC's. However, for the CATV data service ARPL, we use the retail levels reported by financial analysts.⁵⁰

DISCOUNT RATES

Discount rates vary by telecommunications providers based on capital structures and risk. We estimated the cost of capital for the providers in our model by reviewing statistics for the wireline telecommunications industry compiled by Ibbotson Associates.⁵¹ This source provides the cost of capital for different firm sizes within the telecommunications sector; the actual cost of capital for a specific firm within a size category may differ from the average.⁵² For our model, we used a discount rate of 10% for the ILEC and a discount rate of 12.5% for the CLEC and CATV providers.⁵³

V. SIMULATION RESULTS

We use our structural model to simulate the impact of changes in UNE prices on the levels of investment and on ARPL. As described previously, we simulate the effect that a change in UNE prices has on the mass market in two states, New York and Texas. Specifically, we examined the impact of UNE price increases in four service markets: the combined data and voice market in New York and Texas and the stand-alone data market in both states.^{54, 55}

First, we calibrate the structural parameters of the model for each of the four markets using market data for six of the seven available time periods since the initial period is used to form a

⁵⁰ *Ibid.*

⁵¹ See the weighted average cost of capital in Ibbotson Associates, 2002.

⁵² The firm-specific cost of capital approved by state regulators, for example, may differ from our estimates due to a number of factors. The cost of capital used in this paper is an average estimate based on a public source. It is not firm specific and therefore it is likely to be inappropriate for state regulatory proceedings.

⁵³ We examined the sensitivity of the model results to alternative discount rates. While the MPE model results change somewhat when different discount rates are employed, the results are not highly sensitive to small changes in the discount rate.

⁵⁴ In this paper, we consider service-based and/or geographic "markets." For example, telecommunications carriers may provide data services within a specific geographic areas (*i.e.*, a state). Importantly, our use of the term differs from the highly specific definition that is applied in the context of antitrust analysis.

⁵⁵ We did not simulate the voice market alone, because the economics of network investment make it inefficient to offer voice service alone. Instead, voice services are offered together with data services.

time lag. Plugging in the calibrated parameters, we then simulate equilibrium outcomes by uniformly increasing or decreasing UNE prices by a fixed 15% or 30% over all seven periods. The simulated outcomes are summarized by the unweighted average over the six periods, and also by the levels fitted for the final period. Finally, we compare the simulated outcomes for investment and ARPL with the actual levels, interpreting the differences as our predictions of the differences that would prevail under the counterfactual of uniformly higher or lower UNE prices during the study period.

Our simulations confirm that increases in UNE prices tend to increase the aggregate investment in voice and data lines. They also show how the relative distribution of lines varies across types of carrier. In the remainder of this section, we provide the results of model calibration as well as the simulations.

SUMMARY OF PARAMETER CALIBRATION

Calibration involves estimating the seven unknown variables: the four intercept parameters ($A_t^I, A_t^V, A_t^C, A_t^U$) and the three slope parameters (B_t^I, B_t^V, B_t^C). For each period, we calculate parameter values to minimize the (sum of squared) differences between the investments and ARPLs predicted by the model and the actual historical data. With seven unknown parameters and seven data points available for calibration (four investment and three ARPL values), the fitted values exactly equal the actual data. Exhibits 1, 2, 3, and 4 show the actual and calibrated values for the number of lines and ARPL for each of the four types of providers averaged over the six sample periods $t = 2, \dots, 7$ (see columns labeled “actual” and “calibrated”). The same values reported for the last sample period alone (*i.e.*, December 2003) can be found in Tables B-1, B-2, B-3, and B-4 in Appendix B.⁵⁶

⁵⁶ In our view, it is more useful to examine the average results for period $t=2$ through $t=7$ presented in Exhibits 1, 2, 3, and 4 rather than the results for one period. Investment fluctuates over time; therefore, examining results for a single period may lead to erroneous conclusions.

SUMMARY OF SIMULATION RESULTS

Our results show that increasing UNE prices has several effects on both investment and on ARPL (see the “15%” and “30%” columns in Exhibits 1, 2, 3, and 4). For each provider, Exhibits 1, 2, 3, and 4 show the simulated numbers of lines and ARPLs averaged over periods $t = 2, \dots, 7$. In general, with regard to the average impact of a 30% increase and decrease in UNE prices,⁵⁷ we find:

- First, as UNE prices increase, aggregate industry investment in local exchange networks, as measured by the number of service lines, increases.
- Second, when UNE prices increase, the numbers of service lines of the CATV and CLEC-F providers increase significantly in both the combined services market and in the data service market. The relative size of the CATV and CLEC-F increase compared to the ILEC provider. The relative size of the ILEC actually *decreases* in data services when UNE prices increase.
- Third, as expected, the number of service lines of the CLEC-L falls in all markets as UNE prices increase, but (as reported above) at the same time the number of service lines of the CLEC-F increases.
- Fourth, increasing UNE prices tends to stimulate investment more in the data market than in the combined data and voice services market in New York. The increase in the number of data lines in New York resulting from a 30% UNE price increase is about 7% in the data market as opposed to 3% for the combined market.⁵⁸ In Texas, a 30% increase in UNE prices results in an increase in the number of lines of about 6% in both markets.
- Fifth, we find that the direction of the effects is reversed when we decrease UNE prices. Specifically, as UNE prices decrease, CLEC-L service lines increases substantially in all markets and CLEC-F service lines decrease substantially in all markets. In principle, as UNE prices decrease to lower levels, CLEC-F’s size will decline to zero.
- Finally, as UNE prices increase, ARPL also increases. The percentage increase in ARPL may be less than or greater than the percentage increase in UNE prices. This does not necessarily suggest, however, that an increase in UNE prices is translated into an increase in retail prices. This is because ARPL measures total amount spent by the end user on a per-line basis, and thus changes in ARPL reflect the combination of changes in retail prices, additional quantities consumed, as well as the purchase of additional services (possibly enabled by increased levels of investment).

⁵⁷ Our simulation results in Exhibits 1, 2, 3, and 4 also include a 15% increase and decrease in UNE prices.

⁵⁸ These percentages represent a percent change over the actual number of lines.

The discussion in this section is based on simulation outcomes reported as unweighted averages over six periods, $t = 2, \dots, 7$. We find this to be the appropriate basis for interpreting the model results. By definition, average results will differ from results at any point in time. For comparison purposes, results for period 7 alone are included in Tables B-1, B-2, B-3 and B-4 of Appendix B.

NEW YORK RESULTS – MASS MARKET

As of December 2003, the FCC reported approximately 10,356,000 voice and high speed data access lines serving the mass market in New York (see Table A-1 of Appendix A).⁵⁹ As of December 2003, approximately 65% of the mass market lines in the combined market in New York were served by ILECs, 16% by CATV, and nearly 20% by CLECs.

The average UNE-P price in New York declined from \$20.06 in 2000 to \$15.19 in 2002 and remained at that level through 2003 (see Table A-4 in Appendix A). The average UNE-L price in New York also declined, from \$14.81 in 2000 to \$11.49 in 2002. The average UNE price, weighted by the number of data and voice lines, declined from \$19.90 at the end of 2000 to \$15.02 at the end of 2003.

We simulated the effects of a simultaneous increase in UNE-P and UNE-L rates in New York by 15% and 30% in all seven time periods. Simulation results averaged over six periods for New York are shown in Exhibits 1 and 2. Overall, the results indicate that an increase in UNE prices would be accompanied by an increase in investment as measured by the number of service lines in the combined voice and data market as well as in the stand-alone data market. Responses to higher UNE prices vary across the providers. These responses can be expressed as an “investment elasticity” which, in this case, is the percentage change in the number of service lines for a given percentage increase in UNE prices.

Following an increase in UNE prices, the percentage increases in lines for both CLEC-F and CATV are notable and substantial, although the CLEC-F remains small compared to the ILEC

⁵⁹ See FCC, 2004a.

and CATV during the sample period. Results indicate symmetrical effects when UNE prices are reduced, so that we only report the results for UNE price increases below.

Combined Voice and Data Market

Our results show that average investment levels (measured by service lines across all players) increased by approximately 1.6% and 3.2% in the combined market following 15% and 30% increases in UNE prices, respectively (see “% over actual” columns in Exhibit 1). Under the 15% increase scenario, this implies a UNE price elasticity of investment of 0.11.⁶⁰ The elasticities vary across providers. The ILEC has an elasticity of 0.17 and the CATV has an elasticity of 0.49 while the CLEC-F and the CLEC-L have elasticities of 1.05 and -0.60, respectively.

In addition, average ARPL increased from about \$40 per line per month to about \$48 when UNE prices increase by 15% and to about \$56 when UNE prices increase by 30%. As we discussed earlier, it is important to remember that this is not necessarily a price increase, but instead reflects the total amount spent by the end user on a per-line basis. The variation in ARPLs across providers is negligible due to the fact that we force the pricing of the two CLECs’ services to be the same as the ILEC’s.

The model simulation results indicate that, although the line shares are small for both the CLEC-F and the CATV providers, as UNE prices increase, the line shares for these two providers increase substantially in percentage terms. In contrast, the ILEC (starting with a large share of the lines) realizes a small increase in line share. These results are consistent with the marketing literature which predicts that product adoptions follow an S-shaped diffusion curve.⁶¹ The CLEC-F and the CATV provider are on the steep part of the S-curve so that changes that influence adoptions of their service can result in large percentage increases in lines. In contrast, the ILEC is on the flat part of the S-curve close to the “saturation level,” so that such changes will result in a negligible percentage change in lines.

⁶⁰ As defined above, the investment elasticity is defined as the percentage change in the number of lines divided by the percentage change in UNE prices.

⁶¹ See, for example, Bass, 1969.

Data Market

The FCC reports about 2.1 million data service lines in New York for the mass market as of the end of 2003 (see Table B-2 of Appendix B). Our results show that, under the two “but for” scenarios, on average over the six periods, investment levels (measured by service lines) increased by approximately 3.6% and 7.2% in the data market (see the “% over actual” columns in Exhibit 2). In addition, ARPL (*i.e.*, the total amount spent by the end user on a per-line basis) increases from about \$40 to approximately \$45 when prices increase by 15%, and to about \$50 when prices increase by 30%.

The implied investment elasticity in this market under the 15% increase scenario is 0.24 when all providers are combined. Notice that this elasticity is larger than the elasticity of 0.11 in the combined voice-data market in New York. This makes sense as the responsiveness of the combined voice-data market will be dampened by the relatively inelastic investment response in the mature voice market.

CATV is responsible for serving a significant share of data lines in New York’s mass market. As of the end of 2003, based on FCC data, about 70% of data lines in New York State were provided by CATV; the ILEC’s line share was about 24% and CLECs served about 6% of the data market (see Table B-2 of Appendix B).

TEXAS RESULTS – MASS MARKET

As of December 2003, the FCC reported approximately 11,884,000 voice and data access lines serving the mass market in Texas (see Table A-1 of Appendix A). Although the overall telecommunications market size is similar in New York and in Texas, proportionally the mass market is slightly smaller in New York than in Texas; equivalently, the proportions of business voice and data lines are significantly greater in New York.⁶² As of December 2003, over 80% of the mass market lines were provided by ILECs, with an additional 9% served by CATV. Nearly 10% of access lines were served by CLECs.

⁶² As of January 2004, the FCC estimates that the mass market in New York is 68% of lines, whereas in Texas it is 85%. See FCC, 2004a and 2004b.

The average UNE-P rate in Texas declined from \$19.17 to \$18.63 in 2003, while the average UNE-L rate was \$14.15 throughout our study period. The average UNE price, weighted by the number of data and voice lines, declined slightly from \$18.78 at the end of 2000 to \$18.32 at the end of 2003.

We conducted the same simulation for Texas as for New York. Results averaged over six periods for Texas can be found in Exhibits 3 and 4. Overall, the results for Texas are very similar to those for New York. Increasing UNE prices results in an increase in investment in both the combined voice and data market and in the stand-alone data market. Again, we find that the percentage increases in line share for both the CLEC-F and CATV providers are substantial when UNE prices are increased. Although the ILEC and CATV retain the majority of service lines, this is primarily because we are examining a short time span of three years. Similar to the case in New York, we find that decreasing UNE prices reverse the direction of all of the effects of UNE price increases, so these results are not discussed below.

Combined Voice and Data Market

Our results show that investment levels (measured by service lines) increased by approximately 3.2% and 6.5% in the combined market following a 15% and 30% increase in UNE prices, respectively (see the “% over actual” columns in Exhibit 3). Under the 15% increase scenario, this implies a UNE price elasticity of investment of 0.21 which is almost twice as high as the comparable elasticity in New York (*i.e.*, 0.11). The elasticities again vary across the specific providers. The ILEC has an investment elasticity of 0.30 and the CATV has an elasticity of 0.81 while the CLEC-F and the CLEC-L have elasticities of 1.67 and -1.46, respectively. Responsiveness of individual carriers is uniformly greater in Texas compared to New York, consistent with the higher proportion of data lines in New York compared with Texas.

Notably, ARPL (*i.e.*, the total amount spent by the end user on a per-line basis) increases from about \$37 per line per month to about \$51 when UNE prices increase by 15% and to about \$64 when UNE prices increase by 30%.

The model simulation results indicate that, although the line shares are currently small for the CLEC-F and the CATV providers, as UNE prices increase, the line shares for these two providers increases substantially in percentage terms. As discussed under the New York results, this is likely because the facilities-based CLEC and the CATV provider are on the steep part of the S-shaped product adoptions curve.

Data Market

The FCC reported approximately 1.8 million data service lines in Texas for the mass market as of the end of 2003 (see Table B-4 of Appendix B). Our results show that, under the two “but for” scenarios, on average over the seven periods, investment levels increased by approximately 3.0% and 6.0% in the data market (see % over actual columns in Exhibit 4). In addition, ARPL (*i.e.*, the total amount spent by the end user on a per-line basis) increases from \$40 to about \$45 when prices increase by 15% and to about \$49 when prices increase by 30%.

The implied investment elasticity in this market under the 15% increase scenario is 0.20 when all providers are combined. The investment elasticity is similar in the combined voice-data market in Texas (*i.e.*, 0.21). In the data market, the responsiveness of equilibrium investment to changes in UNE prices is similar across the two states – 0.20 in Texas compared to 0.24 in New York.

CATV is responsible for serving a significant share of data lines in the Texas mass market but less than in New York. As of the end of 2003, based on FCC data, about 53% of data lines were provided by CATV; the ILEC’s line share was about 41%; and CLECs served about 6% of the data market (see Table B-4 of Appendix B).

VI. CONCLUSIONS

We draw five principal conclusions from our comparative analysis of UNE pricing.

First, we conclude that policies attempting to stimulate local exchange investment by facilitating entry of service-based competitors can backfire. Our model finds that UNE prices have a substantial impact on investment decisions, not only for providers directly involved in facility sharing (*i.e.*, the ILECs and CLEC-Fs), but also for other retail competitors such as cable

providers. In particular, our model suggests that encouraging the entry of service-based competitors (*i.e.*, CLEC-Ls) simply through the setting of low UNE prices – perhaps below economic cost – can result in lower levels of overall investment (as measured by the number of mass market service lines) than might otherwise be the case.⁶³

Our results go further by offering support for a strategy implicit in the Telecom Act which favors facilities-based competition over facilities-sharing. In particular we find that higher UNE prices foster the growth of a separate network for delivery of high-speed data services rather than enabling service-based competitors that depend on use of incumbents' networks. Empirical studies of European markets have confirmed that facilities-based competition has been more effective in accelerating broadband deployment than has competition based on facilities-sharing.⁶⁴ There is also reason to believe that facilities-based competition will be more effective in delivering greater product variety as well as lower prices to consumers over the longer run.⁶⁵

Second, keeping UNE prices at current levels (or decreasing them further) is likely to have a dampening effect on future investment – especially in the data services market. Over the model period, voice lines represent about 80% to 85% of the market in the two states examined whereas data lines represent only 15% to 20% of the market. As the simulation results demonstrate, increasing UNE prices results in a greater increase in data lines compared to voice lines. In the future, we expect data lines as a percentage of total mass-market lines to grow significantly, changing the mix of service lines in the combined market away from the historical dominance of voice lines. Specifically, using a projection based on current trends, it is likely that data lines will represent about 43% of the mass market service lines by the end of 2008 in New York and 37% of the mass market lines in Texas.⁶⁶ Hence, if we were to use our model to forecast future levels of investment (*e.g.*, over the next five years), and if the percentage of data lines increased – but all other factors in the model remain unchanged – we would expect that an increase in UNE

⁶³ As expected, as UNE prices increase, we find that the percentage of CLEC-L access lines declines in all markets. Eventually, as UNE prices increase to higher levels, hypothetically the CLEC-L providers' market share will decline to zero.

⁶⁴ See Hoffler, 2005, and Distano, Lupi and Manetti, 2005.

⁶⁵ See Woroch, 2002.

⁶⁶ These estimates are based on a simple time trend using FCC historic line data over the model period and projecting five years into the future. This projection does not account for FTTH or regulatory changes.

prices would result in even higher levels of investment than the “but for” case presented in this paper.⁶⁷

Third, our results show that the biggest jumps in line shares caused by higher UNE price are realized by the CATV and the facilities-based CLEC carriers.⁶⁸ In comparison, the impact on ILEC service line share is negligible on an absolute and a relative basis. In the critical case of data lines, the simulation model predicts that ILEC line share actually decreases when UNE prices rise. The CATV and CLEC-F carriers are disproportionately responsible for the industry-wide increase in data lines in these markets.

Fourth, the results of our model have ambiguous implications for the rates for retail local exchange services. Specifically, we find that increased levels of investment may be accompanied by increased ARPL.⁶⁹ The higher ARPL compensates for the increased capital cost that facilities-based providers incur and is not inconsistent with higher retail prices. In fact, a higher ARPL could be caused by either increased usage levels on a per-line basis or higher retail prices. This is one place where our industry model is incomplete for at least two reasons. First, strong competitive forces are present that would limit the ability of facilities-based carriers to raise rates. This is especially true of competition from wireless technologies. Second, regulators will not passively watch as retail rates increase. Our model allows firms to adjust retail prices without restriction when, in reality, regulation imposes limits on rate levels.

Fifth, while our analysis finds a direct relationship between UNE prices and local exchange investment, we have not analyzed the full effect of UNE pricing on consumer welfare. Our analysis does not address the adequacy of the current level or trajectory of investment in the local exchange to best meet consumer expectations and demand. It also does not address the value to consumers of potentially or artificially lower retail prices compared against the value of potentially new and innovative services that result from increased levels of investment in local

⁶⁷ Our current simulation results, combined with this qualitative analysis, lead us to this conclusion. However, we must keep in mind that our model was not built to make forecasts beyond the sample period.

⁶⁸ Note that the MPE model results are symmetric so decreases in UNE prices will result in the biggest market share losses for the CLEC-F and CATV providers in both the combined and data markets.

⁶⁹ It is important to keep in mind that we do not simulate retail prices in our model, but rather report estimates of average revenue per line which is not perfectly correlated with retail prices.

exchange infrastructure. Importantly, we neglect to take account of mobile wireless services which consumers increasingly substitute for fixed line voice services, and soon possibly fixed-line data access.⁷⁰ Nor do we allow for the possibility that the spread of broadband data access will enable new competition in the form of service-based voice over IP providers.

Consumers – and sometimes regulators – are seduced by the prospect of lower retail prices, and may view lower prices, which they expect to result from entrants sharing the ILEC’s facilities, as the sole benefit in measuring consumer welfare. However, it is critical to include all benefits when measuring consumer welfare especially the benefits foregone as a result of the absence of investment in advanced telecommunications services. Such benefits will accumulate continuously over time. The magnitude of these foregone investment benefits, and the resulting cumulative loss in consumer welfare over time, can be tremendous and very likely will swamp any benefits realized as a result of lower retail prices (if such price reductions are ever realized) in the short run. Thus, holding UNE prices at low levels may artificially suppress retail prices, but the benefit may be short lived and lead to forgone consumer welfare over the longer run.

⁷⁰ See Rodini, Ward and Woroch, 2003.

EXHIBIT 1. NEW YORK: VOICE AND DATA MARKET COMBINED SUMMARY OF AVERAGE RESULTS OVER PERIODS 2 THROUGH 7 (SERVICE LINES IN 1000S).

UNE Price % Increase	Actual	Calibrated	15%	% over actual	30%	% over actual
<i>Average Number of Lines Over Periods T = 2 to T = 7</i>						
ILEC	7,011	7,011	7,189	2.5%	7,367	5.1%
CATV	1,107	1,107	1,188	7.3%	1,268	14.5%
CLEC-F	221	221	256	15.7%	291	31.3%
CLEC-L	1,488	1,488	1,353	-9.0%	1,219	-18.1%
Total	9,827	9,827	9,986	1.6%	10,145	3.2%
<i>Average ARPL Over Periods T = 2 to T = 7</i>						
ILEC	\$40.50	\$40.50	\$48.87	20.7%	\$57.24	41.3%
CATV	\$39.03	\$39.02	\$47.40	21.4%	\$55.77	42.9%
CLEC-F	\$40.50	\$40.50	\$48.87	20.7%	\$57.24	41.3%
CLEC-L	\$40.50	\$40.50	\$48.87	20.7%	\$57.24	41.3%

UNE Price % Decrease	Actual	Calibrated	15%	% under actual	30%	% under actual
<i>Average Number of Lines Over Periods T = 2 to T = 7</i>						
ILEC	7,011	7,011	6,833	-2.5%	6,655	-5.1%
CATV	1,107	1,107	1,027	-7.3%	946	-14.5%
CLEC-F	221	221	187	-15.7%	152	-31.3%
CLEC-L	1,488	1,488	1,622	9.0%	1,757	18.1%
Total	9,827	9,827	9,669	-1.6%	9,510	-3.2%
<i>Average ARPL Over Periods T = 2 to T = 7</i>						
ILEC	\$40.50	\$40.50	\$32.13	-20.7%	\$23.76	-41.3%
CATV	\$39.03	\$39.02	\$30.65	-21.5%	\$22.28	-42.9%
CLEC-F	\$40.50	\$40.50	\$32.13	-20.7%	\$23.76	-41.3%
CLEC-L	\$40.50	\$40.50	\$32.13	-20.7%	\$23.76	-41.3%

EXHIBIT 2. NEW YORK: DATA MARKET SUMMARY OF AVERAGE RESULTS OVER PERIODS 2 THROUGH 7 (SERVICE LINES IN 1000S).

UNE Price % Increase	Actual	Calibrated	15%	% over actual	30%	% over actual
<i>Average Number of Lines Over Periods T = 2 to T = 7</i>						
ILEC	355	355	361	1.9%	368	3.9%
CATV	986	986	1,037	5.1%	1,088	10.2%
CLEC-F	4	4	7	70.3%	10	140.5%
CLEC-L	83	83	74	-11.0%	65	-22.0%
Total	1,428	1,428	1,479	3.6%	1,531	7.2%
<i>Average ARPL Over Periods T = 2 to T = 7</i>						
ILEC	\$40.12	\$40.12	\$45.40	13.1%	\$50.68	26.3%
CATV	\$38.71	\$38.70	\$43.98	13.6%	\$49.26	27.3%
CLEC-F	\$40.12	\$40.12	\$45.40	13.1%	\$50.68	26.3%
CLEC-L	\$40.12	\$40.12	\$45.40	13.1%	\$50.68	26.3%

UNE Price % Decrease	Actual	Calibrated	15%	% under actual	30%	% under actual
<i>Average Number of Lines Over Periods T = 2 to T = 7</i>						
ILEC	355	355	348	-1.9%	341	-3.9%
CATV	986	986	936	-5.1%	885	-10.2%
CLEC-F	4	4	2	-64.7%	1	-88.3%
CLEC-L	83	83	92	11.0%	101	22.0%
Total	1,428	1,428	1,377	-3.6%	1,328	-7.0%
<i>Average ARPL Over Periods T = 2 to T = 7</i>						
ILEC	\$40.12	\$40.12	\$34.84	-13.2%	\$29.57	-26.3%
CATV	\$38.71	\$38.70	\$33.42	-13.6%	\$28.15	-27.3%
CLEC-F	\$40.12	\$40.12	\$34.84	-13.2%	\$29.57	-26.3%
CLEC-L	\$40.12	\$40.12	\$34.84	-13.2%	\$29.57	-26.3%

EXHIBIT 3. TEXAS: VOICE AND DATA MARKET COMBINED SUMMARY OF AVERAGE RESULTS OVER PERIODS 2 THROUGH 7 (SERVICE LINES IN 1000S).

UNE Price % Increase	Actual	Calibrated	15%	% over actual	30%	% over actual
<i>Average Number of Lines Over Periods T = 2 to T = 7</i>						
ILEC	9,836	9,836	10,281	4.5%	10,726	9.1%
CATV	712	712	798	12.1%	884	24.2%
CLEC-F	140	140	175	25.1%	210	50.1%
CLEC-L	879	879	686	-21.9%	493	-43.9%
Total	11,566	11,566	11,939	3.2%	12,313	6.5%
<i>Average ARPL Over Periods T = 2 to T = 7</i>						
ILEC	\$36.98	\$36.98	\$50.62	36.9%	\$64.26	73.8%
CATV	\$38.26	\$38.26	\$51.90	35.6%	\$65.54	71.3%
CLEC-F	\$36.98	\$36.98	\$50.62	36.9%	\$64.26	73.8%
CLEC-L	\$36.98	\$36.98	\$50.62	36.9%	\$64.26	73.8%

UNE Price % Decrease	Actual	Calibrated	15%	% under actual	30%	% under actual
<i>Average Number of Lines Over Periods T = 2 to T = 7</i>						
ILEC	9,836	9,836	9,390	-4.5%	8,945	-9.1%
CATV	712	712	625	-12.1%	539	-24.2%
CLEC-F	140	140	105	-25.1%	70	-50.1%
CLEC-L	879	879	1,071	21.9%	1,264	43.9%
Total	11,566	11,566	11,192	-3.2%	10,818	-6.5%
<i>Average ARPL Over Periods T = 2 to T = 7</i>						
ILEC	\$36.98	\$36.98	\$23.34	-36.9%	\$9.70	-73.8%
CATV	\$38.26	\$38.26	\$24.62	-35.7%	\$10.98	-71.3%
CLEC-F	\$36.98	\$36.98	\$23.34	-36.9%	\$9.70	-73.8%
CLEC-L	\$36.98	\$36.98	\$23.34	-36.9%	\$9.70	-73.8%

EXHIBIT 4. TEXAS: DATA MARKET SUMMARY OF AVERAGE RESULTS OVER PERIODS 2 THROUGH 7 (SERVICE LINES IN 1000S).

UNE Price % Increase	Actual	Calibrated	15%	% over actual	30%	% over actual
<i>Average Number of Lines Over Periods T = 2 to T = 7</i>						
ILEC	439	439	449	2.4%	460	4.9%
CATV	600	600	629	4.8%	657	9.5%
CLEC-F	4	4	7	67.1%	9	134.2%
CLEC-L	76	76	67	-11.2%	59	-22.3%
Total	1,119	1,119	1,152	3.0%	1,186	6.0%
<i>Average ARPL Over Periods T = 2 to T = 7</i>						
ILEC	\$40.12	\$40.12	\$44.70	11.4%	\$49.29	22.8%
CATV	\$38.71	\$38.70	\$43.29	11.8%	\$47.87	23.7%
CLEC-F	\$40.12	\$40.12	\$44.70	11.4%	\$49.29	22.8%
CLEC-L	\$40.12	\$40.12	\$44.70	11.4%	\$49.29	22.8%

UNE Price % Decrease	Actual	Calibrated	15%	% under actual	30%	% under actual
<i>Average Number of Lines Over Periods T = 2 to T = 7</i>						
ILEC	439	439	428	-2.4%	417	-4.9%
CATV	600	600	572	-4.8%	543	-9.5%
CLEC-F	4	4	2	-58.7%	1	-82.0%
CLEC-L	76	76	84	11.2%	93	22.3%
Total	1,119	1,119	1,086	-3.0%	1,054	-5.8%
<i>Average ARPL Over Periods T = 2 to T = 7</i>						
ILEC	\$40.12	\$40.12	\$35.54	-11.4%	\$30.95	-22.9%
CATV	\$38.71	\$38.70	\$34.12	-11.8%	\$29.54	-23.7%
CLEC-F	\$40.12	\$40.12	\$35.54	-11.4%	\$30.95	-22.9%
CLEC-L	\$40.12	\$40.12	\$35.54	-11.4%	\$30.95	-22.9%

REFERENCES

- Aron, Debra J., "The effects of below-cost TELRIC-based UNE prices on CLEC and ILEC Investment," *LECG report*, January 2004.
- Banc of America Securities. (2003a) *Free Cash Flow, Revisited: What Does the New Capex Detail Reveal?*, April 2003.
- Banc of America Securities. (2003b) *Broadband Brief: DSL Economics, Game Theory and What Happens to Broadband Pricing Next*, September 2003.
- Bass, Frank A., "A New Product Growth Model for Consumer Durables." *Management Science*, 1969. Vol. 15, No. 5: 215-227.
- Clarke, Richard, Kevin Hassett, Zoya Ivanova, Laurence Kotlikoff, "Assessing the Economic Gains from Telecom Competition," *NBER Working Paper 10482*, May 2004.
- Credit Suisse First Boston. *The Broadband Battle: Are Stable ARPL and Net Adds Sustainable for the Cable Industry?*, June 2004.
- Distaso, Walter, Paolo Lupi and Fabio Manenti, "Platform Competition and Broadband Uptake: Theory and Empirical Evidence from the European Union," working paper, April 2005.
- Ericson, Richard, and Ariel Pakes, "Markov Perfect Industry Dynamics: A Framework for Empirical Work," *The Review of Economic Studies*, 1995. Vol. 62: 53-82.
- Federal Communications Commission. *In the Matter of Unbundled Access to Network Elements (WC Docket No. 04-313) and Review of the Section 215 Unbundling Obligations of Incumbent Local Exchange Carriers (CC Docket No. 01-338)*. Order on Remand. Adopted December 15, 2004; Released February 4, 2005.
- Federal Communications Commission. *Automated Reporting Management Information System (ARMIS)*, Industry Analysis and Technology Division, Wireline Competition Bureau, 2004.
- Federal Communications Commission. (2004)(a) *Local Telephone Competition: Status as of December 31, 2003*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: June 2004.
- Federal Communications Commission. (2004)(b) *High-Speed Services For Internet Access: Status as of December 31, 2003*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: June 2004.
- Federal Communications Commission. (2003)(a) *Local Telephone Competition: Status as of June 30, 2003*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: December 2003.

Federal Communications Commission. (2003)(b) *Local Telephone Competition: Status as of December 31, 2002*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: June 2003.

Federal Communications Commission. (2003)(c) *High-Speed Services For Internet Access: Status as of June 30, 2003*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: December 2003.

Federal Communications Commission. (2003)(d) *High-Speed Services For Internet Access: Status as of December 31, 2002*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: June 2003.

Federal Communications Commission. (2002)(a) *Local Telephone Competition: Status as of June 30, 2002*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: December 2002.

Federal Communications Commission. (2002)(b) *Local Telephone Competition: Status as of December 31, 2001*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: July 2002.

Federal Communications Commission. (2002)(c) *Local Telephone Competition: Status as of June 30, 2001*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: February 2002.

Federal Communications Commission. (2002)(d) *High-Speed Services For Internet Access: Status as of June 30, 2002*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: December 2002.

Federal Communications Commission. (2002)(e) *High-Speed Services For Internet Access: Status as of December 31, 2001*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: July 2002.

Federal Communications Commission. (2002)(f) *High-Speed Services For Internet Access: Status as of June 30, 2001*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: February 2002.

Federal Communications Commission. (2001)(a) *Local Telephone Competition: Status as of December 31, 2000*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: May 2001.

Federal Communications Commission. (2001)(b) *High-Speed Services For Internet Access: Status as of December 31, 2000*, Industry Analysis and Technology Division, Wireline Competition Bureau. Released: August 2001.

Gregg, Billy Jack, *A Survey of Unbundled Network Element Prices in the United States*, Updated January 2004. <www.cad.state.wv.us/Une%20Page.htm>

Gregg, Billy Jack, *A Survey of Unbundled Network Element Prices in the United States*, Updated July 1, 2003. <www.cad.state.wv.us/Une%20Page.htm>

Gregg, Billy Jack, *A Survey of Unbundled Network Element Prices in the United States*, Updated January 1, 2003. <www.cad.state.wv.us/Une%20Page.htm>

Gregg, Billy Jack, *A Survey of Unbundled Network Element Prices in the United States*, Updated July 1, 2002. <www.cad.state.wv.us/Une%20Page.htm>

Gregg, Billy Jack, *A Survey of Unbundled Network Element Prices in the United States*, Updated January 1, 2002. <www.cad.state.wv.us/Une%20Page.htm>

Gregg, Billy Jack, *A Survey of Unbundled Network Element Prices in the United States*, Updated July 1, 2001. <www.cad.state.wv.us/Une%20Page.htm>

Gregg, Billy Jack, *A Survey of Unbundled Network Element Prices in the United States*, Updated April 2001. <www.cad.state.wv.us/Une%20Page.htm>

Hoffler, Felix, "Cost and Benefits from Infrastructure Competition: Estimating Welfare Effects from Broadband Access Competition," Max Planck Institute, Bonn, January 2005.

Ibbotson Associates, *Cost of Capital 2002 Yearbook*. Statistics for SIC 4813 (Telephone communications except Radiophone), 2002.

International Telecommunication Union, "Promoting Broadband: the Case of Japan," ITU: Geneva, 2003.

International Telecommunication Union, "Asia-Pacific Telecoms Indicators: 2004," v. 25, ITU: Geneva, 2004.

International Telecommunication Union, ITU Internet Reports 2004: The Portable Internet, www.itu.int/portableinternet, "Fixed Line Broadband: Top 15, Broadband subscribers per 100 inhabitants, 1 January 2004," 2004.

Ismail, Sherille, and Irene Wu, "Broadband Internet Access in OECD: A Comparative Analysis," Federal Communications Commission OSPP Staff Report, 2003.

Jenkins, Mark, Paul Liu, Rosa Matzkin, and Daniel McFadden, "The Browser Wars – Econometric Analysis of Markov Perfect Equilibrium Markets with Network Effects." *Paper presented at the International Industrial Organization Conference, Northwestern University, April 23-24, 2004.*

Kydland, Finn, "Noncooperative and Dominant Player Solutions in Discrete Dynamic Games". *International Economic Review*, 1975. Vol. 16, No. 2: 321-335.

Lee, Choongok and Sylvia M. Chan-Olmsted, "Competitive Advantage of Broadband Internet: a Comparative Study between South Korea and the United States. *Telecommunications Policy*, 2004. Vol. 28, No. 9/10: 649-677.

Maskin, Eric and Jean Tirole, "A Theory of Dynamic Oligopoly. I: Overview and Quantity Competition with Large Fixed Costs," *Econometrica*, 1988a. Vol. 56: 549-569.

Maskin, Eric and Jean Tirole, "A Theory of Dynamic Oligopoly. II: Price Competition, Kinked Demand Curves, and Edgeworth Cycles," *Econometrica*, 1988a. Vol. 56: 549-569.

New Paradigm Resources Group, Inc., *CLEC Report 2004: Competitive Last Mile Providers*, 18th Edition, 2004.

New Paradigm Resources Group, Inc., *CLEC Report 2003: Competitive Last Mile Providers*, 17th Edition, 2003.

New Paradigm Resources Group, Inc., *CLEC Report 2002: Competitive Last Mile Providers*, 16th Edition, 2002.

New Paradigm Resources Group, Inc., *CLEC Report 2001: Competitive Last Mile Providers*, 15th Edition, 2001.

Organisation for Economic Co-operation and Development. OECD Key ICT Indicators, *Broadband subscribers per 100 inhabitants in OECD countries*, Source: OECD Communications Outlook 2005 (forthcoming), June 2004. <http://www.oecd.org>.

Organisation for Economic Co-operation and Development. *Working Party on Telecommunication and Information Services Policies, The Development of Broadband Access in OECD Countries*, October 29, 2001. <http://www.oecd.org>.

Pakes, Ariel and Paul McGuire, "Computing Markov-Perfect Nash Equilibria: Numerical Implication of a Dynamic Differentiated Product Market," *The RAND Journal of Economics*, 1994. Vol. 25: 55-589.

Pakes, Ariel and Paul McGuire, "Stochastic Algorithms, Symmetric Markov Perfect Equilibrium, and the "Curse of Dimensionality," *Econometrica*, 2001. Vol. 69: 1261-1281.

Reynolds, Stanley, "Capacity Investment, Pre-emption and Commitment in an Infinite Horizon Model," *International Economic Review*, 28:1, 1987, 69-88.

Reynolds, Stanley, "Dynamic Oligopoly with Capacity Adjustment Costs," *Journal of Economics Dynamics and Control*, 15, 1991, 491-514.

Rodini, Mark, Michael Ward and Glenn Woroch, "Going Mobile: Substitution between Fixed and Mobile Access," *Telecommunications Policy*, 27 (2003), 457-476.

Securities and Exchange Commission. *10-K Filings*, 2003. <http://www.edgarpro.com>.

Willig, Robert, William Lehr, John Bigelow and Stephen Levinson, "Stimulating Investment and the Telecom Act of 1996," Draft, Oct. 11, 2002.

Wood, Lisa V., William P. Zarakas, and David E. M. Sappington, "Wholesale Pricing and Local Exchange Competition," *Info*, 2004, Vol. 6, No. 5: 318-325.

Woroch, Glenn A., "Local Network Competition," chapter in *Handbook of Telecommunications Economics*, Martin Cave, Sumit Majumdar and Ingo Vogelsang, editors, North-Holland/Elsevier, 2002.

Woroch, Glenn A., "Open Access Rules and Equilibrium Broadband Deployment," appeared in *Frontiers of Broadband, Electronic and Mobile Commerce*, edited by Gary Madden and Russel Cooper, Physica-Verlag, 2004.

Appendix A

**TABLE A-1. FCC VOICE AND DATA SERVICE LINES FOR MASS MARKET BY STATE:
DECEMBER 2000-2003 ^{(1),(2)}**

Voice Lines: Texas					
Semi-Annual Period	ILEC Voice Lines	CLEC-Owned Voice Lines	CLEC-Leased Voice Lines⁽³⁾	CATV Voice Lines	Total Voice Lines
<i>Dec 2000</i>	10,253,633	106,726	436,137	41,503	10,838,000
<i>Jun 2001</i>	9,815,153	128,487	580,282	74,898	10,598,820
<i>Dec 2001</i>	9,893,811	148,691	699,408	91,669	10,833,580
<i>Jun 2002</i>	9,422,118	146,228	850,347	117,794	10,536,487
<i>Dec 2002</i>	9,260,398	132,240	851,424	124,149	10,368,211
<i>Jun 2003</i>	9,074,170	133,541	928,787	128,435	10,264,932
<i>Dec 2003</i>	8,916,242	125,761	907,071	131,205	10,080,279

Data Lines: Texas					
Semi-Annual Period	ILEC Data Lines	CLEC-Owned Data Lines	CLEC-Leased Data Lines	CATV Data Lines	Total Data Lines
<i>Dec 2000</i>	177,515	3,015	57,284	182,820	420,634
<i>Jun 2001</i>	204,079	3,300	62,701	279,565	549,645
<i>Dec 2001</i>	310,483	2,871	54,543	380,620	748,517
<i>Jun 2002</i>	360,028	3,177	60,368	516,611	940,185
<i>Dec 2002</i>	461,352	4,116	78,202	660,863	1,204,532
<i>Jun 2003</i>	561,179	4,809	91,363	808,061	1,465,412
<i>Dec 2003</i>	735,613	5,623	106,846	955,452	1,803,534

Total Lines: Texas					
Semi-Annual Period	ILEC Total Lines	CLEC-Owned Total Lines	CLEC-Leased Total Lines	Cable Total Lines	Total Lines
<i>Dec 2000</i>	10,431,149	109,741	493,421	224,324	11,258,635
<i>Jun 2001</i>	10,019,232	131,787	642,983	354,463	11,148,466
<i>Dec 2001</i>	10,204,294	151,562	753,952	472,289	11,582,097
<i>Jun 2002</i>	9,782,146	149,405	910,715	634,406	11,476,672
<i>Dec 2002</i>	9,721,750	136,356	929,626	785,011	11,572,743
<i>Jun 2003</i>	9,635,349	138,349	1,020,150	936,495	11,730,344
<i>Dec 2003</i>	9,651,854	131,384	1,013,917	1,086,657	11,883,813

**TABLE A-1. FCC VOICE AND DATA SERVICE LINES FOR MASS MARKET BY STATE:
DECEMBER 2000-2003 (CONTINUED)^{(1),(2)}**

Voice Lines: New York					
Semi-Annual Period	ILEC Voice Lines	CLEC-Owned Voice Lines	CLEC-Leased Voice Lines⁽³⁾	Cable Voice Lines	Total Voice Lines
<i>Dec 2000</i>	7,345,189	277,498	1,061,517	50,218	8,734,421
<i>Jun 2001</i>	6,981,882	317,460	1,204,656	87,348	8,591,346
<i>Dec 2001</i>	7,016,608	317,519	1,151,024	96,243	8,581,394
<i>Jun 2002</i>	6,870,516	275,300	1,251,049	115,251	8,512,116
<i>Dec 2002</i>	6,607,825	151,639	1,344,616	130,941	8,235,021
<i>Jun 2003</i>	6,274,214	132,974	1,670,572	141,028	8,218,789
<i>Dec 2003</i>	6,187,893	107,861	1,808,184	153,454	8,257,392

Data Lines: New York					
Semi-Annual Period	ILEC Data Lines	CLEC-Owned Data Lines	CLEC-Leased Data Lines	Cable Data Lines	Total Data Lines
<i>Dec 2000</i>	137,190	2,272	43,159	305,199	487,820
<i>Jun 2001</i>	202,603	3,457	65,679	467,022	738,761
<i>Dec 2001</i>	295,385	3,184	60,498	669,794	1,028,861
<i>Jun 2002</i>	330,904	4,001	76,020	806,893	1,217,818
<i>Dec 2002</i>	385,006	4,492	85,344	1,280,795	1,755,637
<i>Jun 2003</i>	415,176	5,040	95,766	1,212,442	1,728,424
<i>Dec 2003</i>	498,065	5,949	113,034	1,481,808	2,098,857

Total Lines: New York					
Semi-Annual Period	ILEC Total Lines	CLEC-Owned Total Lines	CLEC-Leased Total Lines	Cable Total Lines	Total Lines
<i>Dec 2000</i>	7,482,379	279,769	1,104,676	355,416	9,222,241
<i>Jun 2001</i>	7,184,485	320,917	1,270,335	554,370	9,330,107
<i>Dec 2001</i>	7,311,993	320,703	1,211,522	766,037	9,610,255
<i>Jun 2002</i>	7,201,419	279,301	1,327,069	922,144	9,729,934
<i>Dec 2002</i>	6,992,831	156,131	1,429,961	1,411,735	9,990,658
<i>Jun 2003</i>	6,689,391	138,014	1,766,338	1,353,470	9,947,213
<i>Dec 2003</i>	6,685,958	113,810	1,921,218	1,635,263	10,356,249

(1) Source: Voice Lines - FCC, "Local Telephone Competition."

Data Lines - FCC, "High-Speed Services for Internet Access."

(2) Mass Market is defined as Residential and Small Business.

(3) CLEC-Leased Voice Lines do not include UNE-L lines for voice service.

TABLE A-2. CAPEX REGRESSION RESULTS BY PROVIDER

Regression Results for ILEC Capex Estimate
Random-effects GLS Regression

SUMMARY OUTPUT

<i>Regression Statistics</i>	
R-Square within	0.449
R-Square between	0.835
R-Square overall	0.681
Observations	315

Group variable (i): ilec

	<i>Coefficients</i>	<i>Standard Error</i>	<i>z Stat</i>	<i>P > z </i>
Intercept	13635.810	22080.360	0.620	0.537
Switches	-57.364	156.166	-0.370	0.713
Inc. Switches	-445.169	2196.390	-0.200	0.839
Fiber	-11.679	3.304	-3.530	0.000
Inc. Fiber	211.552	27.560	7.680	0.000
Access Lines	0.108	0.112	9.640	0.000
Inc. Access Lines	0.821	0.155	5.300	0.000
sigma_u	46348.288			
sigma_e	90246.737			
rho	0.209 (fraction of variance due to u_i)			

Capex Per Access Line = 0.821 * 1000 = \$821

Regression Results for CATV Capex Estimate
Random-effects GLS Regression

SUMMARY OUTPUT

<i>Regression Statistics</i>	
R-Square within	0.012
R-Square between	0.704
R-Square overall	0.165
Observations	39

Group variable (i): catv

	<i>Coefficients</i>	<i>Standard Error</i>	<i>z Stat</i>	<i>P > z </i>
Intercept	72448.220	42089.620	1.720	0.085
Inc. Access Lines	0.678	0.333	2.040	0.042
sigma_u	65800.732			
sigma_e	171634.680			
rho	0.128 (fraction of variance due to u_i)			

Capex Per Access Line = 0.678 * 1000 = \$678

TABLE A-2. CAPEX REGRESSION RESULTS BY PROVIDER (CONTINUED)

Regression Results for CLEC-F Capex Estimate
Random-effects GLS Regression

SUMMARY OUTPUT

<i>Regression Statistics</i>	
R-Square within	0.324
R-Square between	0.756
R-Square overall	0.471
Observations	38

Group variable (i): une-f

	<i>Coefficients</i>	<i>Standard Error</i>	<i>z Stat</i>	<i>P > z </i>
Intercept	52416.270	53115.530	0.990	0.324
Inc. Access Lines	0.765	0.149	5.140	0.000
sigma_u	102399.020			
sigma_e	212379.160			
rho	0.189 (fraction of variance due to u_i)			

Capex Per Access Line = 0.765 * 1000 = \$765

Regression Results for CLEC-L Capex Estimate
OLS Regression

SUMMARY OUTPUT

<i>Regression Statistics</i>	
R Square	0.089
Adjusted R Square	0.073
Root MSE	690000
Observations	58

ANOVA

	<i>df</i>	<i>SS</i>
Regression	1	2614100000000
Residual	56	26757000000000
Total	57	29371000000000

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P > t </i>
Intercept	213195.600	98772.580	2.160	0.035
Inc. Access Lines	0.334	0.143	2.340	0.023

Capex Per Access Line = 0.334 * 1000 = \$334

**TABLE A-3. OPERATING EXPENSES AS A PERCENTAGE OF REVENUE BY STATE:
DECEMBER 2000 – 2003 ⁽¹⁾**

Operating Expenses as % of Revenue: Texas						
Semi-Annual Period	ILEC	CATV	CLEC-F	CLEC-L ⁽²⁾		
	All	All	All	Voice ⁽³⁾	Data ⁽⁴⁾	Combined
Dec 2000	45.3%	60.6%	78.7%	25.0%	45.9%	27.5%
Jun 2001	45.4%	61.9%	77.6%	25.0%	46.3%	27.2%
Dec 2001	45.6%	63.3%	76.6%	25.0%	46.7%	26.6%
Jun 2002	46.7%	62.7%	75.2%	25.0%	43.8%	26.3%
Dec 2002	47.9%	62.1%	73.8%	25.0%	40.7%	26.4%
Jun 2003	49.5%	62.3%	72.4%	25.0%	33.5%	25.8%
Dec 2003	51.1%	62.5%	71.0%	25.0%	24.0%	24.9%

Operating Expenses as % of Revenue: New York						
Semi-Annual Period	ILEC	CATV	CLEC-F	CLEC-L ⁽²⁾		
	All	All	All	Voice ⁽³⁾	Data ⁽⁴⁾	Combined
Dec 2000	45.3%	60.6%	78.7%	25.0%	44.4%	25.8%
Jun 2001	45.4%	61.9%	77.6%	25.0%	44.8%	26.1%
Dec 2001	45.6%	63.3%	76.6%	25.0%	45.3%	26.1%
Jun 2002	46.7%	62.7%	75.2%	25.0%	49.9%	26.5%
Dec 2002	47.9%	62.1%	73.8%	25.0%	47.0%	26.4%
Jun 2003	49.5%	62.3%	72.4%	25.0%	40.9%	25.9%
Dec 2003	51.1%	62.5%	71.0%	25.0%	32.8%	25.5%

(1) Source: ILEC Opex, FCC ARMIS Data. Cable and CLEC Opex, Company Financial Statements (10-Ks).

(2) CLEC-L Opex = SG&A + Total COGS - UNE-P/L rate. CLEC calculations assume SG&A = 25%.

Note that the UNE rate is a component of COGS, so the opex calculation is not a true reflection of CLEC-L's total opex.

(3) Voice Opex = SG&A.

For voice, Total COGS is equal to the UNE-P rate, so these terms drop out of the equation in Footnote 2.

(4) Data Opex = SG&A + Total COGS - UNE-L Rate.

In December 2003, our estimate for Total COGS is less than the UNE-L Rate as a % of Revenue in Texas.

Thus, the Opex estimate is slightly below SG&A.

TABLE A-4. UNE PRICES BY STATE: DECEMBER 2000 – 2003⁽¹⁾

UNE Prices: Texas			
Semi Annual Period	UNE-P Rate	UNE-L Rate	Combined UNE Rate
<i>Dec 2000</i>	\$19.17	\$14.15	\$18.78
<i>Jun 2001</i>	\$19.17	\$14.15	\$18.83
<i>Dec 2001</i>	\$19.17	\$14.15	\$18.93
<i>Jun 2002</i>	\$19.17	\$14.15	\$18.92
<i>Dec 2002</i>	\$19.17	\$14.15	\$18.88
<i>Jun 2003</i>	\$18.63	\$14.15	\$18.35
<i>Dec 2003</i>	\$18.63	\$14.15	\$18.32

UNE Prices: New York			
Semi Annual Period	UNE-P Rate	UNE-L Rate	Combined UNE Rate
<i>Dec 2000</i>	\$20.06	\$14.81	\$19.90
<i>Jun 2001</i>	\$20.06	\$14.81	\$19.85
<i>Dec 2001</i>	\$20.06	\$14.81	\$19.87
<i>Jun 2002</i>	\$15.19	\$11.49	\$15.02
<i>Dec 2002</i>	\$15.19	\$11.49	\$15.03
<i>Jun 2003</i>	\$15.19	\$11.49	\$15.03
<i>Dec 2003</i>	\$15.19	\$11.49	\$15.02

(1) Source: Billy Jack Gregg (NRRI), "A Survey of Unbundled Network Elements in the U.S."

TABLE A-5. AVERAGE REVENUE PER LINE (ARPL) BY STATE: DECEMBER 2000-2003⁽¹⁾⁽²⁾

ARPL: Texas									
Semi-Annual Period	Voice ARPL (2)			Data ARPL			Combined ARPL (3)		
	ILEC	CLEC	Cable MSO	ILEC	CLEC	Cable MSO	ILEC	CLEC	Cable MSO
Dec 2000	\$33.65	\$33.65	\$33.65	\$44.07	\$44.07	\$36.09	\$33.88	\$33.88	\$35.46
Jun 2001	\$34.44	\$34.44	\$34.44	\$44.42	\$44.42	\$36.92	\$34.68	\$34.68	\$36.21
Dec 2001	\$34.40	\$34.40	\$34.40	\$44.76	\$44.76	\$37.75	\$34.72	\$34.72	\$36.85
Jun 2002	\$36.66	\$36.66	\$36.66	\$43.45	\$43.45	\$38.34	\$36.91	\$36.91	\$37.94
Dec 2002	\$36.65	\$36.65	\$36.65	\$42.13	\$42.13	\$38.93	\$36.91	\$36.91	\$38.43
Jun 2003	\$36.66	\$36.66	\$36.66	\$36.04	\$36.04	\$39.74	\$36.63	\$36.63	\$39.15
Dec 2003	\$42.97	\$42.97	\$42.97	\$29.95	\$29.95	\$40.55	\$42.06	\$42.06	\$40.98

ARPL: New York									
Semi-Annual Period	Voice ARPL (2)			Data ARPL			Combined ARPL (3)		
	ILEC	CLEC	Cable MSO	ILEC	CLEC	Cable MSO	ILEC	CLEC	Cable MSO
Dec 2000	\$41.19	\$41.19	\$41.19	\$44.07	\$44.07	\$36.09	\$41.24	\$41.24	\$36.98
Jun 2001	\$42.02	\$42.02	\$42.02	\$44.42	\$44.42	\$36.92	\$42.08	\$42.08	\$37.91
Dec 2001	\$42.01	\$42.01	\$42.01	\$44.76	\$44.76	\$37.75	\$42.10	\$42.10	\$38.47
Jun 2002	\$38.79	\$38.79	\$38.79	\$43.45	\$43.45	\$38.34	\$38.97	\$38.97	\$38.41
Dec 2002	\$38.84	\$38.84	\$38.84	\$42.13	\$42.13	\$38.93	\$38.98	\$38.98	\$38.92
Jun 2003	\$38.79	\$38.79	\$38.79	\$36.04	\$36.04	\$39.74	\$38.66	\$38.66	\$39.62
Dec 2003	\$42.92	\$42.92	\$42.92	\$29.95	\$29.95	\$40.55	\$42.21	\$42.21	\$40.84

(1) Source: Voice - See Billy Jack Gregg. Data - See Credit Suisse First Boston.

(2) Combined ARPL calculated as a weighted average of Voice and Data ARPLs in proportion to their respective line counts.

Appendix B

TABLE B-1. NEW YORK: VOICE AND DATA MARKET COMBINED SUMMARY OF RESULTS FOR PERIOD 7 (SERVICE LINES IN 1000S).

UNE Price % Increase	Actual	Calibrated	15%	% over actual	30%	% over actual
<i>Number of Lines At Period T = 7</i>						
ILEC	6,686	6,686	6,898	3.2%	7,111	6.4%
CATV	1,635	1,635	1,765	7.9%	1,895	15.9%
CLEC-F	114	114	130	14.2%	146	28.4%
CLEC-L	1,921	1,921	1,723	-10.3%	1,524	-20.7%
Total	10,356	10,356	10,516	1.5%	10,676	3.1%
<i>ARPL At Period T = 7</i>						
ILEC	\$42.21	\$42.21	\$51.08	21.0%	\$59.95	42.0%
CATV	\$40.84	\$40.83	\$49.71	21.7%	\$58.58	43.4%
CLEC-F	\$42.21	\$42.21	\$51.08	21.0%	\$59.95	42.0%
CLEC-L	\$42.21	\$42.21	\$51.08	21.0%	\$59.95	42.0%

UNE Price % Decrease	Actual	Calibrated	15%	% under actual	30%	% under actual
<i>Number of Lines At Period T = 7</i>						
ILEC	6,686	6,686	6,474	-3.2%	6,261	-6.4%
CATV	1,635	1,635	1,505	-7.9%	1,375	-15.9%
CLEC-F	114	114	98	-14.2%	82	-28.4%
CLEC-L	1,921	1,921	2,120	10.3%	2,319	20.7%
Total	10,356	10,356	10,197	-1.5%	10,037	-3.1%
<i>ARPL At Period T = 7</i>						
ILEC	\$42.21	\$42.21	\$33.34	-21.0%	\$24.47	-42.0%
CATV	\$40.84	\$40.83	\$31.96	-21.7%	\$23.09	-43.5%
CLEC-F	\$42.21	\$42.21	\$33.34	-21.0%	\$24.47	-42.0%
CLEC-L	\$42.21	\$42.21	\$33.34	-21.0%	\$24.47	-42.0%

**TABLE B-2. NEW YORK: DATA MARKET SUMMARY OF RESULTS FOR PERIOD 7
(SERVICE LINES IN 1000S).**

UNE Price % Increase	Actual	Calibrated	15%	% over actual	30%	% over actual
<i>Number of Lines At Period T = 7</i>						
ILEC	498	498	519	4.1%	539	8.3%
CATV	1,482	1,482	1,571	6.0%	1,660	12.0%
CLEC-F	6	6	13	116.8%	20	233.7%
CLEC-L	113	113	96	-15.2%	79	-30.4%
Total	2,099	2,099	2,198	4.7%	2,298	9.5%
<i>ARPL At Period T = 7</i>						
ILEC	\$29.95	\$29.95	\$36.56	22.1%	\$43.18	44.2%
CATV	\$40.55	\$40.55	\$47.16	16.3%	\$53.78	32.6%
CLEC-F	\$29.95	\$29.95	\$36.56	22.1%	\$43.18	44.2%
CLEC-L	\$29.95	\$29.95	\$36.56	22.1%	\$43.18	44.2%

UNE Price % Decrease	Actual	Calibrated	15%	% under actual	30%	% under actual
<i>Number of Lines At Period T = 7</i>						
ILEC	498	498	477	-4.1%	457	-8.3%
CATV	1,482	1,482	1,393	-6.0%	1,304	-12.0%
CLEC-F	6	6	0	-100.0%	0	-100.0%
CLEC-L	113	113	130	15.2%	147	30.4%
Total	2,099	2,099	2,000	-4.7%	1,908	-9.1%
<i>ARPL At Period T = 7</i>						
ILEC	\$29.95	\$29.95	\$23.33	-22.1%	\$16.72	-44.2%
CATV	\$40.55	\$40.55	\$33.93	-16.3%	\$27.32	-32.6%
CLEC-F	\$29.95	\$29.95	\$23.33	-22.1%	\$16.72	-44.2%
CLEC-L	\$29.95	\$29.95	\$23.33	-22.1%	\$16.72	-44.2%

TABLE B-3. TEXAS: VOICE AND DATA MARKET COMBINED SUMMARY OF RESULTS FOR PERIOD 7 (SERVICE LINES IN 1000S).

UNE Price % Increase	Actual	Calibrated	15%	% over actual	30%	% over actual
<i>Number of Lines At Period T = 7</i>						
ILEC	9,652	9,652	9,990	3.5%	10,328	7.0%
CATV	1,087	1,087	1,181	8.6%	1,275	17.3%
CLEC-F	131	131	152	15.7%	173	31.5%
CLEC-L	1,014	1,014	850	-16.1%	687	-32.2%
Total	11,884	11,884	12,173	2.4%	12,463	4.9%
<i>ARPL At Period T = 7</i>						
ILEC	\$42.06	\$42.06	\$51.79	23.1%	\$61.53	46.3%
CATV	\$40.98	\$40.98	\$50.72	23.7%	\$60.45	47.5%
CLEC-F	\$42.06	\$42.06	\$51.79	23.1%	\$61.53	46.3%
CLEC-L	\$42.06	\$42.06	\$51.79	23.1%	\$61.53	46.3%

UNE Price % Decrease	Actual	Calibrated	15%	% under actual	30%	% under actual
<i>Number of Lines At Period T = 7</i>						
ILEC	9,652	9,652	9,314	-3.5%	8,975	-7.0%
CATV	1,087	1,087	993	-8.6%	899	-17.3%
CLEC-F	131	131	111	-15.7%	90	-31.5%
CLEC-L	1,014	1,014	1,177	16.1%	1,341	32.2%
Total	11,884	11,884	11,594	-2.4%	11,305	-4.9%
<i>ARPL At Period T = 7</i>						
ILEC	\$42.06	\$42.06	\$32.32	-23.2%	\$22.59	-46.3%
CATV	\$40.98	\$40.98	\$31.25	-23.8%	\$21.51	-47.5%
CLEC-F	\$42.06	\$42.06	\$32.32	-23.2%	\$22.59	-46.3%
CLEC-L	\$42.06	\$42.06	\$32.32	-23.2%	\$22.59	-46.3%

TABLE B-4. TEXAS: DATA MARKET SUMMARY OF RESULTS FOR PERIOD 7 (SERVICE LINES IN 1000S).

UNE Price % Increase	Actual	Calibrated	15%	% over actual	30%	% over actual
<i>Number of Lines At Period T = 7</i>						
ILEC	736	736	771	4.8%	806	9.6%
CATV	955	955	1,022	7.0%	1,089	14.0%
CLEC-F	6	6	13	135.6%	21	271.1%
CLEC-L	107	107	86	-19.1%	66	-38.1%
Total	1,804	1,804	1,893	5.0%	1,982	9.9%
<i>ARPL At Period T = 7</i>						
ILEC	\$29.95	\$29.95	\$37.62	25.6%	\$45.30	51.2%
CATV	\$40.55	\$40.55	\$48.22	18.9%	\$55.90	37.8%
CLEC-F	\$29.95	\$29.95	\$37.62	25.6%	\$45.30	51.2%
CLEC-L	\$29.95	\$29.95	\$37.62	25.6%	\$45.30	51.2%

UNE Price % Decrease	Actual	Calibrated	15%	% under actual	30%	% under actual
<i>Number of Lines At Period T = 7</i>						
ILEC	736	736	700	-4.8%	665	-9.6%
CATV	955	955	889	-7.0%	822	-14.0%
CLEC-F	6	6	0	-100.0%	0	-100.0%
CLEC-L	107	107	127	19.1%	148	38.1%
Total	1,804	1,804	1,716	-4.8%	1,634	-9.4%
<i>ARPL At Period T = 7</i>						
ILEC	\$29.95	\$29.95	\$22.27	-25.6%	\$14.60	-51.3%
CATV	\$40.55	\$40.55	\$32.87	-18.9%	\$25.20	-37.9%
CLEC-F	\$29.95	\$29.95	\$22.27	-25.6%	\$14.60	-51.3%
CLEC-L	\$29.95	\$29.95	\$22.27	-25.6%	\$14.60	-51.3%