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DO SWITCHING COSTS MAKE MARKETS MORE OR LESS COMPETITIVE?: THE CASE OF 800-NUMBER PORTABILITY*

Abstract

Do switching costs reduce or intensify price competition in markets where firms charge the same price to old and new consumers? Theoretical models provide an ambiguous answer due to two opposing incentives in firms' pricing decisions. The firm would like to charge a higher price to previous purchasers who are "locked-in" and a lower price to unattached consumers who offer higher future profitability. The net effect relative to a market without switching costs will depend on the mix of old and new consumers and the relative strength of these two effects. I demonstrate this ambiguity in an infinite-horizon theoretical model that, in contrast to previous models, allows for actual switching in equilibrium. This is necessary to understand markets where consumers actually switch because the real costs of switching are shared between firms and those who switch.

800- (toll-free) number portability provides empirical evidence to answer this question. Before portability, a customer had to change numbers to change service providers. This imposed significant switching costs on users, who generally invested heavily to publicize these numbers. In May 1993 a new database made 800-numbers portable. This inter-temporal drop in switching costs and regulations that precluded price discrimination between old and new consumers provide an empirical test of switching costs' effect on price competition.

I use contracts for virtual private network (VPN) services to test how AT&T adjusted its prices for toll-free services in response to portability. I find that AT&T reduced margins for toll-free calls (both switched and dedicated) under VPN contracts as the portability date approached, implying that the switching costs under non-portability made the market less competitive. Toll call services included in these same contracts serve as a control group since their marginal cost is virtually identical to toll-free service but they are unaffected by portability. I find that portability also lowered margins for toll services. I provide evidence that this is due to cross-subsidization across services within contracts by comparing bundled and unbundled contracts. These results suggest that, despite toll-free services growing rapidly during this time period, AT&T's incentive to charge a higher price to "locked-in" consumers exceeded its incentive to capture new consumers in the high switching costs era of non-portability.

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Economic theory is ambiguous about the effect of switching costs on price competition when firms charge the same price to all consumers. This ambiguity is due to two opposing incentives. The firm would like to charge a higher price to previous purchasers who are "locked-in" and a lower price to unattached consumers who offer higher future profitability.[1] Price levels in a market with switching costs relative to a market without such costs will depend on the relative number of old and new consumers and the relative strength of these two effects as determined by firm and consumer discount factors and the incentive for consumers to switch in the absence of switching costs.

Switching costs have important implications for the structure and competitiveness of markets. Even if unable to charge different prices to new and existing consumers due to transactions costs, regulatory constraints or arbitrage possibilities, firms can use aggregate data on purchase history when setting its prices. This can alter the competitiveness of the market and affect the distribution of surplus between consumers and firms. Switching costs are pervasive and can result from a need for compatibility with existing equipment, transaction costs of switching suppliers, costs of learning to use new brands or uncertainty about the quality of untested brands. Klemperer (1995) provides a review of the sources and importance of switching costs. Although economists have developed theoretical models of switching costs, they have performed minimal testing of these models. This is particularly unfortunate given the ambiguous theoretical results.

Klemperer (1995) argues that when firms charge a single price switching costs will generally make markets less competitive for three reasons. First, discounting dampens the firm's incentive to charge a lower price for new consumers. The higher profits gained from "locking-in" these consumers are obtained in the future and therefore firms discount them, whereas profits from consumers already "locked-in" are obtained immediately. Second, raising prices today evokes a

[1] It is not necessarily true that the firm would like to charge a lower price to unattached consumers as described below.

favorable strategic response. A higher price in the current period increases rivals' customer bases leading them to charge higher future prices to take advantage of these "locked-in" consumers.[2] Third, new consumers anticipate paying higher future prices once they are "locked-in," and are less tempted by a current price cut. This makes demand less elastic and leads to higher prices.

Regardless of the persuasiveness of Klemperer's arguments, it is an empirical question whether these effects are strong enough to reduce price competition. In this paper I test the effect of switching costs on price competition in a rapidly growing market, toll-free telephone calls. Since rapidly growing markets have a greater proportion of new consumers there is a higher probability of switching costs leading to increased price competition. In spite of this rapid growth, I find that switching costs led to lower competition in toll-free services.

800-, or toll-free, service is a telecommunications product in which the receiver, rather than the initiator, pays for the cost of a call.[3] Prior to May 1993, local exchange carriers (LECs), due to a computer database limitation, were unable to route a toll-free call to any inter-exchange carrier (IXC) except that which "owned" the number. Once a customer had contracted with an IXC, they could not change their 800-service to a competing carrier without being assigned a new number. This imposed huge switching costs on firms who used 800-numbers. Firms usually publish these numbers widely, imprinting them on stationary, advertisements and business cards making the cost of changing them significant. A change in numbers also negates any consumer recognition the firm has established and could even harm the firm's reputation if consumers encounter difficulty contacting the firm.

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[2] This depends on the assumption of prices as firms' strategic variables so that the firms' strategies are strategic complements in the sense of Bulow, Geanakoplos and Klemperer (1985).

[3] The service is often called 800-service because all toll-free numbers originally began with the numbers "800." Toll-free numbers now also begin with "888" and "877."

In May 1993, installation of a new database in all LECs allowed them to route incoming 800-calls to any IXC. This change allowed consumers of these services to switch IXC providers without changing their phone number. It was necessary for all LECs to implement the database simultaneously since toll-free calls can originate from anywhere in the country. Thus, a known, exogenous technological shock lowered switching costs dramatically in May 1993.[4] It is this change in switching costs that I exploit in my empirical tests.

Due to a regulatory “fairness” doctrine, firms in the 800-services industry had to charge the same price to new and existing consumers. This natural experiment provides an opportunity to test whether changes in switching costs increase or decrease price competition when firms charge the same price to new and old consumers. Consumers enjoyed lower switching costs due to portability. Controlling for other factors, declines in price due to portability would be evidence that switching costs make markets less competitive, while increases in price would be evidence for the opposite.

Using contracts for AT&T virtual private network (VPN) services, I find that portability lowered prices for 800 services implying that higher switching costs under non-portability made the market less competitive. I find that AT&T lowered margins for toll-free services under VPN contracts as the portability date approached. Regulations specified that users could terminate any VPN contract that included toll-free services as of the portability date regardless of the contract’s specified duration. This meant that switching costs under these contracts declined as the portability date approached because existing consumers and potential new consumers were “locked-in” for a shorter period of time.

4 Portability is not completely exogenous if we consider the role of telecommunications firms influencing the Federal Communications Commission (FCC) (the government agency responsible for deciding on portability). If AT&T changed its pricing to influence this decision then there would be a question of causality. AT&T opposed portability so lowering prices with portability, as I find, would not be an obvious method of influence.

I estimate that AT&T lowered its price-cost margins $\left(\frac{p-mc}{p}\right)$ for dedicated (high-volume) toll-free service by 0.000252 for each (expected) day closer portability came (0.092 annualized) and 0.000315 (0.115 annualized) for switched (low-volume) toll-free service. This translates into a decline of 0.088 for dedicated service and 0.110 for switched service in the "average" contract in my data set if portability had been implemented by that time and ignoring strategic responses by AT&T and its competitors. This is relative to margins of 0.550 for dedicated and 0.444 for switched services for the "average" contract. These represent a 16% and 25% decline in margins for dedicated and switched services. These effects are extremely significant and robust to control variables included in estimation [further robustness tests need to be completed].

A useful benchmark for these effects is margins for toll calls in this same set of VPN contracts. These calls have virtually identical marginal cost to toll-free calls but are not directly affected by non-portability of 800-numbers. I find that AT&T also reduced margins on switched and dedicated toll services in response to portability but the effects are smaller. I provide evidence that AT&T cross-subsidized service within VPN contracts by comparing prices in contracts that bundle toll and toll-free services to those that provide only toll services. In the non-bundled contracts the effect of portability on toll service margins is no longer significant and a test of structural change rejects applying the same model to both sets of data.

I address two major questions about these empirical results. First, the FCC subjected AT&T to price regulation on its stand-alone (non-VPN) toll-free services until the portability date. Since AT&T's VPN offerings were subject to tariff review both before and after portability, the coincidence of the FCC lifting price regulations and portability raises a concern of confounding effects if the price regulation of stand-alone services were binding and influenced its tariff reviews. I offer both qualitative and quantitative evidence that the regulatory constraint was not binding. Second, there is a question of whether AT&T was able to price discriminate between old and new consumers by tailoring VPN contracts specifically enough to exclude one group or the other. Both the FCC and the courts considered this issue and determined that AT&T did not. I offer empirical evidence that this is the case by comparing price revisions to existing contracts (which would apply only to existing users if contracts were perfectly tailored) to prices in new contracts (which would apply only to new users if contracts were perfectly tailored). I do not find any significant difference in pricing policies between the two types of contracts.

I also compare less formally a price index for 800-services relative to a price index for all other IXC services around the portability date. It shows that prices for 800-services declined more rapidly than those for other services in the time leading up to and after portability. [This needs to be added.] Overall, my results indicate that AT&T's incentive to charge higher prices to existing consumers subject to the high switching costs of non-portability exceeded its incentive to "lock-in" new users by charging lower prices. Given the rapid growth in 800 services during this time period (AT&T's toll-free minutes were growing over 14% per year), this suggests that switching costs are likely to increase prices in markets with lower growth rates if firms are constrained to charge the same price to new and existing consumers.

Although the primary contribution of this paper is as an empirical test of switching costs models, it makes two secondary contributions. First, it contributes to the theoretical switching costs literature. I develop a theoretical model that shows a drop in switching costs may lead to either an increase or decrease in equilibrium prices. Although this model borrows from previous switching costs models, it is the first infinite-horizon model in which consumers actually switch, a necessity for capturing the effects of a change in the level of switching costs. Previous models are either two-period or assume switching costs are high enough to preclude switching. Second, it contributes to studies of the telecommunications industry. A perennial problem in studies of this industry has been the difficulty of measuring discounts for services, especially business services.

Previous papers have either approximated these discounts or avoided studying business services.[5] I construct a unique time series of toll-free prices that fully captures discounts. My method of construction is useful for studies of business telecommunications markets more generally [this is in section to be added].

In the next section I provide background on the toll-free services industry, while section 2 discusses the regulatory environment. In Section 3 I review the theoretical and empirical studies of switching costs. Section 4 develops a theoretical model of switching costs. Section 5 describes virtual private network services, Section 6 the econometric tests I perform and Section 7 the data. Section 8 discusses the empirical results. I conclude in Section 9.

1. Toll-Free Services and Portability

AT&T offered the first toll-free (inbound WATS) service in the United States in 1967. Prior to this, the initiator of a call paid for its cost. The primary users of the new service were businesses wanting to provide a convenient way for their customers to call them for free. Because of AT&T's monopoly of toll-free service, the local carriers (owned by AT&T at this time) routed all toll-free calls to AT&T. Originally users were not able to choose their own 800-numbers, but in 1981 AT&T installed a new database that made this feasible. Many of these businesses chose "vanity" numbers, in which a memorable phrase could be formed from the letters on the telephone keypad associated with each digit in the telephone number. For example, 1-800-FLOWERS could be associated with 1-800-356-9377 or 1-800-SPIRITS with 1-800-774-7487.

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[5] For example, Knittel (1997) avoids studying business customers: "Residential rates are only used given the higher percentage of businesses that subscribe to discount plans and thus do not pay the retail list rate" (page 529). Even a paper entitled "Competition for 800 Service," by Kaserman and Mayo (1991) contains no actual price data besides a statement that, "For interstate 800 service AT&T has reduced prices by approximately 20% since 1986" (page 405).

After its divestiture in 1984, AT&T was prohibited from providing local service. LECs (formed from the local carriers previously owned by AT&T) were responsible for routing the originating end of an 800-call to the proper IXC. Although use of AT&T's database technology would allow LECs to route calls based on call recipient, the District Court charged with overseeing AT&T's breakup ruled that AT&T retained patent rights over the database. AT&T would remain a monopolist of toll-free services until the LECs could develop an alternative database technology. In 1986, the FCC decided, as an interim measure, that toll-free calls would be routed based on the next three digits after 800 (800-NXX) referred to as NXX screening.[6]

The FCC assigned each IXC one or more NXX prefixes for use in 800-service[7] and the LECs routed all calls beginning with "800-NXX" to the IXC assigned that NXX code. Because of the dependence on NXX, a user who wanted to switch carriers for its toll-free service had to switch numbers. It also meant that a user who wanted a particular vanity number (such as 1-800-FLOWERS) could only choose the carrier with the corresponding NXX code (356 corresponding to FLO). MCI began offering toll-free service in 1987, followed by Sprint and some smaller IXCs in 1988. Although, users now had a choice of carriers, the NXX screening limitations imposed huge switching costs on toll-free users:

> "Patricia Ryan, vice-president of voice services for NatWest, said her company moved the bulk of its voice and 800 numbers to MCI in 1990 but was unwilling to give up its (800) NAT-WEST number. That number is printed on bulletin boards, stationery and brochures, and is used to support customer service, sales and other business calls. 'Of course, the 800 number we would not consider disconnecting was 1 (800) NAT-WEST; I was truly stuck,' Ryan said." - "Carriers Plot Strategies at Dawn of War Over 800 Users," *Network World*, November 9, 1992.

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[6] Any ten-digit phone number can be disassembled, from a switching standpoint, into three components: NPA-NXX-YYYY where NPA is the numbering planning area (NPA) or area code, NXX is the central office code and YYYY is the line number. So for a toll number, NPA would contain the geographical area code, NXX the central office switching station to which the number would be routed and YYYY the line number of the specific residence or business.

[7] Each NXX prefix can accommodate 10,000 numbers.

> "Another reason Colonial Penn didn't leave AT&T is the lack of 800 number portability. The insurance company would have to change 800 numbers had it gone with MCI or US Sprint. 'It would've been an extremely expensive proposition to switch numbers,' Clevenger [vice-president of data operations] said." – Firm Predicts Savings With Tariff 12 Net, *Network World*, February 12, 1990.

> "Heckman [voice services manager for Weyerhaeuser companies] said changing 800 numbers is a Herculean task. 'The key is to get the new number out to everyone. That means customers, business partners, and even other divisions. It requires a great deal of republishing, and it means leaving lines behind for people who don't get the message immediately.' he added." – Net Users Remaining Loyal After AT&T's Recent Outage, *Network World*, January 29, 1990.

After a lengthy regulatory process, the LECs installed new databases on May 1, 1993, which allowed them to assign and route any 800-call to any IXC. This allowed users to switch providers without changing their phone number. It was necessary for all LECs to implement the database simultaneously since 800-calls can originate from anywhere in the country. Thus, a known, exogenous technological shock lowered switching costs dramatically in May 1993:

> "Now, however, with the advent of portability, 800 service subscribers can switch their 800 service while retaining their familiar 800 number, and avoid the costs and inconvenience of having to re-familiarize clients, customers, or other frequent callers." - *Telecommunications Market Sourcebook*, Frost & Sullivan, 1995.

Most popular articles published prior to portability speculated that portability would lower prices for toll-free services:

> "…all 800-number users should benefit from the enhanced competition. Hundreds of long-distance carriers will be fighting aggressively for a bigger share of the $7.5 billion 800-number market." - "Portability Sparks Price Wars," *Catalog Age*, May 1993.

> "The chance of Sprint and MCI making inroads into 800 provision for the big domestic airlines is slim to nil until 800 number portability is in place ..." - "Airlines + Price Wars = Big 800 Traffic," *800-900 Review*, Strategic Telemedia, May 1, 1992.

> "The ruling [mandating portability] could result in big savings for those catalogers whose monthly service costs can reach well into the six figures," - "Portability Adds Fuel to 800 Fire," Karen Burka, *Catalog Age*, October, 1992.

This sentiment has continued in academic articles published since portability. Ward (1993) cites 800-number portability as a reason that long-distance services are more competitive at the writing of his paper than they were in the 1988-1991 period he analyzes. MacAvoy (1995) argues, "That these margins [for inbound WATS service] were increasing rapidly in the latter period when 800 number portability became at least partially available would be counterintuitive in a competitive setting" (page 176). Although some academic studies have referred to 800-number portability, none have rigorously analyzed its effect on price competition.

Switching costs can lower prices in a dynamic setting only if the number of new consumers is sufficiently great relative to the number of old consumers. My data shows revenue growth of 50% from 1985 to 1997. This measure does not tell us whether new or old consumers generated this growth, but this growth rate is sufficiently high that decreased competitiveness due to switching costs is plausible.

2. Regulatory Environment

Since AT&T's divestiture in 1984, the telecommunications regulatory structure has defined three types of markets for 800-services: intra-LATA, intrastate (inter-LATA) and interstate (regardless of whether within the same LATA). The court responsible for the divestiture divided the United States into 161 LATAs (local access and transportation areas) each with one or more LECs acting as a regulated monopolist.[8] During the time period of my study, the LECs, with few exceptions, could not provide service outside of its LATA. I focus on the interstate market for ease in data collection[9] and because of its relative importance in 800-services.[10] The interstate

[8] Most LATAs contained a single LEC but there were some exceptions.

[9] Analyzing intra-state service would require gathering prices from multiple states as well as calculating "wrap-around" discounts. Although IXCs need to file separate tariffs with state public utility commissions for intrastate, inter-LATA service, the FCC allows them to include calls of both types in qualifying for discounts in tariffs filed with the FCC.

[10] Intra-LATA revenues represented less than five percent of total toll-free revenues in 1995 according to *Telecommunications Market Sourcebook*, Frost & Sullivan, 1995. [Add data for intrastate services.]

market is a single national market and includes all calls originating and terminating in different states regardless of whether it is within the same LATA. Under the Communications Act of 1934, the Federal Communications Commission (FCC) regulates the interstate telecommunications market including 800-services. Each state's Public Utility Commission (PUC) regulates intrastate services.

After the AT&T divestiture, the FCC classified it as a dominant carrier in long-distance services and imposed price regulation. The FCC imposed rate-of-return regulation until March 1989 when it switched to price-cap regulation. AT&T's long-distance services were divided into three major baskets with Basket 1 containing residential long-distance services, Basket 2 inbound WATS services and Basket 3 outbound WATS service. AT&T could change its prices within each basket by five percent in either direction of a price cap index set annually by the FCC. The FCC lifted the Basket 1 price caps in January 1995, Basket 2 caps on the portability date and Basket 3 caps in November 1991. The contracts I study are not subject to these price regulations but rather are subject to tariff review. Nonetheless, given the coincidence of portability and lifting the Basket 2 price caps, I must consider the possibility of confounding effects. I do so in Section 8. In October 1995, the FCC reclassified AT&T as a non-dominant carrier in all long-distance services and removed most price regulation.

The FCC required all IXCs to file tariffs stating rates for long-distance services during the time period I study. The "filed-rate" doctrine of the Communications Act of 1934 states:

> "Every common carrier, except connecting carriers, shall, within such reasonable time as the Commission shall designate, file with the Commission and print and keep open for public inspection schedules showing all charges for itself and its connecting carriers for interstate and foreign wire or radio communication between the different points on its own system. . ." [47 U.S.C. 203.a]

Part e) of the same section specifies a fine of $6,000 per offense and $300 per day for failing to file a tariff, although a stronger deterrent for IXCs is their loss of reputation with the FCC. The

Act also prohibits “unfair” price discrimination, although it allows for carriers charging different prices based on time of day, type of service or other dimensions that the FCC deems reasonable:

> “It shall be unlawful for any common carrier to make any unjust or unreasonable discrimination in charges, practices, classifications, regulations, facilities, or services for or in connection with like communication service, directly or indirectly, by any means or device, or to make or give any undue or unreasonable preference or advantage to any particular person, class of persons, or locality, or to subject any particular person, class of persons, or locality to any undue or unreasonable prejudice or disadvantage.” [47 U.S.C. 202.a]

> “. . . That communications by wire or radio subject to this Act may be classified into day, night, repeated, unrepeated, letter, commercial, press, Government, and such other classes as the Commission may decide to be just and reasonable, and different charges may be made for the different classes of communications.” [47 U.S.C. 201.b]

This has come to be known as the requirement that IXCs charge the same price to “similarly-situated” customers. Although the definition of “reasonable,” and therefore allowable, differences between customers has been defined by debate between the FCC and the carriers, the FCC has generally allowed IXCs to tailor prices only by volume purchased, contract length, mix of services and exclusivity clauses. For the class of switching costs models that I wish to test it is only necessary that carriers charged the same price to old and new consumers. I comment on the validity of this assumption in Section 8.

3. Switching Costs Literature

A common theme of switching costs models that constrain the firm to charge a single price is the ambiguous results on competition.[11] The most notable two-firm, two-period models, Klemperer (1987a) and (1987b), both reach this conclusion using different assumptions. Klemperer (1987a) assumes differentiated products and motivates switching by assuming a fraction of the consumers experience a change in tastes between the two periods. In this model some consumers switch in

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[11] There are also switching costs models that consider third-degree price discrimination (see Chen (1997), Nilssen (1992) and Taylor (1999)) and endogenous creation of switching costs (see Caminal and Matutes (1990)). The search costs and network externalities literature are also related.

equilibrium. Klemperer (1987b) considers homogeneous products but assumes that consumers differ in the level of switching costs incurred if they switch firms. In this model no consumers switch in equilibrium. In both models switching costs make the second period less competitive than a market without switching costs. In the 1987a model the firm's incentive to take advantage of consumers who are "locked-in" is greater than its incentive to induce the other firm's consumers to switch. In model 1987b the firm must discount so deeply to attract any of its competitor's customers that it is not worth the loss in profits from its own repeat consumers.

In the first period of both models, prices can be either higher or lower than those in a market without switching costs. There are three effects. Firms price lower in the first period because they recognize the value of "locking-in" consumers. Offsetting this are two factors. Consumers anticipate a firm with a lower first period price will charge them a higher price in the second period. This makes consumers' demand less elastic and tends to increase prices. Also, a firm pricing low to build its first period market share invites a more aggressive response from its rival in the second period. In model 1987a, the net effect depends on the number of consumers whose tastes change relative to the number with unchanged tastes. The more consumers with unchanged tastes, the higher are first period prices. In model 1987b, the fraction of consumers not subject to switching costs determines the net effect. The higher the fraction, the lower are prices.

These two-period models have limited realism. In the first period the firms face demand only from unattached consumers. The second period contains both new and old consumers but an "end-of-the-world" effect distorts the firm's pricing. New consumers in the second period are never valuable as repeat consumers so the firm has no incentive to price lower to capture these consumers. Several infinite-horizon models address these concerns. Beggs and Klemperer (1992) model two differentiated-product firms facing new and existing consumers in each period. Consumers maximize their expected lifetime utility but switching costs are great enough that no one switches in equilibrium. In a symmetric steady-state equilibrium, prices are higher than in a market without switching costs. This result is consistent with that of the second period of the two-period model even though there is no “end-of-the-world” effect to increase prices. The steady-state assumption, however, is crucial for this unambiguous result. The authors comment that if they add a first period in which neither firm has any old customers, prices in that period are lower than in a market without switching costs. Thus, rapid growth may make it possible for switching costs to lower prices. To (1996) extends the Beggs and Klemperer model to focus on switching costs’ effect on market shares but maintains the no switching assumption.

Bils (1989) develops a model in which switching costs lead to counter-cyclical markups. He considers a monopolist with an infinite horizon facing overlapping generations of two-period lived consumers. Consumers are uncertain of the product value when young but learn this value perfectly after purchase. This means that old consumers who like the product have less elastic demand for the product than young consumers. This is analytically equivalent to a switching costs model. During a boom the proportion of unattached consumers in the market increases and the firm prices lower to capture new consumers who have more elastic demand. During a downturn, the firm faces proportionately more attached consumers with less elastic demand and prices higher. This result emphasizes the importance of market growth on the relationship between switching costs and price competition.

Farrell and Shapiro (1988) consider a pure-strategy and Padilla (1995) a mixed-strategy equilibrium in a model with homogeneous products and overlapping generations of homogeneous consumers who live for two periods. In both models, the firms alternate selling to new consumers and the old consumers all buy from the same firm as they did when young so that no switching occurs in equilibrium. Although not constrained to do so, it is optimal for each firm to charge the same price to all its consumers. The equilibrium price is increasing in the level of switching costs, even in a growing market, but this occurs because of the alternation feature of the model. Since the firms alternate selling to new and old consumers, the profits from being in either position are the same and there is no incentive to build market share.

In summary, this theoretical work shows that switching costs may either raise or lower prices although the evidence leans toward less competition. Because it is difficult in most contexts to measure switching costs, limited empirical results are available. Borenstein (1991) finds that gasoline stations price discriminated against consumers of leaded gasoline due to the increased switching costs imposed on these consumers as the stations phased it out in favor of unleaded gasoline. Borenstein's study differs from the issue I wish to examine in that the firms charge different prices to consumers of leaded and unleaded gasoline and the market for leaded gasoline is declining. Elzinga and Mills (1998), using transaction-level data on wholesale cigarettes, show that customers exhibiting characteristics associated with high switching costs are less likely to switch to a new entrant during a price war. Again, this study differs from mine in that firms can price discriminate between old and new consumers.

The two papers closest to mine are Knittel (1997) and Sharpe (1997). Knittel finds evidence that rates for long-distance service did not fall after AT&T's divestiture due to search and switching costs. The fee charged by local phone companies to change long distance providers has a positive effect on margins implying that switching costs made the market less competitive. Advertising has a negative effect on margins, which could proxy for the effect of either search or switching costs (since long-distance firms count payments to consumers for switching charges in their advertising expenditures). Sharpe tests the Klemperer (1987a) model result that prices are more competitive the greater consumer turnover in a market. Sharpe finds that the degree of migration into or out of a local market has a positive effect on bank deposit interest rates paid to depositors.

4. Theoretical Model

The theoretical model I develop in this section serves two purposes. First, it demonstrates that in a dynamic setting in which firms charge a single price to all consumers, an increase in switching costs can result in either higher or lower markups. This is the first infinite-horizon model to show this. Second, it establishes that if switching costs decrease competitiveness then a larger drop in switching costs results in a greater decrease in markups than that from a smaller decline in switching costs. Thus, a firm practicing third-degree price discrimination will lower its price to a consumer experiencing a large drop in switching costs by more than that for a consumer experiencing a smaller drop in switching costs. If, on the other hand, switching costs make markets more competitive, the firm will increase its price to consumers experiencing a large drop in switching costs by more than it increases the price for a consumer experiencing a smaller drop.

My model is the first infinite-horizon, switching costs model in which switching actually occurs. In Klemperer (1987a), switching occurs but the model is limited to two periods. The infinite-horizon models of Beggs and Klemperer (1992), Farrell and Shapiro (1988), Padilla (1995) and To (1996) all assume that switching costs are high enough that consumers never switch. In these models the level of switching costs does not affect prices since all consumers are "locked-in" over the range of switching costs considered. Instead, the authors perform comparative statics by changing the fraction of consumers subject to switching costs. Since portability lowered the *level* of switching costs, it is important for me to consider switching costs over a range that includes the possibility of incomplete "lock-in." Although it is theoretically possible that portability did not lower switching costs sufficiently that any consumers switched post-portability, I offer data later in this section that consumers did. If consumers were completely "locked-in" before and after portability, then it would have no effect on prices.

My model extends the two-period model developed by Klemperer (1987a) into an infinite-horizon, overlapping-generations model with two-period lived consumers. I employ a solution technique similar to that in Beggs and Klemperer (1992) and To (1996). I consider two infinitely lived firms whose 800-services are horizontally differentiated. The firms are located at the extremes of a unit Hotelling (1929) line and are symmetric except possibly in their initial market shares. Consumers of 800-services live for two periods and have heterogeneous and uncertain preferences for the two firms' products.[12]

When young, consumers are uniformly distributed along the line with density one and incur differentiation costs linear in their distance from the firm. For convenience, I normalize the differentiation costs to one.[13] Thus, if a young consumer located at position x on the line purchases from firm A they obtain utility of $r - P_A - x$ where r is the value provided by the product to the consumer located on the firm and P_A is the price charged by firm A. Similarly, if the same consumer purchases from firm B she obtains utility of $r - P_B - (1 - x)$ where P_B is the price charged by firm B. The consumer's preferences (or, equivalently, the product features) are uncertain in that, after experiencing a product when young, the utility a consumer obtains from the two products may change. Specifically, a fraction, μ, of consumers are randomly relocated to a new position on the line between the periods in which they are young and old. This reassignment occurs with equal probability for all consumers and is uniform along the line. The remaining fraction, $1-\mu$, experience no change and maintain their original position.

In each time period each firm first sets its price. Consumers then choose their purchases to maximize the net present value of their expected lifetime utility. A young consumer has the option of purchasing from either firm A or firm B and considers the ramifications her decision will have on her options when she is old.[14] An old consumer has the choice of purchasing from the same firm they purchased from when young or switching to the other firm and incurring

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[12] Consumers of 800-services are primarily firms but I will to refer to them as consumers to distinguish them from the telecommunications providers (firms).

[13] A parameter for differentiation costs only acts as a scale parameter.

[14] I choose r such that the market is covered and not purchasing is sub-optimal.

switching costs of s in addition to the differentiation costs.[15] Between each time period four things happen. First, all old consumers exit the market. Second, a fraction ρ of young consumers, those one period old, also exit the market (exit prematurely). Third, a new generation of young consumers with density one enters the market. Fourth, the uncertainty of preferences for young consumers who remain in the market is resolved.

Each firm is constrained to charge a single price to all consumers in a given period and chooses a sequence of prices to maximize its discounted lifetime profits taking the actions of the other firm as given. The firms' marginal cost is c in each period. I solve for the unique Markov equilibrium in which the firm's customer base is the state variable and the equilibrium price functions are linear. The method of solution is constructive. I first posit the firms' value (profit) and price functions and then solve the consumers' problem to derive the demand function for each firm. Using the demand function I then solve the firms' profit maximization problems by optimizing the Bellman equations. The resulting equations allow me to solve for the unknown constants in the firms' pricing and profit functions.

In solving the model I will focus on firm A since the results for firm B are symmetric. I will let σ_A represent the share of old consumers who purchased from firm A last period, x_A the marginal young consumer in the current period, x_{AB} the marginal old consumer in the current period whose realized preferences differ from her ex-ante preferences and bought from A last period and x_{BA} the marginal old consumer in the current period whose realized preferences differ from her ex-ante preferences and bought from B last period.

Suppose that firm A's value and price functions are (where d, e, k, l, m are unknown constants):

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[15] I again choose r so that the market is covered. Also, I assume consumers incur differentiation costs whenever purchasing, otherwise all old consumers attached to a particular firm would make the same purchase choice.

(1) $\pi_A(\sigma_A) = k + l\sigma_A + m\sigma_A^2$

(2) $P_A(\sigma_A) = d + e\sigma_A$.

There are five cohorts of demand to consider in each time period: old consumers who purchased from A when young and positions were reassigned with density $(1-\rho)\mu\sigma_A$, old consumers who purchased from B when young and positions were reassigned with density $(1-\rho)\mu\sigma_B = (1-\rho)\mu(1-\sigma_A)$, old consumers whose positions remained the same and purchased from A when young with density $(1-\rho)(1-\mu)\sigma_A$, old consumers whose positions remained the same and purchased from B when young with density $(1-\rho)(1-\mu)\sigma_B = (1-\rho)(1-\mu)(1-\sigma_A)$ and new consumers with density one. I now calculate firm A's demand from each cohort.

The marginal old consumer who purchased from A when young and whose position was reassigned is indifferent between buying from A again and switching to B: $r - P_A - x_{AB} = r - P_B - s - (1 - x_{AB})$ which implies: $x_{AB} = \frac{P_B - P_A + 1 + s}{2}$ and demand of $(1-\rho)\mu\sigma_A x_{AB}$. The marginal old consumer who purchased from B when young and position was reassigned is indifferent between switching to A and buying from B again: $r - P_A - s - x_{BA} = r - P_B - (1 - x_{BA})$ which implies: $x_{BA} = \frac{P_B - P_A + 1 - s}{2}$ and demand of $(1-\rho)\mu(1-\sigma_A)x_{BA}$. In these two demand equations we see the effect of "lock-in" due to switching costs. Switching costs lower the elasticity of consumers who are part of the firm's customer base and increase the elasticity of those who are not. I will choose parameter values such that all consumers whose preferences remain unchanged purchase from the same firm again (full "lock-in") so that demand is $(1-\rho)(1-\mu)\sigma_A$ from those who purchased from A when young and 0 from those who purchased from B when young.

The marginal new consumer is indifferent between buying from firm A and firm B including the effect it has on their second period utility. In Appendix 1, I show that the position of this marginal consumer is:

(3) $x_A = \frac{1}{2} + b(P_B - P_A)$ where $b = \frac{1}{2(1+\delta_C(1-\rho)(1-\mu+\mu se+(1-\mu)e))}$.

Substituting (2) into (3), I obtain:

(4) $\sigma_A^{'} = \eta - \theta\sigma_A$ where $\sigma_A^{'}$ is next period's market share for firm A and:

(5) $\eta = \frac{1}{2} + be$

(6) $\theta = 2be$

Using (2), the demand equations derived above and the definition of a value function, I get:

(7) $\pi_A(\sigma_A) = (d + e\sigma_A - c)(\sigma_A^{'} + \mu(1-\rho)(\sigma_A x_{AB} + (1-\sigma_A)x_{BA}) + (1-\mu)(1-\rho)\sigma_A) + \delta_F \pi_A(\sigma_A^{'})$

where δ_F is the firm discount factor. Note that

(8) $x_{AB} = \frac{1 + s + e(1-2\sigma_A)}{2}$ and

(9) $x_{BA} = \frac{1 - s + e(1-2\sigma_A)}{2}$.

Firm A chooses its price to maximize its value function taking firm B's choice as given:

(10)

$$\max_{P_A} \quad (P_A - c)\left[x_A(P_A) + \mu(1-\rho)(\sigma_A x_{AB}(P_A) + (1-\sigma_A)x_{BA}(P_A)) + (1-\mu)(1-\rho)\sigma_A\right] + \delta_F \pi_A(x_A(P_A))$$

where x_A is as in (3) (before the equilibrium prices are substituted out).

Appendix 2 explains how I numerically solve this dynamic programming problem. The problem can only be solved analytically when $\mu = 0$ which is an uninteresting case for my purposes since the switching costs parameter does not influence market prices. Instead, I solve the equations numerically as described in the appendix. Appendix 3 shows the markups obtained from different combinations of the parameters $(\rho, \mu, \delta_C, \delta_F, s)$ when both firms are in a steady state with equal shares $(\sigma_A = \sigma_B = 0.5)$.[16] Each sub panel shows the markups obtained for different levels of preference uncertainty (μ - the rows) and switching costs (s - the columns) at given discount factors (δ_C, δ_F) and mix of new and old consumers (ρ). Note that for switching costs values that exceed the total differentiation costs of the furthest consumer from the firm (i.e. $s \geq 1$), switching costs no longer affect the markup charged by the firm.[17] This is the case of complete "lock-in" when no consumers find it optimal to switch.

Shaded boxes in the sub panels indicate regions where an increase in switching costs decreases the equilibrium markup, while unshaded boxes indicate regions where it increases the markup. The first result directly follows:

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[16] The pricing equation is linear in c so markups are independent of c. Prices can be obtained by adding c to the markups in Appendix 3.

[17] This assumes that r is set so that the consumer at 1 is indifferent between purchasing and not. For higher values of r the firms can sustain higher prices.

Result 1: When firms are symmetric and in steady state, an increase in switching costs can either make markets more or less competitive.

When switching costs increase, several forces are at work on equilibrium prices. It is simplest to consider the effects from the perspective of firm A. The effects for firm B are symmetric. First, the higher switching costs allow firm A to charge a higher price to its “locked-in” customer base, both those whose ex-post and ex-ante preferences match and those whose do not match but are not by enough that it is optimal for them to switch to firm B. Second, firm A must offer a lower price to induce consumers whose realized and ex-ante preferences differ to switch from firm B. Third, firm A has an incentive to lower its price to new consumers to build its future customer base. Fourth, because consumers anticipate being “locked-in” once they purchase from a firm they are less tempted by a firm’s price cut and their elasticity declines in the level of switching costs. Fifth, higher switching costs increase the importance of inviting a softer response from its rival, providing an increased incentive to price higher. Sixth, those consumers who actually switch bear switching costs. These costs are shared between consumers who switch and the firm based on the relative demand and supply relationship elasticities. Note that in general the switching costs are borne by a small fraction of consumers $(1-\rho)\mu$ ex-post even though ex-ante all consumers face a positive probability of bearing these costs.

Three of these effects act to lower prices while three act to increase them. Which effect is stronger in aggregate depends on the features of the market. Appendices 2 and 3 identify the effect of several features on markups.

Result 2: When symmetric and in steady-state, firms’ markups are decreasing in: a) probability that consumers exit the market, b) uncertainty of consumers’ preferences, c) firm discount factor and increasing in d) consumer discount factor and e) firm’s initial market share.

Part a) can be seen by comparing sub panels within each panel of Appendix 3. With a higher proportion of new consumers, the firm prices lower because the proportion of “locked-in” consumers is lower and also because a consumer is more likely to exit the market prematurely. Part b) follows from comparing rows within any sub panel. Greater uncertainty leads to a higher probability that the consumer will pay switching costs to obtain their most favored product when old. This decreases the price the consumer is willing to pay when young. Increasing the firm discount factor (compare panel C to D and E to B) decreases price because the firm has a greater incentive to build its market share of future "locked-in" consumers. Increasing the consumer discount factor (compare panel E to C and B to D) has the opposite effect. Consumers are less tempted by a price cut when young, which will "lock" them in when old, if they discount their future utility less. Part e) follows from the fact that the parameter e in equation 2) is positive in all my simulations (discussed in Appendix 2). A firm with a larger initial market share has more to lose by attracting new consumers through a price cut than a firm with a smaller market share.

These results also allow me to evaluate whether increased switching costs lower or increase competitiveness:

> *Result 3: An increase in switching costs is more likely to result in lower markups when the: a) consumer discount factor is lower, b) firm discount factor is higher, c) product uncertainty is greater, and d) probability of premature exit is greater.*

A decrease in the consumer discount factor (compare panel E to C and B to D) widens the regimes in which increased switching costs lowers price. The marginal old consumers earn rents because of the competition between firm A and B. Therefore, although an increase in switching costs lowers consumers' expected second-period utility the firm does not need to adjust the price downward to "make the consumer whole." So the only effect on first-period demand from the increased switching costs is that new consumer demand becomes less elastic (this can be seen in equation 3). A lower consumer discount factor makes the demand elasticity less sensitive to switching costs so an increase in switching costs makes the firm less tempted to cut prices in order to build share for future profits.

An increase in the firm discount factor (compare panel C to D and E to B) widens the regimes in which increasing switching costs lowers markups. With a higher discount factor, the firm wants to price lower to enlarge its future "locked-in" customer base. How strong this incentive is depends on the elasticity of young consumer demand. Since this elasticity is declining in switching costs (see equation 3), increased switching costs leads to a greater incentive to lower prices. A higher firm discount factor amplifies this effect so that increased switching costs are more likely to lead to lower markups when the firm discount factor is higher.

An increase in product uncertainty increases the range of switching costs values that lower markups because consumers are more likely to face these costs the more uncertain the product features. A higher probability that consumers exit the market before old also increases this range because a higher proportion of new consumers in the market leads the firms to discount over a wider range of switching costs to "capture" these new consumers.

My empirical test follows directly from the theoretical results:

> *Empirical Test: In a region where switching costs increase markups, portability will decrease markups for services affected by non-portability but leave markups for other services unaffected. In a region where switching costs lower markups, portability will increase markups for services affected by non-portability but leave markups for other services unaffected. Both of these results assume that some consumers switch in equilibrium. If not, then portability will not affect markups.*

If switching costs other than non-portability were so great that no one switched after portability then the change in regimes would have no effect on prices. Since there is no systematic study of switching subsequent to portability, I have to rely on reports made by the IXCs themselves (who may have an incentive to bias these estimates). Shortly after portability, AT&T claimed that 10,000 users representing over $140 million in revenue switched their numbers to them, while MCI claimed 6,550 users representing over $170 million and Sprint "several thousand" customers.[18] A later article reported an AT&T claim that it had retained 505 out of 531 users of virtual private network services and MCI claimed it had gained $500 million in new commitments (not annualized) since portability.[19]

5. Virtual Private Network Services

To implement the empirical test I estimate the effect of portability on margins for toll-free calls, which are affected by portability, and toll calls, which are not directly affected by portability, purchased in AT&T contracts for virtual private network (VPN) service. In order to understand how I constructed the data set and why I chose VPN service it is necessary to understand some aspects of the tariff process and VPNs.

The IXCs file two types of tariffs. The first type, baseline tariffs, contains rates available to any user. These tariffs contain volume discounts but the carrier does not require the user to pre-commit to a volume level. The second type, contract-based tariffs, provide discounts off the rates specified in the baseline tariffs for users who commit to certain volume levels, bundles of services, exclusivity arrangements and contract duration. Contract-based tariffs also may contain additional criteria that the carrier must meet in configuring and servicing the more complex networks to which these contracts apply. Baseline tariffs are in effect until the carrier files a

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[18] Reported in "Winds of Change Sweeping Over Cooped-Up 800 World," *Network World*, May 3, 1993.

[19] Reported in "AT&T & MCI Report 'Fresh Look' Results," *Internet Week*, August 9, 1993.

subsequent tariff altering the rate,[20] while contract-based tariffs specify a length and are available to any "similarly-situated" customer in the ninety days after its effective date.[21]

Both types of tariffs typically include a one-time charge for installation, fixed monthly charges and per-minute usage charges. I focus on the per-minute usage charges since the firm has an incentive to adjust this price as the level of switching costs vary. As my data demonstrate, IXCs price calls above their marginal cost. Therefore, firms have an incentive to raise or lower this price as switching costs change depending on whether it is more important to harvest or grow its customer base. Since the firms do not tailor the fixed installation or fixed monthly charges to specific services, they cannot be used to price discriminate between users of toll-free and toll services. In my sample per-minute usage charges comprise 55% of the total fees. Since fixed monthly charges represent a significant fraction of the total fees for some options, I include them as a control variable in my empirical tests.

In VPN services an IXC creates a virtual network for medium to large businesses. By specifying ports, corresponding to telephone numbers, within the network and committing to usage volumes, the user receives discounts for calls made to and from these locations. There are two types of port locations within a VPN, depending on whether calls at that location are carried over a dedicated line, thereby bypassing the LEC's switching network, or over switched lines, thereby utilizing the LEC's switching network.[22] Ports with dedicated service are called "on-net" while

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[20] As a dominant carrier, AT&T had to file its baseline tariffs 45 days in advance of their effective date prior to July 1989 when it was lowered to 14 days ("In the Matter of Policy and Rules Concerning Rates for Dominant Carriers," FCC CC Docket No. 87-313, 4 FCC Rcd 2873 Section 328). In October 1995, the posting period for all AT&T domestic services was lowered to one day ("In the Matter of Motion of AT&T Corp. to be Reclassified as a Non-Dominant Carrier, 11 FCC Rcd 3271, Section 12). As non-dominant carriers, MCI and Sprint could file baseline tariffs with one-day notice.

[21] AT&T offered two types of contract-based tariffs. The FCC required the first type, Tariff 12 options, to be filed 45-days before their effective date until October 1995 when the FCC lowered it to 14 days [confirm this and find reference.] The second type, contract tariffs, became effective fourteen business days after filed with the FCC.

[22] In dedicated service the LEC still provides the line but not the switching.

those with switched service are called “off-net.” AT&T’s VPN contracts classify and price calls based on whether the calls originate and terminate “on-net“ or “off-net.” Dedicated service offers lower marginal cost than switched service because the IXC pays lower access fees to the receiving LEC, but higher fixed fees. Inbound and outbound traffic can be aggregated in a dedicated line so that firms will choose dedicated service for locations initiating or receiving high call volumes.[23]

Figure 1 illustrates the two types of toll-free and toll calls which I will consider: OFF/ON and OFF/OFF.[24] A toll-free OFF/ON call originates from a remote location outside the VPN is switched through a LEC to the IXC and then over a dedicated line to an “on-net” 800-number within the VPN. A toll-free OFF/OFF call originates from a remote location outside the VPN is switched through a LEC to the IXC and then switched through another LEC to an “off-net” 800-number within the VPN. A toll OFF/ON call originates from an “off-net” number inside the VPN is switched through a LEC to the IXC and then over a dedicated line to an “on-net” number within the VPN. A toll OFF/OFF call originates from an “off-net” number within the VPN is switched through a LEC to the IXC and then switched through another LEC to a remote location outside the VPN.

[Insert figure 1 here]

Business users could purchase non-VPN toll-free services, but VPN contracts are more convenient for testing the effects of portability for two reasons. First, AT&T began writing contract-based tariffs for VPN services in 1987, well before portability, providing significant data

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23 One consultant I spoke with estimated that any firm with two hundred or more employees would benefit from dedicated service.

24 Two other types of toll calls are possible, ON/ON and ON/OFF, but I do not consider these since toll-free VPN service always originates “off-net.”

on how AT&T altered its pricing in response to portability. For non-VPN services, AT&T did not begin writing contract-based tariffs until early 1992 and changed the baseline tariffs very infrequently. Second, the marginal cost of toll-free and toll OFF/ON calls differed only slightly. The same is true of toll-free and toll OFF/OFF calls.[25] Thus, I can use the toll calls, which are unaffected by non-portability, as a benchmark. There is no analog of a toll OFF/ON or OFF/OFF call in non-VPN service.

6. Econometric Test

My econometric test uses the expected time until portability to identify the effects of switching costs on prices. Once a user had initiated service with an IXC, they were "locked-in" until the portability date. This meant that switching costs under these contracts declined as the portability date approached because existing consumers were "locked-in" for a shorter period of time and potential new consumers anticipated being "locked-in" for a shorter period of time if they contracted with a particular IXC. Because of this, AT&T had an incentive to alter its pricing for services affected by non-portability as the expected date of portability approached. [In future work, I plan to demonstrate these dynamics using my theoretical model.] Since marginal cost was changing over this time period, I test the effects of portability on margins instead of prices. My econometric strategy is to determine the effect of expected time to portability, which proxies for declining switching costs, on margins for VNP services controlling for other factors affecting margins. I therefore employ the following model:

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[25] After portability, the FCC allowed LECs to charge IXCs per query for accessing the new 800 database via the SS7 network to recover the costs of database implementation ("In the Matter of Provision of Access for 800 Service, CC Docket No. 86-10, 8 FCC Rcd 907, January 29, 1993). As I discuss in Section 7, this raised the marginal cost of a toll-free call by about 1.6% above the cost of toll calls for OFF/OFF service and 2.6% for OFF/ON calls. The operational cost of a toll-free OFF/ON call is 0.01 cents lower than for a toll call and 0.07 cents higher for an OFF/OFF call.

$$margin_i = \alpha + \sum_{j=1}^{3} \beta_j I_i^{j+1} + \sum_{j=4}^{7} \beta_j I_i^{j-3} Tport_i + \sum_{j=8}^{11} \beta_j I_i^{j-7} Lag(Share)_i + \sum_{j=12}^{15} \beta_j I_i^{j-11} Size_i + \beta_{16} Duration_i + \beta_{17} Ffee_i + \varepsilon_i$$

An observation is an original or revised price posted in AT&T's contract-based tariffs for any of the four types of VPN services. The indicator variables distinguish the four types of services: ($I_i^1 = 1$ if the price is for an OFF/ON toll call and 0 otherwise, $I_i^2 = 1$ if the price is for an OFF/ON toll-free call and 0 otherwise, $I_i^3 = 1$ if the price is for an OFF/OFF toll call and 0 otherwise, $I_i^4 = 1$ if the price is for an OFF/OFF toll-free call and 0 otherwise). $margin_i$ is the percentage margin on the service $\left(\frac{p_i - c_i}{p_i}\right)$ at the time of the price change and $Tport_i$ is the expected time until portability. I interact $Tport$ with the dummy variables to allow the effect of portability to vary by type of service.

I include $Lag(Share)_i$, the share of the *total* market that purchased in the last period to control for the mix of old and new consumers.[26] As I showed in my theoretical model the margin should increase in the proportion of old consumers who already purchase (see effect of parameter ρ in Result 2). $Size_i$ is the size of the contract in minutes to control for any quantity discounts? I interact both the lagged-share and size variables to allow their effect to vary by type of service. $Duration_i$ controls for the duration of the contract and $Ffee_i$ is the monthly fixed fee under the contract used to control for any effect it has on per-unit margins. I expect $\beta_{12-15} < 0$ due to quantity discounts and $\beta_{8-11} > 0$ but have no prior expectations about the signs of the other coefficients. The indicator variables pick up the mean margin for the three types of services

[26] I tried including a variable to control for the firm's share of the *current* market (i.e. relative to the other firms) but it is highly collinear with the *total* market share and did not change the effects of portability.

relative to OFF/ON toll call margins, the omitted service whose mean price is given by the intercept α. β_{4-7} capture how margins change in response to the closeness of the portability date for each service type.

The effects of portability, and therefore switching costs, on prices depend on the signs of the expected time until portability coefficients. If $\beta_5 > 0$ then portability led to lower margins for OFF/ON toll-free service implying that switching costs made the market less competitive. If $\beta_5 < 0$ then switching costs made the market more competitive. The same test can be made for OFF/OFF services based on the sign of β_7. The sign of β_4 and β_6 measure whether portability affected margins for toll services.

7. Data

My data consists of AT&T prices for domestic VPN service contained in Tariff 12 options filed with the FCC.[27] Each option specifies the charges for a particular combination of usage volume, services mix, contract length, penalty clauses and change fees. Multiple users can, and generally do, sign up for a single option although AT&T does not have to provide the FCC with information about who subscribes to the option. I use data from all Tariff 12 options filed by AT&T between June 1989 and July 1993. [I plan to add a few additional months of data to capture revisions to contracts expiring shortly after portability.] This spans most of the time between the FCC's initial decision to implement portability in February 1989 and the last month in which users could terminate their Tariff 12 contract without penalty, July 1993. Ideally, I would include MCI and Sprint data. AT&T, MCI and Sprint, accounted for over ninety-one

[27] During the time of my study, AT&T also sold VPN services through baseline tariffs for customers who did not pre-commit to purchase a minimum volume level. I do not include these prices because they provide few additional data points and are difficult to pool with the Tariff 12 data due to differences between the two types of tariffs. AT&T also began selling VPN services through Contract Tariffs toward the end of my sample period (February 1992). [These are more directly comparable to Tariff 12 offerings and I plan to add these to my data set.]

percent of 800-services sold at the time of portability. Unfortunately, MCI did not begin filing contract-based tariffs until 1992 and Sprint until 1995.[28]

Since the FCC does not index tariffs in any meaningful way, I obtain them from CCMI, a division of UCG, which provides pricing information and analysis to help telecommunications users obtain the lowest prices.[29] For each tariff option, I recorded the per-minute price for the four different services (OFF/ON toll, OFF/ON toll-free, OFF/OFF toll, OFF/OFF toll-free), effective date, contract duration, contract size (volume commitment) and fixed monthly fee. Since AT&T often revises contracts either at or prior to their expiration, I considered initial postings and revisions as observations. AT&T filed 124 active options during the time period of my study. One of these options did not contain any domestic services and four had particularly complicated discounts[30] leaving me with 119 usable options. It also filed 38 changes to these options providing me with 157 observations.

Since the tariffs tailor per-minute rates to time of day and distance, I used the rate for a one-minute daytime call of four hundred miles which is the most common call placed. In applying the volume discounts within the option I assumed the user exactly met the minimum volume commitment of the option. Users avoid falling below the minimum because penalties usually require paying the shortfall or exceeding the minimum by too far since they could have negotiated further volume discounts under a larger contract.

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[28] MCI did not disclose its contract-based tariffs prior to November 1992 but was forced to do so at that time when the D.C. District Court overruled the FCC's decision to exempt non-dominant carriers from the tariffing process (an approach known as permissive detariffing). Under permissive detariffing, MCI and Sprint had to abide by any tariffs they filed but were not required to file them. MCI began filing contract-based tariffs after the decision and back-filed all outstanding contract-based tariffs. MCI and Sprint chose to file baseline tariffs throughout permissive detariffing even though the FCC did not require them to do so. Sprint was not named in the case and chose not to submit contract-based tariffs until 1995.

[29] I am grateful to George David and Bill Goddard for helping me obtain this data.

[30] [I plan to add these four in a future version of the paper.]

Marginal costs for toll and toll-free VPN service were virtually identical and included access fees and operational costs. IXCs pay LECs access fees to complete their calls. Dedicated service incurs lower per-minute access fees than switched service so that the marginal cost of OFF/ON service is lower than that for OFF/OFF service. Access fees are regulated and published in tariffs filed with the FCC. Since access fees vary slightly across LECS and the telecommunications operations of VPN users generally span multiple LECs, I use an average across all LECs published in FCC (1999). Access fees for toll-free and toll calls are identical within the OFF/ON and OFF/OFF services types. Access fees declined during the period of my study as the FCC shifted the cost of the local infrastructure toward monthly fees for residential long-distance.

After portability the FCC allowed the LECs to charge a per-query fee to the IXCs for each lookup of an 800-number. Since this fee varied from a low of 0.22 cents to a high of one cent per lookup across LECs and VPN users generally span multiple LECs, I average across the nine major LECs and assume the average length of a toll-free call is 3.6 minutes.[31] This adds 0.1246 cents per minute to the cost of toll-free service relative to toll service post-portability.

I take estimates of operational costs from court testimony by AT&T in their June 1990 application to provide intrastate toll-free service in California.[32] I assume operational costs are constant over different output levels. This is an extremely good approximation for long-distance services because operational costs are constant until demand exceeds the capacity of the

[31] The nine LECs for which I have data are Ameritech, Bell Atlantic Corp., BellSouth Corp., Nynex, Pacific Telesis Group, Southwestern Bell Corp., US West Inc., GTE Telephone Co. and Southern New England Telephone Co. This data is taken from “Rates May Deter Use of 800 Portability,” *Network World*, May 10, 1993, pp. 23, 24 and 34. The estimate of 3.6 minutes average call length is taken from Strategic Telemedia (1996), p. 64.

[32] John Sumpter estimated operational costs for switched toll service to be 1.01 cents, switched toll-free service to be 1.08 cents, dedicated toll service to be 1.30 cents and dedicated toll-free service to be 1.29 cents in testimony on behalf of AT&T to obtain authority to provide intrastate service in California. Application of AT&T Communications of California, Inc. (U 5002 C), June 18, 1990 as reported in MacAvoy (1996).

telephone lines. There is significant evidence that the three firms' capacity constraints were not binding during the time period of my study. Huber et. al. (1992, p.321) cites several studies. These include a 1989 FCC study found that carriers other than AT&T were capable of supplying 146 percent of the market even though they served less than a third of the market and an FCC report that found that Sprint, which carried about one-tenth of all traffic at the time, could serve demand well in excess of AT&T's total traffic in 1990. As Kaserman and Mayo (1991) point out, this capacity is fungible across business inbound, business outbound and residential telephone service. Another possible capacity constraint is the available supply of toll-free numbers, but the industry did run out of numbers for the 800 prefix until 1996 and in April 1993 still had 60% of the numbers available (FCC, 1999).

Due to the differing operational costs, the marginal cost of toll-free OFF/ON calls was 0.2% lower than that for OFF/ON toll calls and 0.9% higher for OFF/OFF calls. Post-portability, due to the differing operational costs and database query charges, the marginal cost of toll-free OFF/ON calls was 2.4% above that for toll OFF/ON calls and 2.5% higher for OFF/OFF calls.

Using the prices and marginal costs, I compute the price-cost margin $margin_i = \left(\frac{p_i - c_i}{p_i} \right)$ for each type of service in each option. This provides up to four observations per option for my regression. Not all options included all four types of service so the number of observations is somewhat less than the number of option filings times four.

The time to portability variable measures the expected number of days until the user of the Tariff 12 option could switch carriers unencumbered by either non-portability of their 800-number or contractual obligations. The exit penalties on most Tariff 12 options made early exit unfavorable. Most options required the user to pay the minimum annual charge regardless of how many minutes they consumed. [Provide more detail on penalty clauses.] For options that expired prior to portability this is simply the expected number of days until the portability date. Options that expired after the portability date are somewhat more complicated. On September 30, 1991 the FCC established what it called a "fresh-look" principle that allowed users to terminate Tariff 12 agreements containing 800 services within ninety days of portability without penalty. For contracts written prior to the "fresh-look" decision and expiring after portability I use the contract tenure as the time to portability since at the time of signing the user would not have anticipated the "fresh-look" decision. For contracts written after the "fresh-look" decision and expiring after portability I use time until portability.

More formally, for contracts written prior to September 30, 1991 I set $Tport_i$ equal to $\max\{E[T]-t_i, Duration_i\}$ where $E[T]$ is the expected portability date and t_i is the effective date of the Tariff 12 option. For contracts written after September 30, 1991 and before May 1, 1993 I set $Tport_i$ equal to $E[T]-t_i$. For contracts written after May 1, 1993 I set $Tport_i$ equal to zero. Implementation of portability followed a lengthy regulatory process and there was some uncertainty as to the implementation date. Based on accounts in popular magazines and newspapers I constructed an expected portability date that I summarize in Appendix 4. Since identification of portability effects depends on this proxy it is important that it not serve as a proxy for an alternative explanations of margin changes. I discuss this possibility in Section 8.

Figure 2 provides summary statistics for all variables. I set $Lag(Share_i)$ equal to AT&T's revenue share of the total market in the quarter preceding the effective date of the option. Annual toll-free revenue estimates by firm are available from Levinson, et. al. (1990) from 1985 to 1990 and Strategic Telemedia (1997) from 1992 to 1997. To concatenate these two sources, I stacked them in a regression on an AT&T dummy, an MCI dummy, a source (Levinson versus Strategic Telemedia) dummy and an estimate of total long-distance revenues from the FCC (1998).[33] Using the regression results I obtained predicted values of annual toll-free revenues assuming

[33] I also tried including a time trend but found it to be insignificant.

that Strategic Telemedia was the source. To obtain quarterly revenues, I assumed the same seasonality as total long-distance revenues reported in FCC (1998). I assumed the total market size is equal to the realized market share in the second quarter 1999. [Need to perform sensitivity analysis on this assumption.]

[Insert figure 2 here]

$Duration_i$ is the duration of the contract specified in the tariff 12 option. This duration applied unless both the user and AT&T agreed to alter the duration and create a new Tariff 12 option. $Size_i$ is the minimum annual volume commitment specified in the Tariff 12 option. To calculate $Size_i$, I divide the minimum annual revenue commitment specified in the contract by the average price per minute across all services in the contract. [In the future I plan to use a weighted average of prices according to common usage patterns.] $Ffee_i$ is the monthly fixed fee that the user must pay under the Tariff 12 option.

As the summary statistics show, prices and marginal costs for OFF/OFF are greater than those for OFF/ON services. Prices for toll-free service are above those for toll service, while marginal costs for toll-free service differ only slightly from those for toll service due to the small database query charges and difference in operating costs. As a result margins are greater for toll-free services than for toll services on average. AT&T's share of the total market (measured as 1999 second quarter consumption) grew from a low of 18% in the second quarter of 1989 to a high of 35% in the third quarter of 1993 as its sales grew. The average contract length in the sample was 3.7 years and all options in my sample had durations of three, four or five years. The average contract size was close to 72 million minutes a year but there is significant variation. A few contracts have a size of zero minutes because the minimum annual charge is met through fixed fees alone. The fixed fees averaged $500 thousand per month. The average option was written approximately a year before the expected portability date. Note that this does not mean on average it was written around May 1992 since the expected portability date changed over time. I also constructed two additional variables for further analysis. The first, *Bundled*, is set to one if the option included toll-free services along with toll services and zero if it contained toll services only. About three-quarters of the options were bundled. The second, *Revision*, is set to one if the observation is a revision to an existing option and zero if it is a newly created option. Almost 60% of the observations in my sample are revisions. Note that more than 40% of my observations are unique options but they are considered revisions because my data set begins in June 1989 and many options had already been modified prior to this.

8. Results

The first column of Figure 3 provides the results of the regression. The results indicate that switching costs due to non-portability made the market for toll-free services less competitive and that the magnitude of the effect was economically significant. The time to portability variable is extremely statistically significant for the two types of toll-free services. On average, AT&T reduced its margins by 0.000252 for OFF/ON service and 0.000315 for OFF/OFF service for each (expected) day closer portability was to being implemented. Figure 4 shows the decline in margins that would have taken place on the mean size, duration and fixed fee contract issued at the mean expected time to portability if portability had been implemented by that time. The margins for OFF/ON service would have been almost 16% lower while those for OFF/OFF service would have declined by about 25%. [In a future version of the paper I plan to adjust the standard errors for autocorrelation since I include lagged share in the regression.]

AT&T's lagged market share is has a positive and highly significant effect on margins for all four types of services. This is consistent with the theoretical model in Section 4. As AT&T's share of the total market increased it was able to increase prices to its captive users because of the reduced counterforce to attract new users.[34] Note also that the effect for toll-free services is much greater than that for toll services suggesting that "lock-in" effects are greater for toll-free services. Users received volume discounts for all four types of service (although the coefficient is not significant for OFF/ON toll service). OFF/OFF toll-free users received the steepest discounts, a decrease in margin of 0.000349 for each additional million minutes commitment (this implies a discount of 5.6% for the largest contract in my sample relative to the smallest contract holding all else constant). Contract duration did not have a significant effect on margins, which is likely due to the frequent renegotiation of these contracts before their expiration. Fixed fees also did not significantly affect per-minute margins suggesting these fees are more closely related to fixed costs of providing the contract than per-minute costs. I tried interacting both the duration and fixed fees variables with the service-specific dummies. In both cases the interacted variables were insignificant and did not materially affect the other variables.

[Insert figures 3 and 4 here]

The five characteristics I have included to describe each option perform fairly well in explaining differences in margins across the options. My regression explains about 68% of the variance in the margins on these services. [As future work I plan to expand the characteristics to possibly include penalty clauses, performance requirements and the presence of international services.] Adding additional characteristics will reduce the unexplained variance, but even if I could fully characterize all of the qualitative differences in the contracts through the independent variables an error would still exist due to differences in the negotiating skills of the user. For my purposes, it is only important that these omitted characteristics are uncorrelated with my independent variables.

[34] I tried including a lag of AT&T's share of the existing market in the regression as well but the variable is highly (negatively) correlated with lagged share of the total market and did not significantly change the effect of portability.

The results in Figure 3 suggest that AT&T cross-subsidized services within the Tariff 12 options in that portability also affected the margins for toll services, although the effect is of smaller magnitude. To test for the presence of cross-subsidization in the contracts I compared the margins on toll services in contracts that did not include toll-free service with those that did. The first column of Figure 5 contains a regression of OFF/ON toll service margins on contract characteristics using options that bundle this service with toll-free service. The second column is the same regression for OFF/ON toll service not bundled with toll-free service. Time to portability is significant in the bundled regression and of similar magnitude to that obtained using all the data. In the non-bundled regression, time to portability is not significant. Employing a Chow (1960) test, I reject the null hypothesis that the coefficients are the same in both subsets at a 1.93% significance level. Columns three and four of Figure 5 make a similar comparison for OFF/OFF services. Again, time to portability is significant in the bundled regression but not in the non-bundled regression and the hypothesis that the coefficients are the same in the two subsets is rejected at a significance level of 4.76%. [The non-bundled subsets are small at this point. By expanding my data set I hope to increase the size of these subsets.] These results are consistent with AT&T cross-subsidizing toll-free services with toll services within a contract. As AT&T was forced to reduce its margins on toll-free services with the advent of portability it also reduced the cross-subsidization of toll-free services by toll services.

[Insert figure 5 here]

If AT&T were able to price discriminate between old and new users in their Tariff 12 contracts then my results would be spurious. Although all Tariff 12 options are publicly available and the FCC requires that AT&T makes them available to any “similarly-situated” customer within ninety days of their filing, AT&T could still price discriminate if they tailored the options specifically enough that only a single user qualified. AT&T’s ability to do this is limited by the “filed-rate” doctrine. Since all rate-related items must be filed with the FCC, they are used as information in subsequent negotiations. Moreover, tariffs have the weight of law so even if a user signs a private contract with an IXC, a contradicting tariff will take precedence over the private contract in a court dispute.[35] This provides for transparency of prices across users and, in fact, an industry of consultants and information providers exists to help users assimilate tariff information in negotiating contracts. Kaserman and Mayo (1991, p. 409) argue that, even if allowed, price discrimination based on level of switching costs incurred by the consumer would be difficult to implement. They argue that customers with high switching costs are randomly distributed across industries, firm sizes and geographic locations, making it difficult to implement tariffs sufficiently specific to price discriminate. Moreover, resellers of 800-services can arbitrage away any price differences across tariffs.

The U.S. Court of Appeals addressed the question of whether AT&T engaged in unlawful price discrimination in its Tariff 12 offerings. In the case, the Competitive Telecommunications Association challenged the FCC's finding that AT&T's Tariff 12 filings were non-discriminatory. The Appeals Court agreed with the FCC and concluded that AT&T's Tariff 12 offerings did not violate the 1934 Communications Act because they made the rates available to any customer that meets the contract terms. Specifically, the Court cited a finding of an earlier D.C. Circuit Court decision:

> "Although one normally regards contract relationships as highly individualized, contract rates can still be accommodated to the principle of nondiscrimination by requiring a carrier offering such rates to make them available to any [customer] willing and able to meet the contract's terms." (U.S. Court of Appeals Case No. 92-1013 citing from Sea-Land Service Inc. vs. ICC, 738 F. 2nd 1311, 1317, D.C. Cir. 1984).

There is a way to explicitly test whether AT&T tailored Tariff 12 options sufficiently to price discriminate between old and new users using my data set. If AT&T successfully tailored options to new and existing users then we should see a difference in prices found in new options versus those in revisions to options already filed. New options would be tailored to new users while

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[35] This was reaffirmed in the Supreme Court decision in American Telephone and Telegraph Co. vs. Central Office Telephone, Inc. (108 F.3d 981).

revisions to options already filed would be targeted at existing users. To test for such price discrimination I divided my sample into new and revised prices and perform a test of structural change to see whether different models generated revised and new prices. The second and third columns of Figure 3 show the regressions on the two sub samples. A Chow test yields a test statistic extremely close to zero indicating that the null hypothesis that the coefficients are the same in the two subsets cannot be rejected at any significance level. It is much easier for AT&T to tailor contracts for large users since the pool of large users is very small. To see if contracts for large users are different than those for small users, I divided my sample into two groups: those contracts in the top quartile in size and those below. This cutoff corresponds to contracts greater than $13 million. A Chow test yields a test statistic of 0.744 and a significance level of 77%. The null hypothesis that the coefficients are the same for small and large contracts is not rejected.

A concern with using time to portability as a proxy for switching costs is that the FCC removed price-cap regulation on baseline tariffs for toll-free service simultaneously with portability. If the regulation was binding it may confound the effects of the drop in switching costs. As bundled services, AT&T's Tariff 12 filings were not subject to price caps but were subject to tariff review, meaning that the FCC could review and reject tariffs that did not conform to its regulations.[36] Therefore, the change in regulatory regimes would only affect Tariff 12 offerings if the FCC carried over its treatment of baseline tariff regulation to the Tariff 12 review process and if this regulation was binding in the first place.[37]

There is significant evidence that these regulations did not constrain AT&T's baseline tariff pricing. First of all, the design of the regulation gave AT&T more freedom than it appeared. The

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[36] The treatment of Tariff 12 is described in "In the Matter of Competition in the Interstate Interexchange Marketplace," FCC CC Docket No. 90-132, 5 FCC Rcd 2627, Section 35.

[37] A consultant I talked to who worked for AT&T as a salesperson of services prior to portability claimed that AT&T was not at all constrained by price caps in filing their tariffs and the FCC rarely challenged tariffs.

FCC subdivided Basket 2 into four categories. AT&T could change rates for services within some categories by more than five percent as long as the weighted average across all four categories stayed within the allowed range.[38] The FCC initially set the price cap index at AT&T's existing rates and then adjusted them annually for inflation and reduced them by a 2.5 percent "productivity offset" and a 0.5 percent "consumer productivity dividend." AT&T could also submit tariffs that deviated from the price bands subject to FCC scrutiny. Figure 6 shows data assembled by Hall (1993) showing that AT&T's weighted price was well below the price cap index for Basket 2 services during price cap regulation.

[Insert figure 6 here]

9. Conclusion

In this paper I have tested the effect of switching costs in a market in which firms could not price discriminate between new and existing users. I find that the largest firm in the market reduced its margins due to a decline in switching costs implying that switching costs made the market less competitive. Despite rapid growth in the market, the firm's incentive to exploit its existing "locked-in" users was greater than its incentive to "lock-in" new consumers. These results add to a small body of literature providing empirical evidence to a question theoretically unanswerable and important in many different markets.

[38] Basket 2 included service categories: 1) Readyline 800 (inbound WATS switched), 2) AT&T 800 (classic inbound WATS), 3) Megacom 800 (inbound WATS dedicated) and 4) other 800.

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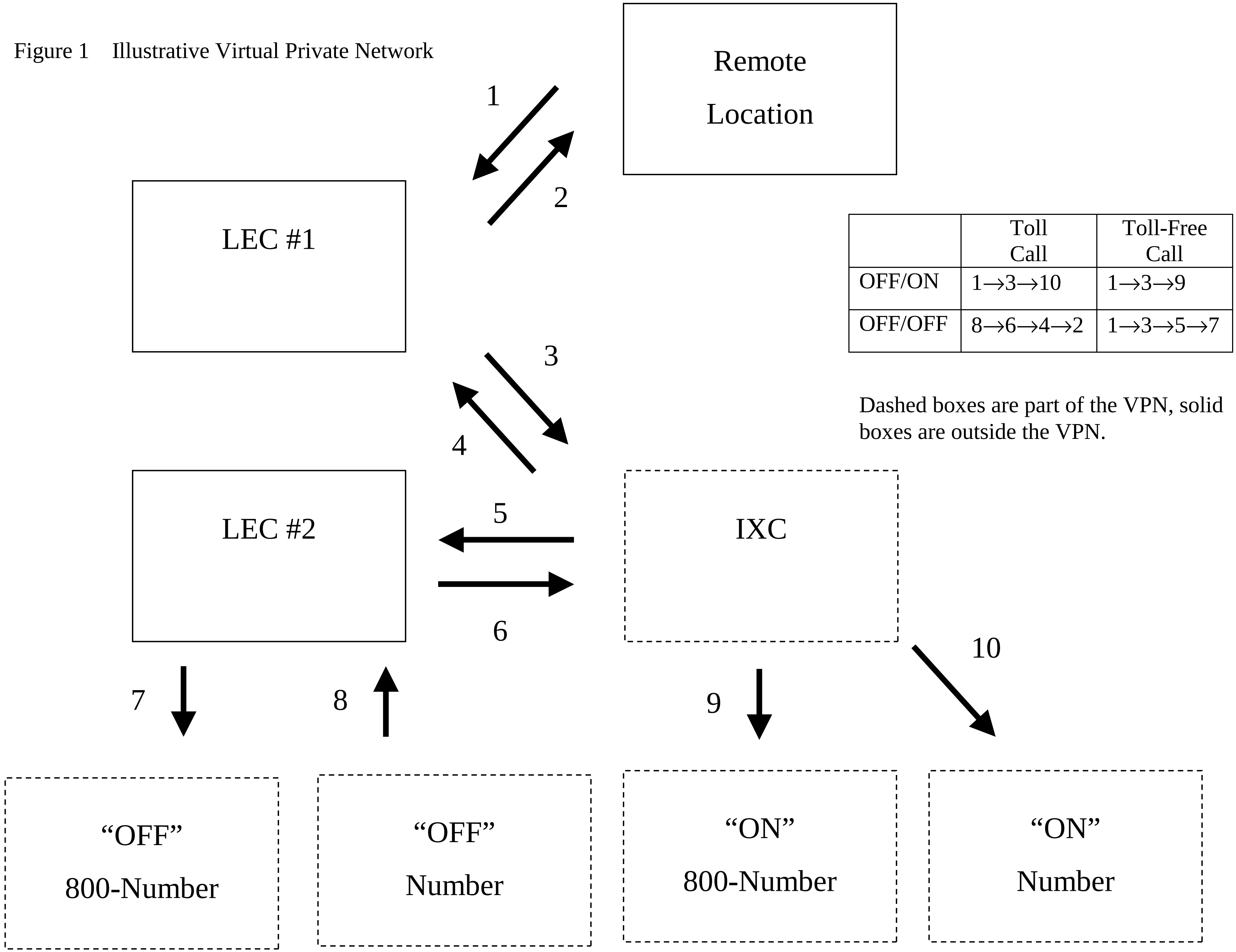
Figure 1 Illustrative Virtual Private Network



	Toll Call	Toll-Free Call
OFF/ON	1→3→10	1→3→9
OFF/OFF	8→6→4→2	1→3→5→7

Dashed boxes are part of the VPN, solid boxes are outside the VPN.

Figure 2 Summary Statistics

Variable	Mean	Std	Min	Max	n
OFF/ON toll service price ($ per minute)	0.0934	0.00901	0.0707	0.1182	156
OFF/ON toll-free service price ($ per minute)	0.1104	0.01497	0.0786	0.1797	133
OFF/OFF toll service price ($ per minute)	0.1280	0.01010	0.0980	0.1649	155
OFF/OFF toll-free service price ($ per minute)	0.1510	0.01896	0.1085	0.1934	122
OFF/ON toll marginal cost ($ per minute)	0.0486	0.00142	0.0470	0.0557	156
OFF/ON toll-free marginal cost ($ per minute)	0.0488	0.00131	0.0470	0.0557	133
OFF/OFF toll marginal cost ($ per minute)	0.0821	0.00363	0.0784	0.1019	155
OFF/OFF toll-free marginal cost ($ per minute)	0.0822	0.00350	0.0784	0.1019	122
OFF/ON toll margin	0.475	0.0490	0.335	0.594	156
OFF/ON toll-free margin	0.551	0.0557	0.402	0.726	133
OFF/OFF toll margin	0.356	0.0585	0.127	0.499	155
OFF/OFF toll-free margin	0.447	0.0743	0.277	0.594	122
Lagged Market Share	0.258	0.0511	0.182	0.350	157
Duration (years)	3.69	0.891	3	5	157
Size (1000s minutes/year)	71,727	114,736	0	762,853	157
Fixed Fee ($1000/month)	502	802	17	5,151	157
Time to Portability (days)	349	182	0	626	157
Bundled	0.777	0.418	0	1	157
Revision	0.580	0.495	0	1	157

Figure 3 Regression of Margins on Contract Characteristics

Dependent variable is margin for one of four types of services offered in Tariff 12 options: OFF/ON Toll, OFF/ON Toll-Free, OFF/OFF Toll or OFF/OFF Toll-Free.

Independent Variable	Base Model	Revised Options	New Options
Constant	0.316*** (0.0711)	0.287*** (0.107)	0.395*** (0.0879)
*Lag(Share)*OFF/ON Toll Dummy*	0.432** (0.201)	0.544* (0.305)	0.188 (0.246)
*Lag(Share)*OFF/ON Toll-Free Dummy*	0.892*** (0.213)	0.822** (0.329)	1.14*** (0.256)
*Lag(Share)*OFF/OFF Toll Dummy*	1.24*** (0.201)	1.16*** (0.306)	1.26*** (0.246)
*Lag(Share)*OFF/OFF Toll-Free Dummy*	1.48*** (0.223)	0.790** (0.353)	2.33*** (0.258)
*Tport*OFF/ON Toll Dummy*	$1.32x10^{-4}$** ($5.64x10^{-5}$)	$1.92x10^{-4}$** ($8.09x10^{-5}$)	$4.11x10^{-5}$ ($7.31x10^{-5}$)
*Tport*OFF/ON Toll-Free Dummy*	$2.52x10^{-4}$*** ($5.94x10^{-5}$)	$2.61x10^{-4}$*** ($8.63x10^{-5}$)	$2.73x10^{-4}$*** ($7.58x10^{-5}$)
*Tport*OFF/OFF Toll Dummy*	$2.15x10^{-4}$*** ($5.64x10^{-5}$)	$2.15x10^{-4}$*** ($8.09x10^{-5}$)	$2.10x10^{-4}$*** ($7.31x10^{-5}$)
*Tport*OFF/OFF Toll-Free Dummy*	$3.15x10^{-4}$*** ($6.25x10^{-5}$)	$1.47x10^{-4}$ ($9.36x10^{-5}$)	$4.95x10^{-4}$*** ($7.62x10^{-5}$)
*Size*OFF/ON Toll Dummy*	$-6.05x10^{-8}$ ($4.10\ x10^{-8}$)	$-7.59x10^{-8}$* ($4.52\ x10^{-8}$)	$-6.83x10^{-7}$*** ($2.29\ x10^{-7}$)
*Size*OFF/ON Toll-Free Dummy*	$-1.31x10^{-7}$** ($5.67x10^{-8}$)	$-9.94x10^{-8}$ ($6.29x10^{-8}$)	$-3.00x10^{-7}$ ($2.37x10^{-7}$)
*Size*OFF/OFF Toll Dummy*	$-1.36x10^{-7}$*** ($4.11x10^{-8}$)	$-1.48x10^{-7}$*** ($4.53x10^{-8}$)	$-4.87x10^{-7}$** ($2.30x10^{-7}$)
*Size*OFF/OFF Toll-Free Dummy*	$-3.49x10^{-7}$*** ($5.82x10^{-8}$)	$-3.03x10^{-7}$*** ($6.50x10^{-8}$)	$-6.36x10^{-8}$ ($2.40x10^{-7}$)
Duration	$2.20x10^{-3}$ ($2.52x10^{-3}$)	$-1.05x10^{-3}$ ($3.46x10^{-3}$)	0.0112*** ($3.42x10^{-3}$)
Fixed Fee	$-4.31x10^{-6}$ ($3.89x10^{-6}$)	$-1.88x10^{-6}$ ($4.41x10^{-6}$)	$-3.21x10^{-5}$*** ($8.79x10^{-6}$)
N	565	320	244
Adjusted R^2	0.681	0.642	0.785

Standard errors are in parentheses. Dummy variables for service-specific intercepts are not shown for space considerations.
* = significant at 10% level, ** = significant at 5% level, *** = significant at 1% level

Figure 4 Estimated Effect of Portability on "Average" Contract

Service Type	Margin Under Non-Portability	Change Due to Portability	Percentage Change
OFF/ON Toll	0.475	-0.046	-9.7%
OFF/ON Toll-Free	0.550	-0.088	-16.0%
OFF/OFF Toll	0.356	-0.075	-21.1%
OFF/OFF Toll-Free	0.444	-0.110	-24.7%

Margin under non-portability is calculated at the mean size, duration and fixed fee at the mean expected time to portability (using AT&T's lagged market share at that time).

Figure 5 Test for Cross-Subsidization

	Dependent Variable			
	OFF/ON Toll Margin		OFF/OFF Toll Margin	
Independent Variable	Bundled Options	Non-Bundled Options	Bundled Options	Non-Bundled Options
Constant	0.292***	0.491***	0.0176	-0.020
	(0.0729)	(0.165)	(0.0607)	(0.254)
Lag(Share)	0.481***	-6.93×10^{-3}	1.18***	1.27*
	(0.199)	(0.463)	(0.166)	(0.713)
Tport	1.20×10^{-4}**	6.35×10^{-5}	1.76×10^{-4}***	2.90×10^{-4}
	(5.63×10^{-5})	(1.29×10^{-4})	(4.69×10^{-5})	(1.97×10^{-4})
Size	-1.35×10^{-7}**	-8.01×10^{-8}	-2.16×10^{-7}***	-7.25×10^{-8}
	(6.40×10^{-8})	(7.32×10^{-8})	(5.33×10^{-8})	(1.13×10^{-7})
Duration	5.28×10^{-3}	-1.86×10^{-3}	-5.37×10^{-3}	-5.17×10^{-3}
	(4.85×10^{-3})	(9.31×10^{-3})	(4.04×10^{-3})	(0.0143)
Fixed Fee	1.40×10^{-7}	2.05×10^{-6}	4.37×10^{-6}	1.86×10^{-5}
	(7.58×10^{-6})	(1.34×10^{-5})	(6.32×10^{-6})	(2.07×10^{-5})
N	121	33	121	32
Adjusted R^2	0.059	-0.0374	0.452	0.091

Standard errors are in parentheses.
* = significant at 10% level
** = significant at 5% level
*** = significant at 1% level

Figure 6 AT&T's Basket 2 Actual Price Index Relative to Price Cap Index

Year	Price Cap Index	Actual Index
1988	100.00	100.00
1989	96.80	97.30
1990	94.00	92.80
1991	93.80	93.40
1992	94.10	92.50
1993	94.10	91.40

Source: Hall (1993) taken from FCC, "Price Cap Performance Review for AT&T", January 23, 1993.

Appendix 1 Position of Marginal Young Consumer

The marginal new consumer is indifferent between buying from firm A and firm B including the effect it has on their second period utility:

$$r - P_A - x_A + \delta_C(1-\rho)\left\{\mu\left[\int_0^{x'_{AB}}\left(r - P'_A - b\right)db + \int_{x'_{AB}}^{1}\left(r - P'_B - s - (1-b)\right)db\right] + (1-\mu)\left[r - P'_A - x_A\right]\right\} =$$

$$r - P_B - (1-x_A) + \delta_C(1-\rho)\left\{\mu\left[\int_0^{x'_{BA}}\left(r - P'_A - s - b\right)db + \int_{x'_{BA}}^{1}\left(r - P'_B - (1-b)\right)db\right] + (1-\mu)\left[r - P'_B - (1-x_A)\right]\right\}$$

where δ_C is the consumers' discount factor and primes indicate next period values. On the left-hand side of the equation is the consumer's discounted expected utility from purchasing from A. The first term is the profit obtained in the current period. The two integrals measure the utility if the consumer's position changes in the next period and are multiplied by μ, the probability that they change. The first integral measures expected utility if the consumer buys from A again while the second integral measures expected utility if they switch to B. The last term on the left-hand side measures the expected utility if the consumers' preferences do not change. The right-hand side is analogous if the consumer purchases from B.

Using $P'_B - P'_A = e(1-2x_A)$, $x'_{AB} - x'_{BA} = s$ and $\left(x'_{AB}\right)^2 - \left(x'_{BA}\right)^2 = s\left(1 + P'_B - P'_A\right) = s\left(1 + e(1-2x_A)\right)$:

$x_A = \frac{1}{2} + b(P_B - P_A)$ where $b = \dfrac{1}{2\left(1 + \delta_C(1-\rho)(1-\mu+\mu se+(1-\mu)e)\right)}$.

Appendix 2 Solving the Theoretical Model

Substituting (8) and (9) into (7) and (4) for σ'_A, I can equate the coefficients in (7) to those in (1) to obtain:

(A1) $k = (d-c)\left(\eta + \mu(1-\rho)\left(\frac{1-s+e}{2}\right)\right) + \delta_F\left(k + l\eta + m\eta^2\right)$

(A2) $l = (d-c)(-\theta + \mu(1-\rho)(s-e) + (1-\mu)(1-\rho)) + e\left(\eta + \mu(1-\rho)\left(\frac{1-s+e}{2}\right)\right) + \delta_F\left(-\theta l - 2m\eta\theta\right)$

(A3) $m = e(-\theta + \mu(1-\rho)(s-e) + (1-\mu)(1-\rho)) + \delta_F m\theta^2$

Maximizing (10), the first-order condition is:

(A4) $(P_A - c)\left[\frac{\partial x_A}{\partial P_A} + \mu(1-\rho)\left(\sigma_A\frac{\partial x_{AB}}{\partial P_A} + (1-\sigma_A)\frac{\partial x_{BA}}{\partial P_A}\right)\right] +$

$[x_A + \mu(1-\rho)(\sigma_A x_{AB} + (1-\sigma_A)x_{BA}) + (1-\mu)(1-\rho)\sigma_A] + \delta_F\left(l + 2mx_A\right)\frac{\partial x_A}{\partial P_A} = 0$

The second-order condition for the problem is:

(A5) $2\left[\frac{\partial x_A}{\partial P_A} + \mu(1-\rho)\left(\sigma_A\frac{\partial x_{AB}}{\partial P_A} + (1-\sigma_A)\frac{\partial x_{BA}}{\partial P_A}\right)\right] + 2\delta_F m\left(\frac{\partial x_A}{\partial P_A}\right)^2 < 0$

I confirm in my numerical solutions that this holds. Substituting the equilibrium market shares (4) for x_A, (8) for x_{AB} and (9) for x_{BA} into the first-order condition yields:

(A6)

$(P_A - c)\left[-b - \frac{1}{2}\mu(1-\rho)\right] + \left[(\eta - \theta\sigma_A) + \mu(1-\rho)\left(\sigma_A s + \frac{1-s+e}{2} - e\sigma_A\right) + (1-\mu)(1-\rho)\sigma_A\right] -$

$\delta_F(l + 2m(\eta - \theta\sigma_A))b = 0$

Solving for P_A and equating the constants to those in (2) yields:

$$\text{(A7)}\quad d = c + \frac{\eta + \mu(1-\rho)\left(\frac{1-s+e}{2}\right) - \delta_F b(l + 2m\eta)}{b + \frac{1}{2}\mu(1-\rho)}$$

$$\text{(A8)}\quad e = \frac{-\theta + \mu(1-\rho)(s-e) + (1-\mu)(1-\rho) + 2\delta_F m\theta b}{b + \frac{1}{2}\mu(1-\rho)}$$

These equations can only be solved analytically when $\mu = 0$ (no uncertainty about preferences) but in this degenerate case the switching costs parameter does not affect equilibrium prices or shares.[1] When $\mu > 0$, I use Mathematica to solve the equations numerically for a given set of parameter values. Regardless of whether the equations are solved analytically or numerically, the procedure is the same. I first solve equations (A8) and (A3) to eliminate m and obtain e as a function of θ. This is a quadratic equation in e which yields up to two roots as a function of θ^2. I then use this result along with (6) to eliminate e and solve for θ as a function of the other parameters. This yields a cubic equation in θ which can yield up to three roots for each of the two possible values for e. This can produce up to six possible values for θ, however, in all the numerical solutions I have obtained thus far there has been a unique valid solution (i.e. $|\theta| \leq 1$).[2]

All of the coefficients can then be calculated. Equation (3) yields b, (5) yields η, (A3) yields b, (A2) yields l, (A7) yields d and (A1) yields k. Finally, I check that the necessary constraints on the problem are satisfied (the second order condition is met, individual rationality for each of the marginal consumer types holds and the marginal young consumer prefers to purchase when young rather than waiting to purchase until old).

In all my numerical solutions, θ has been positive implying that if firms' shares are not equally divided, they converge to one-half in an oscillatory manner. In each period one firm has a dominant "locked-in" share and prices

[1] My model with $\rho = \mu = 0$ corresponds to To (1996).

[2] Note that if $|\theta| > 1$ the firms' shares diverge.

high giving it a smaller share in the next period. This is implied by the fact that e is positive in all my numerical solutions. The smaller share in the next period leads the firm to price lower to build its “locked-in” customer base and so on.

Appendix 3 Equilibrium Markups Obtained in Theoretical Model

Panel A - Same Consumer and Firm Discount Factors $\delta_C = 0.5, \delta_F = 0.5$

Sub Panel A1 - 50% Probability New Consumer Exits $\rho = 0.5$

	Switching Costs (s)										
μ	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	≥ 1.0*
0.1	1.63023	1.63071	1.63122	1.63177	1.63236	1.63298	1.63365	1.63435	1.63510	1.63588	1.63670
0.2	1.51083	1.51078	1.51086	1.51105	1.51137	1.51180	1.51236	1.51304	1.51384	1.51477	1.51583
0.3	1.41178	1.41073	1.40991	1.40930	1.40891	1.40875	1.40880	1.40909	1.40960	1.41034	1.41131
0.4	1.32778	1.32549	1.32353	1.32190	1.32059	1.31963	1.31899	1.31869	1.31874	1.31912	1.31985
0.5	1.25531	1.25166	1.24846	1.24570	1.24339	1.24153	1.24011	1.23914	1.23863	1.23857	1.23897
0.6	1.19192	1.18687	1.18239	1.17847	1.17512	1.17233	1.17010	1.16843	1.16733	1.16680	1.16685
0.7	1.13587	1.12940	1.12364	1.11856	1.11416	1.11045	1.10741	1.10504	1.10336	1.10235	1.10203
0.8	1.08582	1.07796	1.07093	1.06471	1.05929	1.05467	1.05084	1.04779	1.04554	1.04406	1.04338
0.9	1.04079	1.03157	1.02330	1.01596	1.00955	1.00405	0.99946	0.99576	0.99295	0.99103	0.99001

* Assumes that r is set so that consumers located at 0 and 1 are indifferent between not purchasing and purchasing from firm A and B respectively.

Sub Panel A2 - 20% Probability New Consumer Exits $\rho = 0.2$

μ	Switching Costs (s) 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	≥ 1.0*
0.1	2.16688	2.17194	2.17716	2.18255	2.18810	2.19382	2.19971	2.20577	2.21201	2.21844	2.22504
0.2	1.86974	1.87410	1.87883	1.88393	1.88941	1.89528	1.90155	1.90822	1.91531	1.92282	1.93075
0.3	1.66099	1.66323	1.66604	1.66942	1.67338	1.67794	1.68310	1.68888	1.69528	1.70231	1.71000
0.4	1.50329	1.50304	1.50356	1.50485	1.50691	1.50975	1.51339	1.51783	1.52309	1.52917	1.53610
0.5	1.37850	1.37574	1.37394	1.37309	1.37320	1.37428	1.37633	1.37936	1.38339	1.38841	1.39445
0.6	1.27650	1.27131	1.26727	1.26437	1.26260	1.26198	1.26251	1.26418	1.26701	1.27100	1.27617
0.7	1.19111	1.18360	1.17742	1.17258	1.16906	1.16684	1.16594	1.16636	1.16808	1.17112	1.17548
0.8	1.11828	1.10856	1.10037	1.09370	1.08853	1.08484	1.08263	1.08188	1.08260	1.08478	1.08843
0.9	1.05524	1.04341	1.03332	1.02493	1.01822	1.01315	1.00973	1.00792	1.00773	1.00915	1.01217

* Assumes that r is set so that consumers located at 0 and 1 are indifferent between not purchasing and purchasing from firm A and B respectively.

Sub Panel A3 - 0% Probability New Consumer Exits $\rho = 0$

μ	Switching Costs (s) 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	≥ 1.0*
0.1	2.62663	2.63830	2.65031	2.66268	2.67542	2.68853	2.70203	2.71591	2.73020	2.74489	2.76000
0.2	2.12974	2.13910	2.14908	2.15970	2.17097	2.18291	2.19553	2.20884	2.22286	2.23760	2.25308
0.3	1.82396	1.82958	1.83607	1.84342	1.85165	1.86079	1.87083	1.88180	1.89371	1.90657	1.92039
0.4	1.61021	1.61211	1.61508	1.61914	1.62430	1.63056	1.63794	1.64645	1.65610	1.66689	1.67884
0.5	1.44970	1.44812	1.44784	1.44886	1.45119	1.45483	1.45978	1.46605	1.47364	1.48256	1.49280
0.6	1.32342	1.31865	1.31540	1.31368	1.31346	1.31476	1.31756	1.32186	1.32766	1.33495	1.34373
0.7	1.22075	1.21305	1.20710	1.20288	1.20038	1.19958	1.20048	1.20307	1.20732	1.21324	1.22079
0.8	1.13522	1.12479	1.11634	1.10984	1.10527	1.10261	1.10183	1.10291	1.10584	1.11058	1.11712
0.9	1.06260	1.04961	1.03883	1.03023	1.02376	1.01940	1.01711	1.01687	1.01865	1.02241	1.02812

* Assumes that r is set so that consumers located at 0 and 1 are indifferent between not purchasing and purchasing from firm A and B respectively.

Shaded areas indicate regimes in which an increase in switching costs lowers price

Panel B - High Consumer, Low Firm Discount Factor $\delta_C = 0.7, \delta_F = 0.3$

Sub Panel B1 - 50% Probability New Consumer Exits $\rho = 0.5$

	Switching Costs (s)										
μ	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	$\geq$ 1.0*
0.1	1.86920	1.87157	1.87399	1.87647	1.87901	1.88160	1.88426	1.88697	1.88974	1.89258	1.89548
0.2	1.69323	1.69602	1.69899	1.70211	1.70541	1.70888	1.71252	1.71634	1.72034	1.72452	1.72888
0.3	1.55187	1.55419	1.55680	1.55970	1.56289	1.56639	1.57018	1.57429	1.57871	1.58345	1.58851
0.4	1.43493	1.43634	1.43815	1.44039	1.44304	1.44613	1.44964	1.45360	1.45801	1.46288	1.58851
0.5	1.33604	1.33631	1.33711	1.33846	1.34035	1.34280	1.34582	1.34940	1.35357	1.35833	1.36369
0.6	1.25094	1.24997	1.24966	1.25001	1.25104	1.25274	1.25514	1.25823	1.26203	1.26655	1.27181
0.7	1.17667	1.17441	1.17295	1.17227	1.17238	1.17330	1.17502	1.17756	1.18093	1.18515	1.19023
0.8	1.11109	1.10755	1.10491	1.10319	1.10238	1.10249	1.10352	1.10550	1.10842	1.11230	1.11717
0.9	1.05261	1.04778	1.04399	1.04124	1.03951	1.03882	1.03917	1.04057	1.04304	1.04658	1.05122

* Assumes that r is set so that consumers located at 0 and 1 are indifferent between not purchasing and purchasing from firm A and B respectively.

Shaded areas indicate regimes in which an increase in switching costs lowers price

Sub Panel B2 - 20% Probability New Consumer Exits $\rho = 0.2$

μ	Switching Costs (s) 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	≥ 1.0*
0.1	2.67469	2.68594	2.69747	2.70927	2.72136	2.73375	2.74643	2.75941	2.77270	2.78630	2.80022
0.2	2.20413	2.21534	2.22710	2.23941	2.25230	2.26578	2.27985	2.29454	2.30986	2.32582	2.34243
0.3	1.89465	1.90365	1.91341	1.92396	1.93531	1.94748	1.96049	1.97436	1.98909	2.00472	2.02126
0.4	1.67063	1.67695	1.68424	1.69250	1.70177	1.71206	1.72339	1.73577	1.74923	1.76380	1.77947
0.5	1.49866	1.50230	1.50708	1.51304	1.52018	1.52852	1.53808	1.54888	1.56094	1.57428	1.58891
0.6	1.36124	1.36231	1.36471	1.36846	1.37357	1.38006	1.38794	1.39723	1.40795	1.42011	1.43373
0.7	1.24812	1.24677	1.24694	1.24863	1.25186	1.25663	1.26296	1.27086	1.28035	1.29145	1.30416
0.8	1.15287	1.14924	1.14731	1.14708	1.14856	1.15175	1.15666	1.16331	1.17171	1.18187	1.19379
0.9	1.07116	1.06538	1.06147	1.05944	1.05929	1.06103	1.06465	1.07017	1.07761	1.08695	1.09821

* Assumes that r is set so that consumers located at 0 and 1 are indifferent between not purchasing and purchasing from firm A and B respectively.

Sub Panel B3 - 0% Probability New Consumer Exits $\rho = 0$

μ	Switching Costs (s) 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	≥ 1.0*
0.1	3.38404	3.40707	3.43067	3.45488	3.47970	3.50514	3.53122	3.55794	3.58533	3.61339	3.64212
0.2	2.57278	2.59222	2.61256	2.63381	2.65599	2.67912	2.70321	2.72827	2.75433	2.78140	2.80949
0.3	2.11527	2.12987	2.14558	2.16244	2.18046	2.19964	2.22002	2.24159	2.26438	2.28838	2.31361
0.4	1.81127	1.82138	1.83283	1.84562	1.85978	1.87530	1.89222	1.91052	1.93022	1.95131	1.97380
0.5	1.59059	1.59674	1.60443	1.61367	1.62447	1.63683	1.65077	1.66628	1.68336	1.70201	1.72220
0.6	1.42113	1.42376	1.42814	1.43428	1.44217	1.45182	1.46323	1.47641	1.49132	1.50796	1.52630
0.7	1.28576	1.28523	1.28666	1.29004	1.29539	1.30270	1.31196	1.32317	1.33629	1.35131	1.36818
0.8	1.17437	1.17094	1.16969	1.17061	1.17370	1.17895	1.18635	1.19589	1.20754	1.22126	1.23699
0.9	1.08055	1.07443	1.07070	1.06936	1.07041	1.07382	1.07960	1.08771	1.09813	1.11081	1.12566

* Assumes that r is set so that consumers located at 0 and 1 are indifferent between not purchasing and purchasing from firm A and B respectively.

Shaded areas indicate regimes in which an increase in switching costs lowers price

Panel C - Low Consumer, High Firm Discount Factor $\delta_C = 0.3, \delta_F = 0.7$

Sub Panel C1 - 50% Probability New Consumer Exits $\rho = 0.5$

	Switching Costs (s)										
μ	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	≥ 1.0*
0.1	1.38613	1.38392	1.38170	1.37948	1.37726	1.37502	1.37278	1.37054	1.36829	1.36603	1.36376
0.2	1.34528	1.34313	1.34108	1.33911	1.33723	1.33544	1.33374	1.33213	1.33061	1.32918	1.31910
0.3	1.28167	1.27801	1.27453	1.27123	1.26809	1.26514	1.26235	1.25974	1.25730	1.25503	1.25293
0.4	1.22642	1.22114	1.21615	1.21143	1.20699	1.20282	1.19892	1.19529	1.19192	1.18883	1.18599
0.5	1.17780	1.17087	1.16433	1.15819	1.15244	1.14706	1.14206	1.13743	1.13317	1.12927	1.12574
0.6	1.13457	1.12598	1.11792	1.11037	1.10332	1.09677	1.09070	1.08512	1.08000	1.07536	1.07117
0.7	1.09582	1.08558	1.07601	1.06709	1.05879	1.05111	1.04402	1.03753	1.03161	1.02627	1.02149
0.8	1.06082	1.04897	1.03793	1.02767	1.01817	1.00940	1.00135	0.99400	0.98734	0.98135	0.97602
0.9	1.02903	1.01560	1.00313	0.99158	0.98092	0.97112	0.96216	0.95401	0.94665	0.94006	0.93423

* Assumes that r is set so that consumers located at 0 and 1 are indifferent between not purchasing and purchasing from firm A and B respectively.

Shaded areas indicate regimes in which an increase in switching costs lowers price

Panel D - Low Consumer, Low Firm Discount Factor $\delta_C = 0.3, \delta_F = 0.3$

Sub Panel D1 - 50% Probability New Consumer Exits $\rho = 0.5$

	Switching Costs (s)										
μ	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	≥ 1.0*
0.1	1.54657	1.54666	1.54678	1.54692	1.54707	1.54725	1.54744	1.54765	1.54789	1.54814	1.54841
0.2	1.45089	1.45063	1.45042	1.45028	1.45021	1.45019	1.45024	1.45035	1.45052	1.45075	1.45105
0.3	1.36858	1.36771	1.36695	1.36631	1.36579	1.36539	1.36510	1.36493	1.36488	1.36495	1.36514
0.4	1.29676	1.29515	1.29371	1.29246	1.29138	1.29048	1.28976	1.28922	1.28887	1.28869	1.28870
0.5	1.23335	1.23094	1.22878	1.22685	1.22517	1.22372	1.22253	1.22157	1.22086	1.22040	1.22019
0.6	1.17684	1.17361	1.17069	1.16807	1.16576	1.16376	1.16207	1.16068	1.15961	1.15884	1.15839
0.7	1.12606	1.12201	1.11833	1.11503	1.11210	1.10955	1.10736	1.10554	1.10410	1.10303	1.10234
0.8	1.08011	1.07526	1.07085	1.06687	1.06334	1.06024	1.05757	1.05533	1.05353	1.05216	1.05123
0.9	1.03828	1.03265	1.02753	1.02291	1.01878	1.01516	1.01203	1.00939	1.00724	1.00559	1.00443

* Assumes that r is set so that consumers located at 0 and 1 are indifferent between not purchasing and purchasing from firm A and B respectively.

Shaded areas indicate regimes in which an increase in switching costs lowers price

Sub Panel D2 - 20% Probability New Consumer Exits $\rho = 0.2$

μ	Switching Costs (s) 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	≥ 1.0*
0.1	1.94952	1.95164	1.95382	1.95608	1.95840	1.96079	1.96326	1.96580	1.96841	1.97109	1.97385
0.2	1.73845	1.74028	1.74229	1.74448	1.74686	1.74943	1.75219	1.75515	1.75830	1.76164	1.76519
0.3	1.57707	1.57779	1.57881	1.58013	1.58176	1.58370	1.58595	1.58852	1.59141	1.59462	1.59817
0.4	1.44824	1.44757	1.44733	1.44750	1.44809	1.44911	1.45056	1.45244	1.45475	1.45752	1.46073
0.5	1.34222	1.34012	1.33854	1.33749	1.33698	1.33700	1.33755	1.33865	1.34029	1.34249	1.34524
0.6	1.25298	1.24947	1.24660	1.24435	1.24275	1.24178	1.24144	1.24175	1.24271	1.24432	1.24659
0.7	1.17654	1.17169	1.16758	1.16420	1.16156	1.15965	1.15847	1.15803	1.15832	1.15936	1.16115
0.8	1.11014	1.10403	1.09876	1.09432	1.09070	1.08791	1.08594	1.08480	1.08448	1.08499	1.08633
0.9	1.05178	1.04450	1.03815	1.03271	1.02820	1.02459	1.02189	1.02010	1.01922	1.01924	1.02018

* Assumes that r is set so that consumers located at 0 and 1 are indifferent between not purchasing and purchasing from firm A and B respectively.

Sub Panel D3 - 0% Probability New Consumer Exits $\rho = 0$

μ	Switching Costs (s) 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	≥ 1.0*
0.1	2.26381	2.26872	2.27377	2.27895	2.28428	2.28975	2.29537	2.30114	2.30706	2.31314	2.31937
0.2	1.93804	1.94236	1.94698	1.95192	1.95717	1.96275	1.96866	1.97490	1.98149	1.98842	1.99570
0.3	1.71059	1.71310	1.71608	1.71952	1.72344	1.72783	1.73272	1.73810	1.74398	1.75037	1.75728
0.4	1.53960	1.54007	1.54115	1.54284	1.54514	1.54806	1.55160	1.55578	1.56059	1.56605	1.57217
0.5	1.40486	1.40335	1.40258	1.40254	1.40324	1.40468	1.40687	1.40982	1.41353	1.41801	1.42327
0.6	1.29516	1.29179	1.28929	1.28764	1.28685	1.28692	1.28785	1.28966	1.29233	1.29588	1.30031
0.7	1.20363	1.19857	1.19447	1.19135	1.18921	1.18803	1.18782	1.18859	1.19032	1.19304	1.19673
0.8	1.12582	1.11920	1.11366	1.10921	1.10583	1.10353	1.10229	1.10213	1.10303	1.10500	1.10803
0.9	1.05867	1.05062	1.04377	1.03810	1.03361	1.03028	1.02813	1.02713	1.02729	1.02861	1.03107

* Assumes that r is set so that consumers located at 0 and 1 are indifferent between not purchasing and purchasing from firm A and B respectively.

Shaded areas indicate regimes in which an increase in switching costs lowers price

Panel E - High Consumer, High Firm Discount Factor $\delta_C = 0.7, \delta_F = 0.7$

Sub Panel E1 - 50% Probability New Consumer Exits $\rho = 0.5$

	Switching Costs (s)										
μ	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	≥ 1.0*
0.1	1.71818	1.71927	1.72043	1.72165	1.72293	1.72428	1.72569	1.72717	1.72871	1.73032	1.73200
0.2	1.57216	1.57262	1.57326	1.57410	1.57513	1.57635	1.57776	1.57937	1.58118	1.58319	1.58541
0.3	1.45524	1.45429	1.45368	1.45342	1.45349	1.45391	1.45467	1.45579	1.45726	1.45909	1.46128
0.4	1.35866	1.35595	1.35374	1.35204	1.35083	1.35014	1.34995	1.35027	1.35112	1.35249	1.35439
0.5	1.27703	1.27239	1.26843	1.26514	1.26252	1.26057	1.25930	1.25871	1.25880	1.25959	1.26106
0.6	1.20681	1.20017	1.19439	1.18946	1.18538	1.18214	1.17975	1.17820	1.17749	1.17764	1.17865
0.7	1.14555	1.13688	1.12927	1.12269	1.11715	1.11263	1.10911	1.10661	1.10511	1.10462	1.10515
0.8	1.09147	1.08078	1.07136	1.06316	1.05618	1.05039	1.04579	1.04235	1.04008	1.03898	1.03905
0.9	1.04329	1.03059	1.01937	1.00958	1.00120	0.99419	0.98853	0.98420	0.98120	0.97952	0.97916

* Assumes that r is set so that consumers located at 0 and 1 are indifferent between not purchasing and purchasing from firm A and B respectively.

Shaded areas indicate regimes in which an increase in switching costs lowers price

Sub Panel E2 - 20% Probability New Consumer Exits $\rho = 0.2$

	Switching Costs (s)										
μ	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	≥ 1.0*
0.1	2.40982	2.41921	2.42890	2.43890	2.44922	2.45986	2.47084	2.48215	2.49381	2.50582	2.51819
0.2	2.00560	2.01335	2.02170	2.03066	2.04025	2.05049	2.06138	2.07295	2.08520	2.09816	2.11183
0.3	1.74460	1.74894	1.75416	1.76026	1.76726	1.77517	1.78401	1.79380	1.80456	1.81630	1.82905
0.4	1.55708	1.55774	1.55952	1.56246	1.56654	1.57180	1.57823	1.58586	1.59471	1.60479	1.61611
0.5	1.41364	1.41066	1.40909	1.40893	1.41018	1.41284	1.41693	1.42246	1.42943	1.43785	1.44775
0.6	1.29925	1.29278	1.28801	1.28492	1.28350	1.28375	1.28567	1.28925	1.29450	1.30143	1.31004
0.7	1.20524	1.19544	1.18763	1.18179	1.17789	1.17591	1.17584	1.17767	1.18139	1.18700	1.19449
0.8	1.12624	1.11322	1.10252	1.09408	1.08786	1.08383	1.08195	1.08220	1.08457	1.08904	1.09558
0.9	1.05865	1.04251	1.02903	1.01813	1.00973	1.00378	1.00024	0.99908	1.00025	1.00373	1.00950

* Assumes that r is set so that consumers located at 0 and 1 are indifferent between not purchasing and purchasing from firm A and B respectively.

Sub Panel E3 - 0% Probability New Consumer Exits $\rho = 0$

	Switching Costs (s)										
μ	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	≥ 1.0*
0.1	3.04455	3.06588	3.08788	3.11056	3.13393	3.15802	3.18283	3.20838	3.23468	3.26175	3.28960
0.2	2.32616	2.34165	2.35812	2.37560	2.39410	2.41364	2.43422	2.45588	2.47862	2.50247	2.52742
0.3	1.93470	1.94403	1.95463	1.96650	1.97967	1.99415	2.00994	2.02706	2.04552	2.06532	2.08647
0.4	1.67775	1.68153	1.68687	1.69377	1.70224	1.71229	1.72391	1.73711	1.75189	1.76824	1.78614
0.5	1.49225	1.49106	1.49175	1.49430	1.49871	1.50496	1.51306	1.52299	1.53474	1.54828	1.56359
0.6	1.35026	1.34456	1.34106	1.33976	1.34061	1.34360	1.34871	1.35590	1.36516	1.37644	1.38969
0.7	1.23713	1.22724	1.21993	1.21514	1.21283	1.21296	1.21549	1.22038	1.22758	1.23704	1.24868
0.8	1.14432	1.13048	1.11961	1.11162	1.10644	1.10402	1.10430	1.10722	1.11271	1.12069	1.13109
0.9	1.06647	1.04883	1.03456	1.02356	1.01574	1.01101	1.00928	1.01049	1.01454	1.02135	1.03079

* Assumes that r is set so that consumers located at 0 and 1 are indifferent between not purchasing and purchasing from firm A and B respectively.

Shaded areas indicate regimes in which an increase in switching costs lowers price

Appendix 4 Expected Portability Date Timeline

Date	Activities Related to Portability	Expected Portability Date
< 3/31/89	Portability not planned. LECs provide NXX-switching for toll-free calls.	N/A
3/31/89	FCC makes decision to convert database for portability and expects completion in mid-1991. "All BOCs are expected to have the new signaling system [SS7 allowing portability] in place sometime in 1991." *Network World*, "The Numbers Game; Advances in Signaling and Switching are Driving the Evolution of 800 Services," June 19, 1989. "Full SS7 implementation is not expected until 1991." *Network World*, "Toll-Free Services Market Set for Explosive Growth," July 3, 1989.	6/30/91
5/22/90	FCC announces that 1991 deadline for portability unrealistic, will set new deadline. "US Sprint's Canavan said he is hopeful that his company will be able to offer end-to-end services supported by CCS7 [SS7] between some major metropolitan areas next year. 'It will be '92 or '93 before there is significant coverage.'" *Network World*, "Plodding CCS7 Deployment Delays Advanced Services," August 6, 1990.	15 months in future
8/2/91	FCC reschedules portability implementation date to March 1, 1993. "We require the BOCs and GTE [the LECs] to meet our revised access time standard within eighteen months of the date this order is released." FCC CC Docket No. 86-10, 6 FCC Rcd 5421, "In the Matter of Provision of Access for 800 Service, September 4, 1991.	3/1/93

Date	Activities Related to Portability	Expected Portability Date
11/21/92	FCC delays implementation date to May 1, 1993. "Although we here grant a fifty-seven day extension of the deadline for implementation of data base access, we fully expect LECs and IXCs to continue working diligently . . . the progress that the industry has made thus far in the implementation process must continue in order for our May 1 deadline to be met." FCC CC Docket No. 86-10, 7 FCC Rcd 8616, "In the Matter of Provision of Access for 800 Service," November 20, 1992.	5/1/93
5/1/93	Portability implemented.	5/1/93