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AN ANALYSIS OF THE RESIDENTIAL DEMAND FOR ACCESS TO THE TELEPHONE NETWORK

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AN ANALYSIS OF THE RESIDENTIAL DEMAND
FOR ACCESS TO THE TELEPHONE NETWORK

by

Donald Jack Kridel

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and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

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> This ain't no party, this ain't no disco,
> This ain't no fooling around,
> No time for dancing, or lovey dovey,
> I ain't got time for that now.

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ABSTRACT

Universal service is the focal point of the economic dilemma faced by the telecommunications industry. The advent of competition spurred by several regulatory rulings is forcing rates towards economic costs. It is feared that this movement or the erosion of the toll-to-local subsidy with concomitant increases in local prices severely threatens the concept of universal service. To adequately address these fears, accurate elasticity of demand estimates for telephone access are required.

This thesis develops estimates of these demand elasticities for access. These estimates are derived consistently from an underlying theory of demand for access. Furthermore, the simultaneous access and class-of-service choice problems are addressed similarly. This consistent development facilitates model usage and interpretation. For example, the model provides the best available estimate for the size of the network externality.

Taking into account the underlying demand theory and acknowledging the problems associated with the aggregated nature of the data set (census tract data from 1980 Census), a modified probit technique is developed to estimate the demand model. The estimation methodology is implemented using an iterative least square procedure. To analyze the reasonableness of the algorithm and procedure, a Monte Carlo study is performed. In addition, a jackknife technique is

employed to estimate variances of coefficients when the standard measures are unavailable.

The model results are used to analyze the effect of current policy decisions. For example, for a proposed doubling of access prices the demand for access elasticity is found to be quite small, about -.04. A welfare analysis is performed to discuss the costs and benefits associated with moving to cost-based rates. This analysis also provides the basis for rate recommendations to facilitate the transition to competition while attempting to preserve the concept of universal service.

CHAPTER ONE

INTRODUCTION

The telecommunications industry is at once going through a very difficult transition and heretofore unseen public scrutiny and awareness. Since the announcement of the breakup of the Bell System in early 1982, volumes have been written on the industry. The divestiture of the Bell Operating Companies (BOCs) by American Telephone and Telegraph (AT&T) was the largest corporate divorce in history. Some lauded the divestiture as the coming of the new era in telecommunications, e.g., competition in some services, more efficient pricing, etc. Others concentrated on the negatives of the split -- the end of one-stop shopping, AT&T's seeming advantages and the disadvantages of the BOCs, etc. Nonetheless all thought the coming changes unprecedented in the industry.

The item that attracted the most attention, however, was the Federal Communications Commission's Access Charge Plan. While the interstate carriers (primarily AT&T) were to pay subsidy laden rates to the BOCs for access to the customers or end-users, the Access Charge Plan was intended to shift this burden to the customers over some transition period. Thus, the customer was to pay a Carrier Access Line Charge or CALC (later to become End User Common Line Charge or EUCL and later still the Subscriber Line Charge or SLC) to have access to a long distance carrier. The plan met criticism almost immediately. First, the name picked by the FCC can be described as poor at best. The immediate reaction was that it was unfair to pay for access to a carrier if access was not required, e.g., if a particular end-user did not use the toll network. Of course, the EUCL (the name we'll use for the rest of the thesis) had nothing to do with paying for access to a toll carrier. In fact, it was merely a transitional mechanism to shift costs back to the cost-causers. That is to say, the FCC viewed the EUCL as a way to end the well known toll-to-local subsidy.

The second, and the more important criticism directed towards the EUCL plan, was that this shifting of burden would destroy universal service. Suddenly, all emphasis was shifted toward the protection of this oft-cited but rarely defined concept. The typical definition (from the 1934 Communications Act) is "... to make available, so far as possible, to all people of the United States a rapid efficient nation-wide and worldwide wire and radio communications service with adequate facilities at reasonable charges." This definition, however, lends little guidance for policy makers. As a result, the definition for public policy seems to have evolved into today's telephone development or penetration rate. In other words, the development rate we observe today is universal service -- anything lower is not. Obviously, such a discrete definition does not lend itself to public choices that involve costs and benefits. This is especially important given the relative importance that universal service has received in the regulatory proceedings. For example, if a proposed rate design offered very large benefits in toll markets for a small decrease in telephone development, then one would hope that the benefits would be compared with costs and the optimal choice made. However, since this small reduction in development is interpreted to "destroy" universal service, the trade-off between costs and benefits is never adequately evaluated. The status quo is simply chosen and universal service is protected.

This myopic view, however, is being threatened. As described in more detail in the next chapter, competitive market forces are beginning to erode this toll-to-local subsidy. As this subsidy is reduced, either through transitional regulatory schemes similar to EUCLs or through the intervention of competition, local rates will be forced to increase. It should be no surprise that local service (or access) like all other economic goods reacts to price. The degree of this response or the price elasticity should be a key input to regulatory decisions in the industry. In particular, we can see that these elasticities will also be useful by subscriber group. For example, the elasticity of demand for poverty stricken households would be more important to regulators than the price responsiveness of affluent suburbanites. It is the major aim of this study to provide sound estimates of these price elasticities. In particular, we are concerned with developing these elasticity estimates consistently from underlying economic theory.

While there were estimates of price elasticities available (see survey in Chapter Three), these, for one reason or another, were judged to be deficient or not applicable for the situation facing Southwestern Bell Telephone Company (SWBT). A model was needed that could be used by SWBT in filings in the five states that it serves. Studies from areas other than those served by SWBT were not satisfactory for this purpose. The only studies available for general use were an internal SWBT pooled time-series cross-section regression model and the Perl (1983) study. While Chapter Three provides detailed discussions about the technical strengths and weaknesses of these models, introductory comments are required here since they provide an important basis for undertaking our study. The SWBT pooled model was judged deficient since it provided only aggregate price response, e.g., subscriber group responses were unavailable. Aside from the technical weaknesses discussed in the third chapter, the Perl (1983) model was judged deficient since it did not address all subscriber groups of interest in SWBT (e.g., Hispanics and American Indians). Furthermore, there was a political uncertainty surrounding the acceptance by SWBT regulators of the Perl study. This controversy centered around the sponsorship and use of the two Perl studies. The initial Perl (1978) study was commissioned by AT&T and was used in the Justice Department antitrust suit to show that universal service would be severely handicapped by breaking up the Bell System. The 1983 study which yielded lower elasticity estimates was commissioned by Bell Communications Research (BCR) -- a Bell Labs type research organization wholly owned by the divested BOCs. The latter Perl study was used to show that divestiture and associated price changes posed no significant threat to universal service. This apparent contradiction was not lost on regulators.

In addition to the elasticity estimates, our study provides a somewhat unique cost-benefit analysis of a prominent pricing strategy.

The analysis is based on simple welfare calculations well-known to economists. While these have been prepared before, we attempt to discuss the costs from a policy makers perspective. In particular, these costs or reductions in development are split into three mutually exclusive groups. The effects on these groups and responsive price proposals are then addressed. This analysis is detailed in the last section of Chapter Seven.

At this point, it is instructive to move on. The rest of the study will be presented as follows. We begin by providing a brief history of the industry in Chapter Two. In this section, we provide a glimpse at industry pricing historically. We then discuss the key regulatory rulings and their effect. Additionally, the role of technological innovation in the change of industry structure is noted. Chapter Three reviews the existing empirical studies of access demand. This chapter provides a brief discussion of access and a survey of empirical demand studies. We survey the most prominent theories of demand for telephone access in Chapter Four. Using these studies as background, a theory of demand for access to the network is then developed. Using this theory as a starting point, Chapter Five describes the data and details the estimation methodology employed. Model validation is provided in Chapter Six. This testing concentrates on the importance of key model assumptions and includes a comparison of predictions with other research. Chapter Seven provides the model results, i.e., the estimated price responsiveness of access demand. In addition, a welfare analysis based on our model results is provided in the chapter. Ultimately, our contribution will be judged on the results presented in this chapter. Chapter Eight culminates with our conclusions and suggestions for future research. Four appendices follow the final chapter. Appendix A describes estimation problems when using ordinary least squares with discrete data. A brief description of maximum likelihood estimation -- the technique typically used with discrete data -- is also provided. In addition, the problem of predicting with discrete choice models is discussed. Appendix B is a technical appendix that describes our estimation algorithm, Monte Carlo studies, and jackknife techniques. Appendix C contains the original linear probability model, predictions with the model, and a brief discussion of the problems with these predictions. Finally, Appendix D describes an updated version of the SWBT pooled time-series cross-section model discussed in the third chapter.

CHAPTER TWO

A BRIEF HISTORY OF TELECOMMUNICATIONS PRICING

The American telecommunications industry has been and may continue to be a highly regulated industry. The FCC regulates the interstate portion of the industry. This primarily involves setting the rates for interstate toll, WATS, and now interstate access charges. Various state regulatory agencies have responsibility for the intrastate portion of the business. Typically, the state Public Utility Commission sets intrastate toll, WATS, basic exchange rates and now intrastate access charges.

In its infancy, telecommunications was a local service. As long-distance services and system interconnection became a reality, revenues from multi-company services had to be divided. Additionally, the industry was regulated at both the national and state level. The telephone industry developed a system of "separations and settlements" to share these revenues. Each company separated its local exchange costs or revenue requirement into intrastate and interstate. These cost allocations were the basis of the allocation of revenue via the carriers' settlements process.

Prior to 1943, each telephone company recovered its subscriber plant costs (SPC) from its own subscribers. In 1943, the separations process was changed to allocate a portion of SPC to the interstate jurisdiction. The allocation was initially based on relative use, since about 3% of total use was interstate toll then 3% of SPC was allocated to the interstate jurisdiction regulated by the FCC. This "relative use" method was used until 1952 when it was replaced by weighted relative use. This weight is called the subscriber plant factor (SPF), and its current value is approximately 3.3. Thus, the portion allocated to interstate is 3.3 times the current relative use. The increases in relative use and SPF have led to dramatic increases in the portion of costs allocated to the interstate jurisdiction.[1] This in turn causes interstate rates to be higher in order to recover these "costs" or more accurately revenue requirements.

During this same period, the communications industry had been in the midst of a technological revolution. The technology gains were simply a small part of the overall electronic/computer revolution spurred by the invention of the transistor in 1947 by AT&T Bell Labs. Microwave transmission, increased multiplexing of channels, coaxial cable, direct dialing and other advances significantly reduced the cost of telecommunications. For example, the cost of providing long-distance channels declined from about $33 per circuit mile in the late 1950s to less than $4 by the late 1970s or a nominal (real) savings of about 88% (95%). These cost savings, however, were highly skewed toward toll services. Little technological change occurred in the provision of local service.

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1. In 1981, relative use of interstate was 7.9% and hence about 26% of cost was allocated to the interstate jurisdiction. See Johnson, pp. 41, Figure 4.1 for a graphical depiction of the increases in interstate allocation over time.

The skewed technological advances and inflation led to rapid declines in toll costs and increases in local costs. However, the expected declines in toll prices and increases in local prices never occurred. The increased allocation of costs to the interstate jurisdiction via an increasing SPF prevented the expected price changes. As the economic costs of providing toll service declined, the "costs" used for ratemaking were increasing. The prices set to cover regulatory costs were well above the economic costs. Subsequently, large windfalls were produced and used to subsidize local service. This subsidy allowed the price of local service to stay well below its economic cost. It is important to note the vital role of technological innovation in this process. Had innovation not occurred, toll rates would have had to have been increased dramatically to generate the huge subsidy. The incredible technological breakthroughs, however, allowed the regulatory process to simply keep toll rates from falling as quickly as economic pricing principles dictated. In the end, the economic inefficiencies are identical. Increasing toll rates dramatically, however, would have been considerably less (politically) saleable than the slowing of price reductions that actually occurred. Technology eased the burden on the regulator. Unfortunately for the regulator, the technological innovation also ended some barriers-to-entry and paved the way for competitive entry, e.g., microwave radio ended the right-of-way constraint.

Until the late 1950s phone service was provided by a regulated monopolist. The industry was characterized by value-of-service pricing, substantial rate-averaging, huge cross-subsidies and the residual pricing of local service (access). Value-of-service pricing is simply the act of pricing higher for the services or areas with the "highest" value. It is ironic that a regulatory system designed to protect consumers from monopolist pricing should engage in this behavior. This concept was used to price urban services above rural services and support high prices on "luxury" goods, e.g., long-distance service. Rate-averaging was also widespread. The rates for similar services were the same regardless of the cost. For example, a 15-mile interstate toll call had the same price regardless of geography and density.

Perhaps, most importantly, cross-subsidization was a fact of life in the industry. The well-known toll-to-local subsidy was the largest and most visible. The residual pricing of local made this easy operationally. By separating "costs" into interstate and intrastate and determining rate of return and total expense, the intrastate revenue requirement was determined. For all services but local, revenue requirements were then determined by the state commission. Prices were set to recover these "costs" on a service-by-service basis. The difference between the total intrastate revenue requirement and the sum of these service-by-service revenues had to be recovered residually from local. Dividing this difference by the number of residential access lines yielded the price of local.service.[2] Obviously, this resultant price need not have any relationship to the economic cost of

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2. Actually a value-of-service notion was used here as well. Exchange Access Agreements (EAAs) determined the actual number of lines in the local calling area and hence, the larger the EAA, the higher the assigned price.

providing local service. The system also provided a simple mechanism to prevent local rate increases, e.g., reduce allowed expenses, reduce allowable rate of return, or increase revenue requirement on other services (usually toll).

The common pricing policies also led to many other examples of cross-subsidization as well. Since local service was almost uniformly flat-rate (i.e., local usage was priced at zero), large local users were subsidized by small local users. The value-of-service pricing of local service led to the subsidization of rural subscribers by urban subscribers and of residential users by business users. The practice of rate-averaging also led to urban-to-rural transfers and high-density toll rates supporting low-density routes. While cross-subsidization and departures from marginal cost pricing led to losses of economic efficiency, the monopolistic industry structure prevented any kind of market induced response, i.e., competitive entry. The monopolist essentially had complete control over all phases of providing telephone service. Furthermore, the existence of the monopoly obviated the need for the regulators to rule on the fairness of any one price - total rate of return was the only concern. Over the next several years, however, several FCC decisions and/or court rulings allowed competitive responses in several key parts of the telecommunications industry.

In 1948, Hush-A-Phone requested permission from the FCC to sell its noise-reducing cup-like device without interference from the telephone company. Seven years later the FCC ruled against Hush-A-Phone. Upon appeal, however, the FCC decision was reversed. The ruling established that the telephone company had no right to restrict private uses of the telephone as long as no other subscribers were harmed. Perhaps, more importantly, it signalled the start of the competitive intrusion into the sanctuary that the monopolist telephone company had heretofore enjoyed.

The Carterfone was the next competitive challenge to the Bell System. Introduced shortly after the AT&T tariff response to the Hush-A-Phone decision, the FCC informed Carter that its product did not violate commission guidelines but violated the AT&T tariff. Carter responded by filing an antitrust suit against AT&T. The court passed the issue back to the FCC. In 1966, the FCC began investigating the Carterfone. Finally, in 1968 the FCC ruled that the Carterfone violated the AT&T tariff but that the tariff was illegal. The FCC decision allowed connections but enabled AT&T to establish standards which would provide protection for the network. The decision was the first fracture in the total monopoly control that AT&T had enjoyed. While seemingly an innocuous decision to allow consumers to interconnect the Carter device, the decision allowed customers the freedom to attach terminal equipment (e.g., private branch exchanges or PBXs) to the network with only minimal protection standards outlined by AT&T. Since the PBX is essentially a small switching machine, the decision allowed privately owned sub-networks to attach directly to the main telephone network.

In the late 1950s, there was increased demands for point-to-point communication services. The FCC's Above 890 decision in 1959 that allowed private communication networks was another significant crack in the monopoly power of the Bell System. AT&T moved swiftly to reduce its private-line rates. Western Union charged that AT&T was subsidizing its private line rates from toll revenues. To address the legality of AT&T's new Telpak rates, the commission had to consider specific rate and cost data to determine if cross-subsidization was occurring. After over twenty years of proceedings, the Telpak tariffs were withdrawn in 1980. The length of regulatory lag clearly indicated the inability of the regulators to deal with the cross-subsidization issue.

In 1963, Microwave Communications Inc. (MCI) sought FCC approval to provide private-line services between St. Louis and Chicago. The MCI filing and subsequent filings by other specialized common carriers (SCCs) were a direct result of the burgeoning new technologies, especially microwave transmission capabilities. The microwave capability enabled the SCCs to avoid the use of cable which required right-of-way. After eight years of regulatory controversy costing MCI $10 million, MCI connected St. Louis and Chicago in seven months for $2 million. Despite attempts by AT&T to block the MCI application on the basis that the new "creamskimmers" would not be in the best interests of its customers, the FCC felt that MCI (and subsequently other SCCs) would provide new, innovative services not provided by AT&T. Despite its coincidental inability to deal with the Telpak tariffs, the FCC assumed it would be able to deal with the AT&T price response. AT&T responded with a series of de-averaged tariffs - lower rates on higher density routes. As of 1982, some of these tariffs were still being investigated for lawfulness.

As pointed out by Brock (1986) the total impact of the Carterphone and MCI rulings was much greater than the sum of its parts.

The combination allowed MCI's private line network to be connected to local switched network through a PBX. MCI's microwave facilities became another switched network that could be accessed by any telephone through the PBX. MCI called the "shared private line service" Execunet. The FCC initially rejected the MCI offering but was overturned by the Appeals Court. The compromise that surfaced--between restructuring all local/toll rates and violating the court order--was the creation of Exchange Network Facilities for Interstate Access or ENFIA tariffs. The ENFIA tariff allowed some competitive entry but essentially maintained the huge toll-to-local subsidy.

The FCC decided in 1972 to allow competition in the domestic satellite industry. In an attempt to deal with the presumed response of AT&T, the FCC preempted the response by prohibiting AT&T from offering private-line service over its satellite system for three years. Apparently, the commission finally realized that it was ill-equipped to address the critical cross-subsidy issue. Satellites tapped a new market - video distribution for cable networks - something not accomplished by either the Above 890, MCI or SCC decisions.

These decisions left both AT&T and the commission in uncomfortable positions. Heretofore a monopolist, AT&T suddenly was losing market share in the services where the majority of its profits were earned. This required a movement of rates towards cost - a reasonable competitive response. Unfortunately, this is the same response an anti-competitive monopolist would make in attempting to crush new competitors, i.e., predatory pricing. AT&T had to devise rates to thwart its loss of market share and yet, defend these same rates against claims of anti-competitive behavior. The commission was in the unenviable position of attempting to determine whether the AT&T response was competitive or anti-competitive. The length of regulatory lag in previous cases indicates an inability by the commission to deal with these issues. Nonetheless, both AT&T and the FCC seemed dedicated to moving rates towards costs. The state regulators, however, were much more concerned about local rates and were far less dedicated to the movement towards cost-based rates.

Economists (Wenders, 1983 and Kahn, 1982) had long suggested a movement towards cost-based pricing long before the FCC access charge ruling. Marginal cost pricing leads to efficient allocation of resources. Previous studies (Taylor, 1980) have demonstrated that the elasticities for toll services are as much as 10 times larger than the elasticities associated with local service. Hence, the huge welfare gains introduced with the lowering of toll prices would dominate the relatively small welfare losses associated with the increases in local prices. In fact, Wenders (1983) "conservatively estimated" this welfare loss to be in range of $3-5 billion. Wenders also stated that this amount could easily be tripled over the next five years. The equity issue of who wins and who loses has been largely ignored. The typical position taken is that if society chooses to subsidize some users, then the subsidy should come from outside the industry, say the general tax fund. However, regulators, particularly state regulators, were much more concerned with equity than with efficiency.

The AT&T response to losses in market share (where the majority of its profits were earned) was, in large part, the basis for many of the Justice Department's charges in the antitrust case.[3] During the pending litigation, there continued to be pressure for rates to more accurately reflect costs. It was during this environment that the AT&T divestiture of the BOCs was announced. Prior to January 1, 1984, the industry was dominated by the Bell System. AT&T wholly owned Long Lines which provided interstate toll; Western Electric which produced terminal equipment and switching machinery; Bell Labs which provided basic research; and twenty-two BOCs which provided local service and intrastate toll. Despite serving only about one half of land area of the United States, the Bell System served about 80% of the customers in 1981. The other 20% was served by over 1500 independent telephone companies. The divestiture split the old Bell System into eight parts. AT&T retained the interLATA long distance (Long Lines) market, Bell Labs, and Western Electric. The 22 BOCs were merged into 7 Regional Bell Operating Companies (RBOCs) with local service, intra-LATA toll, and interexchange access their primary markets. The plan was to put AT&T into the competitive arena - toll and terminal products - and to have the RBOCs in the monopoly area - local service. However, this distinction between competitive and non-competitive markets was quickly blurred.

In the post divestiture telecommunications industry, the interexchange carriers (IXCs) buy access (to the local subscriber) from the operating companies. This access may come in the form of switched or special access. The price that the toll carriers pay for switched

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3. See McAvoy and Robinson (1983) for discussion.

access include traffic sensitive (TS) and nontraffic sensitive (NTS) elements. AT&T pays about 8¼¢ per originating and terminating minute for premium switched access. The carrier common line (CCL) charge or NTS portion is about 5¼¢ per minute and generates a subsidy of the same magnitude that was generated in the pre-divestiture world.[4] The TS portion is also averaged and above cost in the densest areas. These deviations from cost create significant windows of vulnerability for the local exchange companies (LECs). On the other hand, special access provides no NTS support. Any toll-user large enough to justify the expense of special access could then avoid the 5¼¢ per minute subsidy. The end-user could avoid paying these subsidies by purchasing special access from the LEC (service bypass) or bypass facilities from an IXC or bypass vender (facilities bypass) to the IXC's point of presence. This process could easily be instigated by the IXC.

These regulation induced pricing deformities give AT&T clear incentives to be the leader in providing bypass systems. AT&T's recent behavior is certainly consistent with the intent to engage in bypass. For example, Tariffs 9, 10 and 11, recently approved by the FCC, enable AT&T to disaggregate access from the toll price. In addition, AT&T's new WATS service (MEGACOM) essentially allows AT&T to bypass on the closed-end of WATS. The removal of the structural separation requirement that allowed the merging of AT&T Information

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4. The rates have changed since 1984 in response to the FCC's current $2 EUCL and other rulings.

Systems and AT&T Communications (old Long Lines) allows AT&T to operate as a single point of contact for would-be bypassers.

Furthermore, until the conversion to equal access, the OCCs purchase non-premium access and pay about 55% of what AT&T pays for premium access. The OCC charge, however, is not usage sensitive. Although based on an estimate of 9000 minutes of use, the usage is actually not measured and hence, is priced at zero on the margin. While the OCCs are not legally entitled by the commissions in most states to provide intraLATA toll, they are technically able and willing to do so. The access charge spread creates significant cost advantages for the OCCs. As end-users switch to the OCCs, the LECs lose the revenue generated from the access charge premium and/or from intraLATA toll. While the availability of equal access may reduce these cost advantages, there is no guarantee that the OCCs will upgrade any or all of their access. If access is upgraded, however, the OCCs will be searching for ways to lower access costs to effectively compete with AT&T. Bypass is an obvious method of achieving this goal.

The access charge premium being levied on a usage sensitive basis on the toll carriers makes avoidance or bypass easy. The NTS portion of 5¼¢ per minute is a huge incentive for large toll users to avoid the charge. Furthermore as discussed, the carriers have equally large incentives to promote this type of bypass. Not only does the bypass arrangement allow the carrier to cut costs but it also provides a mechanism to "lock-up" market share. The carriers and large end-users benefit while the LECs and its remaining customers are the losers. For example, the BCR study estimates SWBT's vulnerability to be in excess of 1.5 billion dollars.[5]

The burgeoning technology make this type of direct connection feasible via microwave, cable, or even satellite. The highly concentrated nature of usage (1% of users make 40% of calls) causes this to be a severe problem even if only a few end-users decide to move to bypass. For example, in his Missouri testimony, Weisman (1986) showed that if the largest 440 firms choose their least cost method of access, that SWBT would lose approximately 68 million dollars.[6] Thus, the perception of the RBOCs functioning in a monopolistic environment is incorrect. Competitive pressures are forcing access charges towards cost as well.

The FCC had originally intended to end the (interstate) subsidy by gradually replacing the NTS portion of the access charge with EUCL charges. This step towards cost-based pricing was made for several reasons. The FCC recognized that the NTS charge being recovered on a per-minute basis gave large end-users and IXCs very strong incentives to avoid these charges. The FCC clearly perceived the risk to the local telephone companies and their respective local residence subscribers. Furthermore, the FCC was strongly supportive of the benefits accruing to competition and cognizant of the welfare

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5. For a detailed discussion of bypass, its implications, expected adoption and regulatory impacts see Weisman and Kridel (1986).

6. The breakdown of least cost access for the largest 440 locations is as follows: 408 bypass; 27 special access or service bypass; and 5 remain on switched access.

losses generated by economically inefficient rates. Additionally, the FCC had historically been isolated from the political ramifications of increasing local rates. This isolation, however, was soon to be removed.

When the state regulators and Congress became involved, however, the emphasis switched away from bypass and cost-based pricing towards universal service. The possibility that large numbers of subscribers, especially the economically disadvantaged, would be forced to give up access to the telephone network received tremendous attention. Consumer groups attempted to direct the debate toward this drop-off and other so-called fairness issues. Due to these political and regulatory pressures, the FCC has delayed significantly its original EUCL plans.[7] As a result, access charges are currently being used to attempt to preserve the status quo, i.e., large subsidies from toll users to local subscribers. As we have stated, however, market forces are already in action to erode this subsidy.

The key unanswered question is where the revenue shortfalls will be recovered. The two choices seem to be additional access charges or increases in local service rates. Using reasonable assumptions Brock (1984) has shown that recovering the revenue shortfalls via increased carrier access charges could lead to a spiral

7. House Bill HR4102 and Senate Bill S. 1660 are examples of legislative action. Both of these bills had previsions to limit or block EUCLs. In fact, in April of 1986 Senator Gore introduced the "Telecommunicaitons Equity Act of 1986". The bill would overturn the $2 EUCL already in place. An example of a consumer group response is provided in the last section of our review in the next chapter.

of increasing access charges leading to additional bypass and the increased bypass revenue loss forcing higher access charges and so on without end, i.e., abandonment of the entire switched network. The BCR study assumed the shortfall was recovered from local increases of about $10.20/residence line. Both these studies strongly suggest that ultimately recovery will come from end-users, particularly residence customers.

The industry now finds itself at a crossroads.[8] If the subsidy continues to be generated from access and toll charges, substantial bypass will occur. Bypass will make the amount of the subsidy required from each non-bypasser larger. This degenerative process is not in the best interests of the industry or the consumers. On the other hand, increases in local access rates are political poison to the telephone companies as well as the regulators. Clearly, a reasonable first step towards a solution is an increased understanding of the effects of price changes on telephone development, especially for certain politically important groups. With this discussion as a historical backdrop, we turn to this task presently by beginning our survey of available elasticity estimates.

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8. Other regulatory issues are also of concern. The new competitive environment will lead to faster depreciation rates. It will also put pressure on the LECs to "write-off" economically over valued plant. These changes will also tend to put upward pressure on local prices.

CHAPTER THREE

A REVIEW OF EMPIRICAL TELEPHONE ACCESS STUDIES

In this chapter we will review the existing literature on empirical access demand studies. Before turning to the survey, we will briefly describe the concept of access. The literature review will begin with a synopsis of Taylor's comprehensive 1980 study. All subsequent references to Taylor in this chapter, will refer to the 1980 study. We will only consider the American analyses surveyed by Taylor paying particular attention to the Perl study. After this synopsis we will proceed by discussing several studies completed since Taylor's 1980 study. In particular, we will discuss a pooled time-series cross-section model developed at Southwestern Bell and the new 1983 Perl study. This will conclude our discussion of econometric telephone access demand studies. We will then turn our attention to three studies that are non-econometric in nature. We will comment on the Gordon and Haring FCC study, and on the new trend in LEC-provided studies called drop-off or disconnect studies. Finally, we will conclude the section by briefly addressing a study prepared by a consumer group.

The definition of access to the telephone network is not used uniformly in the industry. Access seemingly is simply defined as having the ability to use the network. This "ability" to access the network, however, is less clear. For example, the 1970 Census used "within the building unit" as access, e.g., a phone in the hall of an apartment would provide access to all dwellers in the apartment. In contrast, the 1980 census specifically queries about the existence of a telephone "in your living quarters". In Arkansas Docket U-3117 the Arkansas Attorney General has argued that coin phones are substitutes for residence access and hence, in some sense, provide access. Consumer groups have suggested that access includes the ability to use unlimited local calling at no charge, i.e., flat-rate pricing provides access but that measured service may not. This notion in conjunction with the widely held notion that universal service is today's development level puts added pressure on the regulatory process. A reasonable response to upward pressure on prices while maintaining some notion of universal service would be to offer lower-priced or lower-grade services. Regulatory approval on these alternatives has been slow, however. In fact, the Texas Commission currently has a moratorium on measured service.

In addition to these industry definitions of access, it seems that there may well be some private notion as well. In particular, we could think of an individual or individual household that has never had phone service. We might expect that this individual would have little or no phone use. Alternatively, we might consider a household that has had telephone service for a long period of time. Now for whatever reason let's assume the household foregoes telephone service. It seems likely, perhaps as a result of habit, that this individual would have strong ties to phone use. That is, we might expect this person to maintain some degree of access by using coin phones or his neighbor's phone quite frequently. This suggests an asymmetry of access depending on the individuals past telephone related behavior. The difficulty in defining access makes these pricing issues even more difficult to analyze. From this point forward, we will use the term access as it is used in the 1980 Census, but will note when the specific definition used could have modeling or planning implications. At this point, however, we shall turn to our discussion of these access studies.

3.1 Econometric Telephone Access Studies

We begin our review of existing studies by summarizing the Taylor findings in Table 3.1. The table provides the basic results and the data set employed in each study.. We will briefly address the Alleman and Feldman studies and then plunge into the Perl study in more detail. In regard to the Alleman paper, Taylor (1980, pp. 72) summed it up best by saying "Alleman's analysis, however, is disappointing, for the theoretic structure that is carefully built up in the early chapters of the study is ignored almost entirely in the empirical chapters." Alleman's dependent variable was telephones per capita. An equation of the following simple form was estimated

$$T/N = a + b_1 p^* + b_2 Y/N ,$$

where

T/N is telephones per capita

p^* is the price variable

Y/N is per capita income.

Table 3.1[a]

Access Elasticity Estimates as of 1980

		Price Elasticity		
Author	Dependent Variables	Service Connection	Basic Service	Income Elasticity
Alleman[b]	main stations	-NA-	-.17	.56
Feldman[c]	main stations	-NA-	-.05	.54
Perl[d]	telephone development	-.02	-.08	.15
Taylor[e]	-NA-	-.03 (±.01)	-.10 (±.09)	.50 (±.10)

a. These results are culled from Taylor (1980) Table 3.1, pp. 80 and Table 5.1, pp. 170.

b. Alleman uses cross-sectional data from the 1970 U.S. Census on 312 cities.

c. Feldman uses cross-sectional data for the 48 states from the fourth quarter of 1973. A separate equation for extensions was estimated.

d. Perl uses cross-sectional data from the 1970 U.S. Census for individuals (1/1000 Public Use Sample).

e. Reflects Taylor's interpretation of his reviewed studies and "was thus highly subjective."

The functional form chosen was log-log. Alleman estimated two models: (1) for flat-rate areas only (this result appears in Table 3.1); and (2) for measured-rate areas only. The price elasticity estimate in the second equation was insignificant. We agree with the "disappointing" label attached by Taylor, but feel obliged to point out that the quality of the data set must be partially blamed.

The Feldman study was a much larger undertaking: thirty-six different categories of service were studied. Here, however, we are concerned only with the residential access section. Feldman explained main telephones by using the local price, state population, per capita personal income and regional dummy variables. Price, however, is measured by average revenue per main station. As discussed by Taylor, this is a poor measure for at least the following three reasons: (1) mains appear on both sides of the equation; (2) variations in quality will be represented in local revenues, e.g., single vs. multi-party service; and (3) local revenue will include charges for custom calling features, terminal products, and local use in measured areas. The key point here is that (Taylor, 1980, pp. 73) "the measure of price should only record shifts in the underlying tariff structure, not movements along it." Aside from the measurement problem, price is statistically insignificant in the Feldman equation (the t-statistic is only 0.9). In addition to the empirical difficulties, very little theoretic structure is provided: there is but 22 pages of text to describe the results presented in 200 plus pages.

The Perl study was estimated on 1970 census data for over 35,000 households. The variable to be explained is basically whether or not the individual household has access to the telephone system - which in aggregate is merely telephone development. Perl uses this variable as the left-hand-side of the equation and economic and demographic characteristics as the independent variables. Perl estimates three different functional forms: (1) linear probability model; (2) logit model; and (3) probit model. Letting $z = x\beta$, the estimating equations for these models may be written as

$$\text{Prob(access}|x) = z + e \tag{3.1}$$

$$\text{Prob(access}|x) = \frac{1}{1 + \exp(-z)} + e \tag{3.2}$$

$$\text{Prob(access}|x) = (2\pi\sigma^2)^{-\frac{1}{2}} \int \exp(-z^2/2\sigma^2)dz + e. \tag{3.3}$$

Perl estimated equation 3.1 with ordinary least squares (OLS) and equations 3.2 and 3.3 with maximum likelihood estimation (MLE). See Appendix A for more details on these estimating techniques. The independent variables were the monthly service price, the service connection charge, a dummy variable for measured service availability, income, age, education, household size, employment indicator, black indicator, male household head without spouse indicator, single person male household indicator, single person female household indicator, a dummy variable for households in the South, and a dummy variable for non-farm areas.

Perl adjusts the monthly service charge in an attempt to measure the minimum charge the household faces. Perl claims that the positive correlation between income and demand would obscure the relationship between price and demand in the estimating equation.

This price strategy has two major problems: (1) using averages; and (2) interpretation of the income-adjusted price as a minimum price.

First, the average prices are obtained from one hundred Revenue Accounting Offices (RAOs). Thus, in Oklahoma, for example, there are fifteen distinct rates based on the number of phones in the local-calling area, but only one RAO. Obviously, there is a high degree of aggregation or mapping error. Texas provides an extreme example of this error since until the state commission was formed in 1976 each locality had its own set of rates.

Perl uses the following equation to income adjust the monthly service price:

$$\pi_i = a_i + b_i M_{ij},$$

where π_i is the average monthly service charge in RAO_i and M_{ij} is the income of j^{th} individual in RAO_i. Perl then uses the estimate of the constant, a_i, as the adjusted price term. It is not at all clear why the output of the equation has anything to do with the minimum price available, however. It merely increases the variance of the observed price and helps reduce the correlation between price and income.[1] Perl attributes this correlation to higher income people purchasing more expensive access. The real culprit, however, is more likely value-of-service pricing.

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1. Why Perl used income (and only income) is not clear. Inclusion of other variables could change the regression results dramatically. In fact if additional variables were used there is no guarantee that the estimate would even be positive.

The Perl estimates are provided in Table 3.2. The probability of access to the telephone network is positively related to income, age, education, employment, and urban households. Alternatively, the probability of access is negatively related to household size, Southern households, households in non-farm areas, nonwhite households, single person households of both sexes, and male-headed households with no spouse. Of particular importance is the negative coefficient on the measured-service availability indicator.

While most of the signs are correct, two merit discussion. The first and most important is the measured-service availability indicator variable. The Perl result indicates, wrongly we think, that the availability of a lower-priced alternative reduces the probability of access or telephone development. It is difficult to create a story that can explain why this coefficient should be anything but non-negative. Additionally, the household size variable has an incorrect sign. As household size increases the number of users and hence total household benefits increase. It is not clear under what circumstances the sign of this coefficient could be correct.[2]

Despite these difficulties, the Perl study was an important contribution to the existing knowledge. As noted by Taylor, however, there is little theoretic foundation. As a result the critical access/

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2. Even if the additional household member is an infant, casual inspection suggests the effect of a birth is to increase the benefits associated with telephone use (and option demand). Perl uses a declining income per capita argument. However, it would seem expenditures for phone service would more likely be made on a household level. Furthermore, if Perl is correct he is essentially arguing he misspecified the model in the first place.

Table 3.2
1978 Perl Model
Coefficient Estimates

Variable	coefficient	absolute value of t-statistic
Price		
access	-.062	5.4
installation	-.011	2.2
measured service available	-.243	5.3
Household characteristics		
income	.078	12.3
age	.035	19.1
income*age	.0003	2.4
education	.116	22.1
race	-.595	13.2
employment	.234	5.1
household size	-.049	4.1
family HH, no wife	-.624	6.3
single male HH	-1.290	22.1
single female HH	-.190	3.1
Geographic characteristics		
nonfarm area	.355	7.6
South	-.348	7.6
constant	-.910	4.1
# observations:	36,703	
R^2:	.146	

use distinction, the subscriber externality, and the call externality are all but ignored. Nonetheless, many valuable estimates provided by Perl were simply unavailable from any other source, e.g., access elasticities by race, income, etc. Table 3.3 presents representative results for the study. The results clearly indicate that access elasticities vary systematically with certain demographic variables, e.g., income and age.

The 1983 Perl study improved on the 1978 study in many ways. First and foremost is an improvement in the matching of prices from telephone company sources to the socio-demographic data on individuals obtained from the 1980 U.S. Census. While the matching is not perfect and we will address this momentarily, it is significantly improved from the 1978 study. The model better analyzes the effect of prices by including both flat and measured prices. Additionally, in the 1983 study the size of local-calling area and additional household characteristics are considered. Finally, an improved prediction methodology was used in 1983 study. Classification was employed in 1983 while the 1978 study used the average individual methodology (see Appendix A for a discussion of these techniques).

We will begin the discussion by addressing the improved price-to-census mapping. To prevent the possible identification of individuals, the Census provides geographic areas that contain at least 100,000 people. In this case, Perl had 1154 geographic areas. Using telephone company data, he could then derive average prices for each of these areas. We still feel that this aggregation or mapping error associated with merging the Census and telephone company data is

Table 3.3[a]

1978 Perl Model

Response to $1 increase in access price

Age and Income Group	Predicted Development	Change in Development
20 years old		
$ 1,500	63.1	-3.1
$ 7,500	78.9	-2.2
$17,500	94.0	-0.7
35 years old		
$ 1,500	79.8	-2.7
$ 7,500	85.3	-1.7
$17,500	97.1	-0.4
55 years old		
$ 1,500	79.7	-2.1
$ 7,500	90.7	-1.1
$17,500	97.6	-0.3
70 years old		
$ 1,500	84.8	-1.7
$ 7,500	93.5	-0.8
$17,500	98.2	-0.2

[a] Table uses $5.75 as current access price. Results are taken from Perl (1978) Tables 5 and 6.

the primary weakness in the Perl analysis. For example, in rural areas, these "county groups" may include several different counties and rates. This is further exacerbated by the fact that these counties may well contain independent telephone companies that have rates quite different from the serving BOC. Furthermore, even in urban areas there may be several unique rates, e.g., the St. Louis area has three different rates.

The 1983 version of the model includes expanded price variables: the flat-rate price in flat-rate only areas; flat-rate price in choice (flat or measured) areas; the measured price in choice areas; the local-calling price for measured service in choice areas; the installation price; and the proportion of the choice area with measured service available.

In addition to all socio-demographic and geographic variables considered in 1978, Perl also considers the effects of the ages of householders other than the head of household, non-English speaking households, family households without a husband present, four density variables, and the log of number of subscribers in the local calling area.

Perhaps, in response to the Taylor criticism Perl adds some motivational discussion in 1983 paper. The following discussion recaps the provided motivation for the study. A model is developed to predict the log of the odds of telephone development as function of x, i.e.,

$$\log \frac{p}{1-p} = a + bx,$$

where p is the probability of a household subscribing to the network and x is a vector of price and socio-demographic characteristics. The motivation for this form of the equation is given as follows. A consumer will subscribe to the network if the benefits exceed the costs. That is,

$$V_a + CS > \pi,$$

where

V_a is the value of having access, independent of usage

CS is the consumer surplus derived from usage

π is the price of access.

For any household, Perl notes that V_a and CS are functions of income, price, other demographics, and unobserved (presumably taste) characteristics. Consequently, Perl writes[3]

$$g(p,y,x,e) > \pi,$$

where

p is the price of usage

x are measured household characteristics

y is the household income

e is unobserved taste characteristics.

Perl then assumes that g is linear in the unknown parameters, i.e.,

$$a + b_1p + b_2y + b_3x - b_4\pi - e.$$

The probability of access may then be written as

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3. In fact, Perl uses a discount rate to combine the recurring and nonrecurring charges. For our purposes, this makes little difference.

$$\text{Prob (access)} = 1 - \int_{-\infty}^{-k} e \, de,$$

where $k = a + b_1p + b_2y + b_3x - b_4\pi$. Perl then assumes the random taste factor is distributed so that cumulative density is logistic. The access probability may now be written as

$$\text{Prob (access)} = 1/(1 + e^{-k}).$$

Perl then questions the plausibility of his assumptions of the logistically distributed taste parameter and of consumer surplus being linear in parameters. Perl deems the logistic distribution reasonable but the linear-in-parameter consumer surplus assumption to be "more heroic" but "not likely to be critical." Perl's basis for these decisions is unclear. The linear-in-parameters assumption is no more or less heroic than usual, i.e., the variables need not be linear only the coefficients.

The motivation just discussed for the model is also an improvement over the 1978 model. However, the development of the section is quite confusing. The reader is never quite sure where the values of access and consumer surplus come from. A consistent yet easy to understand theoretic development section would have greatly improved the readability and the development of the paper.[4] For example, in choice areas (where both flat and measured service are available) there is no mention of how this service choice is made --

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4. This section could have been written following Taylor (1980) or the random utility approach discussed by McFadden (1986). Either approach would greatly increase the end product.

both prices simply appear in the estimating equation. This ultimately leads to contradictory results, i.e., everything else equal, it is possible that a doubling of rates in choice areas could lead to higher repression or demand response than a doubling of rates in areas with only flat-rate service. Furthermore, we find writing the logit equation as the log of the odds to be misleading since Perl is working with individual data.

Let us now turn to the important part of the paper which is the results and discussion. The database is even better than the 1978 database which Taylor described as having "no peers." Some of the best discussion centers around the changes between the two Census periods (or studies). For example, Table 3.4 compares price elasticities at different telephone development and price levels. The table shows a decline in price elasticity over time which Perl claims is related to the increased value of telephone service in 1980 compared with 1970. Another interesting observation presented in Table 3.5 is the shrinking of the differential of development levels across income groups. While overall development increased nearly 6%, the development among the poorest groups increased nearly 9%. This narrowing is even more impressive when we consider that using different definitions of access in 1970 and 1980 implies that these changes in development are probably even larger than the data indicates. This is an important point to policy makers who are concerned with the poorest segment of the population. In addition to the results displayed, many other important results are discussed, e.g., lifeline introduction impact, externalities, value of telephone service, optimal prices, etc. In

Table 3.4[a]
1983 Perl Model
Price Elasticity Estimates
at Alternative Price and Development Levels

Development	Access Price Flat/Measured	Price Elasticity 1983 Model	Price Elasticity 1978 Model
88.0	10/6	-.065	-.075
	20/16	-.131	-.150
	30/26	-.096	-.225
93.0	10/6	-.038	-.044
	20/16	-.076	-.087
	30/26	-.114	-.131
97.0	10/6	-.016	-.019
	20/16	-.033	-.037
	30/26	-.049	-.056

[a] Taken from Perl (1983) Figure 5. 54% of customers are assumed to have measured service available to them.

Table 3.5[a]

1983 Perl Model

Telephone Development by Income Group

Income Group	Telephone Development 1983	Telephone Development 1978
Below poverty	80.2	71.5
1-2 times poverty	89.8	81.3
2-3 times poverty	93.9	86.9
3-4 times poverty	96.3	90.3
4-5 times poverty	97.4	93.0
5-6 times poverty	98.2	94.7
Above 6 times poverty	99.0	97.6
Entire population	93.4	87.5

[a] Taken from Perl's Figure 11

aggregate the model predicts a 3.8% decline in development for a 100% increase in all access prices. Also, the model estimates that approximately one-fourth of those affected by a price increase are below the poverty level, and an additional 40% are between one and two times the poverty level. These results along with the total repression estimate are critical in any policy discussion about universal service. While all these results are interesting, many are dependent on the quality of the model used to estimate the impacts. We now turn to a discussion of the estimated model.

Table 3.6 presents the results of the Perl estimating equation. All signs of variables included in 1983 model that were also in 1978 model are unchanged except the proportion with measured service available. While insignificant, this is obvious improvement. However, household size still has an incorrect sign. Of the new household variables included all the expected signs with the possible exception of the proportion of the household under six years of age.

We turn our attention now to the geographic variables included. In addition to the non-farm and South indicator variables, included in 1978 study, Perl has added several phone density dummies and the number of lines in the local calling areas (in logs). The inclusion of the latter is straightforward. The reason for including the density variables, however, is not obvious. Unfortunately, the presence of the dummy density variables confuses the interpretation of the number-of-lines variable. Typically, this variable would reflect the network externality. The inclusion of the density variables, however, makes this considerably less obvious. Perl's explanation does

Table 3.6
1983 Perl Model
Coefficient Estimates

variable	coefficient	t-statistics[a]
price variables		
flat rate-only	-.049	4.5
flat rate-choice	-.018	2.5
measured rate-choice	-.041	2.1
usage price	-1.718	1.9
installation price	-.003	1.3
% with measured available	.153	0.8
area characteristics		
nonfarm	.109	2.5
South	-.359	8.2
Density (1-100)	-.205	3.4
Density (1001-2500)	-.252	3.4
Density (2501-5000)	-.219	2.6
Density (5000+)	-.334	3.7
# subscribers	.099	4.9
constant	-1.013	9.5
# of observations:	71,479	
R^2:	.099	

Table 3.6, continued

household characteristics	coefficient	t-statistics[a]
income	.130	20.8
income**2	.001	13.7
age	.045	26.3
age*income	-.0003	2.6
education	.147	26.5
race	-.513	11.2
employment	.387	9.3
household size	-.050	3.3
% 6 yrs.	-.742	6.3
% 6-12 yrs.	.424	2.9
% 65+ yrs.	1.341	6.6
No English	-.392	7.1
English poorly	-.148	1.5
Family, no wife	-.872	10.2
Family, no husband	.116	2.1
Single male HH	-1.244	22.4
Single family HH	.145	2.2

[a]absolute value of t-statistics

little to clear up the mystery. To the best of our understanding the density dummies were significant and hence included.[5]

Nonetheless, we conclude our discussion of the 1983 model similar to Taylor's discussion of the 1978 model. There are problems, some not minor. However, on the national level its the only game in town.

The next model we will discuss is an internal SWBT study. The model is a pooled time-series cross-section model of residence access lines for the SWBT territory. The cross-sections are the 5 SWBT states: Arkansas, Kansas, Missouri, Oklahoma, and Texas. The most recent version of the model is estimated using data from the first quarter of 1972 through fourth quarter of 1983. The model was initially built in 1981 and has usually been updated twice annually. The results have been particularly stable. We include this model since it covers the same territory as the model we will develop in Chapter 5. Since the model was developed for internal and rate case purposes, there was no accompanying write-up in the usual sense and hence lacks theoretical motivation. Nonetheless, the results are quite interesting. As mentioned, the estimation technique was pooled regression. In particular, the least squares dummy variable (LSDV) approach was used.

The model was corrected for autocorrelation within cross-sections, heterosedescity across cross-sections and mutual

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5. This is key due to the poor performance of the model when these dummies are excluded.

(partial) correlation between cross-sections. These correction methodologies associated with estimation are discussed in Kmenta (1971). Dynamic effects were included through the use of polynomial distributed lags (PDLs) on the recurring or access price and on real per capita income. Also included as regressors were population, the non-recurring or connection charge, and seasonal dummy variables. The access price is a typical Lespeyres price index - fixed quantities used with each effective tariff. The non-recurring price was calculated in a similar manner but was turned into a recurring equivalent using a discount factor. The optimal lag structures were found to be second degree PDLs with a six-quarter (or one and one-half year) lag on price and a twelve-quarter (or three year) lag on real per capita income. The functional form estimated was log-log. Hence, the coefficients are directly interpretable as elasticities, i.e., the percentage change in residence access lines can be calculated directly from the percentage change in the variable of interest and its associated estimated coefficient. The results of the SWBT equation are presented in Appendix D. In particular, the appendix outlines the study methodology and provides all coefficient estimates and associated t-statistics.

The following points of interest with respect to this model are: (1) the price of access has been incredibly stable through the updating process, always rounding to -.04; (2) the elasticity is remarkably similar to the Perl elasticity for a 100% increase; and

(3) the recurring or monthly access price is roughly ten times as important as the non-recurring or connection charge. This concludes our discussion of econometric models.[6]

3.2 Non-econometric Studies of Telephone Access

The first of these studies to be discussed is the FCC working paper written by Gordon and Haring (GH). The paper discusses whether or not the pricing reforms suggested by the FCC (primarily the EUCL plan) are a threat to the concept of universal service. The section of the paper we are concerned with is the GH interpretation of econometric studies.

The first point addressed is that all factors -- declining toll rates, increases in income, increases in telephone uses, etc. -- that will dampen the impact of the price increase must be considered. This is certainly true if the goal of universal service is to maintain

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6. Two other econometric studies should be noted before we turn to the non-econometric studies. While not concerned with access, per se, the Train, McFadden, and Ben-Akiva (TMB) and Kling papers merit note here. The TMB analysis is a fully discrete analysis of service choice and usage. The estimation technique is nested logit. The lower nest is service choice. The upper nest is (usage) portfolio choice. The study finds somewhat higher usage elasticities, but these are attributable to switching between services. The Kling analysis is similar in spirit to our analysis in Chapter Five. By maximizing consumer surplus, Kling develops a model that explains the customer's class-of-service choice and usage. The findings here are closer to previous studies (local usage elasticities of about .15). These papers are mentioned since our analysis will, in addition to access, provide some class-of-service choice insight. It is important to note that these studies are based on data sets of service choice and use for telephone subscribers. Our data set includes no choice information. Ideally, we would prefer a data set with both subscriber/non-subscriber and choice and usage information. This would allow us to better understand the relationships between subscription and choice. However, no such data sets exist.

the current level of development. If, however, we are interested in the pure price effect or repression, then the other factors should be separated. This points out the obvious fact that the use of the models is related to the policy question we are attempting to answer. It must be stated that these models -- the Perl model and the model we develop in Chapter 5, for example -- are designed to estimate the price effect and hence, are very difficult to use as a forecasting tool. This difficulty centers around the general unavailability of exogenous data to generate forecasts. In this respect, if we are concerned with development levels before and after a price change, then the GH criticism seems right on target. It would seem, however, that policymakers ought to be concerned with the price effect as well as the ultimate development level.

GH then list several reasons why, in their opinion, that the current set of demand elasticity estimates are biased upwards:

(1) The demand curve is shifting out over time. As a result, distant historical data may tend to overestimate the current access elasticity;

(2) Empirical models are misspecified. In particular, GH are concerned with the use of total charges rather than the charges applicable for access only;

(3) Important independent variables are excluded from empirical models. In particular, the exclusion of toll and equipment concern GH. This may be quite important since currently toll rates and equipment prices are falling drastically compared to historical charges.

Our analysis of the three GH criticisms are as follows: (1) Certainly it is true historically that the demand curve has been shifting outward. However, to the extent that this shift is due to variables included in the model it is not a problem. More important, however, is that outward shift/price falling scenario that was true through the seventies has apparently slowed in the eighties. For example, in SWBT since 1980 the real price increase has been 20% with little or no change in development; (2) This observation is correct. However, none of the models we know of (except Feldman) use this weak specification of prices; and (3) Again the point is theoretically correct but what is important is the magnitude. In the SWBT pooled time-series cross-section model toll prices were considered unsuccessfully. However, in light of the expections of increasing local rates with decreasing toll rates, this criticism should be kept in mind.

The last point (GH, pp. 25) made is that demand is highly inelastic, i.e., "When price increases of the magnitude estimated by the FCC staff are combined with (upwardly biased) demand elasticity estimates close to zero, the result is obviously a negligible effect on the overall level of telephone subscribership." GH support this point by their discussion of the elasticity estimates and by pointing out the price increases will "do little more than 'catchup' with the inflation" of the seventies.

Two points merit discussion here. First, however small the actual price impact is, the political realities, at least at the state level, will <u>never</u> allow it to be considered negligible. Second, data in the GH paper show a 4% increase in development between 1970 and

1980. Some portions of this gain are almost surely attributable to real price falling throughout the decade. It is, therefore, not unreasonable to expect some of this development gain to be lost when the price is allowed to "catchup" to inflation.

We now turn to drop-off or disconnect studies. We will first discuss general weaknesses in the methodology and will follow with a discussion of two drop-off studies performed in SWBT territory.

The basic methodology is to survey customers that are disconnecting their phone service after a local price increase. These customers are asked why they have decided to disconnect. The customers are then sorted by the given response. Those that mentioned the increase in the local price are then counted as drop-offs.

The most critical concern is the issue of what drop-off studies measure. Since only disconnecting customers are considered, these studies offer absolutely no insight into the development level or universal service questions. That is to say, since only disconnecting customers are counted, and counted poorly as we'll see below, no inferences may be made about development levels after the price increase. In light of this, it is difficult to understand why the studies are performed at all. The most obvious reason is to create results that help achieve some political goal.[7]

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7. The so-called Michigan study (FCC, 1983) follows in the same footsteps. The study was prepared in response to a request by the Michigan Public Service Commission to have the FCC evaluate the impact of federal decisions on the price and availability of local telephone service. Not surprisingly, the study concluded that "there is no evidence that federal decisions will cause residential subscribers to discontinue service."

The first and most obvious practical problem is that the studies are attempting to discover "why". For example, we consider an individual who lives in a five hundred dollar apartment, spends one hundred dollars for utilities, and one hundred dollars for commuting to and from work. We will consider all other expenses to be fixed and the individuals budget to be exhausted. Now suppose the individual is hit with an unexpected fifty dollar increase in rent. If it were practical, moving might be the immediate response. Suppose, however, it is impractical and he must pay the rent for some period of time. The individual could cut utility expenses fifty percent by being more uncomfortable or reduce the expenses associated with commuting by taking the bus. Suppose now that after several months the individual moves. We can now ask ourselves the question why did this individual move. In our example, it is easy to identify the rent increase as the reason. If, however, we asked him why he moved many responses are possible: (1) apartment too expensive to heat and cool; (2) apartment too far from work; (3) apartment too far from busline; (4) apartment too large; etc. All these responses may be related to the actual cause of the move and perhaps, all were evaluated after the rent increase. Nonetheless, in our example, the rent increase was the catalyst of the move but a direct survey might not elicit this response from the individual. This is even more critical when there may be incentives not to be truthful about one's motives. These types of questions are difficult to survey accurately even with carefully designed and implemented surveys and survey instruments.

These disconnect studies, however, are most often based on the simple non-scientifically designed questionnaires asked by business office personnel at the time of the disconnect. Add to this, the basic fact that people are very uncomfortable admitting their inability to afford a commodity that most of society deems a necessity. Additionally, a severe timing problem plagues these studies. Typically, the studies are instituted immediately after a price increase and continue for only two to three months. However, as revealed in the SWBT pooled model, these price responses may last 18 months. In his Minnesota rebuttal testimony, Perl states that it may take 2-10 years for the effect to be totally worked out. Obviously only the earliest response would be observed in these studies. The last major practical problem is looseness of responses. For example, many respondents answer the "why" query with I have "no further use". It is unclear as to the meaning implied here. As economists having use for the phone at the old price and having no further use at the new higher price is certainly consistent with a price effect. None of these studies, however, include the category "no further use" in the drop-off counts. In addition, most of these studies are designed with the intent of discovering low drop-off numbers rather than attempting to accurately measure drop-off. This bias may be easily seen in almost all studies of this type. For example, the following quote from a Northwestern Bell study (1985) "Northwestern Bell then is charged with proving that these increases do not cause many low income subscribers to leave the network." leaves little doubt about the desired conclusions.

In light of these generic problems, we turn to two studies performed in SWBT territory. The first of these was performed in Missouri. The survey was instituted following a $2.05 increase effective January 1, 1984. Beginning in March 1984 through March 1985, disconnects were analyzed each month. The reason for disconnect was taken from the business office form at the time of the disconnect.

The thirteen months of data is unusually good for a study of this type. The good news, however, ends here. As is typical, the "no further use" disconnects were excluded from this analysis. Why this was done is unclear, especially when one considers that about 25% of total disconnects are in this category.[8] Obviously, we may be under-counting on a large scale. Additionally, disconnects made by customers that connected after January 1, 1984 were automatically excluded from the analysis. The study supported this exclusion by saying that the customer "...determined later he/she could not afford the service, it is felt that in these cases, the rate increase was not the <u>direct</u> cause of the disconnection." This could obviously be false. The customer obviously determined that the benefits of phone service did not exceed its cost. However, these benefits might have easily exceeded the old price which was $2.05 less. Customers whose bill exceeded $50.00 at disconnection were also excluded. This exclusion was made on the basis that "only those who were affected by the local exchange rates" should be included. However, in the

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8. We must admit, however, that the category is cluttered by its status as depository when no other category seemingly applies.

Washington study (1984), it was found that some customers who had decided to disconnect would run up their toll bill in the last month of service.[9] While perhaps this group is not important in magnitude, this points out the obvious biases of the study methodology, i.e., it is much better not to count someone you should than to count someone you shouldn't.

This bias may also be specifically seen when considering the "worst case examined scenario" of the study (where those with bills greater than $50 are also included). The study claims the purpose of this scenario is to "...compile every possible disconnect attributed to the rate increase". However, at no time is the "no further use" category analyzed. The possibility that some who move may not reconnect at their new location due to the new rate is ignored. The study concludes

> ...No one can legitimately dispute that Universal Service remained unchanged by the rate increase when you consider that in the worst case over 99.75% of our customers were unaffected. ...residence exchange lines increased by over 19,000 during the study period. It would be difficult to state that Universal Service is being threatened when the number of residence customers has consistently increased over the past year.

The first part of the statement might be true, given that one accepts the study's count of customers. However, as we have discussed, the data generated to arrive at the 99.75% figure is hopelessly biased. It should be pointed out that if an opponent took the other extreme in

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9. In contrast to the other drop-off studies, the Washington study generally attempted to carefully count and organize the disconnect data.

using the generated data by including all households in the "no further use" category, one could reach just the opposite conclusion. The second point is nonsensical. Nothing can be said about development or universal service by considering only access lines (the numerator). What happens to households or the denominator is obviously just as important.

We now turn to the second study which was performed in Oklahoma. To call this a study is misleading. It would be more accurate to call it a mission. The objective of the mission is to show price has no effect on access demand. The process was instituted following a $2.27 price increase effective February 13, 1985. Disconnects were analyzed for three months, from February 13 through May 15. All exclusions made in the Missouri study were also made here. This left a count of twenty-three that claimed that the price increase was the cause for disconnection. After personal visits from SWBT personnel twelve of these twenty-three decided that the price increase was not in fact the reason for disconnecting. Furthermore, when the connection charge was waived, five of remaining eleven were subsequently convinced to reconnect to the network. Thus, the study concludes that only six households gave up service due to the $2.27 price increase. It is easy to see that the objective of showing no price response was realized. However, it is also obvious that the results are of no value in addressing whether or not universal service is threatened by local price increases. The bias in the design of the study precludes any usefulness in this regard.

Before we turn to the analysis on the opposite extreme, let us clear up our position on this alleged threat to universal service. We do not believe that universal service is substantially threatened by the transition to cost-based rates. This will be discussed in more detail later. However, we think it imprudent to attempt to dismiss these fears simply to achieve the goal of increased local rates. The regulatory process is incredibly political, but it seems to serve no purpose to produce concocted results. Rather it is important to accurately estimate all costs and benefits associated with the transition. This is particularly important since this transition is likely to involve several rate cases spanning several years. The "missions" that seem so useful now may be very expensive later.

The Consumer Federation of America (CFA) study prepared by Cooper, Kimmelmam, and Gilbert is at the opposite extreme, i.e., maximize the costs of the transition so as to delay or prevent it. The tone of the document is, as might be expected when analyzing consumer group response, quite emotional. Several examples of the tone of the document follow: (1) "Customers have been bombarded with rate increases."; (2) "Paying for dial tone has become a major consumer expense."; (3) "...industry developments threaten to weaken or eliminate competition, robbing consumers of any benefits."; (4) "With customers held captive in local exchange..."; and (5) "These dramatic increases are both unnecessary and inequitable." The study analyzes the first year of the AT&T divestiture. Using data obtained from government sources, CFA analyzes the impact of these local price increases with the 1983 Perl model.

The study cites an average increase of flat rate service of 19%. The increase then causes 4 million people to do without a phone.[10] This "drop-off" is obtained using the Perl model which shows a 1.7% decline in development by mid-1985. What CFA calls drop-off is actually repression, i.e., it is not necessarily customers dropping phone service that had it but may also be customers that would have bought phone service not doing so. Furthermore, the Perl model is cross-sectional -- it says nothing about timing. How the mid-1985 time frame is derived is left unanswered. Perl in his Minnesota testimony had suggested the adjustment period could last from two to ten years. Furthermore, when we run the Perl model with CFA monthly service increases, predicted development falls only .4% or 223,000 households. The discrepancy between these (.4 vs 1.7) is inexplicable. Additionally, we consider the conversion from households to people to be misleading and emotionally and politically motivated. Everything else equal, we would expect smaller households to be more likely than large households to forego telephone service. In the same way, we concluded that drop-off studies were not in the long run best interest of the LECs, we think this effort by the consumer groups to be short-sighted. In fact, FCC Chairman Fowler (1986) has really pointed out the errors of the "so-called consumer groups".

In conclusion, we think it is critical to have a complete understanding of the demand relationship of access. Most of the

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10. The original CFA (Kimmelman and Cooper, 1984) study predicted about 750,000 households or 2 million people.

studies, we have discussed, add positively to our understanding of this issue. However, the LEC drop-off studies, the CFA predictions, and to a much lesser extent the (GH) FCC paper, all seem to be dedicated to achieving some policy goal rather than increasing our understanding. While it is probably naive to expect those in politically sensitive positions to be as apolitical as Wenders is in his 1984 article, it is not unreasonable to expect that the studies help rather than hinder our long-run learning process. We turn now to the development of the theory that will support our empirical model which in turn will continue this educational process.

CHAPTER FOUR

A THEORY OF TELEPHONE ACCESS DEMAND

Early in an economist's training one learns that the demand for a good depends on the price of the good, the prices of substitutes and complements, and the consumer's income. These basic tenets gleaned from neoclassical demand theory are only the starting point for a good empirical study. More direction is required. A specific demand theory that incorporates any novel features of the good to be studied should be developed. The following unique features should be incorporated, at least in principle, into any good empirical telephone demand study: (1) a distinction exists between access to the telephone network and use of it; furthermore, option demand, or the right to make calls that may in fact never be made, might be an important benefit for some subscribers; (2) the value of the network to a (potential) subscriber depends on the number of subscribers connected to the network; (3) calls are jointly consumed; and (4) telephone service is priced on a multi-block tariff schedule. We shall expand briefly on each of these below:

(1) access/use distinction: The value of telephone service is derived from using the network. This usage can take the form of making or receiving calls. Usage, however, is conditional on access. When deciding whether or not to buy access, the price of access is compared to the benefits derived from having access. These benefits

are derived from usage and potential usage or option demand. Hence, these access/usage decisions are closely related;

(2) subscriber externality: The telephone network is comprised of many subscribers. Larger networks offer more calling combinations to subscribers. Therefore, everything else equal, larger networks are more valuable to subscribers than smaller networks. When a potential subscriber is evaluating buying access to the network, the decision affects all other subscribers' welfare as well as his(her) own. The public nature of the decision may suggest departure from the "price equals marginal cost" pricing scheme generally considered optimal;

(3) call externality: An individual making a call necessarily implies that someone else receives the call. The receiver of the call typically benefits from the conversation without paying for it. If callers and "callees" make arrangements for returning calls to one another then this call externality is at least partially controlled by the originating party. Again, this externality could have pricing and welfare implications that should not be ignored;

(4) multi-block tariff: Telephone subscribers pay an installation charge when connecting to the network. A monthly charge for access must be paid to remain connected. In many jurisdictions, the monthly access price also includes unlimited local usage. Finally, the user must pay for any usage not included with monthly access (typically long distance or toll usage). Usage is priced with initial and overtime charges and by distance and time-of-day. Furthermore, these charges are different by type of call, i.e., interstate toll calls are tariffed differently than intrastate or local calls.

Before developing a model of telephone demand theory that addresses these unique features, we will look at some recent contributions of other authors. First, we will look briefly at the work of Artle and Averous (1973) and Rohlfs (1974). Since these papers have a different focus than we do, we will spend little time on these studies and include them mainly for historical completeness. More detailed descriptions of these two papers is provided in Taylor (1980). The third paper to be discussed is that of Squire (1973). While Squire's focus is still different than that in this study, he has much more to say about the particular demand points we consider important. We will, therefore, devote more space to Squire's contributions. Lastly, we consider the work of Taylor. Since this work shares our focus almost exactly we will discuss it much more carefully. Throughout these reviews we will attempt to use consistent notation rather than the notation of each author. After the review, we will forge a model of telephone demand theory which closely follows Taylor that we will use for estimation in the next chapter.

Artle and Averous (AA) consider a total population of N individuals - G_0 without telephones and G_1 with telephones. All individuals in G_1 are assumed to speak with each other over the relevant period of time. AA then define a utility function and the dummy variable

$$U^i = U^i(x^i, q^i)$$

$$q^i = \begin{cases} q & \text{for all } i \text{ in } G_1 \\ 0 & \text{for all } i \text{ in } G_0, \end{cases}$$

where q is the number of telephones. It is assumed that the private goods consumed are the same for all individuals in each set G_i, i.e., all individuals in G_1 consume x^1 and all individuals in G_0 consume x^0. Now, the utility function(s) may be rewritten as

$$U^1 = U^1(x^1,q)$$
$$U^0 = U^0(x^0,0).$$

AA now assume the presence of an omniscient social planner that will care for the population. Further, the planner is given a production possibility frontier (F) and is asked to determine the optimal value of q. AA assume the following social welfare function

$$W = W(qU^1(x^1,q),(N-q)U^0(x^0,0)).$$

Maximizing the social welfare function subject to the given production possibility frontier will then yield the optimal q. The solution to this problem is a simple application of the Lagrangian multiplier technique. Solving the Lagrangian problem yields

$$\left(\frac{U^1}{U^1_x} - \frac{U^0}{U^0_x}\right) + q\,\frac{U^1_q}{U^1_x} = (x^1 - x^0) + \frac{F_q}{F_x},$$

where subscripts refer to partial differentiation.

Leaving the discussion of the terms in parenthesis to Taylor, we note that the two ratios are the marginal rate of substitution (and transformation) terms typically encountered in problems of this sort. Note, however, that the ratio of the utilities is multiplied by q, the number of telephones. This leads us directly to the key point made in AA: access to the telephone network is a public good and hence addresses one of our four unique features of telephone demand.

As pointed out by Taylor (1980), however, the AA analysis has its weaknesses. Use and access are not discussed in any meaningful way. The utility associated with telephone access is clearly dependent on the amount of use rather than just access itself. Income and prices are also largely ignored. The Rohlfs paper extends the AA analysis in several meaningful ways. Rohlfs begins by defining two utility functions for each of N individuals as

$$U_i^0 = U_i(x_{i1},\ldots,x_{is})$$
$$U_i^1 = U_i(q_j,x_{i1},\ldots,x_{is}),$$

where

U_i^0 is utility of individual i if he/she does not subscribe

U_i^1 is utility of individual i if he/she subscribes

x_{ik} is the amount of good k consumed by individual i

$$q_j = \begin{cases} 1 \text{ if individual } j \text{ has a telephone} \\ 0 \text{ if otherwise.} \end{cases}$$

Note that the inclusion of q_j explicitly assumes that the utility of a subscriber depends on the number and identity of other subscribers. Rohlfs uses a two-step maximization process. Stated simply this procedure involves comparing the maximum utility achieved with telephone service to the maximum utility achieved without telephone service. Access will be demanded by individual i if

$$\max U_i^1 > \max U_i^0.$$

Rohlfs defines the demand variable, q_i, for individual i as follows:

$$q_i^d = \begin{cases} 1 & \text{if } \max U_i^1 > \max U_i^0 \\ 0 & \text{otherwise.} \end{cases}$$

Assuming all other prices and income are held constant, q_i^d may be written

$$q_i^d = q_i^d(\pi, q_j) \quad \text{for all } j \neq i,$$

where π is the price of access. Rohlfs concept of an "equilibrium user set" is then defined as

$$q_i = q_i(\pi, q_j) \qquad \text{for all } j \neq i \text{ and for all } i.$$

Thus, in equilibrium, access to the system will be demanded by all users and will not be demanded by non-users. Rohlfs shows that for fixed π that the above system of equations does not, in general, have a unique solution. This point is key, because it points out (Taylor, 1980, pp. 24) "... the possibility that a telephone system can grow over a period of time even though external factors (income, price, and the size of the population) do not change." The Rohlfs analysis provides three basic improvements over the analysis of AA. First, the notion of the equilibrium user set ends the requirement for a social welfare function. Second, the two-step utility maximization procedure is a useful device that will be extracted by Squire and Taylor and used later here for our purposes. Third, the price of access appears explicitly in the Rohlfs analysis.

Once again, however, shortcomings remain. As with AA, there is no distinction between access and use. Individual i certainly derives some utility from being able to call individual j. Individuals i and j having access to the telephone system only guarantee the <u>ability</u> to talk. The actual act of conversation or usage of the telephone system will likely lead to quite different, probably larger, utility levels than merely having the ability to talk. This also begins to suggest a difference between individual i calling individual j and being called by individual j. These points will be discussed more at length in the Squire paper.

Squire uses consumer surplus (CS) to measure the benefits associated with placing calls. The i^{th} individual's demand for those calls will depend on both the price of the call and the number of subscribers. This is pehaps an obvious point since to complete a call a "callee" is necessary. The consumer surplus is defined as

$$CS(\bar{N}) = \int_0^{q_i} g_i(z,\bar{N})\, dz - pq_i,$$

where

$CS(\bar{N})$ is the consumer surplus with system size $\bar{N}$

q is the number of calls

g is the inverse demand function

p is the price per call.

Squire sums over individuals to get the total benefits:[1]

$$CS(\bar{N}) = \sum_i \int_0^{q_i} g_i(z,\bar{N})dz - pq_i$$

$$= \int_0^{q} G(z,\bar{N})dz - pq,$$

where $G(q,N)$ is the market conceptual demand curve for originating calls. Squire then turns to the benefits of incoming calls. Using the typical mean-variance approach to the risk-return tradeoff, Squire

1. As Taylor points out this sum necessary implies a logical contradition.

develops a certainty equivalent for the uncertain return associated with an incoming call. Squire then assumes that this certainty equivalent is equal for all individuals. Accordingly the total benefit of making and receiving calls may now be written

$$TB = \sum_i CS_i(\bar{N}) - \sum_i pq_i + bq$$

$$= \int_0^q G(z,\bar{N})dz - pq + bq,$$

where b is the marginal benefit of receiving a call. Now, the marginal subsciber, N, is defined such that the total benefits of access must exactly equal the total cost of access, i.e.,

$$CS_N(\bar{N}) + bq_N^I = \pi,$$

where

π is the monthly access price

q_N^I is the number of incoming calls expected by individual N.

This, in effect, determines optimal system size.

Using constant marginal costs for calls and installations, Squire defines a total cost function:

$$TC = cq + kN.$$

Squire's attention is then focused on maximizing net benefits (TB-TC) by choosing optimal prices p and π. Squire derives an optimal usage price, p* that equals the marginal cost (c) less the benefit derived by receiving the call (b). This clearly points out the public nature of a call or the call externality. Given the optimal usage price one can then derive the optimal access or rental price, π^*. Squire writes this as

$$\pi^* = k + bq_N^I - (\sum_{i=1}^{N} CS(\overline{N}) - \sum_{i=1}^{N-1} CS(\overline{N}-1).$$

Squire then discusses at some length whether π^* would be greater than, less than, or equal to marginal cost. However, for our purposes, the demand specification piece of the paper is the important part.

From our perspective, Squire's piece makes several important contributions. First, the paper explicitly recognizes the key access/use distinction. Second, Squire differentiates between originating and terminating calls and carefully discusses the call externality. Third, through the development of the optimal price of access or rental, Squire accounts, in some sense, for the network or subscriber externality.

The following shortcomings of the analysis are observed. Except for the following quote (pp. 520)

> ... existing subscribers may receive a benefit from a new subscriber, even if they do not call him. For example, if the new subscriber is a doctor, his availability may be considered a benefit even if there is never any actual need to call him. However, one would imagine that the marginal benefit from an extra doctor would decrease quite rapidly, so that is perhaps not too misleading to ignore this externality.

which deals as much with option demand as it does the network or subscriber externality, Squire makes no explicit mention of this externality. While its importance may be suggested, a careful discussion would be valuable.

Additionally, the Squire assumption of equal benefit across individuals for incoming calls could be improved. Merely varying this by individual, say b_n, offers some improvement. It would, however, be sensible to relate the benefits received from incoming calls to those received from outgoing calls. People tend to call and be called by the same people. Also, since we are considering these benefits previous to the actual access decision it would seem logical for the benefits of incoming calls to be related to outgoing calls.[2] These shortcomings, are however, fairly minor when compared to the insights offered by the paper.

We turn now to the work of Taylor (1980). Taylor begins by defining the dummy variable

$$\Psi = \begin{cases} 1 \text{ if consumer has access to telephone network} \\ 0 \text{ otherwise.} \end{cases}$$

We now define the standard neoclassical utility function

$$U = U(\Psi q, x, \Psi N),$$

where

q is the quantity of telephone calls

x is a composite good representing all other goods and services

N is the number of subscribers to the telephone system.

The budget constraint reflects the two-part tariff associated with access and use and is given by

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2. A more subtle point may also be important. Squire discusses the difference between observed and conceptual demand curves caused by varying system size. However, there may also be different observed and conceptual demand curves (with fixed system size) for different incoming call volumes.

$$(\pi + pq) + p_x x = M,$$

where

π is the price of access to the telephone system

p is the price of a call

p_x is the price of the composite good

M is the income of the consumer.

The specification of the consumer's problem recognizes the benefits associated with placing calls and the public or network benefit of the system. Calls made by other subscribers or incoming calls are not included. As pointed out by Taylor, however, while the Rohlfs-type interdependent demand is superior in principle, the specified procedure is more empirically tractable.

The consumer's problem is solved using a two-step procedure similar to the Rohlfs and Squire procedure. First, we assume that access is purchased (Ψ=1) and we maximize utility. The benefits accrued to access (through use) are then compared with the price of access. If the benefits exceed the cost, then access will be purchased and the analysis is unconditional. We set up the following Lagrangian assuming access is purchased:

$$L = U(q,x,N) - \lambda(M - \pi - pq - p_x x).$$

We maximize the Lagrangian with respect to q and x. The first-order conditions are

$$\frac{\partial L}{\partial q} = \frac{\partial U}{\partial q} + \lambda p = 0$$

$$\frac{\partial L}{\partial x} = \frac{\partial U}{\partial x} + \lambda p_x = 0.$$

From these first order conditions and the budget constraint the following demand equations for calls and other goods are derived

$$q = q(p, p_x, N, M - \pi) \qquad (4.1)$$

$$x = x(p, p_x, N, M - \pi).$$

The demand functions are atypical in two ways: (1) the access price is netted from income reflecting the conditional nature of this analysis; and (2) the demand functions depend on the number of subscribers and hence reflect the access externality.

We may now measure the benefits associated with this usage by calculating the consumer surplus:

$$CS = \int_p^{\infty} q(z, p_x, N, M - \pi)dz. \qquad (4.2)$$

Now, access is demanded if

$$CS > \pi.$$

Equivalently, we could write the condition as

$$\Psi = \begin{cases} 1 \text{ if } CS > \pi \\ 0 \text{ otherwise.} \end{cases} \qquad (4.3)$$

If this condition holds, then the previous analysis is unconditional. On the other hand, if the following condition

$$CS < \pi$$

holds, then the demand for calls does not apply. In addition, the typical demand equation for all goods, x, is simply

$$x = M/p_x.$$

We now have the conditions for access for the individual decisionmaker. Taylor then proceeds to extend the analysis to the entire population. The number of subscribers, N, may be written as

$$N = \sum_{i=1}^{N^*} \Psi_i ,$$

where N* is the total population size and the subscript i denotes the i^{th} individual. Using equations 4.2 and 4.3 for all individuals we note that Ψ_i is a function of p, p_x, N, π, and M_i. The Ψ_i will vary across individuals either because of differences in income (M_i) or in preferences (g_i). Taylor assumes that everyone has the same preferences and that differences in Ψ_i will be related to differences in income. This in turn implies that system size, N, depends on the distribution of income. Taylor now writes

$$\begin{aligned} \text{Prob } (CS_i > \pi) &= 1 - F(\pi) \\ &= 1 - \int_0^{\pi} f(CS_i)\, dCS_i , \end{aligned} \qquad (4.4)$$

where f and F are the density and distribution functions of the consumer surplus (CS). Under the Taylor assumptions of identical preferences and different income by individual, the distribution of consumer surpluses will be related to the distribution of income. Employing the change of variable technique, Taylor rewrites expression 4.4 as

$$\begin{aligned} \text{Prob } (CS_i > \pi) &= \text{Prob } (M_i > M^*(\pi)) \\ &= 1 - H[M^*(\pi)] \\ &= \int_0^{M^*(\pi)} h(M_i) dM_i , \end{aligned}$$

where $M^*(\pi)$ is the solution of equation 4.2 when solving for M. Or more conveniently, we may write the proportion of subscribers as

$$\frac{N}{N^*} = \text{Prob}\ (CS_i > \pi)$$
$$= \text{Prob}\ (M_i > M^*(\pi))$$
$$= \int_{M^*(\pi)}^{\infty} h(M_i)\ dM_i. \qquad (4.5)$$

We note that if income for the individual exceeds $M^*(\pi)$ then he/she will purchase access. Thus, in the analysis, network size will be determined by the distribution of income. We could write equation 4.5 as

$$\frac{N}{N^*} = G(p, p_x, N, \pi, Y), \qquad (4.6)$$

where G is a very complicated composite function. Taylor (1980, pp. 39) notes that equations 4.1 and 4.6 "comprise, in general form, a bare-bones model of telephone demand." Note that these equations explicitly distinguish between usage (4.1) and access (4.6).

Taylor goes on to discuss in some detail other attributes of telephone demand. In particular, he discusses option demand and the impact of multi-block (initial, overtime, and time-of-day) prices on usage. While the multi-block effects are important when studying usage, we wish to focus on access and as such will not review these results. We will, however, discuss briefly the section on option demand.

The basic notion of option demand is that the individual receives utility from possessing an option to do something even though he/she may never exercise the option. For example, the ability to make a call should some situation arise (e.g., emergency) yields utility even if the situation never occurs.

Taylor begins his analysis of option demand by defining the following variables

R is total number of calls the individual has the option to make

r is the average proportion of these calls actually made.

Thus, the product rR is the expected value of the number of options to be exercised. Taylor assumes this is included in the consumer surplus calculation. Thus (1-r)R options are not exercised. Assume some value for these options, say w. Equation 4.3 could now be generalized as

$$\Psi_i = \begin{cases} 1 \text{ if } CS_i + w(1-r)R > \pi \\ 0 \text{ otherwise.} \end{cases} \qquad (4.7)$$

Likewise, the threshold value for income is adjusted in the same way. Further assuming that w is subsumed into the shape of G, 4.6 may be rewritten as

$$\frac{N}{N*} = G(p,p_x,N,\pi,Y,r,R). \qquad (4.8)$$

Taylor then splits these options into two distinct types: (1) emergency calls; and (2) pleasure or business calls. Taylor then discusses relative importance and relationships of these two types. The discussion yields a suggestion to include network size and an urban/rural indicator in an attempt to reflect the second and first option types, respectively.

We now turn to a critique of the Taylor approach. Since we follow this approach ourselves the criticism will necessarily be short. The major criticism, that we will extend in a perhaps oversimplified fashion, is the exclusion of incoming calls. Another minor criticism -- one that we would level at ourselves as well -- is the treatment of option demand. The Taylor discussion is quite clear. However, precious few suggestions on how to incorporate option demand into an empirical study are made. In fact, Taylor (1980, pp. 41) referring to equations 4.7 and 4.8 states "Although the foregoing is straightforward in principle, the important question is whether option demand can be dealt with empirically."

Lastly, we would like to comment on the following statement about the network externality (pp. 32)

> ... the system externality might be measured better by the proportion of the population having a telephone rather than just the number of subscribers, which is to say that we assume that the system externality is always positive. However, the popularity of unlisted and unpublished numbers in large systems suggests that this may not always be the case. Almost certainly, the effect of the externality is nonlinear.

We believe the data supports the claim of a nonlinear externality. We, however, suspect that the externality is always positive -- perhaps very, very small at today's large network size but positive. The interesting thing about the quote is the interaction of the subscriber and call externalities. Thus, in isolation we believe the impact of the subscriber externality is non-negative. The total impact, however, as suggested by Taylor, may indeed be negative. This is possible since as network size increases the probability of receiving nuisance (wrong numbers, sales calls, customer surveys, etc.) calls also increases. Hence, the small non-negative subscriber externality may be dominated by the increased probability of negative call externalities. In fact, it would appear that consumers are attempting to avoid these negative call externalities by purchasing unlisted numbers or answering machines to screen calls.

Using this historical perspective, a theory of demand for telecommunications service will be developed that incorporates the four unique features discussed at the beginning of the chapter. The point of departure for modeling telephone demand should be the distinction between access and usage. The decision to subscribe to the telephone network depends upon the costs and benefits of subscription. The costs are clearly the price of subscription and price paid for any calls made. The primary benefits from subscription include the satisfaction from making and receiving calls, i.e., usage. Thus, the decision to buy access clearly depends on the individual's expected usage of the telephone system. Obviously, the ability to use the network depends on having access to it. We will use the Taylor 2-step process: (1) measure usage assuming access is purchased; and (2) compare the benefits (consumer surplus) from usage to the cost of access and determine if access will be demanded.

Assume the usual consumer utility maximization problem subject to a budget constraint, i.e.,

$$\text{MAX} \quad U = U(\Psi q_O, \Psi q_R, x, \Psi N)$$

$$\text{s.t.} \quad (\pi + pq_O) + p_x x = M \text{ ,}$$

where

$$\Psi = \begin{cases} 1 & \text{if the individual subscribes to the telephone network} \\ 0 & \text{otherwise} \end{cases}$$

q_O is minutes of telephone usage originated

q_R is minutes of telephone usage received

N is number of telephone subscribers

x is a composite good representing all other goods and services consumed

π is the price of access to the telephone network

p is the price per minute of telephone usage

p_x is the of price for the composite good x

M is the consumer's income.

Notice the utility function follows Taylor closely with the exception of the inclusion of incoming traffic. The budget constraint, identical to Taylor's, reflects the two-part tariff.

The inclusion of originating and terminating minutes separately in the utility function explicitly recognizes that a call made and received yields different amounts of satisfaction. When an individual makes a call, one knows the "callee" and the desired topic of conversation. The biggest uncertainty involved is whether or not the party will answer the phone. On the other hand, when called, the "callee" knows neither the caller nor the desired conversation theme. Furthermore, the "callee" may be involved in activities that are costly to discontinue in order to answer the phone, e.g., taking a shower. The inclusion of the number of subscribers in the utility function incorporates the subscriber externality explicitly, i.e., the utility of the consumers depends not only on the amount of usage but also on the number of people that can be reached.[3]

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3. We have implicitly assumed that to use the network one must purchase access. However, with coin phones or neighbors, this need not hold. If use is not totally dependent on access then network size may be an argument in the utility function for non-subscribers as well.

We will assume that incoming calls are related to originated calls, e.g.,

$$q_R = f(q_o),$$

where q_R is the number of calls received and q_o is the number of originated calls. The assumption is supportable for many reasons. First, as suggested by Larson, Lehman, and Weisman (1986), implicit contracts may exist between callers and callees. These contracts may partially account for the existance of reciprocal calling patterns. In the long run, at least, individuals are unlikely to receive calls from parties that they never call. Perhaps, more importantly, we should note that in our analysis we are attempting to measure the utility from originating and receiving calls prior to the actual access decision. It seems intuitive that the utility from receiving a call from individual i is somehow related to the utility received from calling individual i. Incorporating this assumption we rewrite the utility function as

$$U = U(\Psi q_o, \Psi f(q_o), x, \Psi N).$$

We begin the two-step procedure by setting up the Lagrangian for maximization assuming that access in purchased:

$$L = U(q_o, f(q_o), x, N) - \lambda(M - \pi - pq_o - p_x x).$$

The first order conditions are

$$\frac{\partial L}{\partial q_o} = \frac{\partial U}{\partial q_o} + \frac{\partial U}{\partial f}\frac{\partial f}{\partial q_o} + \lambda p = 0$$

$$\frac{\partial L}{\partial x} = \frac{\partial U}{\partial x} + \lambda p_x = 0.$$

Solving the first order conditions and the budget constraint yields the demand functions for q_o and x:

$$q_o = q_o(p, p_x, N, M-\pi)$$

$$x = x(p, p_x, N, M-\pi).$$

Notice that these equations look exactly like the demand equations derived by Taylor.

We now proceed to the next step of the procedure by first measuring the benefits associated with usage. The consumer's surplus from originating calls is

$$CS_o = \int_p^{\infty} q_o(z, p_x, N, M-\pi)\,dz.$$

In principle, at least, we can write the benefits associated with incoming calls as a function of the benefits associated with originating calls:

$$CS_R = g(CS_o).$$

Thus, the total benefit associated with usage is the sum of these individual measures:

$$\begin{aligned} CS &= CS_o + CS_R \\ &= CS_o + g(CS_o). \end{aligned}$$

Now, we compare the benefits to the (cost) price of access. Access will be demanded if the benefits exceed the price, i.e.,

$$\Psi = \begin{cases} 1 \text{ if } CS > \pi \\ 0 \text{ otherwise.} \end{cases}$$

We extend this to system size determination or the proportion of households that purchase access to the network by assuming constant income and the following demand function for each individual:

$$q_{0i} = q_0(p, p_x, N, M-\pi) + u_i ,$$

where u_i is an error term that represents a state-of-nature that befalls individual i.[4] We will assume that the u_i are drawn randomly from some probability distribution. Assuming the number of incoming calls are unaffected by u_i, we have the following condition for access:

$$CS + u_i > \pi.$$

We can now write the probability that individual i will purchase access as

$$\text{Prob(access)} = \text{Prob}\ (u_i > \pi - CS). \qquad (4.9)$$

Notice that the proportion of the population that subscribes is simply related to the distribution of u. If, however, we allow income to vary across individuals as well, then equation 4.9 is written as

$$\text{Prob(access)} = \text{Prob}(u_i + CS_i > \pi). \qquad (4.10)$$

Now, the proportion of the population that subscribes to the telephone system is related to the joint distribution of u and the consumer surplus (CS). The consumer surplus in turn depends only on the distribution of income. We are now ready to use this model of telephone demand theory to estimate an empirical model.

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4. One might alternatively interpret the u_i as some difference in preferences in the random utility model. It could alternatively be included inside the function q.

CHAPTER FIVE

ESTIMATION

We continue the analysis of the last section with an explicit demand equation. While the choice of the semi-log demand function went unexplained in Perl (1983), it has several attractive features worth outlining. Since we are dealing with local usage and typically local use is priced on a flat-rate basis, we require a demand function that is defined at a zero price. Furthermore, since consumer surplus is a convenient yet typically accurate measure of benefits (Taylor, 1980 and Willig, 1976), our extensive use of this concept requires a demand fuction with a tractable form for consumer surplus. The semi-log form meets all these requirements. Following Perl, we can write the demand for usage as follows

$$q = Ae^{-\alpha p}y^{\beta}e^{u} \, , \tag{5.1}$$

where

q is minutes of use

p is the price of a minute of use

y is income

u is an error term.

At this point we are ignoring the complications of the network and call externalities as well as other important socio-economic variables, e.g., race, household size, etc.

The consumer surplus or the measure of benefits from q units of use can be calculated by

$$CS = \int_p^\infty Ae^{-\alpha z} y^\beta e^u dz \tag{5.2}$$

$$= Ae^{-\alpha p} y^\beta e^u / \alpha .$$

Access will be demanded if the benefits from access (CS) exceed its cost (π). That is, we have the following condition for access

$$CS > \pi . \tag{5.3}$$

Equivalently taking logs yields the following more convenient forms

$$\ln CS > \ln \pi$$

and

$$a - \alpha p + \beta \ln y + u > \ln \pi , \tag{5.4}$$

where $a = A/\alpha$. Rearranging equation 5.4 yields

$$u > \ln \pi - a + \alpha p - \beta \ln y. \tag{5.5}$$

If we now assume that u is distributed normally with zero mean and variance σ_u^2, then we can write the probability of access as

$$\text{Prob(access)} = \text{Prob}(u > \ln \pi - a + \alpha p - \beta \ln y) \tag{5.6a}$$

$$= 1 - \Phi\left(\frac{\ln \pi - a + \alpha p - \beta \ln y}{\sigma_u}\right), \tag{5.6b}$$

where Φ denotes the distribution function for the standard normal distribution. This is essentially the model estimated by Perl using individual data.

At this point, we have the basis for proceeding with the empirical analysis. We began by positing the typical distributional assumptions on u, i.e., logistic, normal, and uniform. Using these assumptions, we were prepared to estimate the standard discrete models (linear probability, logit, and probit). Due to the size of the data set, it was our plan to use the linear probability model as a searching tool. We decided on this course of action by weighing carefully the costs and benefits of OLS estimation. The costs of OLS (e.g., prediction outside the 0-1 interval) are well-known and are reviewed in Appendix A. The major benefit is the ease and cheapness of estimation that facilitates model development and variable choice. The results of the OLS estimation are shown in Table C.1 in Appendix C. We then attempted to estimate logit and probit models of similar structure. These results were quite surprising, however. The logit and probit models performed very poorly. Indeed, the most obvious failing of the models was that the access price, or the key variable of interest, was very insignificant. At this point we began to question our assumptions and analyze the results of linear probability model more carefully. Of particular interest in the linear regression was the strength of the poverty variable. The surprising strength and magnitude when compared to the income variable suggested that the income distribution was not being adequately modelled.[1] We also began to rethink using individual modelling techniques and assumptions on aggregate data.

At this point, a digression on the data is in order. All economic and demographic data are from the 1980 Census Long Form Questionnaire. All telephone specific data (rates, mileage, measured

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1. Some of the model predictions were unsatisfactory as well. These are discussed in Appendix C.

service availability, etc.) are from the Rates and Costs Organization of Southwestern Bell Telephone (SWBT). These telephone data were provided by wire center requiring matching of wire center boundaries to census geographical units or vice versa. It was felt that the analysis should be carried out at the lowest reasonable disaggregation that allowed accurate matching of telephone company rate data with census economic and demographic data. Since the Census masks any responses that might reasonably identify individuals, the census tract was chosen as the unit of observation.[2] Each census tract is composed of many block groups. These block groups were used to match wire centers to census tracts.[3] Tracts contained entirely in a wire center have the price effective in that wire center. Tracts overlapping wire center boundaries have a population weighted average price from the relevant wire centers. This resulted in 8423 observations from the five SWBT states: Arkansas (AR), Kansas (KS), Missouri (MO), Oklahoma (OK) and Texas (TX). Of these 8423 observations over 6500 had a unique price for the entire tract. The other 1900 or so were averages of two or more prices. This mapping is considerably more accurate than that of Perl. This increased accuracy of our mapping methodology was one of the primary motivations for undertaking the study.

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2. Census tracts in wholly tracted counties; the smaller of Minor Civil Division and place in not wholly tracted counties.

3. If the entire boundary of a block group was inside (outside) a census tract, then the block group was (not) allocated to that wire center. If the block group was only partially contained in a wire center then it was allocated to the wire center that contained the population centroid of the block group.

To account for the aggregated data and income distribution we note that the census tract is the unit of observation and we will aggregate equation 5.6 over the joint distribution of u and y. We assume that the natural logarithm of y is distributed as $N(\mu, \sigma_y^2)$, i.e., y is lognormally distributed. Additionally, we assume that y and u are independent. With these assumptions, we can rewrite equation 5.6 as

$$\text{Prob(access)} = \text{Prob}(u + \beta \ln y > \ln \pi - a + \alpha p) \quad (5.7a)$$

$$= \text{Prob}(w > \ln \pi - a + \alpha p) \quad (5.7b)$$

and we note that w is distributed as $N(\beta\mu, \sigma_u^2 + \beta^2\sigma_y^2)$.

Let V_j denote the proportion of households with phone service in census tract j. This proportion will be given by

$$V_j = \text{Prob}(w_j > \ln \pi_j - a + \alpha p_j). \quad (5.8a)$$

Alternatively, by standardizing w_j, we can write the proportion as

$$V_j = \text{Prob}(w_j^* > (\ln \pi_j - a + \alpha p_j - \beta\mu_j)/(\sigma_u^2 + \beta^2\sigma_{yj}^2)^{\frac{1}{2}}) \quad (5.8b)$$

$$= \text{Prob}(w_j^* > \tilde{w}_j) \quad (5.8c)$$

$$= 1 - \Phi(\tilde{w}_j), \quad (5.8d)$$

where

$$w_j^* = \frac{w_j - \beta\mu_j}{(\sigma_u^2 + \beta^2\sigma_{yj}^2)^{\frac{1}{2}}}$$

$$\tilde{w}_j = \frac{\ln \pi_j - a + \alpha p_j - \beta\mu_j}{(\sigma_u^2 + \beta^2\sigma_{yj}^2)^{\frac{1}{2}}} . \quad (5.9)$$

Equation 5.9 is merely the formula for the probit or z-score, call it F. These probits are observed by tract. Hence, we may write

$$F_j = \frac{\ln \pi_j - a + \alpha p_j - \beta\mu_j}{(\sigma_u^2 + \beta^2\sigma_{yj}^2)^{\frac{1}{2}}} + \varepsilon_j. \quad (5.10)$$

Clearing the fraction we have

$$F_j(\sigma_u^2 + \beta^2\sigma_{yj}^2)^{\frac{1}{2}} = \ln\pi_j - a + \alpha p_j - \beta\mu_j + \varepsilon_j^*, \quad (5.11)$$

where

$$\varepsilon_j^* = \varepsilon_j(\sigma_u^2 + \beta^2\sigma_{yj}^2)^{\frac{1}{2}}.$$

While equation 5.11 offers a number of challenges for estimation, there are several important details that must be considered prior to estimation. First, we should note that there are benefits from receiving calls as well as originating calls. Second, we should also consider that use is split into two parts: local use and toll use. Third, we should discuss the choice of class-of-service that many customers face, e.g., flat-rate service or measured-rate service.

Consider that the consumer receives utility from incoming calls as well as calls he/she originates. Recent research indicates the existence of implicit contracts between callers and "callees", e.g., the number of incoming and outgoing calls are related.[4] The research also indicates the ratio of incoming to outgoing is quite similar across geographies or routes. Additionally, as we noted previously, this analysis is prior to the access decision and hence it seems quite reasonable that an individual might relate expected incoming benefits to expected originating benefits. Hence, we assume the following simple relationship between calls received (q_R) and calls originated (q_O):

$$q_R = \gamma q_O,$$

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4. Other reasons for relationships between callers and "callees" may exist. See Larson, Lehman, and Weisman (1985) for additional discussion.

where γ is a constant between zero and one. Using this relationship, we note that the benefits from receiving calls (as measured by consumer surplus) depend directly on the benefits from placing calls and may be written as

$$CS_R = \gamma CS_0,$$

and that total benefits from placing and receiving calls is

$$\ln CS = \ln(1 + \gamma) + \ln CS_0. \qquad (5.12)$$

Using equation 5.12 we can rewrite 5.11 to include the benefits from receiving calls as follows

$$F_j(\sigma_u^2 + \beta^2\sigma_{yj}^2)^{\frac{1}{2}} = \ln\pi_j - a^* + \alpha p_j - \beta\mu_j + \varepsilon_j^*, \qquad (5.13)$$

where $a^* = a(1 + \gamma)$.

Consider, now, separate local and toll usage demand equations. Since toll calls and local calls are priced differently, we will have separate demand functions for local minutes and for toll minutes. As before, we will assume simple semi-log demand functions for minutes of use, i.e.,

$$q_{OL} = Ae^{-\alpha p}y^{\theta}e^{\varepsilon} \qquad (5.14a)$$

$$q_{OT} = Be^{-\tau z}y^{\Phi}e^{\xi}, \qquad (5.14b)$$

where

q_{OL} is originating local minutes of use

p is the price of a local minute

y is income

q_{OT} is originating toll minutes of use

z is the price of a toll minute.

Now, the benefits the customer receives from originating toll and local minutes, once again measured by CS, are

$$CS_{OL} = \frac{Ae^{-\alpha p}y^{\theta}e^{\varepsilon}}{\alpha} \quad (5.15a)$$

$$CS_{OT} = \frac{Be^{-\tau z}y^{\Phi}e^{\xi}}{\tau}. \quad (5.15b)$$

We will again assume the same simple linear relationship between incoming and outgoing minutes for both local and toll usage:

$$q_{RL} = \gamma_L q_{OL}$$

$$q_{RT} = \gamma_T q_{OT},$$

where q_{RL} denotes local minutes received and q_{RT} denotes toll minutes received. Now, the benefits the customer accrues from receiving calls, measured by CS, are directly related to incoming benefits and may be written as

$$CS_{RL} = \gamma_L CS_{OL}$$

$$CS_{RT} = \gamma_T CS_{OT}.$$

Thus, the benefits from making and receiving local and toll calls, measured by CS, in logs for convenience, are:

$$\ln CS_L = \ln(1 + \gamma_L) + \ln CS_{OL}$$

$$\ln CS_T = \ln(1 + \gamma_T) + \ln CS_{OT}$$

$$\ln CS_L + \ln CS_T = \ln((1 + \gamma_L)(1 + \gamma_T)AB/\alpha\tau) - \alpha p - \tau z + (\theta + \Phi)\ln y + \varepsilon + \xi$$

$$\ln CS_L + \ln CS_T = a^* - \alpha p - \tau z + \beta \ln y + u, \quad (5.16)$$

where

$$a^* = \ln((1 + \gamma_L)(1 + \gamma_T)AB/\alpha\tau)$$

$$\beta = \theta + \Phi$$

$$u = \varepsilon + \xi.$$

The consumer will buy access based purely on local usage if the benefits derived from local usage exceed the access price, i.e.,

$$\ln CS_L > \ln\pi \quad (5.17)$$

Likewise, the consumer will buy access based entirely on toll usage if

$$\ln CS_T > \ln\pi \quad (5.18)$$

Finally, the consumer will buy access based on total (local plus toll) usage if[5]

$$\ln CS_L + \ln CS_T > \ln\pi$$

$$a^* - \alpha p - \tau z + \beta \ln y + u > \ln\pi \quad (5.19)$$

We note, that this separation of use into local and toll components causes no change to equation 5.11 except the the interpretation of the coefficients is different. For example, β is now the income elasticity of total use as opposed to the previous interpretation of the income elasticity of local use.

We now turn our attention to the class-of-service choice concerns. There are three different possibilities for local pricing to consider:

1. Only flat-rate service is available;
2. Only measured-rate service is available;
3. Both flat-rate and measured-rate service is available.

Since the marginal usage price is zero in flat-rate areas, access will be demanded in these areas if

$$u + \beta \ln y > \ln\pi_f - a^* + \tau z, \quad (5.20)$$

5. The condition is sufficient but not necessary. For CS greater than $1 (which certainly holds for all census tracts), the log of the sum exceeds the sum of the logs.

while in measured-rate areas, access will be demanded if

$$u + \beta \ln y > \ln \pi_m - a^* + \alpha p + \tau z, \qquad (5.21)$$

where π_f and π_m denote the monthly fixed access price for flat-rate and measured-rate service, respectively. For choice areas, we note that either 5.20 or 5.21 holds. From these two inequalities, we conclude that access will be demanded if

$$u + \beta \ln y > \min(\ln \pi_f, \ln \pi_m + \alpha p) - a^* + \tau z. \qquad (5.22)$$

From equation 5.22 we also note that class-of-service choice is deterministic, e.g., flat-rate service will be chosen if

$$\ln \pi_f > \ln \pi_m + \alpha p, \qquad (5.23)$$

while measured-rate service will be chosen if

$$\ln \pi_f > \ln \pi_m + \alpha p. \qquad (5.24)$$

Notice, however, that it is quite possible for

$$\pi_f > \pi_m + \alpha p$$

or for flat-rate expenditures to exceed measured-rate expenditures but also violate 5.24. Thus, while choice is deterministic for a given estimate of α, we are not assuming strict bill-minimization.

To include these service choice characteristics in our analysis, we begin by defining the following dummy variables for the three areas of concern:

$$\delta_1 = \begin{cases} 1 & \text{if only flat-rate service is available} \\ 0 & \text{otherwise} \end{cases}$$

$$\delta_2 = \begin{cases} 1 & \text{if only measured-rate service is available} \\ 0 & \text{otherwise} \end{cases}$$

$$\delta_3 = \begin{cases} 1 & \text{if both flat-rate and measured service are available} \\ 0 & \text{otherwise.} \end{cases}$$

Using these dummy variables and incorporating equation 5.16 we can re-write 5.11 as follows:

$$F_j(\sigma_u^2 + \beta^2\sigma_{yj}^2)^{\frac{1}{2}} = \delta_1 \ln\pi_{fj} + \delta_2 (\ln\pi_{mj} + \alpha p_j) + \delta_3 \min(\ln\pi_f, \ln\pi_m + \alpha p_j) - a^* - \beta\mu_j + \tau z_j + e_j. \tag{5.25}$$

Noting that SWBT has no mandatory measured areas (i.e., $\delta_2 = 0$) and adding demographics, we can rewrite equation 5.25 as follows:

$$F_j(\sigma_u^2 + \beta^2\sigma_{yj}^2)^{\frac{1}{2}} - \delta_1 \ln\pi_{fj} - \delta_3 \min(\ln\pi_{fj}, \ln\pi_{mj} + \alpha p_j) = -a^* - \beta\mu_j + \tau z_j - \sum_i b_i x_{ij} + e_j, \tag{5.26}$$

where x_{ij} denotes the socio-demographic variables considered relevant and e_j is the error term. The task at hand is to estimate equation 5.26. At least three peculiar items must to be handled during estimation:

1. The equation is nonlinear in β;
2. The unknown nuisance variance, σ_u^2, is to be estimated;
3. The parameter α appears only inside the min function which makes any derivitive based estimation technique computationally very burdensome and probably impractical.

Notice that if σ_u^2, β and α were known, we could calculate the left-hand-side, say z_j:

$$z_j = F_j(\sigma_u^2 + \beta^2\sigma_{yj}^2)^{\frac{1}{2}} - \delta_1\ln\pi_{fj} - \delta_3\min(\ln\pi_{fj}, \ln\pi_{mj} + \alpha p_j). \tag{5.27}$$

Equation 5.26 could then simply be estimated as a linear regression. Since these parameters are unknown, however, we must resort to an iterative scheme.

The following sequential search process is used:[6]

1. Select initial values for β and α. Search over values of σ_u^2 until the one that maximizes the correlation between actual and predicted F_j is found;
2. Set σ_u^2 as discovered in (1) and keep the initial value of β. Search over α until the value is found that maximizes the correlation between actual and predicted probits (F_j);
3. Set σ_u^2 as discovered in (1) and α as discovered in (2). Re-estimate regression 5.26 to get an estimate of β. Replace estimate of β in 5.27 to get new z_j. Continue this process until the new estimate obtained is less than some prespecified tolerance from the previous estimate.

The model equation summarized in equation 5.26 is estimated using the previously described data. Table 5.1 displays the model actually estimated. Please note the subscript j denoting the census tract has been deleted for notational convenience in all tables. The moving of the toll price to the left-hand-side was necessary due to the structure of toll prices, i.e., all individuals face identical interstate rates and intrastate rates vary little across states. Therefore, we have variation across states but not across tracts within states. Hence, despite many attempts to estimate τ in a meaningful way, we were forced to choose it. Fortunately, there is a

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6. Appendix B provides a more detailed description of the computational algorithm.

Table 5.1

Estimating Equation 5.26

$$F(\sigma_u^2 + \beta^2 \sigma_y^2)^{\frac{1}{2}} - \delta_1 \ln \pi_f - \delta_3 \min(\ln \pi_f, \ln \pi_m + \delta p) - \tau z$$

$$= -a^* - \beta\mu - b_1 \text{ RENTER} - b_2 \text{ RURAL} - b_3 \text{ BLACK} -$$

$$b_4 \text{ SPANISH} - b_5 \text{ AMINDIAN} - b_6 \text{ IMMOB} - b_7 \text{ AVGAGE} - b_8 \text{ MILAGE} -$$

$$b_9 \text{ EMP} + b_{10} \text{ LINES} + b_{11} \text{ HHSIZE} + e$$

Where:

F	are the probits of the census tract development levels
σ_u^2	nuisance variance to be estimated
β	coefficient on income to be estimated
σ_y^2	within census tract variance of log of income
δ_1, δ_3	dummy geographic variables denoting local pricing options
$\ln \pi_f$	log of flat rate access price
$\ln \pi_m$	log of measured rate access price
p	price of a local call
α	coefficient on local usage price to be estimated
z	price of a toll minute
τ	coefficient on toll price (restricted)
μ	is the mean of the log of income
a^*, b_i	coefficients to be estimated (i = 1, 11)
RENTER	% of census tract that rents
RURAL	urban/rural indicator
BLACK	% of census tract that is Black
SPANISH	% of census tract of Espanic origin
AMINDIAN	% of census tract that is American Indian
IMMOB	% of census tract that has not moved since 1975
AVGAGE	average age of census tract
MILAGE	% of census tract that pays mileage charges
EMP	% of census tract that suffered no unemployment in 1979
LINES	# of lines that can be reached in "local calling area"
HHSIZE	log of the average number of people per household

wealth of information on toll elasticities (Taylor, 1980) and a reasonable value for τ could be selected relatively easily.

The estimated coefficients are provided in Table 5.2. All variables have the theoretically correct sign and are statistically significant. The t-statistic for the price of local use and the standard error on the nuisance variance (σ_u^2) are estimated using a jackknife technique (the technique is described in Appendix B).

Summarizing the impact of socio-demographic factors, telephone development is lower for black, hispanic, and American Indian households, lower for renters than for homeowners, lower in rural areas, and lower for households whose members suffer unemployment. On the other hand, telephone development is increased by address longetivity (IMMOB), average age, and the number of telephone lines in the local calling area.

The interpretation of the coefficients is noteworthy. The coefficient for income, 0.97, represents the elasticity for usage with respect to income, e.g., if income were increased 10% then usage would increase 9.7%. In a similar fashion, one could derive elasticities with respect to use for the other variables. For example, the coefficient for IMMOB, .51, multiplied by the mean of IMMOB, .52, yields the usage elasticity, .27, with respect to the mobility variable. The access elasticities, however, can not be observed directly. These elasticities must be induced by changing the values of a variable and then calculating the induced change in development. These results will be presented in Chapter Seven following the discussion of model verification in the next chapter.

Table 5.2
Equation 5.26
Coefficient Estimates

variable	coefficient estimate	t-statistic
INCOME (β)	.97	19.7
PRICE OF LOCAL MINUTE (α)	-6.98	-13.3[a]
PRICE OF TOLL MINUTE (τ)	-2.50	--
PRICE OF ACCESS[b]	-1.00	--
RENTER	-1.56	-14.4
RURAL	-.77	-18.5
BLACK	-1.05	-12.0
SPANISH	-2.42	-22.9
AMINDIAN	-7.27	-14.6
IMMOB	.50	4.7
AVGAGE	.04	8.1
MILAGE	-.43	-3.8
EMP	2.66	13.8
LINES	.39	5.3
HHSIZE	1.10	7.5
Constant (a*)	.70	2.1
Nuisance variance (σ_u^2)	5.1	.06[ac]

R^2 (uncorrected) = .4168
R^2 (corrected) = .4159

[a]Estimated from the standard error arrived at via the jackknife method
[b]Flat rate price in area 1; minimum price in area 3
[c]The standard error is provided here since variances are typically not distributed normally.

CHAPTER SIX

MODEL VALIDATION

Before discussing the results of the study, we will describe the validation tests performed. These validation tests include internal estimation and prediction comparisons and external prediction comparisons. In terms of internal estimation testing, we are concerned with specific assumptions that were made during estimation. In particular, we are concerned with the inclusion of toll benefits, the selection of the toll elasticity, and the use of income and only income to reflect differences in individuals within a census tract. Internal prediction tests will be performed through the use of hold-out samples (ex post unconditional forecasts) and an application of the model to actual price changes (an ex ante conditional forecast). After this discussion we will perform external prediction tests by comparing and contrasting the repression estimates generated from the Perl (1983) model and the SWBT pooled model with the results of the model presented in Tables 5.1 and 5.2. This will conclude our process of model validation.

6.1 Internal Validation: Estimation

Tables 6.1 and 6.2 present the results for a doubling of rates using the model described and estimated in the fifth chapter. We employ sample enumeration as described in Appendix A to generate these tables. While Table 6.1 is a direct application of the sample

Table 6.1
Equation 5.26:
Predictions for Doubling of Rates -- by State

	Actual Development	100% increase with lower priced alternative[a]	100% increase all prices[b]
AR	89.1	84.6 (-4.5)	83.6 (-5.5)
KS	95.3	--	93.1 (-2.2)
MO	95.4	92.3 (-3.1)	92.3 (-3.1)
OK	92.7	--	88.8 (-3.9)
TX	91.4	89.6 (-1.8)	87.4 (-4.0)
SWBT	92.5	90.0 (-2.5)	88.8 (-3.7)

Numbers in parenthesis are repression estimates in basis points.

[a] measured service, where available, is the lower priced alternative and its price is unchanged

[b] both flat rate and measured rate, where available, are doubled

Table 6.2
Equation 5.26:
Predictions for Doubling of Rates -- Southwestern Bell Subgroups

	Actual Development	100% Increase with lower priced alternative[a]	100% Increase all prices[b]
ALL	92.5	90.0 (-2.5)	88.8 (-3.7)
RURAL	90.1	86.0 (-4.1)	85.7 (-4.4)
URBAN	93.0	90.8 (-2.2)	89.4 (-3.6)
POOR, RURAL	83.7	77.4 (-6.3)	77.2 (-6.5)
POOR, URBAN	85.0	80.5 (-4.5)	77.8 (-7.2)

Numbers in parenthesis are repression estimates in basis points.

[a]measured service, where available, is the lower priced alternative and its price is unchanged

[b]both flat rate and measured rate, where available, are doubled

enumeration technique, the rows of Table 6.2 require specific discussion. The first three rows (ALL, RURAL, and URBAN) are simple straight-forward applications, i.e., take the weighted average over the appropriate tracts. The concept of a "poor" tract, however, needs elaboration. We order the tracts from poorest to richest, based on the percentage of households that are poverty stricken. The poorest twenty-five percent of the tracts are then used as our definition of "poor".[1] The fourth and fifth rows are simply the intersection of "poor" and rural or urban, respectively. This definition of poor is used throughout the rest of this chapter. The columns reflect the availability of measured service in some areas. The statewide availabilities are as follows: (1) Arkansas 10.4%; (2) Kansas and Oklahoma no measured service; (3) Missouri 2.2%; and (4) Texas 58.4%. These two prediction tables, chosen to detail differences across states, subgroups, or pricing options, along with differences in coefficient estimates will be the basis of comparison between models as we relax certain key assumptions. For each assumption relaxed, we will present a table that displays coefficient estimates (a hybrid of Tables 5.1 and 5.2) and prediction tables analogous to Tables 6.1 and 6.2.

The first assumption we will vary is the inclusion of toll benefits. To arrive at an estimatable form we were forced to make an approximation in equation 5.19. Table 6.3 presents the results of the

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1. The upper quartile was chosen on the basis of convenience and accuracy. For example, the development of this quartile (88.9%) compares quite favorably with the actual development (88.4%) for "poor, urban" households in Missouri (the only state for which we had access to any individual data).

Table 6.3
Estimating Equation with
Toll Excluded

$$F(\sigma_u^2 + \beta^2 \sigma_y^2)^{\frac{1}{2}} - \delta_1 \ln \pi_f - \delta_3 \min(\ln \pi_f, \ln \pi_m + \alpha p)$$

$$= -a^* - \beta\mu - b_1 \text{ RENTER} - b_2 \text{ RURAL} - b_3 \text{ BLACK} -$$

$$b_4 \text{ SPANISH} - b_5 \text{ AMINDIAN} - b_6 \text{ IMMOB} - b_7 \text{ AVGAGE} - b_8 \text{ MILAGE} -$$

$$b_9 \text{ EMP} + b_{10} \text{ LINES} + b_{11} \text{ HHSIZE} + e$$

variable	coefficient estimate	t-statistic
INCOME (β)	1.01	19.4
PRICE OF LOCAL MINUTE (α)	-6.84	--
PRICE OF ACCESS	-1.00	--
RENTER	-1.63	-14.3
RURAL	-.80	-18.3
BLACK	-1.15	-12.3
SPANISH	-2.67	-23.9
AMINDIAN	-7.52	-14.2
IMMOB	.56	5.1
AVGAGE	.04	8.1
MILAGE	-.45	-3.7
EMP	2.82	13.8
LINES	.37	4.7
HHSIZE	1.17	7.6
Constant (a*)	-.12	-0.3
Nuisance variance (σ_u^2)	5.7	--

R^2 (uncorrected) = .4169
R^2 (corrected) = .4150

estimation when we ignore or exclude the benefits associated from toll. Tables 6.4 and 6.5 present the results of simulating a doubling of rates using the equation displayed in Table 6.3. As can be observed from comparing Tables 5.2 and 6.3, the coefficient estimates are very similar. Indeed, the largest difference is between the constant terms. Notice, for example, that the income coefficient changes only from .97 to 1.01. The repression estimates also are very similar. For example, the total repression for SWBT when rates are doubled is 3.7% in our model and 4.0% in the model where toll is excluded. The patterns across geographic areas and customers groups are also quite similar.

Another potential problem associated with the inclusion of toll benefits is the choice of the toll elasticity. While we have chosen the elasticity of one half to conservatively estimate the cross-elastic effects of the toll price, we thought it interesting to observe the effects of changes in this coefficient on the model. For this comparison a toll elasticity of .7 was used. As can be seen by comparing Table 6.6 with Table 5.2 and Tables 6.7 and 6.8 with Tables 6.1 and 6.2, the differences here are even smaller than the previous case when toll was excluded.

In moving from equation 5.6 to equation 5.7, we are implicitly assuming that all differences between individuals within a census tract are related to income. We can vary this assumption by relating these individual differences to age instead of income. The results of this estimation are displayed in Table 6.9. The similarity of these results to those presented in Table 5.2 is striking! Despite changing completely the underlying distributional assumption of individual

Table 6.4
Equation with Toll Excluded:
Predictions for Doubling of Rates -- by State

	Actual Development	100% increase with lower priced alternative[a]	100% increase all prices[b]
AR	89.1	84.3 (-4.8)	83.2 (-5.9)
KS	95.3	--	92.7 (-2.6)
MO	95.4	92.0 (-3.4)	91.9 (-3.5)
OK	92.7	--	88.5 (-4.2)
TX	91.4	89.5 (-1.9)	87.2 (-4.2)
SWBT	92.5	89.8 (-2.7)	88.5 (-4.0)

Numbers in parenthesis are repression estimates in basis points.

[a]measured service, where available, is the lower priced alternative and its price is unchanged

[b]both flat rate and measured rate, where available, are doubled

Table 6.5
Equation with Toll Excluded:
Predictions for Doubling of Rates -- Southwestern Bell Subgroups

	Actual Development	100% Increase with lower priced alternative[a]	100% Increase all prices[b]
ALL	92.5	89.8 (-2.7)	88.5 (-4.0)
RURAL	90.1	85.7 (-4.4)	85.4 (-4.7)
URBAN	93.0	90.6 (-2.4)	89.1 (-3.9)
POOR, RURAL	83.7	77.2 (-6.5)	76.9 (-6.8)
POOR, URBAN	85.0	80.3 (-4.7)	77.6 (-7.4)

Numbers in parenthesis are repression estimates in basis points.

[a]measured service, where available, is the lower priced alternative and its price is unchanged

[b]both flat rate and measured rate, where available, are doubled

Table 6.6
Estimating Equation with
High Toll Elasticity

$$F(\sigma_u^2 + \beta^2 \sigma_y^2)^{\frac{1}{2}} - \delta_1 \ln \pi_f - \delta_3 \min(\ln \pi_f, \ln \pi_m + \alpha p) - \tau z$$

$$= -a^* - \beta\mu - b_1 \text{ RENTER} - b_2 \text{ RURAL} - b_3 \text{ BLACK} -$$

$$b_4 \text{ SPANISH} - b_5 \text{ AMINDIAN} - b_6 \text{ IMMOB} - b_7 \text{ AVGAGE} - b_8 \text{ MILAGE} -$$

$$b_9 \text{ EMP} + b_{10} \text{ LINES} + b_{11} \text{ HHSIZE} + e$$

variable	coefficient estimate	t-statistic
INCOME (β)	.95	19.8
PRICE OF LOCAL MINUTE (α)	-7.69	--
PRICE OF TOLL MINUTE (τ)	-3.50	--
PRICE OF ACCESS	-1.00	--
RENTER	-1.53	-14.5
RURAL	-.75	-18.6
BLACK	-1.02	-11.8
SPANISH	-2.32	-22.5
AMINDIAN	-7.19	-14.7
IMMOB	.47	4.6
AVGAGE	.04	8.1
MILAGE	-.43	-3.8
EMP	2.61	13.8
LINES	.40	5.6
HHSIZE	1.07	7.5
Constant (a*)	.93	2.8
Nuisance variance (σ_u^2)	4.9	--

R^2 (uncorrected) = .4171
R^2 (corrected) = .4162

Table 6.7
High Toll Elasticity Equation:
Predictions for Doubling of Rates -- by State

	Actual Development	100% increase with lower priced alternative[a]	100% increase all price[b]
AR	89.1	84.7 (-4.4)	83.7 (-5.4)
KS	95.3	-- (-2.2)	93.1
MO	95.4	92.4 (-3.0)	92.3 (-3.1)
OK	92.7	--	88.9 (-3.8)
TX	91.4	89.4 (-2.0)	87.4 (-4.0)
SWBT	92.5	89.9 (-2.6)	88.8 (-3.7)

Numbers in parenthesis are repression estimates in basis points.

[a]measured service, where available, is the lower priced alternative and its price is unchanged

[b]both flat rate and measured rate, where available, are doubled

Table 6.8
High Toll Elasticity Equation:
Predictions for Doubling of Rates -- Southwestern Bell Subgroups

	Actual Development	100% Increase with lower priced alternative[a]	100% Increase all prices[b]
ALL	92.5	89.9 (-2.6)	88.8 (-3.7)
RURAL	90.1	86.0 (-4.1)	85.7 (-4.4)
URBAN	93.0	90.7 (-2.3)	89.5 (-3.5)
POOR, RURAL	83.7	77.3 (-6.4)	77.1 (-6.6)
POOR, URBAN	85.0	80.3 (-4.7)	77.9 (-7.1)

Numbers in parenthesis are repression estimates in basis points.

[a]measured service, where available, is the lower priced alternative and its price is unchanged

[b]both flat rate and measured rate, where available, are doubled

Table 6.9
Estimating Equation with
Age As Random Variable

$$F(\sigma_u^2 + \theta^2 \sigma_A^2)^{\frac{1}{2}} - \delta_1 \ln \pi_f - \delta_3 \min(\ln \pi_f, \ln \pi_m + \alpha p) - \tau z$$

$$= -a^* - b_0 \text{ INCOME} - b_1 \text{ RENTER} - b_2 \text{ RURAL} - b_3 \text{ BLACK} -$$

$$b_4 \text{ SPANISH} - b_5 \text{ AMINDIAN} - b_6 \text{ IMMOB} - \theta \text{ LNAVGAGE} -$$

$$b_8 \text{ MILAGE} - b_9 \text{ EMP} + b_{10} \text{ LINES} + b_{11} \text{ HHSIZE} + e$$

variable	coefficient estimate	t-statistic
INCOME	.98	19.4
PRICE OF LOCAL MINUTE (α)	7.69	--
PRICE OF TOLL MINUTE (τ)	-2.50	--
PRICE OF ACCESS	-1.00	--
RENTER	-1.71	-15.7
RURAL	-.81	-18.9
BLACK	-1.09	-12.0
SPANISH	-2.51	-23.1
AMINDIAN	-7.47	-14.6
IMMOB	.44	4.2
LNAVGAGE (θ)	1.01	7.8
MILAGE	-.45	-3.9
EMP	2.47	13.1
LINES	.33	4.4
HHSIZE	1.28	8.6
Constant (a*)	-1.08	-2.0
Nuisance variance (σ_u^2)	4.9	--

R^2 (uncorrected) = .4232
R^2 (corrected) = .4223

differences, the coefficients are amazingly similar. The repression estimates provided in Tables 6.10 and 6.11 are also nearly identical. In fact, the repression estimate for the SWBT territory when all rates are doubled is identical to our model using income.

Another implicit assumption in moving from equation 5.6 to equation 5.7 is that the individual differences are related to income and only income. Thus, in principal at least, we could think of the individual differences being related to several (or all) demographic variables of interest. That is to say, we could include the mean and variance of all the variables in the same way we treated income in the previous derivations of the model. Practically, however, two very large problems prevent this generalization. First, an already cumbersome estimation technique would become totally unwieldy. Second, and perhaps more important, is the fact that the normalization in equation 5.9 would include covariance terms that are unobservable in our data set. To elaborate on these problems, yet still provide some sort of test about the importance of our assumption, we will relate the individual differences to two variables: income and age. This should provide some insight into the problem while remaining somewhat manageable. To begin, we use the following simple demand function:

$$q = Ae^{-\alpha p} y^{\beta} \, AGE^{\theta} \, e^{u}$$

Deriving the consumer surplus and going through the steps outlined above in equations 5.2 through 5.22, we arrive at the following equation

Table 6.10
Equation with Age:
Predictions for Doubling of Rates -- by State

	Actual Development	100% increase with lower priced alternative[a]	100% increase all price[b]
AR	89.1	84.7 (-4.4)	83.7 (-5.4)
KS	95.3	--	93.0 (-2.3)
MO	95.4	92.4 (-3.0)	92.5 (-3.1)
OK	92.7	--	88.9 (-3.8)
TX	91.4	89.5 (-1.9)	87.5 (-3.9)
SWBT	92.5	89.9 (-2.6)	88.8 (-3.7)

Numbers in parenthesis are repression estimates in basis points.

[a]measured service, where available, is the lower priced alternative and its price is unchanged

[b]both flat rate and measured rate, where available, are doubled

Table 6.11

Equation with Age:

Predictions for Doubling of Rates -- Southwestern Bell Subgroups

	Actual Development	100% Increase with lower priced alternative[a]	100% Increase all prices[b]
ALL	92.5	89.9	88.8
		(-2.6)	(-3.7)
RURAL	90.1	86.1	85.8
		(-4.0)	(-4.3)
URBAN	93.0	90.7	89.5
		(-2.3)	(-3.5)
POOR, RURAL	83.7	77.6	77.4
		(-6.1)	(-6.3)
POOR, URBAN	85.0	80.3	78.0
		(-4.7)	(-7.0)

Numbers in parenthesis are repression estimates in basis points.

[a]measured service, where available, is the lower priced alternative and its price is unchanged

[b]both flat rate and measured rate, where available, are doubled

$$F_j(\sigma_u^2 + \beta^2\sigma_{yj}^2 + \theta^2\sigma_{Aj}^2 + 2\beta\theta\sigma_{yAj}) - \delta_1 \ln\pi_{fj} - \delta_3 \min(\ln\pi_{fj}, \ln\pi_{mj} + \alpha p_j) = -a^* - \theta\mu_{Aj} - \beta\mu_j + \tau z_j - \sum_i b_i x_{ij} + e_j , \quad (6.1)$$

where σ_{yA} is the covariance between income and age and μ_A is the mean of age. The problems are that now there is an additional parameter that must be arrived at through iteration and σ_{yA} is not observed. Table 6.12 provides estimates for equation 6.1 under the simple assumption that the unobserved covariance term is constant across observations.[2]

Once again, perhaps surprisingly, the coefficient estimates are similar. For example, the income coefficient changes from .97 to 1.05. Tables 6.13 and 6.14 display the results of simulating this model for a doubling of rates. Once again, the results are comparable to Tables 6.1 and 6.2. However, these repression estimates are uniformly lower. Nonetheless, it would seem, that this generalization does not significantly change the results of our model.

6.2 Internal Validation: Prediction

Another internal test of the model involves the use of holdout samples or ex post unconditional forecasts. That is, we estimated the model over some subset of the data and then compared model predictions for the included and excluded data points. We excluded data in the

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2. The covariance is set to the covariance between the means of income and age across the entire sample.

Table 6.12

Estimating Equation 6.1

Income and Age as Random Variables

$$F(\sigma_u^2 + \beta^2 \sigma_y^2 + \theta^2 \sigma_A^2 + 2\beta\theta\sigma_{YA})^{\frac{1}{2}} - \delta_1 \ln \pi_f -$$

$$\delta_3 \min(\ln \pi_f, \ln \pi_m + \alpha p) - \tau z = -a^* - \beta\mu - b_1 \text{ RENTER} -$$

$$b_2 \text{ RURAL} - b_3 \text{ BLACK} - b_4 \text{ SPANISH} - b_5 \text{ AMINDIAN} - b_6 \text{ IMMOB} -$$

$$\theta \text{LNAVGAGE} - b_8 \text{ MILAGE} - b_9 \text{ EMP} + b_{10} \text{ LINES} + b_{11} \text{ HHSIZE} + e$$

variable	coefficient estimate	t-statistic
INCOME (β)	1.05	18.5
PRICE OF LOCAL MINUTE (α)	-8.08	--
PRICE OF TOLL MINUTE (τ)	-2.50	--
PRICE OF ACCESS	-1.00	--
RENTER	-1.87	-15.4
RURAL	-.87	-18.3
BLACK	-1.17	-11.7
SPANISH	-2.73	-22.5
AMINDIAN	-8.06	-14.2
IMMOB	.52	4.4
LNAVGAGE (θ)	1.23	8.5
MILAGE	-.57	-4.4
EMP	2.87	13.2
LINES	.33	4.0
HHSIZE	1.42	8.6
Constant (a*)	-1.74	-2.9
Nuisance variance (σ_u^2)	4.1	--

R^2 (uncorrected) = .4145

R^2 (corrected) = .4136

Table 6.13
Equation 6.1
Predictions for Doubling of Rates -- by State

	Actual Development	100% increase with lower priced alternative[a]	100% increase all price[b]
AR	89.1	85.2 (-3.9)	84.3 (-4.8)
KS	95.3	--	93.1 (-2.2)
MO	95.4	92.6 (-2.8)	92.6 (-2.8)
OK	92.7	--	89.3 (-3.4)
TX	91.4	89.5 (-1.9)	87.9 (-3.5)
SWBT	92.5	90.2 (-2.3)	89.2 (-3.3)

Numbers in parenthesis are repression estimates in basis points.

[a]measured service, where available, is the lower priced alternative and its price is unchanged

[b]both flat rate and measured rate, where available, are doubled

Table 6.14

Equation 6.1

Predictions for Doubling of Rates -- Southwestern Bell Subgroups

	Actual Development	100% Increase with lower priced alternative[a]	100% Increase all prices[b]
ALL	92.5	90.2	89.2
		(2.3)	(-3.3)
RURAL	90.1	86.4	86.2
		(-3.7)	(-3.9)
URBAN	93.0	90.8	89.8
		(-2.2)	(-3.2)
POOR, RURAL	83.7	78.4	78.2
		(-5.3)	(-5.5)
POOR, URBAN	85.0	81.9	79.0
		(-4.1)	(-6.0)

Numbers in parenthesis are repression estimates in basis points.

[a]measured service, where available, is the lower priced alternative and its price is unchanged

[b]both flat rate and measured rate, where available, are doubled

following proportions: (1) five percent excluded; (2) twenty-five percent excluded; and (3) fifty percent excluded. The included samples were drawn without replacement. Thus, for the case of five percent of the sample being excluded, we estimated twenty models -- one for each sample. With these twenty models we predicted the error for included observations and excluded observations. These errors were then averaged over the twenty models. Similarly, we used four and two models for the 25% and 50% excluded cases, respectively. The results, which speak for themselves, are presented in Table 6.15.

The last internal test involved using the model to predict or forecast the effect of actual price increases in Texas. This test or ex ante conditional forecast was performed for two reasons: (1) check accuracy of model predictions; and (2) clarify the concept of repression vis-a-vis dropoff. The model predicts repression or the reduction of development from what otherwise would have occurred. Notice that, in general, it is difficult to pinpoint the accuracy of a repression prediction since we only observe one development level (or the other). Non-economists, however, attempt to interpret this repression as drop-off, i.e., multiply the decline in development by the number of households and interpret this product as the number of households that disconnect from the telephone system. In our test, actual data for 1980 will be used as the base case. Using statewide changes from 1980 to 1985, census tract figures are "adjusted" to better reflect 1985. Armed with these updated census tract figures, we will generate a prediction for 1985. While there is no observed 1985 development with which to compare our prediction, we can

Table 6.15
Hold-out Sample Test

	Average % Error Included Observations	Average % Error Excluded Observations
5% excluded	2.1	2.1
25% excluded	2.1	2.1
50% excluded	2.2	2.2

Table 6.16
Prediction Test - Texas

	1980	1985	Change
Households	3,729,787	4,447,200	19.2%
Households with Telephones	3,410,165	4,002,480	17.4%
% Development	91.4%	90.0%	-1.4%
Residence Access Lines	3,553,270	4,120,181	16.0%

Table 6.17
Perl Comparison
All Rates Doubled

	Perl	Our Model	Difference
AR	-7.0	-5.5	-1.5
KS	-2.1	-2.2	0.1
MO	-2.2	-3.1	0.9
OK	-2.6	-3.9	1.3
TX	-3.3	-4.0	0.7

calculate the predicted increase in households with phones by multiplying the development prediction and the number of households in 1985. We now compare the predicted percentage increase in households with telephone service to the actual percentage increase in the number of residence access lines served by SWBT in Texas (from company reports). The results are displayed in Table 6.16. We should note that over the five-year period there may have been changes, not explicitly controlled for in the model which would cause development to increase, e.g., the proliferation of personal computers which makes telephone service intrinsically more valuable. Thus, as discussed above the decline in development predicted may not occur. Nonetheless, for purposes of this example we assume these changes external to the model are held constant. Notice that while predicted development falls 1.4% (1.0% is attributable to price increases) the number of households with telephones increases. This clarifies to some extent the distinction between repression and drop-off. Furthermore, we notice the model predicts a 17.4% increase in households with phones while the actual number of access lines have increased 16% -- a fairly accurate prediction over a five-year period.

6.3 External Validition: Prediction

We turn now to external testing or the comparison of our results with other studies previously discussed in Chapter Three. We will concentrate on the comparison of our model with the SWBT pooled model and the Perl (1983) study. We restrict our comparison to these models since the SWBT pooled model covers the same territory and might be expected to be similar and the Perl study is considered the industry standard.

Since the SWBT pooled model yields a single estimate of the elasticity of demand, .04, it can be quickly compared to the model results presented in Table 6.1. For a doubling of rates over the entire SWBT territory, the model predicts a repression estimate of 3.7% or an elasticity of .037. Obviously, this is quite close to the pooled elasticity. For comparison, the aggregate Perl elasticity for a 100% price increase is .038.

Many comparisons can be made to the Perl model. For example, we can compare repression estimates by state as shown in Table 6.17. While the estimates vary slightly, all are of similar magnitude. Furthermore, we could compare repression predictions within consumer or geographic groups, e.g., the poor. While these comparisons suffer from the fact that Perl results are nationwide while our results are for SWBT territory only, they will be suggestive of similarities and/or differences in model predictions. The comparison may be further weakened by different measures of "poor". A doubling of rates in the Perl model produces a 9.1% repression estimate for the poor. Our model, on the other hand, estimates a repression figure of 6.9%. More interesting, perhaps, are the estimates of the number of poor that are affected, i.e., the percentage of total households that repress or forego access which in fact are poor. The Perl model estimates that twenty-seven percent of affected households are poor (poverty stricken) compared to our estimate of twenty percent. In conclusion, we find the model to be relatively insensitive to key input assumptions. Furthermore, model predictions fall well within the acceptability range established by previous studies. This concludes model testing and we turn now to model results.

CHAPTER SEVEN

RESULTS

In this chapter we will provide the model predictions that will be the basis of the subsequent welfare analysis. These model predictions provide estimates of the price responsiveness of access demand. As such, the discussion will focus around the use of these estimates within the industry. A somewhat atypical welfare analysis will then be performed. While its basis is common within the economics profession, the splitting of costs into three sets is somewhat unique. In addition to its uniqueness, this analysis provides insights into potential pricing policies to help mitigate the costs of declines in development.

7.1 Model Results

Now that the model has been validated, we can use it to predict the impact of many pricing or policy decisions. We produce four tables that will display the predicted effects of some of the most frequently discussed pricing policies. These tables differ from the results presented in Tables 6.1 and 6.2 in that these are based on current measured service availability (detailed in Table 7.1). In addition to the choice availability change, the Arkansas measured price was changed to 55% of the flat-rate price (from about 35% in 1980) to more accurately reflect the actual choice available to customers. Since having a lower priced alternative plays so large a role in the ultimate repression prediction, we felt updating these variables produced the best available repression estimates for policy analysis. All results in these tables are derived using the sample enumeration method as described in Appendix A.

Table 7.1 shows the effects of a doubling in access rates for flat-rate service only. Additionally, the impact of a doubling of the measured access rate is also included. For example, doubling all rates would lead to a 5.6% decline in development in Arkansas while doubling only the flat-rate would lead to a 2.5% drop in development.

The effects of these pricing policies on specific subscriber groups (poor, rural, etc.) are of particular interest to regulators, legislators, and the telephone companies. Table 7.2 shows the impacts of 100% price increases (as in Table 7.1) for particular subscriber groups in Southwestern Bell territory. Household repression is provided in addition to the basis point decrease in development, e.g., 50,300 rural customers would be expected to forego access if all prices were doubled. It should be reiterated that, following our previous discussion on repression, the 50,300 represents an estimate of repressed households not disconnects.

Table 7.3 presents the results of the model simulation for the current FCC Access Charge plan. The plan involves a $2 EUCL and offsetting reduction in the NTS portion of access charges which was passed on to toll users. This amounts to a 3.6 cent reduction for interstate toll (state by state declines are detailed in the table). For example, in SWBT territory the EUCL (with its associated toll

Table 7.1
Development and Repression
100% Access Price Increases -- By State

	Actual Development	100% increase with lower priced alternative[a]	100% increase all prices[b]
AR	89.1	86.6 (-2.5)	83.5 (-5.6)
KS	95.3	--	93.1 (-2.2)
MO	95.4	94.6 (-0.8)	92.4 (-3.0)
OK	92.7	--	88.8 (-3.9)
TX	91.4	90.5 (-0.9)	87.5 (-3.9)
SWBT	92.5	91.0 (-1.5)	88.8 (-3.7)

Numbers in parenthesis are repression estimates in basis points.

[a]measured service, where available, is the lower priced alternative and its price is unchanged. The current measured service availability for the states is: AR: 40.2%, KS: 0; MO: 62.8%; OK: 0; and TX: 72.3%.

[b]both flat rate and measured rate, where available, are doubled

Table 7.2

Development and Repression

100% Access Price Increases -- Southwestern Bell Subgroups

	Actual Development	100% Increase with lower priced alternative[a]	100% Increase all prices[a]
ALL	92.5	91.0 (-1.5) [-107,200]	88.8 (-3.7) [-264,400]
RURAL	90.1	86.9 (-3.3) [-37,700]	85.8 (-4.4) [-50,300]
URBAN	93.0	91.9 (-1.1) [-66,000]	89.4 (-3.6) [-216,100]
POOR, RURAL	83.7	78.2 (-5.5) [-7,500]	77.2 (-6.5) [-8,900]
POOR, URBAN	85.0	83.0 (-2.0) [-11,800]	77.9 (-7.1) [-42,000]
NOT POOR, URBAN	94.9	94.0 (-.9) [-48,700]	92.2 (-2.7) [-146,100]

Numbers in parenthesis are repression estimates in basis points.

Numbers in brackets are estimates of number of households effected.

[a]same definitions as in Table 6.18

Table 7.3
Effects of "Current" FCC Access Charge Plan[a]
By State

	Actual Development	$2 Increase	$2 EUCL with toll price decrease[b]
AR	89.1	87.8	88.2
		(-1.3)	(-0.9)
KS	95.3	94.9	95.1
		(-0.4)	(-0.2)
MO	95.4	94.5	94.7
		(-0.9)	(-0.7)
OK	92.7	91.8	92.0
		(-0.9)	(-0.7)
TX	91.4	90.3	90.7
		(-1.1)	(-0.7)
SWBT	92.5	91.5	91.8
		(-1.0)	(-0.7)

Numbers in parenthesis are repression estimates in basis points.

[a]$1 EUCLs in June 1985 and 1986.

[b]Using the percent of total toll that is interLATA and the 3.6 cent reduction, we generate the following toll price reductions by state: AR: 2.2¢; KS: 2.4¢; MO: 2.2¢; OK: 2.0¢; and TX: 3.0¢.

price reduction) would produce 0.3% less repression (1.0 - 0.7) than a comparable price increase (without a toll offset). This tranlates into a toll cross elasticity of approximately one half the size of the own-price elasticity. To produce predictions for this pricing policy, an additional assumption is required. In particular, the $2 increase applies to today's rates which are higher than the rates that existed in 1980. To compensate for this fact, we apply an additive in 1980 that is equal (on average) in percentage terms to the $2 EUCL today, i.e., $2 relative to today's average rate multiplied by the average rate in 1980 yields the price additive used to generate the table. Alternatively, we could have deflated $2 to 1980 dollars using a consumer price index. We decided, however, since the prices appeared in the equation as logarithms that the percentage approach was the more correct method.

Furthermore, the model can be used to estimate the impacts of "targeting the subsidy". Table 7.4 shows the effects of a $1 EUCL with and without a lifeline service, i.e., when all SWBT households on poverty are excluded from the $1 EUCL repression is reduced by twenty-five percent (0.4 vs. 0.3). The effect can be seen for different subscriber groups by comparing columns two and three for any row in the table. In addition, estimates of local-service revenue are provided for the total SWBT territory. The derivation for the price increase to simulate the $1 EUCL is the same as described above. Here, we wish to isolate the impact of the $1 EUCL from poverty stricken households. Since we have census tract data instead of individual data, however, this is not a straightforward exercise. We

Table 7.4
Effects of Initial $1 EUCL[a]
Southwestern Bell Subgroups

	Actual Predicted	$1 EUCL	$1 EUCL Poor exempted
TOTAL SUBSCRIBERS	6,608,500	6,580,200	6,587,300
TOTAL LOCAL REVENUE	$44.1	$50.1 [+12.0]	$49.5-50.1 [+10.6-12.1]
ALL	92.5	92.1 (-0.4)	92.2 (-0.3)
RURAL	90.1	89.7 (-0.4)	89.8 (-0.3)
URBAN	93.0	92.6 (-0.4)	92.7 (-0.3)
POOR, RURAL	83.7	83.0 (-0.7)	83.3 (-0.4)
POOR, URBAN	85.0	84.1 (-0.9)	84.5 (-0.5)

Numbers in parenthesis are repression estimates in basis points.

Numbers in brackets are estimates of the percentage change in local access revenues.

Subscriber and revenue estimates are for 1980.

[a]The initial $1 of FCC Access Charge Plan was instituted June 1, 1985.

take the price additive as described above and mulitply this by the percentage of households in each census tract not poverty stricken. This product is then the price increase for that census tract. For example, if fifty percent of the households in a given census tract are poverty stricken, then that tract will have its price increased by fifty percent of the price additive corresponding to the $1. This methodology should provide a conservative estimate of the impact of insulating the poor from the increase, i.e., the difference between columns two and three is a reasonable lower bound estimate. The rationale for this estimate being conservative is that the increase in the average rate in the tract produces more reaction among the poverty stricken households than the reduction in the average produces among the remaining households.

The results displayed in Tables 7.1 through 7.4 make several points very clear. Repression, while quite small, is not zero. It would seem to be in the best interest of the telephone companies to acknowledge this immediately in any regulatory proceeding. The universal service question has received tremendous attention. Consumer groups, the Congress, and regulators are openly concerned about its preservation. Any attempt by the telephone companies to seek local increases without addressing the associated impact on universal service will surely bring an emotional response from at least one of these groups. If the filing is not accompanied with the telephone company's estimate of repression and plan to minimize it, any subsequent response will appear hurried and politically motivated.

There is also no denying that certain groups are more adversely affected (refer to rows 2-4, Table 7.2). For example, the "poor urban" decline in development is nearly twice that of SWBT as a whole. These groups, however, are not as large as the emotional and political debate would indicate, e.g., from the second column of Table 7.2 we see that only 51,900 (8,900 + 42,000) of the 264,000 repressed households are "poor". A lifeline offering could substantially reduce the impact on these subscriber groups (compare columns 2 and 3 in Table 7.4). In fact, any lower-priced alternative tends to reduce repression (compare columns 3 and 4 for Texas and column 4 for Oklahoma in Table 7.1 - the difference in these columns for Texas is due to availability of lower-priced alternative). Additional insight into this point can be gained from comparing Tables 7.1 and 6.1. The only difference between these tables, except for the noted measured price change in Arkansas, is the degree to which measured service is available. Thus, we can compare the second columns of the tables for Missouri and Texas to verify that the model will predict that increased measured availability leads to lower overall repression. While the differences are small (one-tenth of one percent for each state), nonetheless the result confirms the intuitive notion that overall repression will be lower even when all rates are doubled. This point is related to underlying choice regarding class-of-service. For example, if a subscriber has flat-rate service then the doubling of the flat rate will have an effect of equal or smaller magnitude if there is alternative to flat (measured service in our case). This result is theoretically pleasing and in contrast to the Perl (1983) results. Additionally, policymakers should find this useful as they search for rate designs to mitigate the impact of increasing rates on universal service.

As mentioned above, a lifeline offering will help mitigate the negative impact of any local access price increase. Table 7.4 makes this point quite clearly. Perhaps, more interesting, is the prediction that revenue may be higher. Thus, depending on the marginal cost of providing the service, the telephone company may also be better off. Another interesting calculation can be made using Table 7.4. The increase in revenue due to the imposition of the $1 EUCL is $6 million (50.1 - 44.1). The decline in the number of households that would be expected to subscribe to the network is 28,300 (6,608,500 - 6,580,200). Thus, the cost to keep these 28,300 households on the network is 6.1 million dollars or $212 per household per month.

Up to this point we have concentrated on the impact of price on development. There are, however, other variables of interest. In particular, we will consider the impact of income and the number of lines in the local calling area. These impacts may be simulated in the same way price was. For example, we consider a ten percent increase in income.[1] This change yields .39 percentage point increase in development or an access elasticity of .039. While this may seem small, we must recall that over 90% of the households have telephones and as such, their access decision would be unaffected by the increase in income.

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1. Since both the mean and variance of income appear in the equation, care should be taken with analysis of this type. Only small changes in income should be simulated.

More interesting from a theoretical point of view, however, is the impact of the number of lines in the local-calling area. This elasticity can be interpreted as a measure of the subscriber or network externality. The externality appears very small at present levels of development and network size, for an increase of 10% in the number of lines implies only an .035 percentage point increase in development. Taken at face value, this small subscriber externality provides little economic justification for access subsidies, especially at the current high levels. This concludes our presentation of the model results.

7.2 Welfare Analysis

Now that we discussed the perceived costs (in terms of development repression) of an increase in local rates, we can turn to the benefits. We will discuss the benefits associated with a representative rate proposal: local rates are doubled and toll rates are reduced by one-half. While this proposal would still leave toll prices significantly above costs, it provides insight into the effects of "cost-based" rates. In SWBT territory, approximately 1518 million minutes of toll with an average price of 28 cents are generated monthly over 10.7 million lines (7.7 million of these are residence).[2] Once again to be conservative and consistent with our derived model in

2. Quantity and lines data are from company reports for early 1985. The price is a weighted average of LATA and interLATA ARPMs. See Weisman (1986) for details.

Chapter Five, we will use a toll elasticity of .5.[3] Figure 1 details graphically the following analysis. The gain in consumer welfare (measured by the area under the toll demand curve and between 28 cents and 14 cents) for a move from 28¢ to 14¢ is 239.1 million dollars per month. Of this amount, 212.5 million is direct toll savings. The additional 26.6 million dollars of increased benefit is welfare gain due to the increased use of toll services. Assuming a fifty-fifty split between residence and business originating minutes, approximately 106 million dollars per month would flow directly to residential ratepayers. This amounts to about $13.75 per residential customer per month. The direct welfare gain of about 13.3 million dollars accounts for another $1.73 per month of direct benefits. Additionally one might reasonably expect that reduced costs of production (telephone service) would lead to a reduction in the end product price of firms. The approximate $15 increase in producer surplus could be expected to make its way to the residential customers through these reduced prices for consumer products. Thus, the average residence ratepayer could expect approximately $15 direct benefits and the possibility of an additional $15 in indirect benefits. On the other hand, the doubling of rates would cost the average SWBT ratepayer about $11. The average ratepayer is $4 better off per month at the new rates than he/she was at the old rates. The additional indirect benefits are above and beyond this $4 direct benefit.

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3. Using Taylor's "consensus" of .75 for interstate and internal SWBT estimates of LATA (.40) and intrastate (.53) elasticities would yield a "best guess" estimate of about .65.

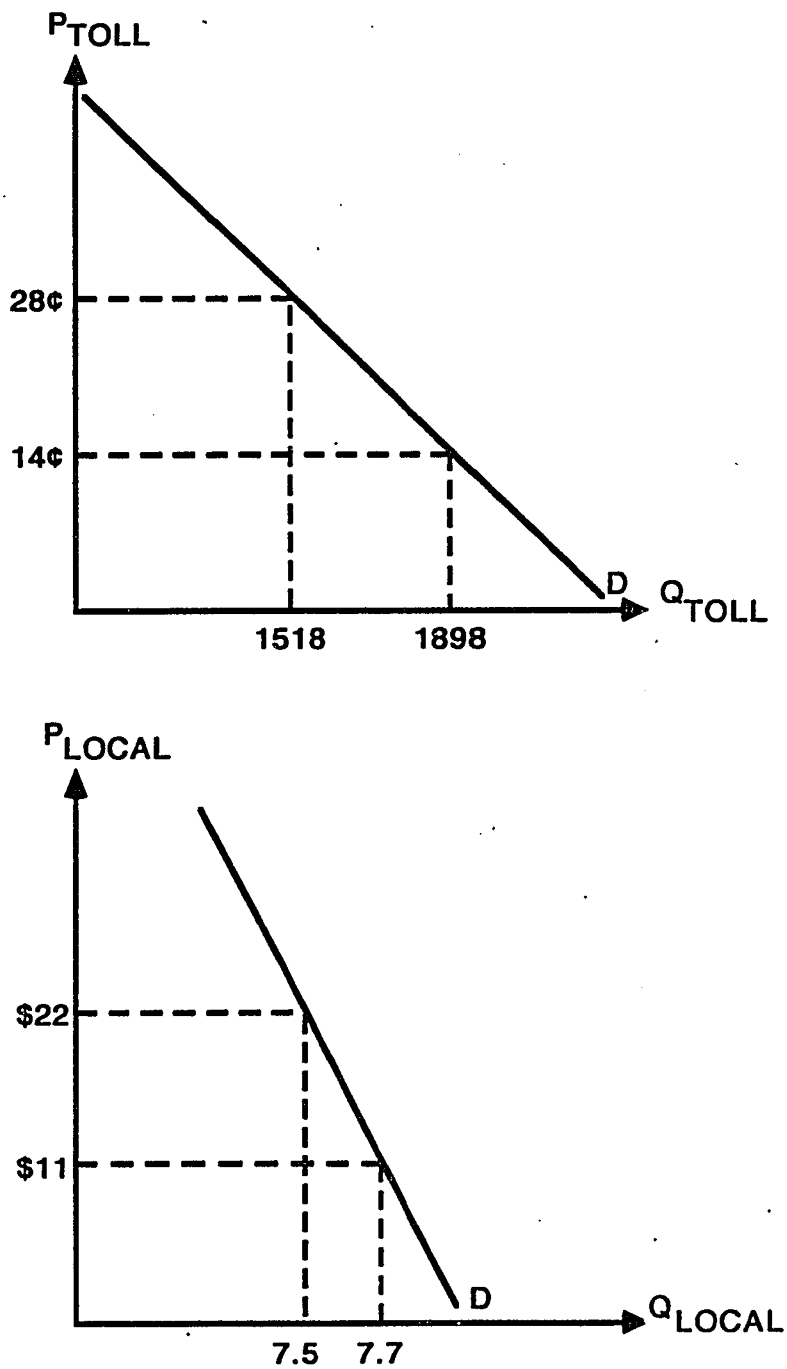

Figure 1: Fundamental Graphic for Welfare Analysis

The costs associated with this rate strategy are related to access repression. From Table 7.1, we see that development for SWBT would fall 3.7% when all local rates are doubled. However, when we include the effects of the toll price reduction of 50%, the repression estimate falls to 2.8% or approximately 200,000 customers. Assuming an average value of $16, this amounts to a welfare loss of 3.2 million dollars (or the area under the local demand curve and between $11 and $22).[4]

As can easily be seen from these calculations the benefits totally dominate the costs. However, the stumbling block is the reduction in telephone development. An additional 200,000 households without phones is a very difficult sale to regulators. This is true despite the fact that any change of this magnitude would likely be phased in and accompanied by additional service offerings (lifeline, expanded LMS, etc.). Each of these would tend to reduce the ultimate number households affected.

In order to better analyze the development repression and potential impact on universal service, we will divide the 200,000 households into three sets: (1) those with ability to pay constraints; (2) those strictly with willingness to pay constraints; and (3) a set that face either willingness or ability to pay constraints. The first set corresponds to our "poor" classification and amounts to about 20% of the total. The second set is made up of households that earn over

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4. We know these customers value service between $11 and $22. We take the half way point for convenience.

twice the poverty level and accounts for about 40% of the total. The last set is made up of households that earn between one and two times poverty level income and accounts for the final 40%.[5] While it is easy to define the dividing lines between these sets in theory, it is not quite so straightforward in practice. Here, we chose convenient yet reasonable dividing lines.

To increase the understanding of the discussed rate plan, we will now describe the impacts on these three sets. The first set or those with an ability to pay problem is not difficult to deal with. While politically sensitive, there has already been substantial attention paid to rate designs (e.g., lifeline) specifically tailored to prevent development reductions for this set. The industry seems dedicated to preserving telephone development for society's disadvantaged. Additionally, while from an economist's perspective the subsidy to this set should be externally funded, the numbers are small enough such that through careful rate design it could possibly be generated internally if absolutely required.

The second set or those who could easily afford service but simply decide not to are also easily addressed. These optimizers are making rational economic choices - in exactly the same way some individuals choose to drive a Ford even when they could afford a Mercedes. In this sense, as policy planners, we could and should ignore this set in terms of its ultimate impact on universal serivce.

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5. The estimate of the size of this third set is from Perl. The second set is simply the remainder. The first set is estimated by both our model and the Perl model with very similar results.

Alternatively, however, if we decide that is important for one reason or another to keep these individuals on the telephone network, then alternative tariff designs could substantially meet this goal. This alternative design may include expansion of LMS and alternative LMS plans, i.e., a continum of access price/usage price offerings.

The third set is the problematic set. While some sort of lifeline service could be designed, it would be necessary for the LECs to act as welfare agents. While the subscribers in the first set have been designated needy by society (through the food stamp program for example), the would-be subscribers in this set have not been so labelled. Therefore, for the LECs to institute a lifeline type program for those needy individuals in this set, it would require the LECs to screen the needy from the non-needy. This is clearly an expensive proposition. While alternative tariff designs would also mitigate the impact in this set, it would work less well than on the optimizers since we do not know the mix of optimizers and needy in this set.

Nonetheless, we have shown that of the 200,000 at least 120,000 could be maintained on the network through innovative rate design. This design involves "targeting" the subsidy for those that need it and increasing the numbers and types of optional tariff plans. While the number of additional households without phone service may still seem large, it is important to note that choices involve costs. Indeed, if we do not move to reduce toll rates (through reduced access charges), competitive forces will cause the subsidy to disappear anyway. One lesson that should have been learned from the last two decades is that there is no such thing as a little competition. The competitive fringe that now threatens the LECs will certainly expand. There seems little doubt that the competitive incursion will eventually drive out all cross-subsidies. If we proactively move rates toward costs, however, then we will provide lower toll rates to all customers (not just the largest ones) and preserve network integrity as well. We view this discussion and the results of Table 7.3 as further evidence in line with Perl (1983), Bell Communications Research (1984) and Brock (1984) that a EUCL-type transition plan is preferable to allowing bypass to occur unchecked.

Finally, we must note at this point that regulators are wary of granting large local rate increases to the LECs that are already performing well-above expectations. This performance is misleading, however, since its basis is a continuation of the pre-divestiture separation of toll revenues to provide the local subsidy. To convince the regulators otherwise, will require consistent recommendations. These recommendations must be based on current market information on bypass, toll and local services, etc. Otherwise, the current trends will certainly continue. That is to say, we will continue to pay the costs of divestiture (added complexity, etc.) while the benefits (lower toll rates, etc.) will be delayed further into the future except for the largest customers.

CHAPTER EIGHT

CONCLUSIONS

The focus of this research has been on determining the residential price elasticity of demand for access to the telephone network. In particular, we have derived these elasticities of demand for distinct subscriber groups, e.g., the poor, urban versus rural, etc. We have approached this issue by determining an appropriate estimation methodology for a somewhat unique data set. The estimation methodology was consistently developed from a theory of demand for access.

The primary contribution of this research has been the development of these price elasticity of demand estimates from a consistent underlying economic theory. The few existing high quality empirical studies all lacked theoretic motivation and/or consistency. This theoretic foundation facilitates model interpretation, use and critique. For example, the interpretation, of the estimated coefficients being derived from the underlying usage equations, is new to studies of this type. While we were primarily interested in access to the network rather than the form of access (e.g., flat or measured service), the theoretic structure also provides a simple class-of-service choice framework. That is, based on the size of the coefficient on the local usage price, the class-of-service (flat or measured) is determined for that individual census tract. While the unavailability of any access/choice data set necessarily makes our class-of-service choice framework somewhat naive, it is a significant improvement over the handling of service choice in previous access studies.

Many of the other contributions of this research also flow from the adoption of the underlying economic theory into the empirically estimated model. In particular, the estimate of the subscriber externality flows directly from the supporting theory and is the best available measure. In contrast, as described in Chapter Three, the Perl (1983) measure is suspect due to the inclusion of the unexplained density variables. Furthermore, while additional assumptions and an approximation was required, the measure of the cross elasticity of access with respect to the toll price is the only available proxy. This estimate is especially valuable for policy makers since all transitional plans involve toll prices falling as local prices increase. The accompanying welfare analysis is also potentially valuable to policy makers. While previous welfare analyses have concentrated primarily on increases in aggregate benefits, we have also attempted to disaggregate the costs or expected decline in telephone development into three mutually exclusive sets. Viewing the expected decline in this way suggests rate design innovations and supporting arguments to mitigate the political opposition to prospective price changes.

Lastly, our development of the estimation technique for aggregate proportion data is unique. While data of this type is atypical, there may well be other examples of similar data where our technique or one that is similar could be used. Included in this estimation description is a discussion of a Monte Carlo study to assure reasonableness of the computing algorithm and estimation methodology. Furthermore, a jackknife technique was described to estimate the standard errors of coefficients on the left-hand-side of the estimating equation. Within empirical demand studies in general, and telecommunication studies in particular, these are somewhat novel.

The economic expertise within the industry, however, is far from perfect. The incredibly political and adversarial nature of rate cases makes it difficult for studies of this type to be used correctly. This in turn leads to producing "results" rather than studies (recall our discussion of drop-off studies in Chapter Three). Furthermore, we assumed away certain critical details in our welfare analysis. In particular, the marginal cost estimates required to derive optimal prices are unknown. Only lately, has the industry become interested in obtaining measures of economic costs (historically, costs calculated for regulators were the only interest). For example, despite its many pro-competitive rulings the FCC continues to use fully distributed cost studies (FDC) to set rates. Economic research into these costing issues within the industry has only just begun (Taylor, 1986). Much of our discussion on mitigating price effects centered on the increased availability of local measured service (LMS) and lifeline. However, very little is known about these choice situations. These choices must be well understood before economically optimal rates can be designed. As noted in Chapter Three, the Train, McFadden, and Ben-Akiva and Kling studies have started the learning process in the right direction with respect to service choice. The selection of lifeline service, however, has not been studied at all. Research into these costing and choice areas is required before the industry can hope to achieve some measure of economic efficiency.

APPENDIX A

ESTIMATION AND PREDICTION WITH DISCRETE DATA

In this section we will discuss some technical details of estimation and prediction using discrete data. We will discuss the limitations of using least squares and provide a brief description of maximum likelihood estimation. Finally we detail the methods of predicting aggregate market behavior with discrete choice models.

A.1 Ordinary Least Squares

To analyze the problems of using ordinary least squares (OLS) with discrete data, let us begin with the typical assumptions. That is,

$$y = X\beta + u$$

where

y is the dependent variable

X is a matrix of independent variables

β is a vector of parameters to be estimated

u is the stochastic error term.

The OLS estimator of β is

$$\hat{\beta} = (X'X)^{-1}X'y.$$

The estimator is unbiased, consistent, and efficient under certain general assumptions. These standard assumptions are

(1) $E(u) = 0$

(2) $E(uu') = \sigma^2 I$

(3) X is fixed set of numbers with full rank or if X is stochastic that it is independent of u.

The first assumption of zero mean is not a problem here. However, the second assumption of a non-autocorrelated and homoscedastic error term is important. Notice that in the case of discrete data the dependent variable is either zero or one. Hence, the error term u must be

$$u_i = -X_i\beta \quad \text{if } y_i = 0 \qquad \text{(A.1)}$$
$$\quad\; 1 - X_i\beta \quad \text{if } y_i = 1,$$

where X_i denotes the ith row of the matrix X. Following Dhrymes (1978), the variance of this error term is defined as

$$\text{var}(u_i) = (1 - X_i\beta)^2\, F(X_i\beta) + (X_i\beta)^2[1 - F(X_i\beta)] - [E(u_i)]^2$$
$$= F(X_i\beta)[1 - F(X_i\beta)], \qquad \text{(A.2)}$$

where F(.) is the cdf. Thus, we clearly violate the homoscedastic assumption in (2). It has been suggested (Goldberger, 1964), that Aitken estimators be used to solve this problem. That is, we simply estimate equation A.2 with

$$\hat{y}_i(1 - \hat{y}_i),$$

where $\hat{y}_i = X_i\hat{\beta}$ and $\hat{\beta}$ is the standard OLS estimate. A two-step weighted least squares approach is used. The first step to get the OLS estimates of β and the second step to get the ultimate estimates of β. Note, however, that this approach is dependent on all estimates of the dependent variable being between zero and one. If any estimates fall outside this range, however, the two-step procedure will fail. The suggestion has been made that one could impose additional constraints to guarantee that the estimates are between zero and one. This suggestion is, however, typically not optimal since (Dhrymes, 1978, pp. 333) "...then we no longer deal with simple techniques; if we are to engage in more complicated procedures, there are far better methods than constrained least squares."

Aside from these technical problems is an interpretation or practical problem that is at least as significant. It is intuitively appealing and obvious to interpret y as the probability of success given the observed X. However, we know probabilities must lie between zero and one. If any predicted value is outside this range we have an obvious contradiction. Notice that even if all values "in-sample" are between zero and one, there are other values (possibly of interest) that will violate the condition "out-of-sample." This possibility makes it practically impossible to use this model in real world applications.

To conclude, while OLS is simple that is its only attribute with discrete data. While we have presented the discussion under the assumption that the dependent variable is binary, it makes little difference if instead, the dependent variable falls in the unit interval. The costs discussed above significantly outweigh the benefit of simplicity and hence OLS is not an optimal estimation tool when using discrete data.

A.2 Maximum Likelihood Estimation

A better analytic tool when dealing with discrete data is maximum likelihood estimation (MLE). In the general case, MLE is defined as follows. A sample, $x_1,\ldots,x_n$, is drawn from a distribution with the density function $f(x \mid \theta)$. The parameter θ is unknown. The likelihood function, L, is defined as

$$L(x_1,\ldots,x_n \mid \theta) = f(x_1 \mid \theta)\ldots f(x_n \mid \theta).$$

The θ, say $\hat{\theta}$, that maximizes L(.) for observed $x_1,\ldots,x_n$ is said to be the maximum likelihood estimator of θ. The MLE has some powerful statistical properties:[1]

1. The invariance property: if $\hat{\theta}$ is the MLE of θ, then $u(\hat{\theta})$ is the MLE of $u(\theta)$;[2]
2. If the Cramer-Rao Lower Bound is reached by an unbiased estimator, then the MLE reaches it;
3. For large sample size n, the MLE attains Cramer-Rao Lower Bound in an asymptotic sense and is asymptotically normal with mean θ.

Additionally, the MLE has the very intuitive property of maximizing the probability of observing what in fact was observed. However, finding the MLE may be quite difficult in practice - depending of course on the function L. In general we seek the solution to the following n equations:

$$\frac{\partial L}{\partial \theta_i} = 0, \qquad i = 1,\ldots,n.$$

The solution of these first-order conditions can be quite cumbersome

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1. This list is not meant to be all inclusive. For more details, see Taylor (1974).

2. This assumes u is a monotonic function in θ, with a single-valued inverse.

since they are typically nonlinear. Two procedures are often used to solve the problem: (1) Newton techniques; and (2) gradient methods.

The Newton techniques are usually used when the second derivatives are able to be calculated without too much difficulty and L is globally concave. The algorithm for a single coefficient proceeds as follows:

1. Choose initial estimates for θ say θ^0;
2. Linearize the function $\frac{\partial L}{\partial \theta}$ at θ^0; set this linear approximation equal to zero; the θ^1 that solves equation is the new estimate;
3. Continue until $\theta^{i+1} - \theta^i$ is in some sense small.

The gradient methods differ from the Newton technique in the use of the matrix of second derivatives or the Hessian. Many gradient techniques are available (Scales, 1985). Here we briefly mention two of the more popular types: Modified Newton and variable metric methods. The Modified Newton techniques use a positive definite approximation to the Hessian. This overcomes one potentially dibilitating weakness of the Newton method. Variable metric methods, the newest of the techniques, are designed to converge rapidly but require large storage. Details on the Hessian approximation in variable matrix method, differences with other gradient methods, and clarifying discussion may be found in Scales (1985).

We now turn to the use of MLE techniques with discrete data. The problem could be motivated as Taylor (see Chapter 4 equations 4.1 through 4.6 for a review of this approach) or Perl (see Chapter 3 for review) did. These approaches start with consumer surplus (CS) and assume - either through taste or income - that this CS is related to an underlying distribution. Assuming some probability distribution then leads to a likelihood function which will then be maximized to yield coefficient estimates. Alternatively, one could use the random utility model pioneered by McFadden.[3] In either case, we could write the likelihood functions in general terms as follows

$$L\ (\text{Sample} \mid \theta) = \prod_{n=1}^{N} \prod_{i=1}^{J_n} p\ (i_n \mid x_n, \theta)^{\Psi_{in}}\ p\ (x_n),$$

where

L denotes the likelihood of observing the sample given θ, the unknown parameter vector.

$p(i_n \mid x_n, \theta)$ is the conditional probability of choosing alternative i, given θ and x_n, a vector of alternative and/or individual attributes

$$\Psi_{in} = \begin{cases} 1 & \text{if individual n chooses alternative i} \\ 0 & \text{otherwise} \end{cases} \quad \text{for all i}$$

$p(x_n)$ is the marginal probability of observing x_n

N is the number of individuals (or sample size)

J_n is the choice set faced by individual n.

For computational convenience, we take logs of the likelihood function yielding

$$\log L = \sum_{n=1}^{N} \sum_{i=1}^{J_n} \Psi_{in} \log p\ (i_n \mid x_n, \theta) + \sum_{n=1}^{N} \log p\ (x_n).$$

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3. See Train (1986) and McFadden (1986) for discussion.

For random samples or exogenously stratified samples, the second term does not depend on θ and hence disappears. We now have

$$\log L = \sum_{n=1}^{N} \sum_{i=1}^{J_n} \Psi_{in} \log p(i_n \mid x_n, \theta).$$

At this point, specification of p(.) will lead to a specific likelihood function that can than be maximized to yield parameter estimates. The typical specifications of p(.) as logistic, normal, or uniform leads to the logit, probit, and linear probability choice models.

A.3 Predicting with Discrete Choice Models

In this section we will discuss the prediction problem as generally encountered with discrete choice models. With this as a backdrop, we will proceed to discuss the added difficulties presented by our use of census tract or aggregated data.

Generally we are concerned with aggregate or market demand, e.g., what proportion of households have telephones. Discrete choice techniques, however, primarily focus on the individual, i.e., what is the probability that some individual will have phone service. Obviously, we need a mechanism that provides the necessary market information from our sample of individual behavior.

Five different methodologies have been used to arrive at aggregate predictions:

1. Average individual;
2. Classification;

3. Statistical differentials;

4. Explicit integration;

5. Sample enumeration.

Before discussing these methods, we denote W_i as the proportion of the population that selects alternative i and it is defined as follows:

$$W_i = \int_x p(i|x)p(x)\, dx,$$

where

$p(i|x)$ is the probability of choosing alternative i given characteristics x

$p(x)$ is the marginal density of x.

The problem may be viewed as attempting to estimate W_i in the "best" way. We turn now to discussion of the five frequently used methods listed above. Ben-Akiva and Lerman (1985) provide additional discussion on the methods for prediction described here.

The average individual is very easy to understand. Define a "representative" individual that has the average characteristics. Evaluate the probability for this "representative" individual. That is, calculate $p(i|\bar{x})$ and use this probability for the average individual as the average for the population. The problem with this procedure is that almost all of these discrete models are nonlinear and hence the expectation of the function is not equal to the function of the expectation. Figure 2 should provide visual clarification for a problem of this type.

Classification may be viewed as a simple but logical extension of the average individual approach. Since the average individual

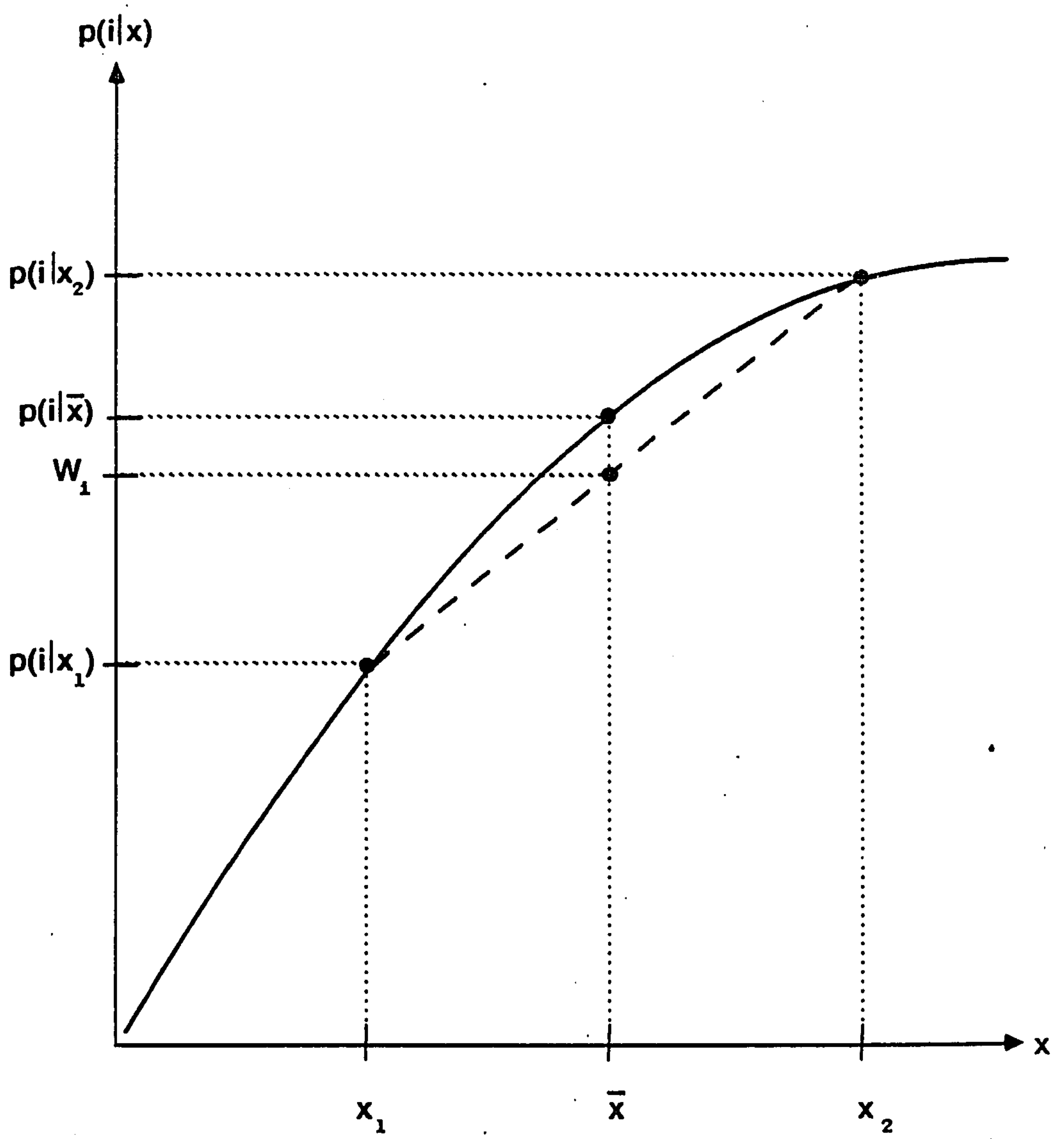

Figure 2: Error Associated with "Average Individual" Prediction

method's accuracy is negatively related with the variance of the characteristics (x), we can improve the approach by classifying the population into disjoint, homogenous subgroups. Then we need only to apply the average individual methodology to each subgroup. These subgroup predictions could then be weighted by class sizes to generate a market or population prediction. However, classifying individuals into homogenous subgro ps may be a formidable task. Furthermore, those homogenous subgroups that provide accurate forecasts may not be the subgroups of interest with respect to policy analysis. In addition, the class sizes may well be unknown and thus cause the researcher yet another estimation problem.

Using the equation for W_i, one could expand $p(i|x)$ using a second-order Taylor's series around $\bar{x}$. This procedure known as statistical differentials yields a "correction" to the average individual forecast or prediction. However, this method is not necessarily more accurate than the average individual forecast. To improve accuracy many higher-order terms and moments of $p(x)$ may be required. Unfortunately, these items may be incredibly difficult to forecast and/or calculate.

The fourth scheme involves approximating $p(x)$ with some distribution and then explicitly or directly integrating to derive W_i. Obviously, this approach could become mathematically quite cumbersome.

The fifth and final approach is sample enumeration. This approach is quite intuitive. We simply calculate the probability of selecting alternative i for each (randomly selected) individual and average these probabilities. That is, the equation becomes

$$W_i = \frac{1}{N} \sum_{n=1}^{N} p(i|x_n).$$

This estimator of W_i is consistent assuming the underlying coefficient estimates are consistent. This method is easily adaptable to specific problems or concerns and non-random sampling situations. For example, it is quite straight forward to produce forecasts for specific subgroups.

While none of these approaches clearly dominates the others, most applications have used classification or sample enumeration. Sample enumeration is the most flexible in analyzing the impacts of various policies on different subgroups of the population. Since we are interested in exactly this type of analysis, we will use sample enumeration for our forecasts of state and subgroup development rates.

Since our predicted probabilities for telephone access are for census tracts rather than individuals and population varies by tract, these probability estimates need to be weighted to generate a market forecast. Hence, the formula for W_i becomes

$$W_i = \frac{1}{N} \sum_{n=1}^{N} \frac{H_n}{H} p(i|x_n), \qquad \text{(C.1)}$$

where

H_n is the number of households in census tract n

H is the total number of households

N is the number of census tracts.

All predictions in the text are calculated using this sample enumeration procedure. For example, to estimate the repression associated with a doubling of rates the following procedure is employed. First we estimate predicted development rates for each census tract. Using equation C.1 we calculate a base case development level. All rates are then doubled. We then simulate new predicted development rates for each census tract at the new prices. Once again using equation C.1, we estimate an aggregate development level. The difference between the base case and new development levels is then the estimate of repression.

APPENDIX B

TECHNICAL NOTES ON ESTIMATION

In this section we will discuss the technical details of the computing algorithm used to estimate the coefficients of the model described in Chapter Five. Additionally, we will provide fairly detailed descriptions of the methodologies used in the Monte Carlo study and the jackknife technique referred to in the text.

B.1 Computing Algorithm

To estimate an equation of the type displayed in Table 5.1 in Chapter Five, our computing algorithm works as follows. The user supplies initial values for the unknown coefficients to be used on the left-hand-side of the equation (σ_u^2, β , and α). Given these values the left-hand-side is calculated using equation 5.27. An ordinary least squares (OLS) regression is then performed on the equation, which is of the type presented in 5.26. Rearranging the equation by adding the price terms to the right-hand-side and then multiplying by the SQRT($\sigma_u^2 + \beta^2\sigma_y^2$) term yields an estimate of F, say FHAT. The correlation between F and FHAT is now calculated. This correlation between the actual and predicted probits or z-scores is then the objective function to be maximized.

Our lack of knowledge of relevant range of σ_u^2 and observed flatness of the objective function led to the choice of a modified binary search routine. For example, the sequence of coefficients, given a initial value of one and assuming that the objective function continues to increase, would be 1, 1.9, 2.8, 11.8, 101.8, etc. If the value of the objective function at 1.9 exceeded its values at 1 and 2.8, however, then the procedure checks values on each side of 1.9. Unlike a typical binary search that would split these intervals in half, i.e., evaluate the objective function at 1.45 and 2.35, our modified method selects these intermediate points based on objective function values. This selection is weighted by the value of the objective function, e.g., the larger the difference between objective functions values evaluated at two points, the closer the new evaluation point is to previous point with the higher objective function value. This modification leads to a faster solution. The procedure continues until the percent change in the coefficient is less than some prespecified tolerance, typically one half of one percent.

This procedure is used to estimate both σ_u^2 and α. Since α appears only in the minimum function on the left-hand-side, additional estimation problems must be addressed. Note that once α obtains some value, say α_{max}, that it has no effect on the objective function, i.e., $\ln \pi_f$ is always less than $\ln \pi_m + \alpha_{max} p$. Furthermore, in our data set the value of the objective function at α_{max} (and beyond) tended to be very close to the objective function value at the optimal α . The sequence used in the search routine noted above then could easily "jump over" α_{max}. Since the objective function is non-decreasing for all α greater than α_{max} the sequence would just continue until the maximum iteration limit was reached. To circumvent this problem a limit on step size could be employed. The sequence could be restricted to a given maximum step size, e.g., 1, 1.5, 2, 2.5, etc. Thus, the "jumping over" problem could be eliminated during estimation. While this step size limiting increased the number of necessary iterations it was required for most regression runs.

The estimation of β presented new problems since it appeared on both sides of the equation. One could have brought β to the left-hand-side and proceeded in the same way as with σ_u^2 and α. However, a direct convergent routine was selected. Given the initial value of β, say β_0, the OLS regression provides new estimate, say β_1. Now, plug β_1 into the left-hand-side of the equation using equation 5.27, and re-estimate the OLS regression to get another estimate β_2. Continue this procedure until the percentage difference between the new estimate β_{i+1} and the old estimate β_i is less than some prespecified tolerance. This procedure required fewer iterations to converge and did not require calculation of the objective function. Hence, it was much more efficient in terms of required computing resources.

B.2 Jackknife Technique

The estimation methodology created other problems as well. In addition to the problems associated with the estimation of σ_u^2, α, and β, we needed a mechanism to test the statistical significance of these parameter estimates. To estimate these standard errors associated with those parameter estimates, we used a jackknife technique.

Primarily used by statisticians, the jackknife technique is a nonparametric method for estimating the bias and/or variance of some statistic of interest. The technique involves selecting g subsamples of size h from the total sample (of size n). Using estimators based on a sample size of (g-1)h where the i^{th} group of size h has been removed, the jackknife can be used to estimate the variance of a statistic or reduce the bias of a statistic (see Miller (1974), pp. 1 for an example of the latter use of the jackknife). Typically, the jackknife is employed by using g=n and h=1, i.e., n samples of size n-1. While this typical case is "probably the best form of the jackknife to use in any problem "(Miller, 1974, pp.2), it may well be computationally infeasable with large data sets.

The jackknife has been used with linear regressions. In particular, it may be used to learn about the sampling distribution of the coefficient estimates (Efron, 1977). Simply stated, we remove a row at a time from the X matrix and estimate the model on this reduced data set.

As pointed out above the typical jackknife methodology involves selecting n random samples of size (n-1) and estimating the model coefficients for each data set of size (n-1). Then, with these n estimates of the model coefficients, a variance can be calculated. With 8423 observations and a highly non-linear estimation methodology producing average computing costs of $480 per subsample, this typical jackknife at a cost of 3.8 million dollars was simply computationally and monetarily impractical. Instead, twenty samples excluding five percent of the total sample were used. The model shown in Table 5.1 was estimated for each of the twenty samples. From these twenty sets of coefficient estimates variances were calculated in the usual fashion,i.e., $\sum_i (\beta_i - \overline{\beta})^2/n$. The standard deviation or the square root of these variances was used to divide the coefficients and obtain t-statistics. Table B.1 presents the results of the technique. It is interesting to note that with exception of α the mean estimates from the jackknife are equal to our coefficient estimates presented in Table 5.2.

B.3 Monte Carlo Study

Monte Carlo experiments were conducted to test the feasibility of the estimation algorithm just described. The model tested was very similar to estimating equation in Table 5.1 except the independent variables MILAGE, LINES, HHSIZE, and the toll price were not included. The first stage of the Monte Carlo study was for 10 sets of coefficients. The coefficient range was chosen to be well outside the coefficient estimates we had observed in preliminary analysis. For example, the income coefficient (β) was varied from .4 to 1.25 while all early estimates were between .9 and 1.05. The F's were generated with the following equation:

$$F = \frac{-a^* - \beta\mu - \sum_i b_i x_i + \ln\pi_f + \min(\ln\pi_f, \ln\pi_m + \alpha p)}{(\sigma_u^2 + \beta^2 \sigma_y^2)^{\frac{1}{2}}} + e,$$

where the e are randomly drawn observations from a standard (unit) normal distribution.

The error term (e) is calculated using the following procedure. Using a linear congruential method (Prime Subroutines Reference Guide), a random number is generated from an input seed. The input seed is the time of day in centiseconds. Using two such randomly generated numbers, the following equations from Fishman

Table B.1
Jackknife Results

Coefficient	Range of estimates from jackknife	Mean of estimates from jackknife	Variance of estimate from jackknife
σ_u^2	4.95 to 5.2	5.1	.003
β	.95 to .99	.97	.0002
α	-6.81 to -8.56	-7.19	.27
EMP	2.58 to 2.80	2.66	.003
RENTER	-1.52 to -1.61	1.56	.0008
RURAL	-.75 to -.78	.77	.00007
BLACK	-1.01 to -1.11	1.05	.0006
SPANISH	-2.38 to -2.50	2.42	.0007
AMINDIAN	-7.06 to -7.55	7.27	.015
IMMOB	.44 to .55	.50	.0012
AVGAGE	.0343 to .0416	.04	.000003
MILAGE	-.38 to -.48	-.43	.0009
LINES	.31 to .42	.39	.0005
HHSIZE	.99 to 1.15	1.10	.0019

(1973) are used to generate two independent variates that are distributed normally:

$$X_j = \mu + (-2\sigma^2 \log U_j)^{\frac{1}{2}} \cos 2\pi U_{j+1}$$
$$X_{j+1} = \mu + (-2\sigma^2 \log U_j)^{\frac{1}{2}} \sin 2\pi U_{j+1},$$

where

X_j, X_{j+1} are the returned normal variates

U_j, U_{j+1} are the input random variables.

Table B.2 shows the average percent error for each coefficient estimate over the 10 experiments. Each experiment was conducted with a sample size of 500. 100 realizations per experiment were performed.

The purpose of this initial procedure was to insure that, given a fairly wide range of coefficient values, the estimation methodology yielded "reasonable" estimates.

The second stage of the Monte Carlo study used a single set of coefficients. The coefficients were selected to be "near" the estimates obtained during preliminary analysis on the entire data set. The F's were generated in the same way, i.e., using the following equation:

$$F = \frac{-a^* - \beta\mu - \sum_i b_i x_i + \ln\pi_f + \min(\ln\pi_f, \ln\pi_m + \alpha p)}{(\sigma_u^2 + \beta^2 \ \sigma_y^2)^{\frac{1}{2}}} + e.$$

Now, however, we will draw e from a N(0, .25) in addition to a N(0,1). These normal variates were derived in the same manner as described previously. The N(0, .25) was chosen to yield R^2s similar to those observed using the actual data. Hence, the N(0,1) experiments could be viewed a "fat-tailed" experiments. Table B.3 displays the results for the N(0,1) experiments. Table B.4 displays the results for the

TABLE B.2

First Stage Monte Carlo

Variable	Range of Actual Coefficients	Mean % Error
σ_u^2	3.0 to 6.0	7.8%
β	.4 to 1.25	3.5%
α	5.0 to 12.5[a]	0.7%
EMP	-3.0 to 1.5	10.5%
RENTER	1.3 to 2.1[a]	2.6%
RURAL	.25 to 1.25[a]	6.3%
BLACK	.25 to 2.0[a]	3.1%
SPANISH	1.25 to 2.5[a]	0.3%
AMINDIAN	2.0 to 8.0[a]	4.7%
IMMOB	.2 to 2.0	1.0%
AVGAGE	.01 to .07	6.2%

[a] sign of actual coefficients is negative.

TABLE B.3
Second Stage Monte Carlo
N(0,1)

Variable	Actual Value	Mean Predicted Value n = 500	Mean Predicted Value n = 1000
σ_u^2	4.5	3.94 (1.08)	3.95 (.57)
β	1.05	1.02 (.14)	1.00 (.07)
α	6.0	6.88 (18.0)	6.76 (13.1)
EMP	-2.25	-1.98 (1.73)	-2.02 (.83)
RENTER	.80	.71 (.39)	.72 (.18)
RURAL	.75	.69 (.07)	.71 (.04)
BLACK	.75	.66 (.25)	.69 (.15)
SPANISH	1.50	1.38 (.27)	1.42 (.13)
AMINDIAN	4.00	3.84 (4.87)	3.81 (2.48)
IMMOB	-1.00	-.99 (.43)	-.97 (.22)
AVGAGE	-.04	-.04 (.00048)	-.04 (.00024)

Numbers in parenthesis indicate variance of estimate.

TABLE B.4

Second Stage Monte Carlo

N(0,.25)

Variable	Actual Value	Mean Predicted Value n = 500	Mean Predicted Value n = 1000
σ_u^2	4.5	3.90 (.26)	3.94 (.14)
β	1.05	.98 (.031)	.99 (.017)
α	6.0	6.63 (8.39)	6.45 (3.70)
EMP	-2.25	-2.06 (.44)	-2.08 (.21)
RENTER	.80	.73 (.09)	.73 (.05)
RURAL	.75	.70 (.016)	.71 (.009)
BLACK	.75	.69 (.067)	.70 (.034)
SPANISH	1.50	1.42 (.065)	1.42 (.032)
AMINDIAN	4.00	3.72 (1.22)	3.75 (.62)
IMMOB	-1.00	-.93 (.11)	-.93 (.05)
AVGAGE	-.04	-.04 (.00014)	-.04 (.00007)

Numbers in parenthesis indicate variance of estimate.

N(0,.25) experiments. The second stage of the Monte Carlo study was specifically undertaken to observe the behavior of the estimator as the sample size was increased and as the variance of error term changed. As can be seen from analyzing Table B.3, the coefficient estimates appear mildly biased with the bias ranging from about 1-12% depending on coefficient. For example, the bias in the income coefficient is approximately 2.8%. The bias is affected only slightly by increases in sample size but appears to decline moderately for most coefficient estimates. The variance of the estimates, as one might expect, falls by about one-half as the sample size doubles. The same general conclusions can be observed in Table B.4. However, the reduction in bias as sample size increases is more readily observed here. It is also interesting to note that while the variances are much smaller in the N(0,.25) case, the mean estimates are virtually unchanged. This seems to suggest that the fatness of the tails of the error distribution have little degrading impact on the estimation methodology. We are still assuming, however, the error distribution is symmetric.

The third and final stage of the Monte Carlo study used the same set of actual coefficients as did the second stage of the Monte Carlo study. 'Actual' and predicted development and repression rates were obtained for 100 realizations. This involves solving the model for all one thousand census tracts for the 'actual' coefficients and the one hundred sets of coefficient estimates. Using sample enumeration as described in Appendix A, we derive an 'actual' base case development level and one hundred base case predicted development levels. We then change the appropriate prices and simulate the models again. At this point we have 'actual' and predicted development estimates at the new prices. The results of this process are displayed in the table below. The first row displays 'actual' development and repression rates. The second row provides predicted development and repression rates using average coefficient estimates. The third row displays predicted development and repression rates obtained by averaging the predicted development levels over the 100 realizations. As can be seen, the models predictions are quite close to the 'actual' figures. It is interesting to note that even where the model overpredicts (the second row) development, it also overpredicts repression. This result is somewhat surprising, but satisfying, since logit and probit models that overpredict development generally underpredict the responsiveness to changes in exogenous variables.

Table B.5

Third Stage Monte Carlo

Repression and Development Predictions

	Current	Double Flat Rate		Double Flat & Measured Rate	
actual	91.4	87.6	(-3.8)	86.3	(-5.1)
predicted[a]	91.8	87.9	(-3.9)	86.6	(-5.3)
predicted[b]	91.3	87.2	(-4.1)	85.9	(-5.4)

[a]coefficients averaged.

[b]predicted values averaged.

The Monte Carlo results suggest that the estimation technique provides reasonable coefficient estimates. The existence of the small bias and the apparent slow rate at which it disappears concerns us econometrically. However, development and repression estimates are the important items for telephone company and industry policy. The accuracy of these estimates - suggested both by the Monte Carlo studies and comparison with our current state of knowledge - should, nonetheless, make the study quite useful for planning and policy analysis.

APPENDIX C

LINEAR PROBABILITY MODEL

This section describes the original linear probability model or OLS specification. Table C.1 displays the regression specified and coefficient estimates. The results of these runs were originally supplied to the FCC (Southwestern Bell Supplemental Filing to FCC Dockets 78-72, Phase 1 and 80-236). All coefficients have the theoretically correct sign and are statistically significant. As noted in the discussion of our modelling efforts in Chapter Five, the size of the poverty coefficient was surprising. This was one of the key clues that eventually led us to the technique ultimately used. In addition to the estimation problems some of the predictions from the OLS model were also not satisfying. Repression estimates are provided in Tables C.2 and C.3 to help clarify this point. These tables are directly comparable to Tables 6.1 and 6.2. While the pattern of these estimates is quite different and counterintuitive by state, the aggregate SWBT repression estimate is identical (3.7 percent). In contrast, however, an important observation is the different impact of the price structure on certain subscriber groups (compare "POOR, RURAL" to "POOR, URBAN"). These results are somewhat suspect since they seem to suggest that lower-priced alternatives need not reduce repression. This result is primarily due to the fact that both flat and measured prices affect the development in choice areas. This pricing structure, at least in linear models, produces unreasonable results. It is interesting to note that this is the same price structure which leads Perl (1983) to the inconsistent results discussed previously in Chapter Three.

TABLE C.1

Original OLS Specification

$$\text{Development} = a + b_1 \delta_1 \pi_f + b_2 \delta_3 \pi_f + b_3 \delta_3 \pi_m + b_4 \delta_3 + b_5 \text{ RURAL} + b_6 \text{ MEDINC} + b_7 \text{ POVERTY} + b_8 \text{ BLACK} + b_9 \text{ SPANISH} + b_{10} \text{ AMINDIAN} + b_{11} \text{ RENTER} + b_{12} \text{ AVGAGE} + b_{13} \text{ IMMOB} + b_{14} \text{ EMP} + b_{15} \text{ MILAGE} + b_{16} \text{ LINES} + e$$

where MEDINC is the log of median household income
POVERTY is the % of households that are poverty stricken
all other variables defined as in Table 5.1

Variable	Coefficient	t-statistic
$\delta_1\pi_f$	-.00280	-3.9
$\delta_3\pi_f$	-.00292	-1.7
$\delta_3\pi_m$	-.01011	-3.2
δ_3	.04462	3.5
RURAL	-.03873	-18.6
MEDINC	.03379	10.3
POVERTY	-.15316	-13.7
BLACK	-.03275	-7.5
SPANISH	-.10645	-20.0
AMINDIAN	-.16746	-6.9
RENTER	-.09760	-19.7
AVGAGE	.00086	5.0
IMMOB	.02543	5.1
EMP	.10637	10.6
MILAGE	-.02228	-4.0
LINES	.00001	2.9
CONSTANT (a)	.81631	54.7

R^2 (uncorrected) = .467
R^2 (corrected) = .466

Table C.2

OLS Equation

Predictions for Doubling of Rates -- by State

	Actual Development	100% increase with lower priced alternative[a]	100% increase all prices[b]
AR	89.1	86.6 (-2.5)	85.8 (-3.3)
KS	95.3	--	93.6 (-1.7)
MO	95.4	93.2 (-2.2)	93.1 (-2.3)
OK	92.7	--	91.0 (-1.7)
TX	91.4	89.5 (-1.9)	86.3 (-5.1)
SWBT	92.5	90.6 (-1.9)	88.8 (-3.7)

Numbers in parenthesis are repression estimates in basis points.

[a] measured service, where available, is the lower priced alternative and its price is unchanged

[b] both flat rate and measured rate, where available, are doubled

Table C.3

OLS Equation

Prediction for Doubling of Rates -- Southwestern Bell Subgroups

	Actual Development	100% Increase with lower priced alternative[a]	100% Increase all prices[b]
ALL	92.5	90.6	88.8
		(-1.9)	(-3.7)
RURAL	90.1	88.4	88.0
		(-1.7)	(-2.1)
URBAN	93.0	91.0	88.9
		(-2.0)	(-4.1)
POOR, RURAL	83.7	82.1	81.9
		(-1.6)	(-1.8)
POOR, URBAN	85.0	83.0	81.2
		(-2.0)	(-3.8)

Numbers in parenthesis are repression estimates in basis points.

[a] measured service, where available, is the lower priced alternative and its price is unchanged

[b] both flat rate and measured rate, where available, are doubled

APPENDIX D

RESIDENCE BASIC EXCHANGE MODEL

This section provides an attachment that describes the SWBT pooled model discussed in Chapter Three. This attachment is an update (reflecting a model update extending the model through 1983) of the documentation filed in SWBT rate cases. For example, see the attachments in Egan's 1983 Missouri testimony. The document briefly describes the estimation methodology, the data used, and provides all coefficient estimates with t-statistics.

SOUTHWESTERN BELL RESIDENCE BASIC LOCAL EXCHANGE SERVICE DEMAND MODEL

Presented below are the results of ongoing research of the demand for residence basic local exchange service in the five Southwestern states-Arkansas, Kansas, Missouri, Oklahoma and Texas. The model specification includes the effects of the monthly recurring and nonrecurring prices of residence basic service, the rate of inflation, real per capita income, market size and seasonality. The specification recognizes the importance of habit persistence on the demand for residence basic service by incorporating dynamic lagged effects of the key explanatory variables. Specifically the Almon polynomial distributed lag technique is used to introduce dynamics. The model is estimated with pooled cross-sectional time-series data for the five Southwestern states over the period from first quarter 1972 through fourth quarter 1983.

The Southwestern Bell Residence Basic Exchange Service Demand Model is presented below. The model is linear in the logarithms of the variables and the specification is as follows:

$$\ln Q_{TEL} = \sum_{i=1}^{5} a_i D_i + \sum_{k=o}^{11} b_k (\ln Y)_{t-k} + \sum_{k=o}^{5} c_k \ln \frac{P_R}{P_{CPI_{t-k}}} + d \ln \frac{P_N}{P_{CPI}} +$$

$$f \ln N + \sum_{i=1}^{3} g_i S_i + e,$$

where

Q_{TEL} = Total residence main telephones in service

D = State-specific intercept variables

Y = Real per capita nonfarm personal income

P_R = Price index of residence basic local exchange service recurring monthly charge

P_N = Price index of residence basic local exchange service minimum nonrecurring charge

P_{CPI} = Consumer price index

N = Population

S = Qualitative seasonal variables

e = Stochastic error term.

The coefficients a, b, c, d, f, and g are the unknown parameters to be empirically estimated. The optimal lag structure utilizes second-degree polynomials with lags of 6 quarters on recurring price and 12 quarters on income. In each case, the effect of the furthermost lag on the demand for residence basic local service is assumed to be zero.

The following table presents the estimation results of the preferred specification. The resultant elasticity estimates are all statistically significant and all have the theoretically correct sign. The long-run recurring price elasticity is -.039, the noncurring price elasticity is -.0036, and the long-run income elasticity is .62. The resultant elasticities are the best unbiased estimates available and appear directly beneath their respective variable names.

Table D.1
Southwestern Bell Residence Basic Exchange
Service Demand Model

Long-run Elasticities:

$\ln Y$	$\ln \frac{P_R}{P_{CPI}}$	$\ln \frac{P_N}{P_{CPI}}$	$\ln N$
.62[b]	-.039[c]	-.0036	.92
(18.4)	(5.0)	(2.7)	(19.6)

Seasonal Coefficients:

S1	S2	S3
.003	-.008	.003
(9.6)	(23.0)	(9.2)

Summary Statistics

R^2 = .999 D.W. = 1.42 S.E. = 0.811

Individual Quarterly Elasticities:

b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9
.095	.087	.079	.071	.063	.055	.047	.039	.032	.024
(8.7)	(11.4)	(15.2)	(18.7)	(17.3)	(13.1)	(9.9)	(7.8)	(6.3)	(5.3)

b_{10}	b_{11}	c_0	c_1	c_2	c_3	c_4	c_5
.016	.008	-.0072	-.0080	-.0080	-.0072	-.0056	-.0032
(4.6)	(4.0)	(2.3)	(4.6)	(4.6)	(3.5)	(2.9)	(2.5)

	Intercept	Autocorrelation Coefficient	R^2
Arkansas	7.56 (30.5)	.969	.992
Kansas	7.67 (30.0)	.929	.998
Missouri	7.71 (31.9)	.966	.985
Oklahoma	7.79 (31.3)	.999	.999
Texas	7.72 (34.3)	.920	.998

Note: Numbers in parentheses are absolute values of t statistics. The model is corrected for autocorrelation within states, heteroskedascity between states, and mutual correlation between states. The model is estimated using generalized least squares (GLS).

DATA DESCRIPTION AND SOURCES

Q_{TEL} - Quantity of residence main telephones in service, including lines terminating in customer-provided equipment, from Company report Monthly Report #7.

P_R - Laspeyres price index for residence basic exchange service recurring monthly charge. Documentation available upon request.

P_N - Price index for residence basic exchange service minimum nonrecurring charge. Documentation available on request.

P_{CPI} - Consumer price index, from the U.S. Department of Labor. Regional price index data are available by selected SMSA's and by major geographical areas. Whenever possible the regional deflators were used.

Y - Real nonfarm personal income per capita. The personal income data are from the U.S. Department of Commerce. The regional CPI data used for deflators are from the Department of Commerce, and the population data are from the U.S. Bureau of the Census.

N - Total resident population, from the U.S. Census Bureau.

S1, S2, S3 - Qualitative binary (0/1) variables to account for seasonality. S1 is assigned a value of unity in the first quarter of each year and zero elsewhere; S2 and S3 are defined similarly.

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