NORTHWESTERN UNIVERSITY

THE UNIFORM SETTLEMENTS POLICY IN INTERNATIONAL TELECOMMUNICATIONS: A NONCOOPERATIVE BARGAINING MODEL OF INTERMEDIATE PRODUCT THIRD DEGREE PRICE DISCRIMINATION

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Abstract

I develop a noncooperative bargaining model to address the effects of the uniform settlements policy (USP) in international telecommunications. The model predicts that the USP may increase (resp. decreases) access charges in markets where, under the USP, U.S. firms carry more (resp. less) outbound than inbound traffic. Since traffic in most voice markets is net outbound from the U.S., this calls into question the FCC's recent decision to apply the USP to voice.

The model is also used to draw general conclusions about the effects of forbidding third degree price discrimination in intermediate product markets. Whereas previous models *assume* monopoly price leadership in both the constrained and unconstrained regimes, I endogenously determine the degree to which the monopolist controls price by introducing bargaining between the monopolist and each downstream firm. The model explicitly incorporates the threat each firm has to impose costly delays on firms with which it negotiates. Equilibrium prices reflect how these threats interact with the rule forbidding third degree price discrimination.

In the regime where discrimination is allowed the monopolist bargains with each buyer over the incremental producer surplus generated by each contract. There is a unique stationary subgame perfect equilibrium in which such a monopolist cannot exercise price leadership if bargaining costs (as captured by the costs of delayed service) are small relative to the discounted profits available. In

contrast, forbidding price discrimination provides the monopolist with a credible commitment to refrain from bargaining with all but the first buyer to sign a contract. This allows it to set higher prices than when price discrimination is not forbidden.

Surprisingly, introducing free entry downstream does not increase the bargaining power of the monopolist in the unconstrained regime. This demonstrates that the degree to which the monopolist controls price depends not on the number of buyers it sells to, but on its ability to make credible commitments. Forbidding price discrimination provides it with just the commitment it needs to set a take-it or leave-it price as the downstream market becomes competitive.

Preface

A generous amount of support, both intellectual and moral, made the completion of this dissertation much less trying. I am indebted to my advisors and colleagues for the former, numerous family and friends for the latter.

I thank my committee members, Steve Matthews and Dan Sullivan, and my committee chairman, John Panzar, for suggestions, observations and stimulating discussions that helped point me in the right direction whenever I needed guidance. In particular, I thank Steve Matthews for detailed comments on an early version of Chapter 3 that dramatically improved my understanding of the bargaining model.

Special thanks are due John Panzar, who encouraged pursuit of this problem before either of us recognized where it might lead. Many of my breakthroughs came at 6 A.M. as I recalled one of his three or four word suggestions, realizing the depth of its meaning days after hearing it. Without his encouragement and guidance this dissertation would have been much more difficult to complete.

As always, my parents were there with love and support over the past four years. More than for the material assistance, I thank them for always supporting whatever I've chosen to pursue.

My greatest debt is to Laura, who endured, yet supported what was sometimes an unaccommodating vent of frustration. She has the wisdom to teach patience by example. While I was not always the best student, this was the most important lesson learned throughout this dissertation, and I thank her for it dearly.

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Chapter 1: Introduction

Motivation

In April 1979, the Federal Communications Commission (FCC) initiated the first of several actions that are radically changing the international telecommunications market place. Viewing prices as excessive in the voice segment of the market, they considered two broad policy options: 1) open formal rate hearings hoping to determine "appropriate" prices or 2) open entry hoping that competition would hold rates down to cost. Their decision was to open entry to the greatest extent possible.[1]

Unfortunately, the welfare properties of a perfectly competitive closed economy cannot be extended to the international telecommunications services market where large fixed costs may preclude perfect competition in the U.S., and the foreign half of the network is monopoly controlled. Most foreign governments are likely to maintain these monopolies well into the future with the unfortunate consequence that they will remain "bottlenecks" in the provision of service. Foreign monopolies interact with U.S. firms in two ways. First, they serve as upstream suppliers of "access to the foreign network", an input used in fixed proportions by U.S. firms to produce "calls to the foreign country". Second, they are also downstream demanders of "access to the U.S. networks". Each foreign monopoly controls not only

[1]"Order in the Matter of Preliminary Audit...," Docket No. 20778, released January 29, 1980, 1-2.

the number of U.S. carriers allowed to access its network, but also the allocation of U.S. bound traffic across U.S. carriers. These advantages place foreign carriers in a relatively strong bargaining position vis-a-vis their U.S. counterparts in the process that determines the division of international revenues. An important question is whether U.S. entry will allow foreign monopolies to use these advantages to raise the price for access to their networks, reduce the price paid for access to U.S. networks, and ultimately, increase the price paid by U.S. consumers for international service.

To avoid these potential hazards, the FCC has continued to enforce the *uniform settlements policy* (USP), designed to prevent foreign monopolies from playing U.S. carriers against one another to obtain more favorable agreements. The USP requires that 1) access charges paid or received by all U.S. carriers to or from a particular foreign monopoly must be equal, and 2) the access charge paid by U.S. carriers to a particular foreign monopoly must be equal to the charge paid by that foreign monopoly to U.S. carriers.[2] Constraint 1 forbids third

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[2]Readers familiar with the international settlements formula should notice that, under the USP, what I term the "access charge" is often termed "one half the accounting rate" in policy discussions. The accounting rate refers to the basic "unit of account" from which carriers in particular country-pair markets determine the access charge they pay. The "division of tolls" determines what share of the accounting rate each country pays. For example, suppose the accounting rate between the U.S. and France is $2.00, and the division of tolls is 75-25 in favor of France. Then France pays the U.S. $.50 per call-minute for access to the U.S. network, while the U.S. pays French Telecom $1.50 per call-minute for access to the French network. In this terminology the USP requires all U.S. carriers to 1) agree to the same accounting rate and 2) agree to a 50-50 division of tolls. It should be clear that there is no loss of generality in switching from one terminology to the other, and I find the notion of an access charge

degree price discrimination in the markets for access to both the foreign and U.S. network and is subsequently referred to as the "price discrimination constraint." Constraint 2 is referred to as the "50-50 division of tolls." The FCC argues: "the policy of maintaining uniform accounting rates [i.e. access charges] exists to protect the U.S. public interest by protecting U.S. carriers from making concessions which may ultimately be detrimental to U.S. ratepayers" (FCC 1985, 28423). Their logic, however, provides no rigorous support for the policy, and as I demonstrate in Chapter 2, is internally inconsistent. Hence, in light of the recent entry in the voice market and the continuing rivalry in the telex and telegraph markets, a second important question is whether the USP operates according to the FCC's optimistic view.

The purpose of this dissertation is to address these questions using a game theoretic model incorporating the way entry, forbidding price discrimination, and the 50-50 division of tolls affect the strategic possibilities of both foreign and domestic players. As it turns out, many of the issues that arise are ones that have long been present, but heretofore unaddressed, in a broad class of markets for intermediate products — markets with few firms on one side, and a monopoly or monopsony on the other. Hence, answers to questions raised in international telecommunications have implications for questions concerning entry, price discrimination, and vertical integration for markets falling into this class.

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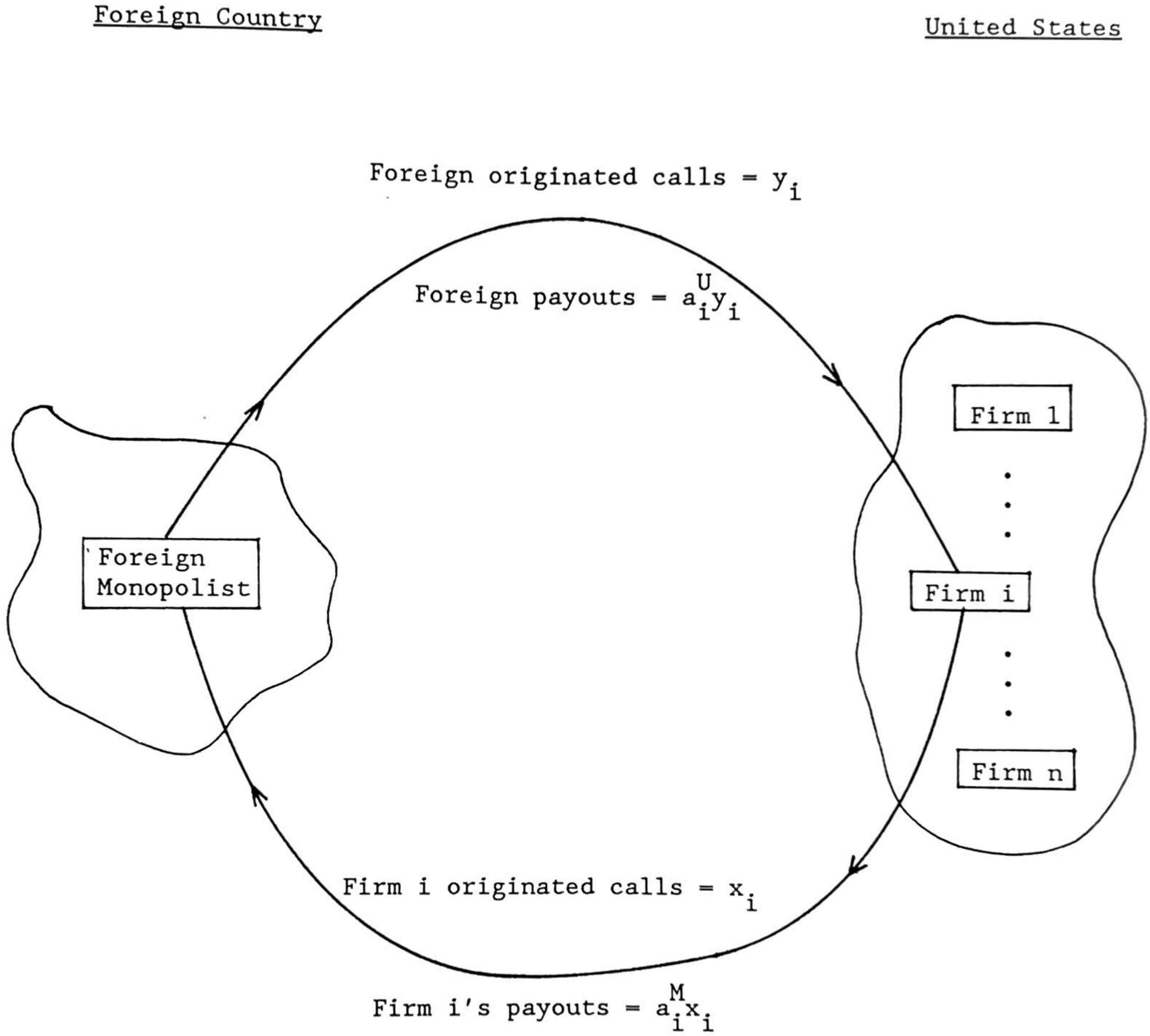
as a "price" much less confusing.

To understand the major issues that arise in international telecommunications it is useful to begin by separating the two vertical chains of production comprising a stylized country-pair market for international service. Figure 1.1 illustrates such a market with $n \geq 1$ U.S. carrier(s) and a single foreign carrier. The upper half of the figure represents transactions necessary for calls, telex or telegraph traffic outbound from the foreign country to the U.S. To transmit y_i units (call-minutes) of service to the U.S. the foreign carrier must first gain y_i units of *access* to firm i's network. Historically, this is accomplished by signing an *operating agreement* with firm i specifying a price, a_i^U, which the foreign carrier agrees to pay for each unit of access. In this vertical chain the foreign carrier is a monopsony buyer of access to the U.S. network, and if $n \geq 2$, U.S. carriers are rivals competing for the right to carry inbound traffic. Taken separately, this chain is constrained by only the price discrimination constraint of the USP, which requires that $a_i^U = a_j^U \equiv a^U$.

Similarly, the lower half of Figure 1.1 summarizes the same transactions for traffic flowing outbound from the U.S. For access to the foreign network firm i agrees to pay a_i^M dollars per call-minute to the foreign carrier. In this vertical chain the foreign carrier is a monopoly seller of access to U.S. carriers, who are rivals in the market for U.S. outbound calls. The price discrimination constraint requires that $a_i^M = a_j^M \equiv a^M$; combining both chains, the 50-50 division requires $a^U = a^M$.

Figure 1.1

A Stylized Country-Pair Market



Uniform Settlements Policy Requires:

1) $a_i^U = a_j^U = a^U$, $a_i^M = a_j^M = a^M$ (price discrimination constraints)

2) $a^U = a^M$ (50-50 division of tolls)

Now, suppose that initially the U.S. market is monopolized by firm 1, as the voice market was by AT&T prior to 1985. A crucial institutional characteristic of this market is that the pre-entry access charges, a_1^U and a_1^M, were not set unilaterally by either the foreign monopolist or firm 1. Rather, they were determined through bilateral *negotiations*. It follows that the effects on access charges of both allowing entry and the USP depend on how these policies alter the relative bargaining abilities of foreign and U.S. carriers in each vertical chain. This suggests a minimal requirement for any model of this industry: it should endogenously determine the degree to which carriers in each country control access charges.

The second important institutional characteristic is that each individual carrier makes its own pricing (or output) decision after access charges are negotiated.[3] Thus, the second requirement for the model is that, conditional on negotiated access charges, it should allow for rivalry between carriers. A third characteristic is that each carrier controls access to its own network and can unilaterally

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[3]Article 3 of the "Final Acts of the World Administrative Telegraph and Telephone Conference," International Telecommunications Union, Geneva 1973 states that "The circuits and installations provided for the international telephone service shall be sufficient to meet all requirements of the service" (Ploman 1982, 244). Hence, a goal of the International Telecommunications Union, responsible for all international telecommunications regulation within the United Nations, is that each country be prepared to handle as much traffic as it is sent. While this does not preclude joint production decisions, it does provide carriers with a "legal" basis for making the decisions independently, and therefore implies that any production agreements should be self enforcing. This is the view taken throughout this dissertation.

terminate its operating agreement with any foreign carrier.[4] The added requirement for the model is that it should incorporate the threat each carrier has to refuse to sell access to or buy access from any other carrier.

These three institutional characteristics, 1) negotiations over intermediate product price, 2) rivalry in the downstream market, and 3) the ability to stop buying or selling the intermediate product at any time, are common to many markets for intermediate products. Yet, there have been relatively few models of vertical chains of production incorporating all three. Nevertheless, they provide the basis for the models in Chapters 3 and 4 that address half of the international telecommunications market -- the vertical chain representing U.S. outbound calls.

The Price Discrimination Constraint and Outbound Traffic

Chapter 3 argues that the price discrimination constraint of USP may result in higher access charges, a higher marginal cost for U.S. firms, and therefore, higher rates paid by U.S. consumers for international service. Chapter 4 argues that allowing entry in the presence of this constraint eventually transfers all the bargaining power to the foreign monopolist, allowing it to set a take-it or leave-

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[4]Article 20 of the "International Telecommunication Convention," Malaga-Torremolinos, 1973, states: "Each Member reserves the right to suspend the international telecommunication service for an indefinite time...provided that it immediately notifies such action to each of the other Members through the medium of the Secretary-General." (Ploman 1982, 238).

it price for access to its network. In contrast, the foreign monopolist does not gain all the bargaining power under free bargaining even as the U.S. market becomes competitive. Each of these conclusions is contrary to conventional wisdom as well as to the views held by the FCC.

These conclusions are drawn from a non-cooperative bargaining model developed to address general questions about the effects forbidding third degree price discrimination in intermediate product markets. Whereas previous models of price discrimination *assume* monopoly price leadership in both the constrained and unconstrained regimes, I endogenously determine the degree to which the monopolist controls price by introducing bargaining between the monopolist and each downstream firm. The model explicitly incorporates the threat each firm has to impose costly delays on firms with which it negotiates. Equilibrium prices reflect how these threats interact with the rule forbidding third degree price discrimination.

In the regime where discrimination is allowed the monopolist bargains with each buyer over the incremental producer surplus generated by each contract. There is a unique stationary subgame perfect equilibrium in which such a monopolist cannot exercise price leadership if bargaining costs (as captured by the costs of delayed service) are small relative to the discounted profits available. In contrast, forbidding price discrimination allows the monopolist to credibly set a higher input price, generally leading to strictly lower welfare than when price discrimination is allowed.

Although the models are quite different, these results are reminiscent of the well known conjecture of Coase (1972) formally proved using game theoretic models by Bulow (1982) and Stokey (1981): A durable good monopolist unable to credibly refrain from making additional sales to low valuation customers after making high priced sales to high valuation customers lowers price to marginal cost very quickly to keep buyers from waiting too long to purchase the good. In those models the monopolist can increase all prices if it can credibly limit its total output, effectively committing itself not to cut prices to sell to low valuation buyers.

In the bargaining model of Chapter 3, contracts are durable in the limited sense that they last until one of the parties decides to renegotiate. In determining the initial contract price the monopolist attempts to "play buyers against one another" as long as both buyers remain unsigned. However, the monopolist must bargain bilaterally with the last unsigned buyer. Buyers correctly anticipate the benefits of being the last to sign a contract (the monopolist can no longer play one against the other), and therefore, have a credible threat not to accept the price the monopolist would charge if it could set a take-it or leave-it price. Forbidding price discrimination allows the monopolist to set a higher price than in the unconstrained regime by providing it with a credible commitment to refrain from bargaining over price with the last unsigned buyer.

The conclusion that the monopolist is not a price leader in the unconstrained regime is strengthened in Chapter 4, where the model is generalized to allow for any finite number of buyers. First, I argue that in the unconstrained regime, downstream entry does not necessarily increase the bargaining power of the monopolist. Intuitively, each firm's bargaining power derives from the size of the incremental loss it can impose (by delaying service) on each firm with which it negotiates. As the number of buyers increases, the loss each can impose on the monopolist falls, but so does the loss that the monopolist can impose on each buyer. Entry transfers bargaining power to the monopolist only if the profit earned by each buyer grows relative to seller's incremental profit from selling to that buyer.

It is precisely this intuition that allows strong conclusions to be drawn about the welfare properties of a bargaining equilibrium with free entry in the unconstrained regime. Ignoring the integer constraint, downstream profits equal zero in free entry equilibrium. But this implies that the monopolist cannot impose any loss on downstream firms, and therefore has *no* bargaining power. For an important class of models (constant marginal cost upstream, U-shaped average costs and Cournot rivalry downstream) I show that this leads to the following, somewhat counterintuitive, result: As bargaining costs become small, and as the minimum efficient scale of downstream firms falls relative to final product demand, equilibrium approaches a first best.

No claim is made that this kind of market would operate this way over a long period of time. The driving force behind this result is the inability of the monopolist to commit itself to bargain with only a subset of available buyers. One expects, therefore, that it would attempt to find a way to make such a commitment. It turns out that forbidding price discrimination allows it to do just this. Indeed, using the same model, I show that forbidding price discrimination transfers all the bargaining power to the monopolist as the minimum efficient scale of downstream firms falls relative to final product demand. This is because buyer bargaining power is now determined not by the ability of each buyer to impose losses on the monopolist, but rather, by monopolist's ability to play buyers against one another to determine *the* initial price.

To see this intuitively, divide the bargaining game into two phases.[5] Phase one is the bargaining that occurs before any initial agreements have been signed; phase two is the bargaining that occurs after the first agreement has been signed. In the unconstrained regime, phase two bargaining is not constrained. Hence, buyers can wait to be the last to sign a contract, at which point they have about the same bargaining power as the monopolist. But when price discrimination is forbidden, all phase two agreements must match the initial one. That is, phase two bargaining is not allowed, implying that all bargaining occurs in phase one. Since the ability of the monopolist to play buyers against each other in phase one increases with the number of buyers, entry increases its bargaining power.

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[5] I am indebted to Steve Matthews for suggesting this interpretation.

The upshot of Chapters 3 and 4 is that the uniform settlements policy may be the cause, not the remedy of the whipsawing problem in international telecommunications markets. This is true not only in markets with one-way traffic outbound from the U.S., of which there are few, but also for markets with two-way traffic in which the 50-50 division of tolls is not enforced. When the latter is enforced, however, the analysis of two-way traffic changes.

The 50-50 Division and Two Way Traffic

Allowing for two-way traffic by adding the second vertical chain and then enforcing the 50-50 division of tolls complicates the analysis of USP in two ways. First, it introduces the fourth and final institutional characteristic crucial to understanding the international telecommunications market: foreign monopolies control the allocation of U.S. bound traffic across U.S. carriers. With multiple U.S. carriers this allows the monopolist to threaten to divert traffic away from those refusing its terms, and therefore gives it more control over the access charge it pays. Second, the 50-50 division of tolls, which has no effect in markets with one-way traffic, now requires that an equal access charge be paid for traffic flowing in both directions.

Chapter 5 argues that, in the absence of the USP, the price for access to the U.S. network is driven down to marginal cost as U.S. carriers compete for inbound traffic. Equilibrium in the market for calls outbound from the U.S. is that derived in Chapter 3, with the price for access to the foreign network lying between foreign marginal cost and the price the foreign monopolist would unilaterally set. It then demonstrates that the USP may give the foreign monopolist complete control over the *uniform access charge* (one satisfying both the price discrimination constraint and the 50-50 division of tolls) whenever there are two or more U.S. carriers. This is due to the way the 50-50 division combines with the price discrimination constraint to *allow* (not to prevent) the monopolist to play U.S. carriers against one another. Whether this raises or lowers the access charge paid by U.S. carriers depends on whether the foreign monopolist prefers a relatively high or relatively low uniform access charge.

Why might the foreign monopolist unilaterally set a low uniform access charge? Observe that with two-way traffic the uniform access charge affects not only each firm's revenues from inbound traffic, but also its marginal cost in the market for its own outbound traffic. That is, the 50-50 division effectively operates as a commitment by the FCC to retaliate by raising the charge for access to the U.S. whenever the foreign monopolist raises the charge for access to the foreign network. In setting the charge, the monopolist takes into account both changes in revenues from traffic inbound from the U.S. as well as the automatic retaliation of the U.S. For the special case where the demand for calls outbound from the U.S. is independent of the price of calls in the opposite direction,[6] I show that the foreign monopolist prefers a low uniform access charge whenever the volume of traffic inbound to the U.S. is greater than the volume flowing in the opposite

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[6] I argue in Chapter 5 that this is an important intermediate case.

direction. Since this is the case in most telex markets, I argue that USP has reduced access charges, and therefore the price of outbound telex traffic. However, when the net traffic flow is outbound from the U.S., as it is in most voice markets, foreign carriers prefer higher uniform access charges than U.S. carriers. In this case, the USP may increase U.S. firms' marginal cost, leading to higher U.S. prices.

Related Literature on Price Discrimination, Bargaining, and International Telecommunications

Many real world markets for intermediate products have the characteristic that each firm's market share is large enough relative to total production for it to impose *some* loss on others by refusing to buy or sell their products. It follows that each firm has bargaining power, that this power may change with the policy regime, and therefore that assuming price taking behavior on either side of the market may seriously distort policy conclusions. Such an assumption is valid in comparative policy analysis only if relative bargaining powers are independent of the policy regime. The major theoretical point of this dissertation is that this assumption is probably not valid, *ipso facto*, in analyses of the effects of intermediate product price discrimination on input prices and welfare.

This point was recognized by A.C. Pigou (1932) in the fourth edition of *The Economics of Welfare*. Leading up to his discussion of price discrimination, he notes:

> "When a degree of non-transferability, of commodity units on the one hand or of demand units on the other hand, sufficient to make discrimination profitable, is present, the relation between the monopolistic seller and each buyer is, strictly, one of bilateral monopoly. The terms of the contract that will emerge between them is, therefore,...subject to the play of that 'bargaining'..." (Pigou 1932, 278).

Despite this recognition, I know of no models of third degree price discrimination in intermediate product markets that allow for bargaining. Indeed, Katz (1987), which assumes monopoly price leadership in both regimes, appears to be the first formal analysis of any kind.

Katz considers a situation where an upstream monopolist sells an input to two downstream Cournot duopolists, one of which has a greater incentive to integrate backward into the supply of the input. He finds that, when there is integration in neither regime (i.e. whether discrimination is or is not forbidden), total output, and therefore welfare, is lower when price discrimination is practiced than when it is forbidden (Katz 1987, Proposition 1). The reason is that in order to prevent backward integration, the discriminating monopolist finds it optimal to raise the prices charged to both downstream firms, with the greater increase going to the firm without the integration threat. This increases the profits of the firm with the integration threat, preventing integration, but also increases each buyer's marginal cost, reducing output and welfare.

His model is similar to the one in Chapter 3 in its assumption of downstream rivalry as well as its requirement that equilibrium depend on the credible threats of buyers (i.e. to integrate backward in his model) in each regime. It differs in his assumption that the monopolist is a price leader. My model introduces bargaining between the monopolist and each downstream firm. Hence, input prices are generally lower in the no discrimination regime than they are in Katz's model since buyers have some bargaining power. But the major distinction between the results lies in the effect of forbidding price discrimination.

To contrast the results, note that because Katz assumes the monopolist is a price leader in both regimes, any negative welfare effects from price discrimination occur only when discrimination is *realized*. In contrast, price discrimination is never realized in the model of Chapter 3 (though it would be if downstream firms were not symmetric). Rather, forbidding price discrimination has negative welfare consequences because it eliminates the threat that each buyer has to reject an offer with the hope of becoming a bilateral bargainer symmetric with the seller. Eliminating this threat gives the monopolist more bargaining power, and therefore more control over the input price. Since Katz assumes that the monopolist is always a price leader, this effect cannot occur in his model.

The models in Chapters 3 - 5 are based on the non-cooperative bargaining model of Rubinstein (1982). He analyzed a very natural infinite horizon game in which a buyer and seller alternately offer a price at which to exchange an indivisible good. Bargaining takes place through time; hence, impatience, due to either the fear that profit opportunities will disappear or the real value of time, drives agents to reach agreement. Remarkably, he demonstrated that a *unique* subgame perfect equilibrium exists in two-person alternating offer bargaining games under very general assumptions about agents' time preferences.

An older approach to bargaining, the cooperative, or axiomatic approach, has also developed models exhibiting unique equilibria. The most popular is the two-person bargaining model of Nash (1950). Binmore (1986a), in a paper written long before it was published, related the two approaches by demonstrating that the Rubinstein equilibrium approaches a time-preference version of the asymmetric Nash bargaining solution as bargaining costs become small relative to the discounted value of the profits available. Nevertheless, there remains a sense in which Nash's model is less satisfactory than the non-cooperative approach: since it does not explicitly account for time, an improper choice of either the disagreement point or the bargaining weights may allow non-credible threats to influence the equilibrium. To be sure, the threat points in the Nash bargaining solution can be restricted to rely, in some sense, on credible threats. But as Binmore, Rubinstein, and Wolinsky (1986) have shown, the "threat point" in the time preference model generally should not depend on threats at all. They show that the availability of an "outside option" to one of the players that pays less than he receives in the non-cooperative equilibrium to the game ignoring that option should not have any effect on equilibrium. Moreover, outside options that do affect the outcome enter the Nash bargaining solution as a constraint, not as the threat point. If one accepts the non-cooperative formulation as a reasonable description of the bargaining process, this calls into question many previous models of union/employer bargaining where outside options have often been identified with the disagreement point.

The moral of this story, they argue, is that the non-cooperative approach should be used to help identify the disagreement point and the bargaining weights in cooperative formulations of two-person bargaining games. More generally, the non-cooperative approach can be used to help suggest which axioms apply to different bargaining environments. This view reflects an attitude now widely held (though certainly not unanimous) that axiomatic solution concepts should be "justified" by demonstrating their equivalence to one or more non-cooperative games. The advantage of this approach is that it allows the modeler to account more naturally for threats that are inherently dynamic in nature: eg. "If you don't accept this price today, I will go bargain with another firm tomorrow." While I do not attempt to axiomatize the solutions derived in Chapters 3 and 4, the analysis is suggestive of how this might be done. In particular, Chapter 3 shows that equilibrium input prices in the unconstrained regime are determined by a version of the Nash bargaining solution applied to the incremental profits of the firms in each bilateral encounter. Chapter 4 goes on to show that equilibrium in the regime forbidding price discrimination can be interpreted as an asymmetric Nash bargaining solution where the bargaining weights are endogenously determined.

Since finishing an earlier version of Chapter 3, I have learned of five recent papers that examine bargaining between upstream and downstream firms using similar models. Jun (1987), Horn and Wolinsky (1988), and Davidson (1988) each examine non-cooperative models of bargaining between employers and multiple or joint unions. Horn and Wolinsky (1987), and Viehoff (1987) examine models of bargaining between upstream and downstream oligopolists. The alternating offer bargaining game in each paper is similar to that in Chapter 3. In particular, each has independently demonstrated that equilibrium input prices (or wage bills) are determined by a version of the Nash bargaining solution applied to the incremental profits of the firms in each bilateral encounter. None of these papers, however, is concerned with the effects of forbidding price discrimination.

Since Rubinstein's discovery of a unique equilibrium in the alternating offer game, there has been an increased interest in developing a non-cooperative foundation for competitive behavior. Papers by Rubinstein and Wolinsky (1985), Binmore and Herrero (1985), and Gale (1985) each develop models in which agents meet in pairs and bargain over how to split the gains from reaching agreement. The natural question to ask in these models is whether there is a subgame perfect equilibrium equivalent to the Walrasian equilibrium. Gale's paper shows that there is, in the limiting economy as bargaining costs grow small.

In the bargaining model of Chapter 4, the natural question to ask is whether the upstream monopolist becomes a price leader as the number of downstream firms grows large. I show that it does not, in the free bargaining regime, even as the downstream market become competitive.

This shows that the real issue in explaining monopoly price leadership is not the number of buyers it sells to, but whether it can commit itself to setting a take-it or leave-it price. I show that a rule forbidding price discrimination provides precisely the commitment it needs.[7]

The original motivation for this dissertation was to undertake a complete welfare analysis of the effects of entry into the international voice market. Kwerel (1984) pointed out that foreign international telecommunications monopolies controlling half of each international circuit might be able to extract *all* the welfare gains from U.S. competition if 1) U.S. and foreign carriers were maximizing joint profits prior to entry, and 2) the foreign monopolist unilaterally set the charge for access to its own network.[8] It seemed to me, however, that neither of these conditions was satisfied. In particular, I did not think that entry would lead to a perfectly competitive outcome, and pre-entry access charges were subject to negotiations.

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[7]The recognition that commitment plays *an* important role in determining the degree to which a monopolist controls price goes back at least as far a Schelling (1960). What I find interesting about the result in Chapter 4 is that in the absence of market imperfections (eg. bargaining frictions, fixed costs, asymmetric information, etc.) commitment plays *the* important role, with *no* role for the number of downstream firms.

[8]This follows immediately from a well known "theorem" from the vertical integration literature (eg. Scherer 1980, 302): In a market where an upstream monopolist controls an input used in fixed proportions by competitive downstream firms, final product price equals the fully integrated monopoly price.

It became apparent very quickly, however, that the multilateral bargaining problem posed by relaxing Kwerel's second condition was not at all trivial. In pursuit of a solution to this problem, the focus has shifted to the more narrow questions regarding voice, telex, and telegraph: how do negotiations determine equilibrium prices before and after entry, how does the uniform settlements policy affect these negotiations, and what are the welfare consequences of the USP?

This focus leaves out many of the major issues of concern in this market: eg. international peak-load pricing (Dansby 1983); the effects of competition in new services (i.e. product differentiation), the availability of private leased circuits, the multinational provision of international services, and the speed of technological change (Eward 1985); the efficient planning and use of international cable and satellite facilities (Johnson 1986); vehicles for interconnection when U.S. carriers are not granted direct access (Friedan 1983); jointly efficient international pricing; and the list goes on and on. With the exception of Dansby (1983), each of these authors proceeds very informally, providing more questions than answers. My hope is that the model developed in this dissertation will suggest how these and other questions in international telecommunications might be addressed more formally. In particular, the hope is that the model provides a framework for other models to incorporate international negotiations, an element that I view as crucial to understanding how this market works.

Chapter 2. The Uniform Settlements Policy: An Historical Perspective

There are three segments of the international telecommunications services market motivating this dissertation: 1) voice (i.e international long distance calls), 2) telex, and 3) telegraph. Although it was monopolized by AT&T until 1985, the recent entry of MCI and Sprint has raised the question of whether the USP should be enforced in the voice segment. In its recent *Order on Reconsideration*, (FCC 1987), the Commission tentatively ruled that the policy applies, though in a somewhat weaker form than in the telex and telegraph markets.[1] In any case, AT&T still controls most of this market so it may be too early to assess the effects of the USP on access charges by looking at the data. However, the USP originated in the telex and telegraph segments where some degree of rivalry has existed for most of this century. A brief examination of this history provides insight into the effects of the USP in telex and telegraph as well as suggesting potential effects in voice.

Legal History

The FCC has been very clear about the intended consequences of the USP. They state: "Our primary responsibility is to U.S. users, not U.S. carriers...Thus, while we prefer to see U.S. carriers rather than foreign administrations maximize their revenues through accounting rate

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[1] See Chapter 5 and Appendix A for a discussion of how the rules have been relaxed for the voice market.

[i.e. access charge] actions, our goal is to facilitate the development of a competitive marketplace characterized by lower rates and greater service/carrier options for users" (FCC 1985, 28419). In pursuit of this goal, they have long feared that unrestrained competition among U.S. firms in telex and telegraph markets might do more harm than good. Frequently, this fear has led them to prevent U.S. firms from signing international agreements that they thought were contrary to the public interest. The first example was in 1936 when they refused to allow Mackay Radio and Telegraph to go into operation between the U.S. and Norway. In the proposed contract, the Norwegian PTT (Postal, Telephone and Telegraph Administration) had agreed to route all new U.S. bound telegraph traffic over Mackay's new circuit. The FCC argued:

> "Inasmuch as the [foreign] telegraph administration controls every word of outgoing radiotelegraph traffic, the competing American radio companies would be dependent upon it for their traffic...Each would be interested in increasing its share of the total traffic. To expect the telegraph administration to play the competing companies against each other is simply to expect that the administration will be headed by good business men, loyal to their national interests. To rely upon companies which are bitter competitors not to make concessions to the administration which controls all outgoing radiotelegraph traffic is to provide an exceedingly tenuous basis upon which to rest public interest" (FCC 1936, 599).

The FCC's basic fear was that the Norwegian PTT would "whipsaw" U.S. firms into paying more for access to the Norwegian network while accepting less for access to their own. This, they argued, would put upward pressure on the price of final service.

Two potential threats that foreign monopolies might use have been cited. As in the Mackay case a PTT might threaten to divert (profitable) U.S. bound traffic from one U.S. carrier to another if the first carrier does not agree to new access charges. Alternatively, a PTT might threaten to terminate its operating agreement with any U.S. carrier refusing to accept less favorable terms. The USP was designed to prevent foreign monopolies from using these threats to gain an advantage harmful to U.S. ratepayers. In the words of the FCC, "This Commission has long maintained a policy of uniformity to preclude 'whipsawing' of U.S. carriers by foreign correspondents. The policy protects the interest of the U.S. and, in particular, the U.S. ratepayer from the adverse effects 'whipsawing' can produce" (FCC 1980, 128).

The puzzling feature of this and many similar statements by the FCC is that to my knowledge, they have never described the mechanism by which the USP benefits U.S. ratepayers. Phrases like "whipsawing" and "play U.S. carriers against one another" have not been made precise. The implicit assumption is that forbidding price discrimination and requiring a 50-50 division of tolls prevents foreign monopolists from credibly threatening (or carrying out threats) to take actions adversely affecting U.S. ratepayers. Yet, neither the threat to reallocate outbound traffic nor the threat to terminate an operating agreement is directly affected by either of these constraints. That is, a foreign monopolist constrained by the USP may find it optimal to threaten to terminate operating agreements or adjust U.S. bound traffic of all U.S. firms not agreeing to its terms as long as at least one U.S. firm does agree.[2] Thus, the USP fails to directly attack either

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[2] This has also been pointed out by Evan Kwerel (1984).

mechanism cited by the FCC as a potential tool for foreign monopolies to gain bargaining advantages over U.S. carriers.

To understand the effects of the USP, one must first understand how it constrains both foreign and U.S. carriers in the bargaining process determining equilibrium access charges. Under the USP, bargaining in a typical country-pair market proceeds roughly as follows. Before initiating service, the foreign monopolist negotiates with U.S. carriers, possibly attempting to "play them against one another," to determine an access charge. This initial charge is not affected by the price discrimination constraint, but it must specify a 50-50 division of tolls. When the initial contract is signed the parties in agreement begin service at the agreed upon charge.

Subsequently, the foreign monopolist may allow other U.S. carriers access. At this point the USP again comes into play. Under current FCC policy, any U.S. carrier reaching agreement to operate at access charges in violation of either the price discrimination constraint or the 50-50 division of tolls must file a request for waiver of the USP with the FCC.[3] After reviewing any objections filed by other carriers, the Commission determines whether a waiver of the USP is in the public interest. Citing its "long standing policy of uniformity," it has become standard practice for the Commission to reject waiver requests

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[3]See Appendix A for a more precise summary of the USP and the procedure for granting waivers.

in both the telex and telegraph markets.[4] Hence, individual carriers proposing non-uniform access charges are usually required to bring agreements into line with existing agreements before being granted the right to begin (or renew) service.

Notice from this description that there are two phases of the bargaining process during which the USP constrains negotiations. In *phase one*, before any agreements have been signed, the initial agreement is constrained by the 50-50 division of tolls. In *phase two*, after an initial agreement has been signed, additional agreements must specify the same price as the initial agreement. The fact that the USP impedes access charge reductions favorable to individual U.S. carriers in phase two is not sufficient reason to argue against the policy. On the other hand, the fact that it also prevents access charge increases unfavorable to individual carriers in phase two is not sufficient to argue in its favor. Arguments for or against the USP should be based on the effects it has on equilibrium access charges and the implied price of final service as determined via the constraints on both phase one and phase two.

The FCC has not provided arguments along these lines. Rather, it bases support of the USP on historical precedent, often citing the Mackay Radio and Telegraph decision as the first official assertion of its beneficial effects. Unfortunately, it is apparent that current FCC

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[4]See, for example, FCC (1974) and (1977), where TRT Communications, an international telex and telegraph carrier, was not allowed to implement a lower non-uniform access charge for telex service between the U.S. and the United Kingdom; see also FCC (1985), (1986), and (1987) for other recent examples.

policy makers have not carefully read the Mackay decision. Mackay's proposed contract contained the following paragraph, which was sharply criticized by the commissioners present in 1936:

> "Neither party during the continuance of this agreement shall, by modification or renewal of existing agreements or otherwise, enter into an agreement with a third party concerning radiotelegraph traffic between Norway and the United States of America upon terms more favorable than those covered in this agreement or its modification" (FCC 1936, 598).

Notice that by preventing each carrier from agreeing to any other price with a third party, this provision is formally identical to the USP if it specifies a 50-50 division of tolls (as this agreement did). But the 1936 Commission stated: "Clearly, such a provision could not be said to be in the interest of the American public" (p. 598). Hence, the commissioners addressing the Mackay case in 1936 did not favor the USP. In fact, a careful reading of the case shows that Mackay's proposed access charge was identical to the charge already in existence — the uniformity issue did not even arise:

> "Applicant's witnesses testified that...the division of tolls contemplated by the applicant and the Norwegian Administration will be the same as now effective between RCA Communications, Inc., and the Norwegian Administration on their circuits; to wit, an equal division after the deduction of the out-payments of the Administration and the company, respectively...the testimony was that the out-payments would be the same as those now effective between RCA Communications, Inc., and the Norwegian Administration" (FCC 1936, 595).

It appears, then, that any argument supporting the USP based on the Mackay decision is fallacious.

Rather than contract uniformity, the overriding fear of the 1936 Commission was how future access charges might change throughout the industry to divert revenues to Norway:

"Although applicant testified that it expects the division to be the same as that on the RCA Communications circuit to Norway, the division can be altered by simple agreement between applicant and the telegraph administration...It is impossible to foresee the ultimate maximum of concessions which a company will make in a desperate effort to get or retain traffic. The Commission should not invite such a situation by granting an application on the facts of the present case, and especially where no offsetting benefits to the public have been shown" (FCC 1936, 599).

Indeed, the proposal was rejected because of Commission fears, fears widely held throughout the great depression, that additional entry would bring about "destructive competition" among U.S. carriers competing for inbound traffic and access to the foreign network. The current Commission's error was to misinterpret the 1936 Commission's concern about destructive competition as calling for uniform settlements. But this interpretation is nowhere to be found in the Mackay case.

This mistaken "precedent" does not end with the 1936 decision. In 1951 Mackay applied for the right to carry telegraph traffic in the U.S./Portugal and U.S./Holland markets (FCC 1951). The current Commission argues that "because the terms of the proposed operating agreement were identical to the terms of the agreements already in effect, our concern was assuaged and the application to place another competitor into the market was granted" (FCC 1985, 28420).

Clearly, there is a problem with this logic. In both 1936 and 1951, Mackay's proposed contract was identical to existing contracts.

Entry was not allowed in 1936, but it was allowed in 1951. Therefore, it was not the uniform agreement that assuaged the fears of the 1951 Commission. It was, in fact, their observation that "...a national policy in favor of competition as set forth in the antitrust laws [had] been expressly extended to the field of international communications" (FCC 1951, 734).

My own reading of the post 1951 case history does not reveal any instance where the beneficial effects of the USP supposedly cited in the Mackay case are restated. Consequently, the policy continues to be based on past arguments which do not exist. Readers familiar with the passage and enforcement history of the Robinson-Patman Act, part of which is equivalent to the price discrimination constraint of the USP, will not find any of this confusion surprising. Indeed, the Robinson-Patman Act has probably been the most widely, and imprecisely, debated antitrust law ever passed.[5] The reason for much of the confusion, I think, is that a rigorous framework incorporating how these laws constrain strategic possibilities on both sides of the market has not been put forth.

To this point, this chapter has argued that the USP fails on two accounts. First, it does not address the threats cited by the FCC that foreign monopolies might use to whipsaw U.S. carriers. Second, the FCC mistakenly asserts the existence of historical precedent establishing

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[5]See, for example, Bork (1978), and Posner (1977). Scherer (1980) provides a good summary of the anti-competitive effects of the Act. Chapter 3, section 5 offers a brief analysis in terms of the bargaining model developed there.

the need for the policy. Hence, an understanding of the policy is not to be found either in current or past Commission statements. Before turning to a rigorous model, it remains to examine the data to see if anything can be learned there. I consider two recent examples of opportunistic behavior on the part of foreign monopolies. Not surprisingly, each verifies that the USP does not prevent foreign monopolies from exercising the threat to terminate operating agreements or to reallocate U.S. bound traffic across U.S. carriers. More importantly, each suggests that the policy may be failing to meet its stated objective of protecting the U.S. ratepayer in the telegraph market.

Case 1: The COMTELCA Telegram

In 1983 a consortium of Central American countries known as COMTELCA sent a telegram to each U.S. telegraph carrier announcing that on a given date they would put new higher access charges into effect in the market for telegraph service between the U.S. and each COMTELCA country.[6] In each U.S./COMTELCA market, U.S. outbound traffic exceeded inbound traffic, implying that the proposed change would favor the COMTELCA countries.[7] The threat used was their assertion that

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[6]COMTELCA (Comision Tecnica Regional de Telecomunicaciones) is composed of the telecommunications administrations of Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua. See (FCC 1985, 28421).

[7]This point is explained more thoroughly in Chapter 5.

"thereafter, they would deal only with those carriers agreeing to the new charge" (FCC 1985, 28422).

Following the waiver request procedure outlined above, Western Union International was the first U.S. carrier to file a petition with the FCC for waiver of the uniform settlements policy to increase the access charge applicable for service to each COMTELCA country. Similar waiver requests were immediately filed by Western Union Telegraph Co. and FTC Communications. Subsequently, FTC Communications, ITT World Communications, MCI International, RCA Global Communications, TRT Communications, and Western Union International -- all the U.S. telegraph carriers operating in these markets -- sent the COMTELCA administrations a joint telex informing them that the signatories had agreed to the new access charge effective November 1, 1983. Since no U.S. carrier objected to the new charge, the proposed change was allowed by the FCC.

Prior to the change, U.S. carriers paid $.1773 per word for access to each COMTELCA network. After the change they paid $.2365 per word. Hence, the increased access charge raised each firms marginal cost by 33 percent. While final service prices rose only a few percentage points in each market, the net revenues of all U.S. carriers combined (i.e. net of payments to the COMTELCA countries) fell by 28 percent from 1982 to 1984.[8] It appears, then, that COMTELCA was able to extract revenue from U.S. firms by using one of the threats the USP was

[8]While the average price per word for service to Costa Rica declined (I'm not sure why), the price to the other four countries rose by an average of 5 percent from 1982 to 1984.

designed to address. Since one of the FCC's goals is to protect U.S. carriers from this kind of whipsawing, it appears that the policy did not work in this case.

Case 2: The CEPT Telegram

In another instance, on August 19, 1983, RCA Global Communications filed a request with the FCC for waiver of the uniform settlements policy in order to raise the access charge for telegraph traffic between the U.S. and 13 CEPT countries.[9] Again the net traffic flow was outbound from the U.S. implying that the increase would favor the foreign carriers. Other U.S. carriers filed similar waiver requests. Each had received a telegram from CEPT that read:

> "If...your agreement cannot be obtained, we will be forced...to reconsider the agreement reached by us up to the present time and we will take measures for a new breakdown of the traffic and therefore a radical change in the infrastructure" (FCC 1985, 28421).

Notice that both the threat to terminate operating agreements and to reallocate outbound traffic was used by CEPT. The access charge paid by U.S. carriers increased from $.1577 per word to $.2365 per word -- an increase of 50 percent -- on January 1, 1984.

Table 2.1 shows how this increase in marginal cost may have been reflected in increased prices for final service. It compares the 1982 average price per word (nominal and real) and number of words outbound to each country with the same variables in 1984. The nominal price of

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[9] CEPT (Conference European des Administrations des Postes et des Telecommunications) is composed of 26 European PTTs.

Table 2.1

Telegraph Price Increase after CEPT Telegram

Country	1982 Price	1982 Words	1984 Price	1984 Words	%ΔPrice	%ΔReal Price
Austria	$.1943	1,295,086	$.2426	866,580	24.9	16.2
Belgium	.2135	1,671,614	.2639	1,113,442	23.6	14.9
Finland	.2111	549,489	.2178	418,760	3.2	-5.5
France	.2209	8,208,943	.2567	5,253,587	16.2	5.5
West Germany	.1800	7,678,938	.2239	6,134,936	24.3	15.7
Ireland	.1506	1,249,949	.1526	835,447	1.3	-7.4
Luxembourg	.1970	219,269	.2168	170.261	10.1	1.3
Netherlands	.1866	2,382,800	.2037	1,456,315	9.2	0.4
Norway	.2215	1,139,593	.2649	777,285	19.6	10.9
Spain	.2209	3,134,151	.2557	2,320,076	15.8	7.1
Sweden	.2047	1,708,767	.2540	1,200,908	24.1	15.4
Switzerland	.1860	3,674,308	.2359	2,830,714	26.8	18.1
Yugoslavia	.1889	869,168	.2415	816,043	27.8	19.2

Source: Statistics of Communications Common Carriers, 1982, 1984.
Notes: %ΔReal Price based on CPI from March of each year.

service to each country rose, with an increase of over 20 percent to eight of the thirteen countries. The real price of service to all but two countries rose, with an average increase of 8.6 percent across all thirteen countries.

Of course, the conclusion that increased access charges raised final service prices is only true if changes in other variables were not part of the cause. Since the general trend of cable and satellite circuit utilization charges has been downward, it is probably reasonable to assume that other components of marginal cost did not rise.[10] Hence, unless demand turned much more inelastic or U.S. carriers became much more collusive, it can be concluded that the prices rose because of the increase in access charges.

In each of these examples, foreign monopoly action increased the access charge, and therefore U.S. marginal cost, putting upward pressure on the price of final service. Since the threats used were precisely those the USP was designed to address, each represents a case where the USP apparently failed to meet the FCC's objective of preventing foreign monopolies from whipsawing U.S. carriers in ways harmful to both U.S. carriers and ratepayers. Despite these and other failures, the FCC continues to enforce the USP in the telex and telegraph segments and recently decided to enforce it (though less stringently) in the voice segment. It is important, therefore, to develop a better understanding of its effects.

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[10] See Johnson (1986) for a detailed discussion of the decline in circuit utilization charges.

Chapter 3: A Bargaining Model of Third Degree Price Discrimination.

This chapter develops a non-cooperative bargaining model that takes a first step toward addressing the puzzle posed in Chapter 2: Why were foreign monopolies able to unilaterally increase access charges in the CEPT and COMTELCA telegrams despite the uniform settlements policy? To begin to answer this question it proves convenient to examine separately the two vertical chains of production comprising a typical country-pair market for international telecommunications service. The model in this chapter considers only the role of upstream seller played by a foreign monopolist, ignoring its role as a downstream buyer. This is analogous to a situation in which U.S. firms carry only outbound traffic. Equilibrium is characterized under free bargaining, in which case there is no constraint on access charges, and in a regime forbidding price discrimination. The two are then compared to see how the policy affects access charges.

There are three reasons for considering this half of the vertical chain of production separately. First, equilibrium access charges derived in the unconstrained regime of the market for outbound traffic represent a natural benchmark from which to judge the effects of the USP in markets with two-way traffic. This analysis is deferred to Chapter 5. Second, the 50-50 division of tolls does not appear to be strongly enforced in all markets. When this is true, the analysis of this chapter completely characterizes the effects of the USP on the price two U.S. carriers pay for access to the foreign network. Finally, to my knowledge, the effects of forbidding third degree price discrimination have not been examined in a bargaining model. The analysis in this chapter begins to fill this gap.

3.1. The Unconstrained Regime

The Model

Consider a market where an upstream monopolist, M, and two downstream buyers, firms 1 and 2, bargain over the contract price each pays for a continuous flow of an intermediate product (e.g. "access"). This product is used in fixed proportions to produce a continuous flow of a final product (e.g. calls). Contracts are infinitely lived;[1] hence, firms are assumed to maximize their instantaneous profit flows at every instant. The intermediate product is produced at constant marginal cost c. Downstream firm i produces the final product at constant marginal cost $w + a_i$, where w is marginal cost of production due to other competitively sold inputs, and a_i is the contract price firm i pays for the intermediate good (i = 1, 2). Initially, there is no constraint on the a_i — i.e. price discrimination is not forbidden.

All firms share the common discount rate $\delta \in (0,1)$, and the final product has a continuous, downward sloping inverse demand function

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[1]This is not crucial for the analysis. It will become apparent that in equilibrium agents wish to reopen negotiations only after cost or demand shocks, the effects of which are not the concern of this model.

$P(X)$. To simplify the analysis I assume that $P(X) = \alpha - \beta X$, where α and β are positive constants, and $\alpha > w + c$. The linear demand assumption allows me to establish the existence of equilibrium in a straightforward way and yields unambiguous welfare results. The discussion of how it can be relaxed is deferred to Chapter 4.

Given a vector of contracts, (a_1, a_2), downstream firms are Cournot duopolists at each point in time.[2] The model is one of complete information — demand, cost functions, and the discount factors are assumed to be common knowledge.

Since the main modelling innovation of this chapter centers around the bargaining framework I adopt, a digression is in order to discuss different ways that the bargaining problem might be addressed. There are three procedures one might follow. First, one could ignore the bargaining problem altogether, as all of the previous literature on price discrimination that I am aware of has done. For example, it might be argued that an upstream monopolist selling to multiple downstream buyers can set prices unilaterally. This approach is adopted by Michael Katz (1987) in his analysis of the welfare effects of price discrimination in intermediate goods markets. But this immediately begs the question: Why is the monopolist more able to commit to being a price leader than either buyer? The usual answer to this question suffers from a misunderstanding of the difference between a monopsonist buying from two constant marginal cost sellers and a

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[2]All of the analysis goes through with differentiated product quantity competition when inverse demands are given by $P_i = \alpha - \beta x_i - \gamma x_j$, $\gamma < \beta$.

constant marginal cost monopolist selling to two buyers. In the former case, a simple Bertrand argument suggests that such a monopsonist effectively acts as a price leader, setting price equal to marginal cost. But in the present case, the monopolist generally increases profits by selling to additional downstream firms as its derived demand function shifts outward. Hence, each buyer can impose a loss on the monopolist by leaving the market and therefore has some bargaining power. Katz analyzes the effects of forbidding price discrimination by constraining only the price-setting seller. Yet, if forbidding price discrimination also constrains buyers' decisions, as it will in a bargaining model, one should be suspicious of an analysis failing to incorporate this constraint. For this reason I reject this approach.

A second approach would be to appeal to cooperative game theory, searching for a solution in the core or for one of the various value solutions. But the core to the full information game analyzed in this paper is huge, and value solutions do not capture what seem to be the most important strategic features present in this kind of market.[3] Moreover, cooperative solution concepts say nothing about the process that leads to a particular solution. But in the international telecommunications market, for example, there are two specific "whipsawing" stories with specific strategic features.

Instead, I adopt a third, recently developed alternative by using non-cooperative (strategic) bargaining theory. The basic elements of

[3]The Shapley Value (Shapley 1953), for example, assigns value to coalitions that intuitively should never form and therefore allows seemingly non-credible threats to influence the outcome.

the strategic approach to bargaining are the following.[4] An extensive form game explicitly representing a sequence of players' offers and accept/reject decisions is analyzed with the hope of finding a unique subgame perfect equilibrium. Ceteris paribus, players prefer to accept an offer "today" over the same offer "tomorrow," since delay is costly. The advantage of using the extensive form is that it allows the modeler to use his best judgement to capture the important strategic features in a given bargaining environment.

Returning now to the one seller two buyer model, a crucial strategic feature in this market is that the monopolist only requires agreement with one downstream firm to realize some gains from trade, while each downstream firm requires agreement with (the only) monopolist to realize any gains from trade. This asymmetry appears to turn the bargaining process in favor of the monopolist by allowing it to leave one buyer to bargain with another. An extensive form game incorporating this asymmetry is shown in Figure 3.1. Since this game is designed to capture the effects of the CEPT and COMTELCA telegrams discussed in Chapter 2, I call it the *telegram game*.

Bargaining in the telegram game proceeds as follows. Just before period zero the monopolist sends a telegram to each buyer announcing that at time zero all existing agreements will be terminated, and bargaining over new prices will begin. Then, in each even (odd) period before any new agreements have been signed, the monopolist meets with

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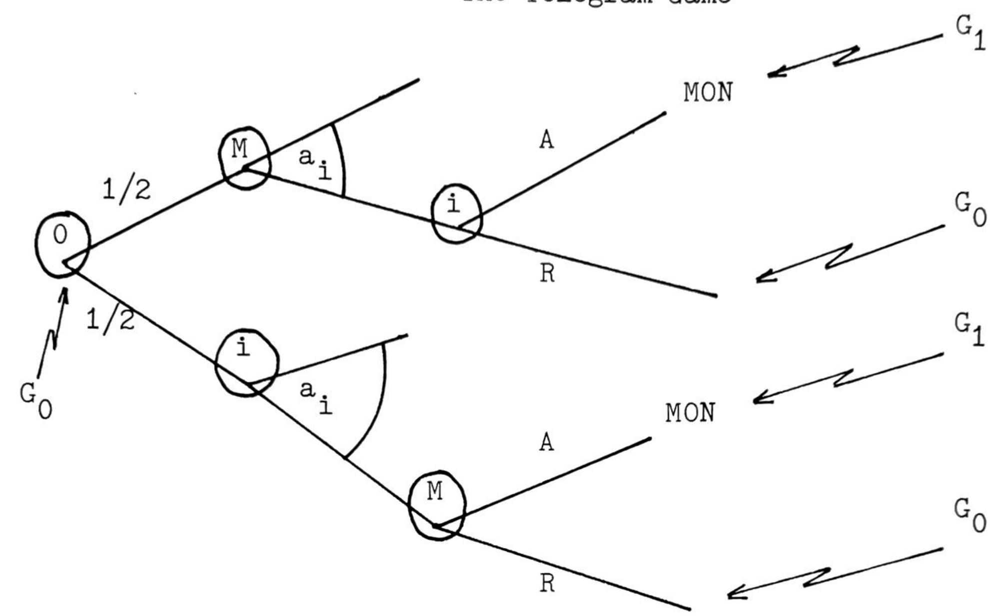
[4] Rubinstein (1982) represents the seminal work in non-cooperative bargaining theory. See Sutton (1986) and Binmore, Rubinstein and Wolinsky (1986) for an introduction to the basic model.

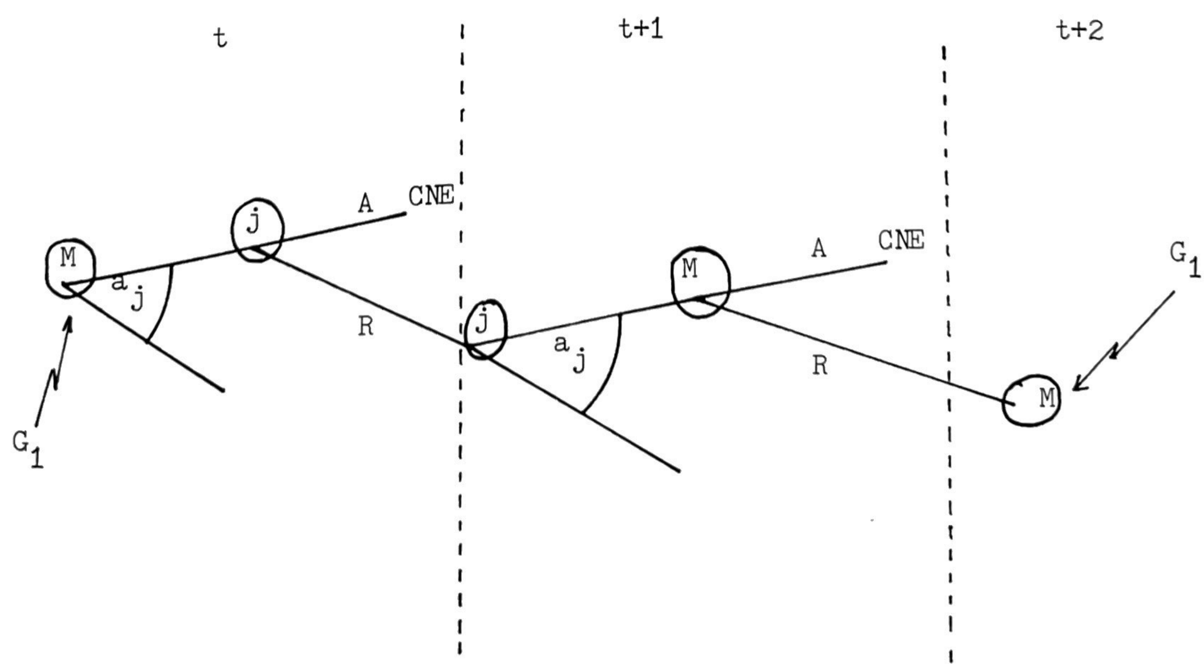
Figure 3.1

The Telegram Game



A = "Accept"
R = "Reject"
0 = "Chance" mover
MON = Begin producing monopoly output
CNE = Begin producing Cournot Nash equilibrium output.

The Subgame after buyer i has signed a contract: G_1



firm 1 (firm 2). During this meeting a "proposer" is randomly chosen to offer a price; the other responds "accept" or "reject". If the offer is rejected, the monopolist meets with the other buyer next period under the same conditions. If the offer is accepted at time t, the buyer who proposed or accepted immediately begins producing the (downstream) monopoly output, and the monopolist begins bargaining with the remaining buyer at time t+1. In this *subgame* the monopolist and remaining buyer alternate offers each period with the monopolist making the first offer.[5] Upon reaching the second agreement each buyer immediately begins producing its Cournot Nash equilibrium output. The game continues in this way until both buyers have reached agreement.[6]

Following the usual procedure, a subgame perfect equilibrium (SPE) will be derived by proceeding up each branch of the game tree shown in Figure 3.1, using backward induction. Consider the subgame after an offer, $\bar{a}_j$, made by the monopolist at time t is accepted by firm j before firm i has reached agreement. At time t, firm j begins producing the (downstream) monopoly output, $x_{mj}(\bar{a}_j)$, allowing the upstream monopolist to earn (flow) profits $U_{mj}(\bar{a}_j) = (\bar{a}_j - c)\, x_{mj}(\bar{a}_j)$. At time t + 1, the monopolist makes an offer to firm i. Since it is already earning profits from firm j, the payoff to the monopolist from reaching agreement with firm i is the *incremental* profit obtained

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[5]The assumption that firms alternate offers in the subgame rather than randomly determining the proposer each period serves to simplify the analysis and does not affect any of my conclusions.

[6]One could allow the monopolist or either buyer to choose to leave the game at any time, but these strategies are strictly dominated by the choice to continue bargaining.

by moving from monopoly to Cournot equilibrium downstream. Let $x_i(a_i, \bar{a}_j)$ be the Cournot equilibrium output of firm i when the monopolist and firm i agree on the price a_i after firm j has agreed to $\bar{a}_j$. Letting U_i be the incremental profits earned by the upstream monopolist by signing with firm i, and π_i the incremental (and absolute) profits of firm i,

$$(3.1)\quad U_i(a_i, \bar{a}_j) = (a_i - c)\, x_i(a_i, \bar{a}_j) + (\bar{a}_j - c)\, (x_j(\bar{a}_j, a_i) - x_{mj}(\bar{a}_j))$$

and

$$(3.2)\quad \pi_i(a_i, \bar{a}_j) = P(x_i(a_i, \bar{a}_j) + x_j(\bar{a}_j, a_i))\, x_i(a_i, \bar{a}_j) - (a_i + w)\, x_i(a_i, \bar{a}_j).$$

The total profits of the monopolist after signing with firm i are

$$(3.3)\quad U(a_i, \bar{a}_j) = (a_i - c)\, x_i(a_i, \bar{a}_j) + (a_j - c)\, x_j(\bar{a}_j, a_i).$$

Assuming continuous discounting at the interest rate r, the discounted present value (discounted to time t) of the profit streams earned by the monopolist and firm j are

$$(3.4)\quad \frac{(1 - \delta)}{r}\, U_{mj}(\bar{a}_j) + \frac{\delta}{r}\, U(a_i, \bar{a}_j),$$

and

$$(3.5) \qquad \frac{(1-\delta)}{r}\,\pi_{mj}(\bar{a}_j) + \frac{\delta}{r}\,\pi_j(\bar{a}_j, a_i),$$

where $\pi_{mj}(\bar{a}_j) = P(x_{mj}(\bar{a}_j))\; x_{mj}(\bar{a}_j) - (w + \bar{a}_j)\; x_{mj}(\bar{a}_j)$ and $\delta^t = e^{-rt}$. In what follows, statements such as "the monopolist receives $(1-\delta)U_{mj} + \delta U$" are taken to mean that it earns $(1-\delta)U_{mj}/r + \delta U/r$ in present value. This terminology involves no loss of generality under the assumptions of infinitely lived contracts.

Under the linear demand assumption it can be verified that

$$(3.6) \qquad \pi_{mj}(\bar{a}_j) = \frac{(\alpha - w - \bar{a}_j)^2}{4\beta},$$

$$(3.7) \qquad \pi_i(a_i, \bar{a}_j) = \frac{(\alpha - w - 2a_i + \bar{a}_j)^2}{9\beta},$$

$$(3.8) \qquad U_{mj}(\bar{a}_j) = \frac{(\alpha - \bar{a}_j)\bar{a}_j}{2\beta},$$

$$(3.9) \qquad U(a_i, \bar{a}_j) = \sum_i (a_i - c)\,\frac{(\alpha - w - 2a_i + \bar{a}_j)}{3\beta},$$

and

$$(3.10) \qquad U_i(a_i, \bar{a}_j) = (2a_i - \bar{a}_j - c)\,\frac{(\alpha - w - 2a_i + \bar{a}_j)}{6\beta}.$$

Let

$$A_i(\bar{a}_j) = \left\{ a_i \;\middle|\; U_i(a_i, \bar{a}_j),\ \pi_i(a_i, \bar{a}_j) \geq 0,\ \frac{\partial U_i(a_i, \bar{a}_j)}{\partial a_i} \geq 0 \right\}$$

be the set of all individually rational input prices over which the monopolist and firm i have a conflict of interest. It is easy to verify that (3.6) - (3.10) satisfy the following properties.

<u>Property 3.1</u>. (Existence of individually rational trades). For all $\bar{a}_j \geq c$, there exists some $a_i \in A_i(\bar{a}_j)$ such that $U_i(a_i,\bar{a}_j)$, $\pi_i(a_i,\bar{a}_j) > 0$.

<u>Property 3.2</u>. (Continuity) π_i, π_{mi}, U_i, U_{mi} are twice continuously differentiable on the interval $[c,\infty)$.

<u>Property 3.3</u>. (Monotonicity) π_i is strictly decreasing in a_i.

<u>Property 3.4</u>. (Monotonicity) U_i is strictly concave in a_i, and U is strictly concave.

Property 3.1 guarantees that the monopolist and firm i find it profitable to reach an agreement. Properties 3.3 and 3.4 insure that the set $A_i(\bar{a}_j)$ is convex.

Define the functions V_{Mi} and V_i as follows:

$$(3.11)\quad V_{Mi}(a_i,\bar{a}_j) = \min \{ a' \in A_i(\bar{a}_j) \mid U_i(a',\bar{a}_j) \geq \delta\, U_i(a_i,\bar{a}_j) \}$$

$$(3.12)\quad V_i(a_i,\bar{a}_j) = \max \{ a' \in A_i(\bar{a}_j) \mid \pi_i(a',\bar{a}_j) \geq \delta\, \pi_i(a_i,\bar{a}_j) \}$$

V_{Mi} (V_i) is the lowest (highest) input price contract which, if agreed upon today, would leave the monopolist (firm i) at least as well off as it would be by agreeing to the input price, a_i, tomorrow.

While Properties 3.1 - 3.4 guarantee existence, the following guarantees uniqueness in the subgame after one firm has signed a contract.

<u>Property 3.5</u>. (Increasing compensation for delay) For $k \in \{1,2,M1,M2\}$, $j \neq k$, the functions $D_k(a,\bar{a}_j) \equiv a - V_k(a,\bar{a}_j)$ are strictly increasing in a.

Property 3.5 asserts that the increase (decrease) in the input price necessary to compensate the monopolist (firm i) for a delay of one period increases as the profitability to the monopolist (firm i) of that input price increases.

Equilibrium

First, the equilibrium to the subgame just described is characterized. Given Properties 3.1 - 3.5, the following Lemma is nearly a direct consequence of the results in Rubinstein (1982).

<u>Lemma 3.1</u>. For all $\bar{a}_j \geq c$ there is a unique subgame perfect equilibrium (SPE) to the subgame (call this the Rubinstein equilibrium). The equilibrium is such that $S_i(\bar{a}_j)$ is the offer made by the monopolist every time it is his turn to make an offer, and $R_i(\bar{a}_j)$ is the offer made by firm i every time it is i's turn to make an offer where S_i

and R_i are given by the unique solution to equations (3.13) - (3.15):

$$(3.13)\quad g(a,\bar{a}_j) \equiv \underset{a' \in A_i(\bar{a}_j)}{\operatorname{argmax}} \ \pi_i(a',\bar{a}_j) \quad \text{s.t.} \quad U_i(a',\bar{a}_j) \geq \delta\, U_i(a,\bar{a}_j)$$

$$(3.14)\quad h(g,\bar{a}_j) \equiv \underset{a' \in A_i(\bar{a}_j)}{\operatorname{argmax}} \ U_i(a',\bar{a}_j) \quad \text{s.t.} \quad \pi_i(a',\bar{a}_j) \geq \delta\, \pi_i(g,\bar{a}_j)$$

$$(3.15)\quad S_i(\bar{a}_j) = h(g(S(\bar{a}_j),\bar{a}_j),\bar{a}_j)), \qquad R_i(\bar{a}_j) = g(S_i(\bar{a}_j),\bar{a}_j)$$

In equilibrium, the monopolist plans to accept any offer greater than or equal to $R_i(\bar{a}_j)$ while firm i plans to accept any offer less than or equal to $S_i(\bar{a}_j)$ every period in which each must respond.

<u>Proof</u>: See Appendix B

While it is not trivial to show that the history-independent offers R_i and S_i are the unique SPE offers (this was Rubinstein's major insight), the intuition for why they are SPE offers is straight forward. Observe that, conditional on the accept/reject decisions in the Lemma, the best the monopolist (firm i) can do in each period in which it makes an offer is to offer an input price maximizing its incremental profits subject to leaving firm i (the monopolist) just indifferent between accepting, or waiting for the offer expected next period. It is easy to see that the offers in Lemma 3.1 satisfy these intuitive conditions. This completes the analysis of the subgame.

Lemma 3.1 aids the characterization of subgame perfect equilibrium in the telegram game by guaranteeing a unique outcome in the subgame after only one buyer has signed a contract. The next step is to use this observation to derive equilibrium strategies in the subgames before either buyer has signed a contract.

Let $\pi(a_1,a_2) \equiv \pi_1(a_1,a_2)$. Then, since buyers are using the same technology, $\pi_2(a_2,a_1) = \pi(a_2,a_1)$, and for $i \in \{1,2\}$, the definitions $\pi_m(a) \equiv \pi_{mi}(a)$, $U_m(a) \equiv U_{mi}(a)$, $S(a) \equiv S_i(a)$, and $A(a) \equiv A_i(a)$ can be used to eliminate redundant subscripts. One more implication of the linear demand assumption (verified in Appendix B) is used to guarantee existence.

Property 3.6. $U(a,S(a))$ is strictly concave, and $\pi(a,S(a))$ is strictly decreasing in a.

With symmetric buyers, it is natural to investigate symmetric equilibria where, in a given period t, the monopolist plans to offer the same price to both buyers, and each buyer plans to offer the same price as the other buyer. In addition, the telegram game is stationary in the sense that the subgame beginning at time t before either buyer has signed a contract is identical to the subgame beginning at time t+n ($n \geq 1$) under the same circumstances.[7] This suggests looking for an

[7] While the subgame beginning at time t is identical to that beginning at time t+n, the accumulated history of the game is not the same. Thus, the analysis in this chapter does not rule out the possibility that other equilibria exist where strategies at time t depend on the accumulated history through time t-1. While I have not

equilibrium where the monopolist and each buyer offer these prices in *every* period before either buyer has signed a contract. Subgame perfect equilibria of this type are referred to as *stationary subgame perfect equilibria* (SSPE).

Proposition 3.1. There exists a SSPE to the telegram game. In equilibrium the monopolist (firm i) offers a^* $(\hat{a})$ in every period before either buyer has signed a contract where a^* and $\hat{a}$ are given by the solution to equations (3.16) - (3.18):

$$(3.16) \quad f(\hat{a},a^*) \equiv \underset{a \geq c}{\operatorname{argmax}} \ (1 - \delta)\, U_m(a) + \delta\, U(a,S(a)) \quad \text{s.t.}$$

$$(1 - \delta)\, \pi_m(a) + \delta\, \pi(a,S(a)) \geq \frac{1}{2}\, \delta^2 \left[\pi(S(\hat{a}),\hat{a}) + \pi(S(a^*),a^*) \right]$$

$$(3.17) \quad k(\hat{a},a^*) \equiv \underset{a \geq c}{\operatorname{argmax}} \ (1 - \delta)\, \pi_m(a) + \pi(a,S(a)) \quad \text{s.t.}$$

$$(1 - \delta)\, U_m(a) + \delta\, U(a,S(a)) \geq \frac{1}{2}\, \delta \left[(1 - \delta)\, (U_m(\hat{a}) + U_m(a^*)) + \delta\, (U(\hat{a},S(\hat{a})) + U(a^*,S(a^*)) \right]$$

$$(3.18) \quad a^* = f(\hat{a},a^*), \qquad \hat{a} = k(\hat{a},a^*)$$

Buyers plan to accept offers less than or equal to a^* and reject offers greater than a^* in any period before either buyer has signed a contract. The monopolist plans to accept offers greater than or

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been able to find other equilibria, neither do I know that they do not exist.

equal to $\hat{a}$ and reject offers less than $\hat{a}$ in any period before either buyer has signed a contract. In any subgame where one buyer remains unsigned, players' strategies are those given in Lemma 3.1.

Proof: Let us first interpret problems (3.16) and (3.17). Suppose the game proceeds to period t without any agreements being signed and that the monopolist is chosen to propose a price. In deciding whether to accept or reject the offer, the buyer weighs the profit from accepting against the profit from rejecting. If it rejects, it expects the other buyer and the monopolist to agree on either a^* or $\hat{a}$ (with probability 1/2 for each) in period t+1, and then to receive its Rubinstein equilibrium contract in period t+2 (by Lemma 3.1). The expected profit of this outcome is given on the right hand side (RHS) of the constraint in problem (3.16). If it accepts, it expects the monopolist and remaining buyer to agree to the Rubinstein equilibrium contract in period t+1. This is the profit on the LHS of the same constraint. Hence, problem (3.16) says that in every period before either buyer has signed a contract, the monopolist offers a price maximizing its profits subject to expecting the buyer to accept. Problem (3.17) represents similar behavior on the part of each buyer whenever it is chosen to propose. Clearly, a^* and $\hat{a}$ must solve these problems to be SSPE offers.

To demonstrate that they are SSPE offers it must be shown that the monopolist (firm i) earns more by having a^* ($\hat{a}$) accepted at time t than it does by waiting for a 1/2 chance to receive $\hat{a}$ (a^*) at time t+1 (t+2). Since $(1 - \delta)U_m(a) + \delta U(a,S(a))$ is nondecreasing over the range relevant for bargaining, the constraint in problem (3.17) implies $a^* > \hat{a}$, from which it follows that the monopolist earns more by having a^* accepted today. Similarly, since $(1 - \delta)\ \pi_m(a) + \pi(a,S(a))$ is decreasing in a, and $a^* > \hat{a}$, the constraint in problem (3.17) implies that firm i prefers to have $\hat{a}$ accepted today over waiting for $\pi(S(a^*),a^*)$ two periods later.

Finally, by the theorem of the maximum, (eg. Varian 1984, 327) f and k are continuous functions on the convex, compact set $\{(a_1,a_2) \mid a_i \in [c,a'],\ i \in \{1,2\}\}$ where $a' = \text{argmax}\ \{(1 - \delta)U_m(a) + \delta U(a,S(a)) \mid a \geq c\}$. A straightforward application of Brouwer's fixed point theorem guarantees that a solution satisfying the equations in (3.18) exists. Q.E.D.

The dynamic nature of the telegram makes it cumbersome to compare it with equilibria derived in other policy regimes or under different assumptions about the bargaining process. The next section shows that, plausibly interpreted, the telegram game has a static representation related to the Nash bargaining solution. This allows a simple comparison between the SSPE in the unconstrained regime, the price the monopolist would unilaterally set, and the SSPE when price discrimination is forbidden which is derived in section 3.3.

3.2. Small Costs of Delay and the Nash Bargaining Solution

Since Rubinstein's seminal bargaining paper in 1982 there has been an increased interest in what Myerson (1986), Binmore (1986b), and others have called "the Nash Programme." The basic idea, first suggested by Nash (1953), is that cooperative solution concepts in game theory (eg. the Nash bargaining solution, the Shapley value) should be "justified" by demonstrating that there is at least one interesting and relevant extensive form game that generates the same solution. This section contributes to the Nash Programme by demonstrating the equivalence of the SSPE to the telegram game and a time preference version of the Nash bargaining solution in an intuitively appealing limit.

As a benchmark for comparison with the SSPE of the telegram game, let $\mathbf{a}^L = (a^L, a^L) \equiv \text{argmax}\ \{U(a_1, a_2) \mid a_i \in A_i(a_j),\ i, j \in \{1,2\},\ i \neq j\}$ be the price set by the monopolist when it *exercises price leadership*. In its current form, Proposition 3.1 does not allow a meaningful comparison between the SSPE prices and this static definition of price leadership when the discount factor is less than one. However, this problem disappears under the plausible assumption that the opportunity cost of disagreement between bargaining rounds is small relative to the discounted present value of future profits earned after agreement is reached. A convenient way to introduce this assumption is to write the discount factor as $\delta = e^{-rz}$, where $r \in (0,1)$ is each firm's implicit rate of time preference and $z > 0$ is the length of time between successive offers in the bargaining game. For fixed r, the cost of disagreement relative to discounted profits is a declining function of z. The notion that disagreement costs are small is captured by taking the limit of the SSPE prices as z approaches zero, or equivalently, as δ approaches one.

As a further justification for this limit, note that immediately after an offer is rejected, each firm (including the monopolist) would like the next offer to be made as quickly as possible because delay is costly.[8] Interpreting z as the minimum time that must elapse before the next offer can physically be made, and maintaining the assumption that firms cannot credibly commit to bargaining delays in advance, it is natural to take the limiting equilibrium as z approaches zero as the benchmark bargaining outcome. Henceforth, this will be considered *the* equilibrium outcome in the regime where price discrimination is allowed.

Binmore (1986a) was the first to recognize the equivalence between the limiting equilibrium of Rubinstein's two-person bargaining game and a time-preference version of the Nash bargaining solution. Since the telegram game includes Rubinstein's as a subgame, one expects that its limiting equilibrium also bears some relation to Nash's solution.

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[8]Admati and Perry (1986), in a model with incomplete information, show that when each player can choose the time between its response and the next offer (subject to being greater than some fixed value), strategic delays may arise in equilibrium as a mechanism for the buyer to communicate its strength. Since the telegram game is one of full information, this kind of delay would not arise if bargainers were allowed to choose their speed of response after an offer has been rejected.

Denoting the dependence of a^* and $\hat{a}$ on δ by writing them as $a^*(\delta)$ and $\hat{a}(\delta)$, the following proposition verifies this intuition.

<u>Proposition 3.2</u>. $\lim_{\delta \to 1} a^*(\delta), \hat{a}(\delta) = a^N$, where a^N solves

$$(3.19) \qquad a^N = T(a^N) \equiv \operatorname{argmax} \left\{ [U(a,a^N) - U_m(a^N)]\, \pi(a,a^N) \mid a \in A(a^N) \right\}$$

<u>Proof</u>: The proof proceeds by first verifying three claims.

Claim 1: There exists δ' such that for all $\delta \in [\delta',1)$, the constraints in problems (3.13) and (3.14) (henceforth referred to as "constraint (3.13)" and "constraint (3.14)") bind in equilibrium.

Suppose constraint (3.13) does not bind. Then firm i can offer a price slightly less than R_i without violating the constraint. This increases firm i's profits, contradicting the definition of R_i. Hence, constraint (3.13) binds for all $\delta \in (0,1)$.

Suppose that for all $\delta' \in (0,1)$, there exists some $\delta \in [\delta',1)$ such that constraint (3.14) does not bind. Then there exists a sequence $\{\delta_t\} \to 1$ such that $\partial U_i(S_i,\bar{a}_j)/\partial a_i = 0$ for all $\delta_t > \delta'$, and therefore $\partial U_i(S_i,\bar{a}_j)/\partial a_i \to 0$. I show that this yields a contradiction.

Expanding the RHS of both constraints about the price on the LHS of each constraint (and assuming that constraint (3.14) does not bind) yields

$$(3.20) \qquad \frac{\partial U_i(t,\bar{a}_j)/\partial a_i}{U_i(R_i,\bar{a}_j)} = \frac{(1 - \delta)}{\delta} \frac{1}{(S_i - R_i)}$$

and

$$(3.21) \qquad \frac{-\pi_i(S_i,\bar{a}_j)}{\partial \pi_i(v,\bar{a}_j)/\partial a_i} > \frac{\delta}{(1 - \delta)} (S_i - R_i)$$

for some t, v ϵ $[R_i, S_i]$. Since the LHS of (3.21) is bounded, $R_i \rightarrow S_i$ as $\delta \rightarrow 1$, and therefore t and v also converge to the same price, say $\tilde{a}(\bar{a}_j)$. Multiplying (3.20) by (3.21) and taking the limit as $\delta \rightarrow 1$ yields 0 > 1, a contradiction. Hence, there exists δ' such that constraint (3.14) binds for all $\delta \in [\delta', 1)$.

Claim 2: $S_i(\cdot) \rightarrow T(\cdot)$ as $\delta \rightarrow 1$.

By Claim 1, the inequality in (3.21) should be replaced by an equality. Multiplying the resulting equation by (3.20) yields

$$(3.22) \qquad \frac{\partial U_i}{\partial a_i} \pi_i + \frac{\partial \pi_i}{\partial a_i} U_i = 0,$$

which is the first order necessary (and sufficient) condition for $\tilde{a}(\bar{a}_j) = T(\bar{a}_j)$. Since $S_i(\cdot) \rightarrow \tilde{a}(\cdot)$, this implies that $S_i(\cdot) \rightarrow T(\cdot)$.

Claim 3: There exists δ'' such that for all $\delta \in [\delta'', 1)$, constraints (3.16) and (3.17) bind in equilibrium.

Suppose constraint (3.17) does not bind. Then each buyer can reduce its offer without violating the constraint. This increases its profits, contradicting the definition of $\hat{a}(\delta)$. Note also that, since the LHS of (3.17) converges to the RHS, $\hat{a}(\delta) \to a^*(\delta)$ as $\delta \to 1$.

Suppose that for all $\delta'' \in (0,1)$, there exists some $\delta \in [\delta'',1)$ such that constraint (3.16) does not bind. Letting a′ be the limiting value of $\hat{a}$ and a^*, this implies that $\pi(a',S(a')) > \pi(S(a'),a')$, which implies that $a' < S(a')$. I show that this yields a contradiction.

When the constraint in (3.16) binds, that problem can be written as max $\{U(a_1,a_2) \mid a_2 \le S_2(a_1)\}$ when $\delta = 1$. It is easy to see that, since $\partial S_2/\partial a_1 = 1/2$ (see the verification of Property 3.6), the first order conditions to this problem imply that the gradient of U points to the northwest. By the symmetry and quasiconcavity of U, this implies that $a_1 > a_2$, which contradicts the preceding paragraph.

Claims 1 - 3 can now be used to verify the proposition. Imposing equality in constraints (3.16) and (3.17) (Claim 3), it is easy to see that $a' \to S_i(a')$. Since $S_i(\cdot) \to T(\cdot)$ (Claim 2), $a' \to T(a')$. This implies that a′ solves (3.19) in the limit as $\delta \to 1$. Q.E.D.

Observe the sense in which a^N is a Nash bargaining solution. Given two utility functions, threat points, and a convex utility possibility set, Nash's (1950) solution to the bilateral monopoly problem is uniquely determined by the payoff allocation maximizing the product of the utility gains over the threat points. In terms of (3.19), the monopolist and remaining buyer find themselves in a bilateral monopoly situation after the first buyer has agreed to a^N. The monopolist's total profit from agreeing to a' with the second buyer is $U(a',a^N)$; the buyer's total profit is $\pi(a',a^N)$. The monopolist's threat point is $U_m(a^N)$, the amount it earns from the first buyer while negotiating with the second. The buyer's threat point is zero since the monopolist is the only seller of the input.[9] Since the frontier of the set $\{ (U(a,a^N),\pi(a,a^N)) \mid a \in A(a^N) \}$ is concave (this is easily verified in the linear demand constant marginal cost case) the problem on the RHS of (3.17) solves this Nash bargaining solution. Setting the price that maximizes (3.17) equal to a^N implies that both contracts solve the Nash bargaining solution simultaneously.

This solution is intuitively interpreted as follows. Two agents representing the upstream monopolist act "as if" they bargain separately, and simultaneously with an agent from each buyer. Each pair agrees on an equitable and efficient division (i.e. they satisfy Nash's axioms) of the incremental profits to be divided given the other agreement, and the two agreements must be consistent.

Equation (3.22) allows a simple proof by contradiction that price leadership does not occur in the limiting SSPE to the telegram game. For, suppose that price leadership does occur. Then, since $\partial U_i/\partial a_i = 0$ and $\partial \pi_i/\partial a_i < 0$, equation (3.22) implies that $U_i = 0$, which in turn, implies that $a^L = c$. But $\partial U_i(c,a^N)/\partial a_i = x_i(c,a^N) > 0$, contradicting

[9] As Binmore, Rubinstein, and Wolinsky (1986) have suggested, the threat points in the time preference model should be identified with the profits earned while in disagreement.

the assumption of price leadership. Hence,

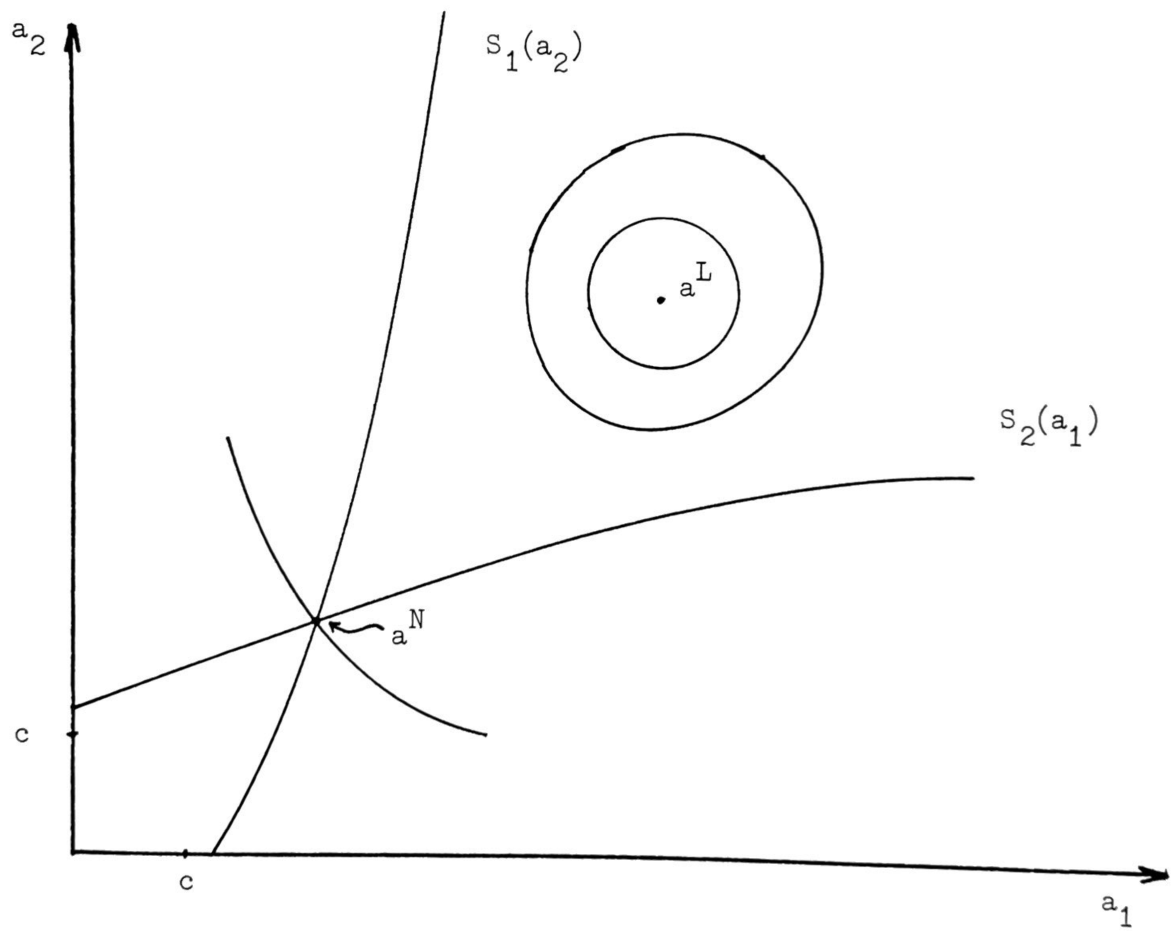
<u>Proposition 3.3</u>. The monopolist does not exercise price leadership in the limiting SSPE to the telegram game. That is, $a^N < a^L$.

The intuition for this can be seen by observing Figure 3.2, which illustrates the profit contours of the monopolist and the functions $S_i(\cdot)$ in input price space when δ is very close to one. The key idea is that for δ close to one, buyer i rejects offers greater than $S_i(a_j)$ if it then expects buyer j to agree to a_j next period. For, after rejecting such an offer, i expects to wait a very short time before receiving a lower price. Similarly, the monopolist rejects offers from i less than $S_i(a_j)$ if it then expects to agree to a_j next period. These two conditions, along with the condition that the agent chosen to propose makes an offer maximizing its profits subject to expecting acceptance, imply that the only SSPE offers are given by a^N, the price at which S_1 intersects S_2.

The major force preventing the monopolist from offering a price higher than a^N is each buyer's ability to credibly reject a high price, expecting to agree to a lower price two periods later. This threat is credible because the last buyer to sign a contract has some bargaining power. That is, given an agreement between the monopolist and one buyer, adding the second buyer shifts out the derived demand for the monopolist's intermediate product creating an additional surplus over which the monopolist and second buyer bargain. It should not be

Figure 3.2

Equilibrium in the Unconstrained Regime



surprising that the monopolist generally does not receive all the surplus in this phase of the negotiation, and therefore, that forward looking buyers do not accept inordinately high prices early in the negotiations before either buyer has signed a contract.

Proposition 3.2 was derived under the assumption of infinitely lived contracts. However, contracts in some markets, including many in international telecommunications, are open-ended, specifying prices to be in effect until either party decides to renegotiate. Another appealing feature of the limiting equilibrium is that introducing renegotiation does not change the outcome: firms cannot gain by unilaterally renegotiating their contracts.

Of course, renegotiation is not allowed in the telegram game, and it is not clear how it would change equilibrium for $\delta < 1$. Nevertheless, a constructive two-step approach to the single seller two buyer bargaining problem that could have been taken is to 1) specify a bargaining procedure for each bilateral encounter, and then 2) *define* equilibrium as a price such that no player wishes to unilaterally reopen negotiations. The simultaneous Nash bargaining solution in Proposition 3.2 represents one such solution.

That this interpretation brings the bargaining problem back to the axiomatic approach should not cause any discomfort. For, as Binmore, Rubinstein, and Wolinsky (1986) have suggested, the non-cooperative approach complements the axiomatic approach by suggesting which set of axioms are plausible in different situations. The simultaneous Nash bargaining solution is an example of how this view works. The requirement that Nash's axioms hold in *each* bilateral encounter has a certain amount of intuitive appeal. But this was not recognized, or so it appears, in the literature on vertical chains of production until it was derived as the limiting equilibrium of a non-cooperative bargaining game.[10]

3.3. Forbidding Price Discrimination

Proposition 3.3 in the last section demonstrates that the "invisible hand" of the market has the power to discipline a monopolist bargaining with firms that are rivals in their downstream market -- such a monopolist is not a price leader. This section considers how this disciplining factor is affected by a rule forbidding third degree price discrimination.

Let us first recall the two phases of the bargaining process in which forbidding price discrimination constrains negotiations. In phase one, before any contracts have been signed, there is no direct constraint on the initial agreement. In phase two, the subgame after an initial agreement has been signed, the second agreement must match the initial one. Hence, the equations characterizing equilibrium are the same as in the unconstrained regime except that the second agreement is constrained to equal the first.

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[10] Viehoff (1987), Jun (1987), Davidson (1988), and Horn and Wolinsky (1987) and (1988) all independently obtain results similar to Proposition 3.2.

As before, let a^* and $\hat{a}$ be the SSPE offers of the monopolist and each buyer respectively. These must satisfy

$$(3.23) \quad \tilde{f}(\hat{a},a^*) \equiv \underset{a \geq c}{\text{argmax}} \ (1 - \delta)\, U_m(a) + \delta\, U(a,a) \quad \text{s.t.}$$

$$(1 - \delta)\, \pi_m(a) + \delta\, \pi(a,a) \geq \frac{1}{2}\, \delta^2 \left[\pi(\hat{a},\hat{a}) + \pi(a^*,a^*) \right],$$

$$(3.24) \quad \tilde{k}(\hat{a},a^*) \equiv \underset{a \geq c}{\text{argmax}} \ (1 - \delta)\, \pi_m(a) + \pi(a,a) \quad \text{s.t.}$$

$$(1 - \delta)\, U_m(a) + \delta\, U(a,a) \geq \frac{1}{2}\, \delta \left[(1 - \delta)\, (U_m(\hat{a}) + U_m(a^*)) + \delta\, (U(\hat{a},\hat{a}) + U(a^*,a^*)) \right],$$

and

$$(3.25) \quad a^* = \tilde{f}(\hat{a},a^*), \qquad \hat{a} = \tilde{k}(\hat{a},a^*).$$

It is straightforward to show that a unique solution to (3.23) - (3.25) exists, and therefore that a unique SSPE exists.

As in the free bargaining regime a convenient characterization of equilibrium is found by taking the limit as $\delta \to 1$. It can be shown that there exists δ' such that the constraints in problems (3.23) and (3.24) bind for all $\delta \geq \delta'$. Imposing these constraints, expanding the RHS of each equation about the price on the LHS of that equation, and rearranging yields

$$(3.26)\quad (1-\delta)\,\pi_m(a^*) + (\delta-\delta^2)\,\pi(a^*,a^*) = \frac{1}{2}\,\delta^2\,\frac{d\pi(t,t)}{da}\,(\hat{a}-a^*)$$

and

$$(3.27)\quad (1-\delta)^2\,U_m(\hat{a}) + (\delta-\delta^2)\,U(\hat{a},\hat{a})$$

$$= \frac{1}{2}\,\delta\left[(1-\delta)\,\frac{\partial U_m(v)}{\partial a} + \delta\,\frac{dU(v,v)}{da}\right](a^*-\hat{a})$$

for some t, v ϵ $[\hat{a},a^*]$, where the operator d/da indicates the the total derivative with respect to a. Equation (3.26) has the following intuitive interpretation: the monopolist increases a^* up to the point where the buyer's expected loss from rejecting, the LHS of (3.26), is equal to its expected gain, the RHS of (3.26). Equation (3.27) has a similar interpretation for optimal buyer behavior.

Now, notice that as δ approaches one, the LHS of (3.26) approaches zero. Since $d\pi/da$ is bounded above by zero this implies that $\hat{a}$, a^*, t, and v all converge to the same price, call it a^F. Dividing (3.26) by (3.27) and taking the limit as δ approaches one yields

$$(3.28)\quad \frac{dU}{da}(\pi_m+\pi) + \frac{d\pi}{da}U = 0,$$

or equivalently,

$$(3.29)\quad \left[\frac{\partial U}{\partial a_i} + \frac{\partial U}{\partial a_j}\right](\pi_m+\pi_i) + \left[\frac{\partial \pi_i}{\partial a_i} + \frac{\partial \pi_i}{\partial a_j}\right](U_i+U_m) = 0.$$

Equation (3.29) characterizes the equilibrium price, a^F, when price discrimination is forbidden in markets where bargaining costs are small relative to the discounted value of profits available.

3.4 Comparing the Regimes

Equilibrium prices in the two regimes can now be compared by comparing equations (3.22) and (3.29). This is simplified by noting that under the linear demand assumption, $\partial\pi_i/\partial a_j = -(1/2)\ \partial\pi_i/\partial a_i$, and $U_m = 3U_i$. Note also that $\partial U/\partial a_i = \partial U_i/\partial a_i$. Substituting these conditions into (3.27) yields

$$\left[\frac{\partial U_i}{\partial a_i} \pi_i + \frac{\partial \pi_i}{\partial a_i} U_i \right] + \frac{\partial U_i}{\partial a_i} \pi_m = 0. \tag{3.28}$$

The term in brackets is the first order necessary condition for the simultaneous Nash bargaining solution. The second term is either positive, or, if the monopolist is a price leader, equal to zero. But it cannot equal zero; if it did the simultaneous Nash bargaining solution and price leadership would both hold, contradicting Proposition 3.3. Hence, the second term is greater than zero, implying the term in brackets is less than zero when evaluated at a^F. By the quasiconcavity of $\pi_i(a,a)U_i(a,a)$ in a, this implies that $a^N < a^F$, and demonstrates the following proposition.

Proposition 3.5. Forbidding price discrimination in the telegram game strictly increases input prices. This leads to a higher final product price, and therefore lower welfare than when price discrimination is not forbidden.

Ironically, this model implies that the uniform settlements policy, far from being a remedy, may be the precise cause of the "whipsawing" problem in international telecommunications markets. This is true with respect to the market for traffic originating in the U.S. if 1) U.S. firms carry only outbound traffic, or 2) the 50-50 division of tolls is not enforced, and demand is independent across countries.

Intuitively, forbidding price discrimination eliminates bargaining in phase two of the game, the subgame after an initial contract has been signed. Recall, however, that it is precisely the fact the monopolist bargains with the second buyer in phase two of the unconstrained regime that prevents it from setting a higher price in phase one. Forbidding price discrimination removes this disciplining factor, allowing the monopolist to demand a higher price in phase one.

There is a subtlety in Proposition 3.4 that is unfortunate from the point of view of policy. Note that with symmetric buyers, price discrimination is not observed in the free bargaining regime. Nevertheless, forbidding price discrimination leads to higher input prices throughout the downstream industry. Hence, Proposition 3.4 demonstrates that no conclusions about the welfare consequences of forbidding price discrimination can be drawn by observing whether it occurs in the unconstrained regime. This sharply distinguishes the present model from other analyses of third degree price discrimination (e.g. Katz 1987) where the absence of observed price discrimination in the unconstrained regime indicates that forbidding discrimination has no effect. The difference is that other models *assume* monopoly price leadership in both regimes (i.e. that the monopolist has all the bargaining power) so that incentives for discrimination are present only if buyers have different elasticities of demand. In contrast, I assume that all players initially have some bargaining power in determining prices and then observe how relative bargaining powers change when price discrimination is forbidden.

3.5 A Note on the Robinson-Patman Act

Of all the antitrust statutes, the Robinson-Patman Act has probably been subjected to more attacks by economists than any other. The infamous Section 2a forbids an upstream monopolist from charging different prices to different purchasers of "goods of like grade and quality" where the effect "may be substantially to lessen competition or tend to create a monopoly in any line of commerce, or to injure, destroy, or prevent competition with any person who either grants or knowingly receives the benefit of such discrimination or with customers of either of them." For the purposes of this chapter, the Act forbids price discrimination causing damage at the secondary level -- i.e. damage to the buyer charged the higher price. While no attempt is made here to delineate the long list of criticisms against it, let me mention the most common one and how it relates to the analysis of this chapter.

Bork (1978) emphasizes the most common criticism. In considering the effects of a "cartelist" — i.e. a group of colluding upstream firms — offering a price concession to a buyer with bargaining power, he argues:

> "It is difficult to see why we should do anything but rejoice when a seller in such a situation is forced to give a discriminatory discount. This may be the beginning of retaliatory discounts that move the price lower for all customers, in which case the discount and the price instability it causes represent a clear social gain" (Bork 1978, 390).

Forbidding price discrimination, he argues, makes credible each cartel member's commitment not to give selective discounts — discounts that would ultimately destroy the cartel agreement. Hence, Bork's view is that forbidding price discrimination prevents socially beneficial competitive price cuts.

The bargaining model in this chapter is concerned with a different kind of commitment, the effects of which do not rely on the presence of upstream rivalry. Even without such rivalry, forbidding price discrimination provides the monopolist with a commitment not to lower price in the subgame after an initial contract has been signed. Like the cartel model, discrimination may not actually occur in the unconstrained regime. But forbidding it prevents discrimination that would occur, if it were legal, off the equilibrium path. The essence of requiring equilibrium to be subgame perfect is to recognize how

Chapter 4: Downstream Entry and Forbidding Price Discrimination

Chapter 3 demonstrated that forbidding intermediate product third degree price discrimination can have harmful welfare consequences even if discrimination does not occur in the unconstrained regime: it may raise input prices throughout the downstream industry. This chapter takes the analysis one step further by demonstrating that the negative effects of forbidding price discrimination are intensified when there is free entry downstream.

4.1 N-Firm Bargaining

The Bargaining Process, Assumptions, and Notation

The single seller two buyer telegram game examined in Chapter 3 has a natural generalization to the case of N buyers. Just before time zero, before any contracts have been signed, assume that each buyer is randomly queued and labelled 1, 2,..., N according to whether it is the first, second,..., or nth buyer in line. At time zero the monopolist meets firm 1 and is randomly chosen either to propose or listen to an offer. If the offer is accepted firm 1 immediately begins producing the (downstream) monopoly output, and the monopolist decides whether to continue bargaining with firm 2 in the next period. If it continues bargaining and a second agreement is reached, firm 2 and firm 1 begin producing the 2-firm Cournot Nash equilibrium output. As the third, fourth,..., jth agreements are reached, all buyers who have signed begin producing the 3-firm, 4-firm,..., j-firm Cournot Nash equilibrium output.

If the original offer between firm 1 and the monopolist is rejected, firm 1 must go to the back of the queue, and firms are relabelled as follows: 1 becomes N, and $i \neq 1$ becomes $i-1$. Similarly, after j agreements have been signed the remaining firms have labels $j+1, j+2, \ldots, N$. If the monopolist and the firm labelled $j+1$ end their meeting in disagreement, then firm $j+1$ becomes N, and those labelled $j+k$, $k \neq 1$, become $j+k-1$.

Just as the subgame after one buyer had signed was important in the two-firm case, so is the subgame after N-1 firms have signed important in the N-firm case. To simplify the analysis it is assumed that the monopolist makes the opening offer in this subgame, and then alternates offers with the remaining buyer until final agreement is reached. Allowing the proposer to be chosen randomly in each period in this subgame changes nothing of substance.

There are many other bargaining procedures that could be considered, and these may or may not lead to same conclusions as the one just described. It seems clear, however, that this one allows the monopolist to exercise its strongest possible credible threat: to send a firm to the back of the queue if agreement is not reached immediately. Hence, if the equilibrium of this game errs in any direction, it should err by giving the monopolist too much bargaining power.[1]

The monopolist produces a normal input, $X = \Sigma x_i$, at constant marginal and average cost c, where x_i is the amount purchased by firm i. Final product inverse demand is P(Y) where $Y = \Sigma y_i$ is total output and y_i is the output of firm i. Downstream technology, assumed freely available to all firms, is represented by the cost function

$$W(y_i, a_i, \mathbf{w}) = \begin{cases} K + V(y_i, a_i, \mathbf{w}), & y_i > 0 \\ 0, \quad y_i = 0 \end{cases}$$

where K is a fixed cost that is not sunk[2], V is the variable cost function, and $\mathbf{w}$ is the price vector (henceforth suppressed) of other competitively sold factors. Firms share the common discount rate $\delta = e^{-rz}$, where r is each firm's implicit rate of time preference, and z is the time between successive offers in the bargaining game. To reflect the belief that bargaining costs are small I focus on the limiting equilibrium as $z \to 0$.

Attention is restricted to downstream markets whose demand and cost conditions satisfy the following assumptions.

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[1]For example, one could allow the monopolist to choose which buyer it approaches each period. In the two buyer case this generates an additional asymmetric equilibrium in which the monopolist stays with the same buyer until that buyer signs. This equilibrium is supported by the belief held by each buyer that the monopolist will always stay until agreement is reached with that buyer. But this leads to a *worse* outcome for the monopolist since, by delaying agreement, the first buyer can effectively impose a loss on the monopolist equal to the profits it earns from both buyers.

[2]The role of sunk costs is discussed in section 4.3.

Assumption 4.1. $P(\cdot)$ is twice continuously differentiable, with $P'(Y) < 0$; there exists $\bar{Y}$ such that for all $Y \geq \bar{Y}$, $P(Y) = 0$; and $P(0) = \bar{p} < \infty$.

Assumption 4.2. $V(y,a)$ is twice continuously differentiable with with $V_y(y,a) \geq 0$, $V_{yy}(y,a) \geq 0$, $V_{ya}(y,a) > 0$, for all $y \geq 0$, $a \geq c$, $V_a(y,a) > 0$ for all $y > 0$, $a \geq c$; and $\bar{p} > V_y(0,c)$.

Assumption 4.3. For all $\mathbf{y} = (y_1\ y_2,\ldots,y_n) >> 0$, $n \geq 1$, and $a_i \geq 0$, $nP''(Y)y_i + (n+1)P'(Y) - V_{yy}(y_i,a_i) < 0$ for all i.

Assumption 4.4. For all $\mathbf{y} >> 0$, $P'(Y) + y_iP''(Y) \leq 0$ for all i.

Assumption 4.1 says that the demand curve is downward sloping and intersects both axes. Assumption 4.2 says that marginal cost is upward sloping, x is a normal input, and monopoly production is profitable if fixed costs are small and the price of x is low. I focus on symmetric equilibrium whenever downstream firms are charged the same price for the intermediate product. Assumptions 4.1 - 4.3 guarantee that, for small enough a and K, such an equilibrium exists, is stable, and is unique among equilibria restricted to be symmetric.

Assumption 4.4 says that each firm's marginal revenue is steeper than the demand function at all output combinations. In the language of Bulow, Geanakoplos, and Klemperer (1985) this means that each firm views its output as a *strategic substitute* for that of every other firm. It implies that an increase in any one firm's output reduces the equilibrium output of each of the other firms. This assumption holds if the demand function is concave, or not too convex.

Letting $\mathbf{a} = (a_1, a_2, \ldots, a_n)$ be the vector of prices paid for the monopolized input by the n firms in production, $y_i(\mathbf{a})$ is each firm's equilibrium output, and $x_i(\mathbf{a}) = V_a(y_i(\mathbf{a}), a_i)$ is its equilibrium input demand. The (flow) equilibrium profits of the monopolist and downstream firm i are given by

$$(4.1) \qquad U_n(\mathbf{a}) = \Sigma\ (a_i - c)\ x_i(\mathbf{a})$$

and

$$(4.2) \qquad \pi_{i,n}(\mathbf{a}) = P(Y(\mathbf{a}))\ y_i(\mathbf{a}) - W(y_i(\mathbf{a}), a_i).$$

The monopolist's incremental profit from reaching agreement with firm i when it is the nth buyer to sign is

$$(4.3) \qquad U_{i,n}(\mathbf{a}) = U_n(a_i, \mathbf{a}_{-i}) - U_{n-1}(\mathbf{a}_{-i})$$

where $\mathbf{a}_{-i} = (a_1, \ldots, a_{i-1}, a_{i+1}, \ldots, a_n)$ and $\mathbf{a} = (a_i, \mathbf{a}_{-i})$, a notational convention followed throughout the rest of this chapter. Let

$$A_{i,n}(\mathbf{a}_{-i}) = \left\{ a_i \mid \pi_{i,n}(\mathbf{a}),\ U_{i,n}(\mathbf{a}) \geq 0;\ \frac{\partial U_{i,n}(\mathbf{a})}{\partial a_i} \geq 0 \right\},$$

the set of all input prices over which the monopolist and firm i have a conflict of interest in the subgame after firms other than i have agreed to prices $\mathbf{a}_{-i}$. This set is assumed to be convex for all i, n.

Whenever $\mathbf{a} = (a,\ldots,a)$, let $y_i(a,n) \equiv y_i(\mathbf{a})$ be the symmetric Cournot equilibrium output of each firm. This mild abuse of notational convention will be followed whenever symmetry is imposed and it causes no ambiguity.

Under Assumptions 4.1 - 4.4, the equilibrium output and profit functions satisfy several useful properties used in the derivations below. In particular, Appendix C verifies that the following properties hold in symmetric equilibrium.

Property 4.1. $\frac{\partial y}{\partial n} < 0, \quad \frac{\partial Y}{\partial n} > 0, \quad \frac{\partial x}{\partial n} < 0, \quad \frac{\partial X}{\partial n} > 0.$

Property 4.2. $\frac{\partial \pi_{i,n}}{\partial a_i} < 0, \quad \frac{d\pi_{i,n}}{da} \to 0$ as $n \to \infty$.

Property 4.3. $U_{i,n} = 0$ implies that $\frac{\partial U_{i,n}}{\partial a_i} > 0$.

Property 4.4. $\frac{\partial \pi_{i,n}}{\partial n} < 0$; for all $a \geq 0$, for all $K > 0$ such that some N-firm equilibrium exists, there exists $N'(K,a) < \infty$ such that $\pi_{i,N'}(a) = 0$.

N-Firm Equilibrium Under Free Bargaining

The single seller two-buyer analysis of the free bargaining regime in section 3.2 generalizes in a straightforward way to the case of N ≥

3 downstream buyers. To see how, recall that in the two buyer case the limiting stationary equilibrium price is completely determined by what happens in the subgame after one buyer has signed a contract. That is, the monopolist (firm i) does not sign an initial contract at a price lower (higher) than it expects to receive only a short time later. Similarly, the limiting stationary equilibrium with N buyers is driven by the subgame after all but one have signed a contract. Since buyers are symmetric, the first, second,..., nth contract each converges to the same price as $z \to 0$; this price is the Rubinstein equilibrium to the subgame after N-1 buyers have signed.

Consider the subgame after all buyers except firm i have signed. If there exists a SPE to this subgame, the monopolist's offer, S, and firm i's offer, R, must satisfy

$$(4.3)\quad g(a,\mathbf{a}_{-i}) \equiv \underset{a' \in A_{i,N}(\mathbf{a}_{-i})}{\operatorname{argmax}} U_{i,N}(a',\mathbf{a}_{-i}) \text{ s.t. } \pi_{i,N}(a',\mathbf{a}_{-i}) \geq \delta\pi_{i,N}(a,\mathbf{a}_{-i}),$$

$$(4.4)\quad h(g,\mathbf{a}_{-i}) \equiv \underset{a' \in A_{i,N}(\mathbf{a}_{-i})}{\operatorname{argmax}} \pi_{i,N}(a',\mathbf{a}_{-i}) \text{ s.t. } U_{i,N}(a',\mathbf{a}_{-i}) \geq \delta U_{i,N}(g,\mathbf{a}_{-i})$$

and

$$(4.5)\quad S(\mathbf{a}_{-i}) = g(h(S(\mathbf{a}_{-i}),\mathbf{a}_{-i}),\mathbf{a}_{-i}), \quad R(\mathbf{a}_{-i}) = h(S(\mathbf{a}_{-i}),\mathbf{a}_{-i})$$

where $\mathbf{a}_{-i}$ is the vector of prices agreed to by all firms other than i. Focusing on situations where bargaining costs are small, bargaining equilibrium is defined as follows.

Definition 4.1. Let $S(\mathbf{a}_{-i},z)$ be the monopolist's equilibrium offer in the subgame after all but firm i have signed, explicitly accounting for its dependence on z. An *N-firm equilibrium under free bargaining* is a price a^0 (which depends on N) such that $a^0 = \lim_{z \to 0} S(a^0,\ldots,a^0,z)$.

Binmore (1986a) demonstrated that as $z \to 0$, equilibrium to the subgame (as defined by equations (4.3) - (4.5)) approaches the Nash bargaining solution (with threat points set equal to zero) if the frontier of the set

$$\{ (U_{i,N},\pi_{i,N}) \mid a_i \in A_{i,N}(\mathbf{a}_{-i}) \}$$

is concave. However, since the curvature of the frontier generally depends on the third derivative of the demand function, concavity is not guaranteed by Assumptions 4.1 - 4.4. If it is not concave, the Nash bargaining solution is not even defined.[3] The following proposition establishes a convenient characterization of the limiting equilibrium that does not require the frontier to be concave.

Proposition 4.1. Let a^0 be an N-firm equilibrium under free bargaining, and let $\mathbf{a}^0 = (a^0,\ldots,a^0)$. Then, for all $i \in \{1,\ldots,N\}$,

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[3]The usual way to get around this problem is to allow agents to randomize over the set of possible outcomes. It is difficult, however, to interpret this kind of randomization in a game where agents explicitly exchange offers.

$$(4.6) \quad \frac{\partial U_{i,N}(a^0)}{\partial a_i} \pi_{i,N}(a^0) + \frac{\partial \pi_{i,N}(a^0)}{\partial a_i} U_{i,N}(a^0) = 0.$$

Proof: First I argue that the constraints in problems (4.3) and (4.4) bind in equilibrium for z close to zero. Suppose the constraint in problem (4.4) does not bind. Then for all $z > 0$, firm i can reduce its offer below R by a small amount while still satisfying the constraint. But by Property 4.2, this increases firm i's profits, contradicting the definition of R.

Next, suppose that for all $\omega > 0$, there exists some $z' \in (0,\omega]$ such that the constraint in problem (4.3) does not bind. This implies that there is a sequence $\{z_t\} \to 0$ such that $\partial U_{i,N}(S(a_{-i},z_t),a_{-i})/\partial a_i = 0$ for all $z_t < \omega$, and therefore that $\partial U_{i,N}(S(a_{-i},z_t),a_{-i})/\partial a_i \to 0$. I will show that this yields a contradiction.

In equilibrium, $U_{i,N}$ is non-decreasing in a neighborhood below both S and R; otherwise both the monopolist and firm i would want to reduce price. Since the constraint in problem (4.4) binds, this implies that $S > R$ for z close to 0. Furthermore, by the continuity of $U_{i,N}$ and the fact that the constraint in problem (4.4) binds, either $U_{i,N} \to 0$, or $S \to R$ as $z \to 0$. But $U_{i,N} \to 0$ and Property 4.3 together imply that $\partial U_{i,N}/\partial a_i \not\to 0$, yielding a contradiction.

Suppose, then, that $S \to R$. Expanding the right hand side (RHS) of each constraint about the price on the LHS of that constraint and rearranging the resulting expressions yields

$$(4.7)\qquad \frac{-\pi_{i\ N}(S,a_{-i})}{\partial \pi_{i\ N}(v,a_{-i})/\partial a_i} > \frac{\delta}{(1-\delta)}(S-R)$$

and

$$(4.8)\qquad \frac{\partial U_{i,N}(t,a_{-i})/\partial a_i}{U_{i,N}(R,a_{-i})} = \frac{(1-\delta)}{\delta}\frac{1}{(S-R)}$$

where t, v ϵ [R,S]. Since $S \rightarrow R$, t and v also converge to the same price, call it $\bar{a}$. Multiplying equations (4.7) by (4.8) and taking the limit as $z \rightarrow 0$ implies $0 > 1$, which is a contradiction. Therefore, there exists ω such that the constraint binds for all z ϵ $(0,\omega]$.

It remains to show that equation (4.6) is satisfied for all such z. Change the inequality in equation (4.7) to an equality. If both $U_{i,N}(\bar{a},a_{-i})$ and $\pi_{i,N}(\bar{a},a_{-i})$ equal zero, then equation (4.6) is satisfied trivially. If neither, or one of them equals zero, then (4.7) and (4.8) can be rearranged and divided (without dividing by zero) to yield equation (4.6). Q.E.D.

From equation (4.6) it is not immediately obvious how the equilibrium price varies with N. However, there is an immediate corollary describing equilibrium for any given number of buyers.

Corollary 4.1. For all $N < \infty$ such that an N-firm equilibrium exists, the monopolist does not exercise price leadership in an N-firm equilibrium under free bargaining.

Proof. This follows from the demonstration in the proof of Proposition 4.1 that $\partial U_{i,N}/\partial a_i \not\to 0$.

Example: Bargaining Power and the Number of Downstream Firms

One might expect, quite naturally, that most plausible measures of the monopolist's bargaining power would rise with the number of downstream firms. However, a simple example shows that this intuition is wrong. Suppose $P(Y) = \alpha - Y$, $W(y,a) = ay$ ($K = 0$, $x = y$), and $c = 0$. Then, the equilibrium output of each downstream firm is $y = (\alpha - a)[1/(N+1)]$, and straightforward calculations yield

$$U_i(a,\ldots,a,N) = \frac{(\alpha - a)a}{N(N + 1)}, \tag{4.9}$$

$$\frac{\partial U_i(a,\ldots,a,N)}{\partial a_i} = \frac{\alpha - 2a}{N + 1}, \tag{4.10}$$

$$\pi_i(a,\ldots,a,N) = \frac{(\alpha - a)^2}{(N + 1)^2}, \tag{4.11}$$

and

$$\frac{\partial \pi_i(a,\ldots,a,N)}{\partial a_i} = \frac{-2N(\alpha - a)}{(N + 1)^2}. \tag{4.12}$$

Substituting these expressions into equation (4.6) and solving for equilibrium price yields $a^0 = \alpha/4$, independently of N. Hence, entry has no effect on the equilibrium input price when final product demand is linear and firms have constant marginal and average costs.

Although it may have been unexpected, this result is really quite intuitive. When bargaining costs are small, each firm's bargaining power is proportional to the size of the incremental loss it can impose (by delaying service) on each firm with which it negotiates. As the number of buyers increases, the loss each buyer can impose on the monopolist, U_i, falls, but so does the loss that the monopolist can impose on each buyer. Entry transfers bargaining power to the monopolist only if the profit earned by each buyer weighted by the slope of the monopolist's profit function grows relative to seller's (symmetrically weighted) incremental profit from selling to that buyer. It turns out, in the linear case, that entry changes these functions such that equilibrium input price is held constant.

It is clear why the apparent advantage the monopolist holds early in negotiations is really no advantage at all: each buyer can credibly threaten to reject high prices in favor of waiting for a more symmetric bargaining position after a very short delay. There are two ways the monopolist could improve its plight. One way would be to take some action credibly committing itself not to bargain so symmetrically with buyers signed in later periods. Alternatively, it could try to change the rules of the game to eliminate buyers' credible threats. The next section examines how a rule forbidding price discrimination does precisely this.

Forbidding Price Discrimination

Generalizing from the single seller two buyer case when price discrimination is forbidden proceeds along the lines of the derivation in section 3.3. Let a^* and $\hat{a}$ be the SSPE offers of the monopolist and each buyer in every period before any contracts have been signed. In equilibrium, firm 1 (resp. the monopolist) must be indifferent between accepting and rejecting a^* (resp. $\hat{a}$) when the time between offers is sufficiently close to zero.[4] The equations reflecting these indifference constraints when there are N buyers are

$$(4.13)\quad (1 - \delta)\,\pi_{1,1}(a^*) + (\delta - \delta^2)\,\pi_{1,2}(a^*) + \ldots + (\delta^{N-2} - \delta^{N-1})\,\pi_{1,N-1}(a^*) + \delta^{N-1}\,\pi_{1,N}(a^*) = \frac{\delta^N}{2}\left[\pi_{1,N}(a^*) + \pi_{1,N}(\hat{a})\right],$$

and

$$(4.14)\quad (1 - \delta)\,U_1(\hat{a}) + (\delta - \delta^2)\,U_2(\hat{a}) + \ldots + (\delta^{N-2} - \delta^{N-1})\,U_{N-1}(\hat{a}) + \delta^{N-1}\,U_N(\hat{a}) = \frac{\delta}{2}\Big[(1 - \delta)\,U_1(\hat{a}) + \ldots + \delta^{N-1}\,U_N(\hat{a}) + (1 - \delta)\,U_1(a^*) + \ldots + \delta^{N-1}\,U_N(a^*)\Big],$$

---

[4] The demonstration that these indifference constraints bind for z close to zero follows a line of argument similar to that in Proposition 4.1, and hence, is omitted.

where $\mathbf{a}^* = (a^*, \ldots, a^*)$ and $\hat{\mathbf{a}} = (\hat{a}, \ldots, \hat{a})$.

Expanding the RHS of each equation about the price on the LHS of that equation yields

$$(4.15) \qquad (1 - \delta)\, \pi_{1,1}(\mathbf{a}^*) + (\delta - \delta^2)\, \pi_{1,2}(\mathbf{a}^*) + \ldots + (\delta^{N-1} - \delta^N)\, \pi_{1,N}(\mathbf{a}^*) = \frac{\delta^N}{2} \frac{d\pi_{1,N}(\mathbf{t})}{da} (a^* - \hat{a}),$$

and

$$(4.16) \qquad (1 - \delta)\, [\, (1 - \delta)\, U_1(\hat{\mathbf{a}}) + (\delta - \delta^2)\, U_2(\hat{\mathbf{a}}) + \ldots + (\delta^{N-2} - \delta^{N-1})\, U_{N-1}(\hat{\mathbf{a}}) + \delta^{N-1}\, U_N(\hat{\mathbf{a}})\,]$$
$$= \frac{\delta}{2} \left[(1 - \delta) \frac{dU_1(\mathbf{v})}{da} + (\delta - \delta^2) \frac{dU_2(\mathbf{v})}{da} + \ldots + (\delta^{N-2} - \delta^{N-1}) \frac{dU_{N-1}(\mathbf{v})}{da} + \delta^{N-1} \frac{dU_N(\mathbf{v})}{da} \right] (a^* - \hat{a})$$

for some t, v ϵ $[\hat{a}, a^*]$, where $\mathbf{t} = (t, \ldots, t)$, and $\mathbf{v} = (v, \ldots, v)$. As $z \to 0$, the LHS of (4.15) goes to zero, implying that $\hat{a} \to a^*$. Hence, as $z \to 0$, $\hat{a}$, a^*, t, and v all converge to the same price, say a^F. Dividing (4.15) by (4.16) and taking limits yields[5]

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[5]If dU_N/da or U_N goes to zero, the equations are divided in the way that avoids dividing by zero.

$$(4.17)\qquad \frac{dU_N}{da}\,(\pi_{1,1} + \pi_{1,2} + \ldots + \pi_{1,N}) \;+\; \frac{d\pi_{1,N}}{da}\,U_N \;=\; 0.$$

Definition 4.2. An *N-firm equilibrium when price discrimination is forbidden* is a price, a^F, satisfying equation (4.17).

An interesting connection between the asymmetric Nash bargaining solution and this equilibrium facilitates its interpretation. Assuming that the frontier of the set

$$\{\, (\pi_{1,N}, U_N) \mid a_i \in A_{i,N}(a_{-i}),\ a_i = a_j\ \forall\, i, j \,\}$$

is concave, an asymmetric Nash bargaining solution with threat points set equal to zero can be defined as a price solving

$$(4.18)\qquad \max \left\{ \pi_{1,N}(a)^{\lambda}\, U_N(a)^{1-\lambda} \;\middle|\; a_i \in A_{i,N}(a_{-i}),\ a_i = a_j\ \forall\, i, j \right\}$$

where $\lambda / (1 - \lambda)$ measures the bargaining power of firm 1 relative to that of the monopolist. The first order necessary (and sufficient) condition for an interior solution is

$$(4.19)\qquad \frac{dU_N}{da}\,\pi_{1,N} \;+\; \frac{\lambda}{1 - \lambda}\,\frac{d\pi_{1,N}}{da}\,U_N \;=\; 0.$$

Now, let $\lambda = \pi_{1,N} / (\pi_{1,1} + \pi_{1,2} + \ldots + \pi_{1,N-1} + 2\pi_{1,N})$, which implies that $\lambda/(1 - \lambda) = \pi_{1,N} / (\pi_{1,1} + \pi_{1,2} + \ldots + \pi_{1,N})$ is firm 1's relative bargaining power. Then equation (4.19) reduces to equation (4.17).

Hence, N-firm equilibrium when price discrimination is forbidden can be interpreted as an asymmetric Nash bargaining solution where firm 1's equilibrium relative bargaining power is determined simultaneously with the input price.

This also leads to the following intuitive comparative statics result. Holding the input price constant, an increase in N decreases $\pi_{1,N}$ and increases $\pi_{1,1} + \cdots + \pi_{1,N}$, leading to a decrease in firm 1's relative bargaining power. This reduces the first order condition (4.19), and therefore raises the equilibrium price. Hence, an increase in the number of downstream firms reduces firm 1's relative bargaining power leading to an increase in the equilibrium price.

In the free bargaining example of the last section the monopolist's bargaining power did not rise with the number of downstream firms. Why are these results different? The reason is that when price discrimination is forbidden, buyer bargaining power no longer derives from the ability to impose incremental losses on the monopolist; rather, it derives from the monopolist's ability to play buyers against each other to determine *the* initial price. The easiest way to see this is in terms of the two phases of the bargaining game in which forbidding price discrimination affects negotiations. Phase one is the bargaining that occurs before any initial agreements have been signed; phase two is the bargaining that occurs after the first agreement has been signed. In the unconstrained regime, phase two bargaining is not constrained. Buyers can therefore wait to be the last to sign a contract, at which point they have about the same bargaining power as the monopolist. In contrast, forbidding price discrimination effectively disallows phase two bargaining. This means that all bargaining occurs in phase one. But the ability of the monopolist to play buyers against each other in phase one increases with the number of buyers as the threat to send disagreeable buyers to the end of the queue carries more force. This allows the monopolist to demand a higher price in phase one.

4.2. Free Entry

Assume there are a large number of firms contemplating entry in the downstream industry. The entry process is modelled by breaking the game into two stages. In the first stage N firms enter, in the second stage N-firm equilibrium is determined. Ignoring the integer constraint, firms are required to earn zero profits in free entry equilibrium.

Definition 4.3. An *equilibrium with free entry under free bargaining* is a price $a^0(K)$ and a number $N^0(K)$ such that $\pi_{i,N^0}(a^0,\ldots,a^0) = 0$, and a^0 is an N^0-firm equilibrium under free bargaining.

Definition 4.4. An *equilibrium with free entry when price discrimination is forbidden* is a price $a^F(K)$ and a number $N^F(K)$ such that $\pi_{1,N^F}(a^F,\ldots,a^F) = 0$, and a^F is an N^F-firm equilibrium when discrimination is forbidden.

The effects of entry in each regime are now easily derived utilizing Properties 4.1 - 4.4 along with these definitions. First, consider the unconstrained regime. By Property 4.4 there will be a finite number of firms in equilibrium. Therefore, Property 4.2 implies $\partial\pi_{i,N}/\partial a_i < 0$ in equilibrium. Since downstream profits are zero due to free entry, it follows from equation (4.6) that the monopolist's incremental profits are equal to zero. And since $X(a^0(K),N^0(K)) - X(a^0(K),N^0(K)-1) > 0$ for all $N^0 < \infty$ (Property 4.1), this implies that $a^0(K) = c$.

<u>Proposition 4.3</u>. Suppose the integer constraint is ignored. Then, for all $K > 0$ such that firms earn nonnegative profits in some N-firm equilibrium under free bargaining, $a^0(K) = c$.

At first blush this is a very counterintuitive result. It says that downstream free entry drives input prices down to marginal cost in markets where firms meet sequentially and bargain over price. It is not so surprising, however, after considering how the zero profit condition affects the bargaining process. Under free bargaining, the monopolist's bargaining power in each bilateral encounter derives from its ability to impose a loss on that buyer. But each buyer recognizes that it will earn zero profits in free entry equilibrium. This implies that the monopolist has no bargaining power, and therefore no influence over price. The resulting equilibrium is degenerate, where, conditional on the number of firms that enter, $a^0(K) = c$ is the only price yielding non-negative profits to the monopolist and each downstream firm.

To complete the analysis in the free bargaining regime, consider what happens as fixed costs become small. First, note that as $K \to 0$, $N^0(K) \to \infty$. To see this, suppose instead that $N^0(K) \to (\bar{N} - 1) < \infty$, and $y \to \bar{y}$. Then, since

$$
\begin{aligned}
P(\bar{N}\,\bar{y})\,\bar{y} - W(\bar{y},c) &\geq P(\bar{N}\,\bar{y})\,\bar{y} - W_y(\bar{y},c)\,\bar{y} \\
&= [P(\bar{N}\,\bar{y}) - W_y(\bar{y},c)]\,\bar{y} \\
&= -P_y(\bar{N}\,\bar{y})\,\bar{y}^2 > 0,
\end{aligned}
$$

there exists a $\bar{K}$ small enough for entry to be profitable.[6]

It is easy to verify that $P(N^0 y^0) \to W_y(y^0, a^0)$ as $N^0 \to \infty$. Since $a^0 = c$, it follows that final product price approaches the perfectly competitive equilibrium price.

<u>Proposition 4.4</u>. As $K \to 0$, equilibrium with free entry under free bargaining approaches first best.

Though it is certainly contrary to conventional wisdom, this conclusion is no more startling than the conclusions of Bulow (1982), Stokey (1982), and Gul, Sonnenscein and Wilson (1986), who demonstrate that price may fall to marginal cost in durable good monopoly. The

[6]This line of argument is due to Mankiw and Whinston (1986).

problem facing the monopolist in those models as well as the present model is how to make binding commitments. In the durable good case, a monopolist unable to commit itself to sell only to "high valuation" buyers cannot resist the temptation to lower price each period -- eventually all the way to marginal cost -- to continue earning profits from low valuation customers. As Coase (1972) first suggested, price may fall to marginal cost "in the twinkling of an eye" if buyers have rational expectations.

It seems to me, however, that there are still many examples of durable good monopolists earning supra-normal profits over extended periods of time. Hence, my interpretation of this result is not that durable good monopoly always (or even usually) comes close to first best, but rather, that the monopolist has an enormous incentive to develop ways to commit itself not to lower price so quickly. Similarly, I would not predict that an upstream monopolist selling to a large (possibly infinite) number of downstream oligopolists has no influence over input prices. Such a monopolist would find ways to make the commitments necessary to retain as much influence over price as possible.

Consider how forbidding price discrimination accomplishes this in markets where fixed costs are small. In the limit as $K \to 0$, $N^F(K) \to \infty$, and $d\pi_{i,N}/da \to 0$ (Property 4.2). Since $\pi_{1,1} + \ldots + \pi_{1,N}$ is positive in equilibrium, equation (4.17) implies

Proposition 4.5. As $K \to 0$, bargaining equilibrium with free entry when price discrimination is forbidden is such that $dU_{N^0}/da = 0$. That is, the monopolist sets a take-it or leave-it price.

Hence, forbidding price discrimination provides the commitment necessary to transfer all the bargaining power to the monopolist when downstream firms have small fixed costs.

4.3. The Role of Sunk Costs

The analysis to this point has assumed the absence of sunk costs. But suppose that a fraction $\gamma \in (0,1]$ of the fixed cost is sunk. Since bargaining occurs after entry, i.e. after sunk investments have been made, this part of fixed cost is not included in calculations of downstream profits used for bargaining. The profit of buyer i relevant for determining an N-firm bargaining equilibrium using equations (4.6) and (4.17) is $R_{i,N}(a) \equiv \pi_{i,N}(a) + \gamma K$. However, sunk costs are still used by each firm to calculate the profitability of entry. In a free entry equilibrium, each buyer's total profits are driven to zero, but $R_{i,N} > 0$. This implies that input prices are not driven down to marginal cost, and therefore weakens Proposition 4.4. Returning to the example in section 4.1 suffices to highlight the major points. Suppose $P(Y) = \alpha - Y$, $W(y,a) = K + ay$, $x = y$, and $c = 0$. All the functions remain the same as in the previous example except that $R_{i,N}$ is substituted for $\pi_{i,N}$ in equation (4.6). An equilibrium with free entry under free bargaining now satisfies

$$\left[\frac{\alpha - 2a}{N + 1}\right]\left[\frac{(\alpha - a)^2}{(N + 1)^2} - (1 - \gamma)K\right] + \left[\frac{-2N(\alpha - a)}{(N + 1)^2}\right]\left[\frac{(\alpha - a)a}{N(N + 1)}\right] = 0,$$

and

$$\frac{(\alpha - a)^2}{(N + 1)^2} - K = 0.$$

Solving for the equilibrium input price yields

$$a^0 = \frac{\alpha}{2}\frac{\gamma}{(1 + \gamma)}.$$

The role of sunk costs can now be seen by examining how a^0 varies with the parameter γ. With no sunk costs ($\gamma = 0$), the input price equals zero (upstream marginal cost) as predicted by Proposition 4.4. As fixed costs become completely sunk ($\gamma \to 1$), the input price rises to $\alpha/4$, the price derived in the previous example under the assumption that $K = 0$. This occurs because fixed costs are irrelevant for bargaining when they are completely sunk. As $K \to 0$, the price the monopolist would unilaterally set approaches $\alpha/2$. Hence, in the limiting economy as $K \to 0$, the equilibrium outcome varies between first best ($a^0 = 0$) and an outcome intermediate between first best and monopoly price leadership ($a = \alpha/4$) as the fraction of fixed costs that are sunk varies from zero to one.

It should be pointed out that while sunk costs preclude the first best outcome of Proposition 4.4, their presence does not alter the result in Corollary 4.1 that the monopolist is not a price leader for all finite N. Furthermore, it is generally true (i.e. under Assumptions 4.1 - 4.4) that when K = 0 the monopolist is not a price leader in the limit as N goes to infinity:

Proposition 4.6. Suppose K = 0. Then, $\lim_{N \to \infty} dU_N(a^0)/da > 0$.

Proof: See Appendix C.

It follows from Proposition 4.6 that when all fixed costs are sunk, and therefore buyers bargain as if they had no fixed costs, the monopolist is not a price leader in the limiting equilibrium as fixed costs become small (N goes to infinity).

In contrast to the effect on the unconstrained regime, the presence of sunk costs does not alter the conclusion of Proposition 4.5 that forbidding price discrimination allows the monopolist to exercise price leadership as K falls to zero (N grows large). Hence, the basic conclusion that forbidding price discrimination provides the monopolist with a credible commitment allowing it to control price in downstream markets with small fixed costs remains unchanged.

Many of these points are nicely illustrated in the example. The additional functions needed to extend it to the regime forbidding price discrimination are

(4.18) $$\frac{d\pi_{i,n}(a,\ldots,a)}{da} = \frac{-2(\alpha - a)}{(n + 1)^2},$$

(4.19) $$U_n(a,\ldots,a) = \frac{n(\alpha - a)}{n + 1},$$

and

(4.20) $$\frac{dU_n(a,\ldots,a)}{da} = \frac{n(\alpha - 2a)}{n + 1}.$$

Using these functions along with (4.9) - (4.12), calculations of the equilibrium input price, final product price, and welfare (consumer plus producer surplus), are tabulated in Table 4.1 assuming all fixed costs are sunk, $K \to 0$, and $\alpha = 100$. Several interesting points deserve mention. First, as argued above, the input price rises with the number of downstream firms when price discrimination is forbidden. Indeed, as $N \to \infty$, $a^F(N) \to 50$, which is the price the monopolist would unilaterally set when the downstream market is competitive. Second, while entry increases welfare in both regimes, it increases it much faster in the unconstrained regime. For example, as the number of downstream firms increases from one to five, welfare rises by over 1200 units in the unconstrained regime but by less than 400 units when price discrimination is forbidden. Finally, the percentage increase in welfare from relaxing the price discrimination constraint is quite large for all values of N greater than one. It is already as high as 15 percent when N = 2, rises to 25 percent when N = 5, and peaks at 27 percent when N = 10. This example makes clear that the welfare cost of forbidding price discrimination can be quite large.

Table 4.1

The Welfare Cost of Forbidding Price Discrimination

N	a^0	a^F	P^0	P^F	W^0	W^F	$\frac{W^U - W^F}{W^F}$
1	25	25	63	63	3047	3047	0 %
2	25	38	50	59	3750	3270	15 %
5	25	47	38	56	4296	3426	25 %
10	25	49	32	54	4494	3548	27 %
100	25	50	26	50	4669	3725	25 %
∞	25	50	25	50	4688	3750	25 %

Notes: N is the number of downstream firms, a is the input price, P is the final product price, and W is the sum of consumer and producer surplus. The superscript 0 (F) indicates the unconstrained (constrained) regime. $P(Y) = 100 - Y$, $W(y,a) = ay$, $c = 0$.

4.4. Other Applications

Vertical Integration

Corollary 4.1 and Proposition 4.4 have immediate implications for the incentive of an upstream monopolist to integrate forward into a competitive downstream industry. To be concrete, assume downstream technology is one of fixed proportions, upstream and downstream marginal cost are normalized to zero, there are no fixed costs, and $N = \infty$.

Conventional wisdom holds that the monopolist has no incentive to integrate forward in this market, since the derived demand for its product is identically equal to final product demand (eg. Scherer 1980, 302; Waterson 1984, 89). That is, even without integrating the monopolist earns the rents it would earn if fully integrated by setting the input price (which equals final product price) equal to the fully integrated monopoly price. The bargaining model, in contrast, results in a lower input price prior to integration, and therefore a lower final product price. By integrating forward, the monopolist re-establishes the monopoly price and recovers the full monopoly rent.

In terms of the example in Table 4.1, a fully integrated monopolist earns 50 x 50 = 2500 when the downstream market is competitive ($N = \infty$), while the unintegrated monopolist earns 25 x 75 = 1875. By integrating forward the monopolist increases its profits by 33 percent. Notice that this also provides a normative justification for preventing vertical integration, since integration raises the final product price.

The Robinson-Patman Act and Incentives for Downstream Merger

In the forward to Richard Posner's *The Robinson Patman Act: Federal Regulation of Price Differences* (1976), Yale Brozen quotes a statement by the Federal Trade Commission that comes close to recognizing the effects of forbidding price discrimination discussed in this and the preceding chapter:

> "The Commission's past Robinson-Patman efforts were directed in part to preventing...warehouse distributors from obtaining price reductions from parts manufacturers. To the extent that past Commission action has been successful in preventing...these lower prices and to the extent that they continue to be available, it is not surprising to find ownership chains arising in an attempt to obtain them. Thus, in a very real sense it can be said that past Commission action (enforcement of Robinson-Patman) has contributed to the merger trend now observed" (Posner 1976, Forward).

The Commission realized that "lower prices", which were available in the unconstrained regime, would "continue to be available" if downstream firms merged to create "ownership chains", which would be unaffected by Robinson-Patman restrictions.[7] This intuition is easily verified using the linear example.

Suppose there are two downstream firms. The equilibrium profit of each firm is 625 under free bargaining, 424 when price discrimination is forbidden. If the firms merge, the "ownership chain" earns 1406. Hence, if merger costs are between 156 (= 1406 - 2 x 625) and 558 (= 1406 - 2 x 424) then the firms have an incentive to merge when price discrimination is forbidden but not under free bargaining.

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[7] See section 5 of the Chapter 3 for a brief discussion of the Robinson-Patman Act.

The Noncooperative Foundations of Upstream Monopoly

In the last ten years there has been a great deal of interest in developing non-cooperative foundations of both competitive and monopoly behavior. With regard to competition, this interest stems from the observation that the fictitious, centralized, Walrasian auctioneer is an unsatisfactory analytical device for determining price in markets where agents actually meet in pairs. With regard to monopoly, the focus has been on the effects of product durability on price. The analysis in this chapter is related to both literatures.

Once the assumption of price-taking or price-setting behavior has been removed from both sides of the market another mechanism for price determination must be specified. The approach in this chapter follows that taken by Rubinstein and Wolinsky (1985), Binmore and Herrero (1984) and Gale (1985). Each of these papers examines a market composed of many buyers and sellers exchanging indivisible goods. In each period each agent on the short side of the market is matched with an agent on the long side according to some *matching technology*. During each match one of the parties is randomly chosen to propose a price; the other accepts or rejects. If the price is accepted, trade takes place and the parties involved leave the market. If not, one period elapses and the procedure is repeated until a stationary state is reached, if there is a continuous inflow of new agents (Rubinstein and Wolinsky), or all the goods are sold (Gale, Binmore and Herrero).

Now, suppose that each buyer's reservation price is one, each seller's valuation of the good is zero, and the measure of sellers when the market opens is greater than the measure of buyers. Then the Walrasian equilibrium price, where supply equals demand, is zero. Gale (1985) showed that the non-cooperative equilibrium of the game with no inflow of new agents each period approaches the Walrasian equilibrium as $\delta \to 1$. Hence, as markets become "frictionless", the Walrasian auctioneer is given a non-cooperative game theoretic foundation.

The model in this chapter is more complex than that analyzed by Gale in two main ways. First, it deals with a market for an intermediate product where buyers' reservation price schedules are interdependent. Second, there is imperfect competition that leads to a dead weight loss (though it disappears with entry) downstream. Despite these differences the same kind of question as that considered by Gale can be addressed here. The natural question to ask in Gale's model is whether equilibrium in frictionless markets is Walrasian. The natural question to ask in the present model is whether the monopolist exercises price leadership as the number of buyers rises and frictions become small. As we have seen, the monopolist does not exercise price leadership if bargaining is unconstrained. Hence, pair-wise bargaining does not provide a foundation for monopoly equilibrium in frictionless markets where an upstream monopolist sells to competitive downstream buyers.

4.5. Concluding Remarks

Though he did not speculate on its effects, Pigou (1932) recognized the importance of bargaining in markets where price discrimination is feasible:

> "When a degree of non-transferability, of commodity units on the one hand or of demand units on the other hand, sufficient to make discrimination profitable, is present, the relation between the monopolistic seller and each buyer is, strictly, one of bilateral monopoly. The terms of the contract that will emerge between them is, therefore,...subject to the play of that 'bargaining'..." (Pigou 1932, 278).

He went on, however, to argue:

> "Usually...where discrimination is of practical interest, the opposed parties are, not a single large seller and a few large buyers, but a single large seller and a great number of relatively small buyers. The loss of an individual customer's purchase means so much less to the monopolistic seller than to any one of the many monopolistic purchasers that, apart from combination among all purchasers, all of them will almost certainly accept the monopolistic seller's price...In what follows I assume that the customers act in this way" (Pigou 1932, 278).

This chapter argues that Pigou was wrong in appealing to large numbers to justify his assumption that buyers are price-takers. The point conveyed by Propositions 4.4 and 4.5 is that the degree to which the monopolist controls price depends not on the number of buyers it faces, but on its ability to make binding commitments. I believe that this observation raises serious questions about the validity of comparative policy analysis conducted under arbitrary assumptions about price-setting or price-taking behavior. Unless there is good reason to believe that the degree to which either side controls price is independent of the regime, such assumptions can drastically bias the policy conclusions.

A rule forbidding price discrimination provides one way for the monopolist to commit to take-it or leave it prices when the downstream market is competitive. There are many other commitments that might serve a similar role. One such, lying outside the scope of this model, might be for the monopolist to establish a reputation for toughness in the spirit of Milgrom and Roberts (1982). For example, buyers may not be perfectly informed about whether the monopolist is "tough" or "weak", and a sequence of tough negotiations with a few buyers might allow the monopolist to demand a higher price if the remaining buyers perceive it as tough. Another way might be by limiting its capacity, and therefore refusing to bargain with more than some fixed number of buyers. These possibilities, and others that endogenously determine the degree to which the monopolist controls price warrant further investigation.

Chapter 5: The International Telecommunications Market

The examination of the vertical chain for outbound traffic in Chapters 3 and 4 provides much of the analysis necessary for understanding the effects of the uniform settlements policy in international telecommunications markets. This chapter begins by completing the analysis of the case in which only the price discrimination constraint is enforced by adding the second vertical chain — the market for traffic terminating in the U.S. Given the conclusions of the last three chapters, it is not surprising that negative implications are drawn about the effects of this constraint on both U.S. revenues and final service prices.

Section 2 finally turns to the case where both the 50-50 division of tolls and the price discrimination constraint are enforced. There, I argue that USP can be a very effective instrument for controlling foreign monopolies in markets where the net flow of traffic is inbound to the U.S., as it is in most telex markets. However, the net traffic flow is outbound from the U.S. in most voice and telegraph markets (recall the CEPT and COMTELCA telegrams in Chapter 2). In this case I show that under the USP, the telegram game may exhibit an equilibrium in which the foreign monopolist unilaterally sets the uniform access charge higher than the charge paid by U.S. carriers in a free bargaining equilibrium. That is, the USP may increase the price of final service in voice and telegraph markets.

Section 3 offers some evidence from the telex and telegraph markets that is broadly consistent with the predictions of the telegram game. While definitive conclusions are not drawn, I nevertheless offer recommendations as to whether the policy should or should not be enforced in voice, telex and telegraph. Section 4 concludes with a summary and a brief review of some unanswered questions.

5.1 The Price Discrimination Constraint

It does not appear that the 50-50 division of tolls has been strongly enforced in all international telecommunications markets. For example, prior to the COMTELCA telegram in 1983, U.S. telegraph carriers paid \$.1774 per word for access to COMTELCA networks but received only \$.1577 per word for access to their own. Similarly, U.S. carriers paid \$.1596 for access to the thirteen CEPT networks but received \$.1951 for access to their own networks prior to the CEPT telegram (FCC 1985, 28422).

On the other hand, the price discrimination constraint appears to be much more strongly enforced. In the telex market, for example, proposed access charge modifications are most frequently challenged when one carrier proposes to operate at a lower access charge than all other carriers. Such a reduction in one carrier's marginal cost is viewed by others as a threat to their market shares, and it is easy to argue that it is obviously "unfair" to treat symmetric U.S. carriers differently. However, both foreign and domestic carriers might agree that there is good reason for each country to pay a different access charge. Indeed, the International Telecommunications Union recommends that departures from the 50-50 division may occur when there are differences in facilities across countries.[1] Holding to this recommendation the Commission might see fit to relax its demand that countries pay each other the same rate while still insisting that U.S. firms be treated symmetrically.

This section considers this situation, where only the price discrimination constraint is enforced in markets with two-way traffic. While Chapters 3 and 4 have done most of the work necessary to understand this case, allowing for two-way traffic raises two considerations that have not been addressed. First, nothing has been said about traffic terminating in the U.S., which introduces another dimension over which the foreign monopolist attempts to play U.S. carriers against each other to obtain more favorable agreements. Second, there is a possibility that the demands for final service are interdependent across countries. This implies that there may be rivalry between the foreign monopoly and U.S. carriers after access charges have been set.

Both of these additions significantly complicate the bargaining model. Since the main purpose here is to focus on how the USP alters strategic possibilities available to foreign and domestic carriers,

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[1]The Final Report to the VII CCITT Plenary Assembly (Part III) of Study Group III recommends as a guiding principle that "proportions other than 50-50 may be used when the intercontinental facilities made available by each of the administrations of the terminal countries are not approximately equivalent."

simplifying assumptions are made with the hope that the main conclusions drawn are not significantly altered by relaxing them. First, to avoid potential problems with the existence of equilibrium in the market for traffic terminating in the U.S., assume that U.S. carriers produce access at constant marginal cost. In particular, assume there are two U.S. carriers and one foreign carrier, each having access to the same technology that allows outbound service and access to be produce at marginal cost, c.

The presence of interdependent demands is more difficult to address. It's clear that this could cause many of the properties of the equilibrium profit and output functions used in Chapters 3 and 4 to fail. Moreover, it would greatly complicate the analysis of the price effects of forbidding price discrimination since final service prices would be interdependent across countries. To avoid these problems I appeal to some recent empirical work suggesting that demands may be approximately independent. Specifically, Acton and Vogelsang (1988) find that the elasticity of demand for calls originating in the U.S. with respect to foreign price is not significantly different from zero in the market for voice service between the U.S. and seventeen European countries.

It should be pointed out that there is no *a priori* reason for believing that calls to and from a particular country are either substitutes or complements. For example, a decrease in the foreign price is likely to have two opposing effects. For a given number of connections it may imply that fewer calls originate in the home country. But the total demand for connections may also increase, which may increase the number of calls outbound from the home country, partially or fully offsetting the number of calls shifted overseas. Hence, the independent demand assumption represents an important intermediate case for analyzing the price effects (though not the welfare effects) of the USP.

Under these assumptions (constant marginal cost and independent demands) Chapter 3 completely characterizes the effects of forbidding price discrimination on access charges in the market for traffic originating in the U.S. Recalling the notation used, $a^N > c$ is the equilibrium access charge in the unconstrained regime, and $a^F > a^N$ is the equilibrium charge when price discrimination is forbidden.

Next, consider the market for calls terminating in the U.S. Foreign monopsonies control the allocation of U.S. bound traffic across U.S. carriers and can shift among them instantaneously at almost no cost, provided each U.S. carrier's capacity is not constrained. But capacity is readily available, and it appears that firms can increase it very quickly to handle potentially profitable inbound traffic.[2] Except for the fact that there is only one buyer, this market satisfies the assumptions of the Bertrand model of competition with U.S. firms competing for foreign inbound traffic. It is well known that if

[2]Currently there is a substantial excess capacity of both international satellite and cable circuits to most parts of the world. Hence, U.S. carriers' capacity is not constrained over the oceans (See Johnson 1986 for more details). Moreover, firms in the industry note that carriers can add additional capacity at their own terminal gates in a matter of weeks. (FCC 1986).

sellers have constant marginal cost, no capacity constraints, and face downward sloping industry demand, the unique Bertrand equilibrium access charge equals marginal cost.

It is also straightforward to see that this is the only renegotiation proof equilibrium to the telegram game applied to the inbound traffic case when the time between successive offers in that game is small. For, if the first U.S. carrier signs a contract at any price above marginal cost, the second U.S. carrier will undercut that price almost immediately. Since the foreign monopolist controls the allocation of U.S. bound traffic, it allocates all traffic to the carrier with the lower price. But once the first carrier's operating agreement is effectively terminated, it proceeds to undercut the other carrier in the next round, and so on. Equilibrium, where all bargaining ceases, occurs only when the access charge equals marginal cost.

The FCC has spent a great deal of time arguing that the price discrimination constraint of the USP prevents foreign monopsonies from whipsawing U.S. carriers in exactly this way. They might find it surprising, therefore, that the argument just presented holds independently of whether or not price discrimination is forbidden. This policy prevents two U.S. firms from simultaneously receiving two different access charges, but the argument does not depend on either operating at, or having the potential to operate at two different charges. In either regime the foreign monopolist can terminate one operating agreement as it begins sending traffic to the other lower priced carrier. Hence, forbidding price discrimination has no effect in the market for traffic inbound to the U.S.

This conclusion points to a fundamental difference between the effects of forbidding price discrimination in the market for outbound versus inbound traffic. For traffic outbound from the U.S., adding a second U.S. carrier after an original contract has been signed always increases the profit potential of the foreign monopolist, who earns some profit from the second agreement. The monopolist cannot play U.S. carriers against each other in the unconstrained regime because each firm has a credible threat to reject a high price, waiting for the bilateral bargaining position it expects by doing so. Forbidding price discrimination eliminates this threat, and this allows the monopolist to play buyers against each other to determine the initial access charge.

Compare this with the market for traffic inbound to the U.S. In that market adding a second carrier has no potential to increase the monopolist's profits once the access charge has fallen to marginal cost. In either regime U.S. carriers bid for the right to carry any inbound traffic, and this drives the access charge they pay down to their marginal cost.

These conclusions, along with those in Chapter 3 are summarized as follows.

Proposition 5.1. Suppose that the demand for calls originating in the U.S. is independent of the foreign price. Then, enforcing only the price discrimination constraint of the USP raises the access charge U.S. firms pay, from a^N to a^F, and therefore raises the price of calls originating in the U.S. Furthermore, since $a^U = c$ in both regimes, the total revenue of U.S. carriers falls.

The FCC has been very clear about the intended consequences of the USP. They state: "Our primary responsibility is to U.S. users, not U.S. carriers...Thus, while we prefer to see U.S. carriers rather than foreign administrations maximize their revenues through accounting rate [i.e. access charge] actions, our goal is to facilitate the development of a competitive marketplace characterized by lower rates and greater service/carrier options for users" (FCC 1985, 28419). Proposition 5.1 argues that enforcing only the price discrimination constraint of the USP does not achieve either the goal to protect users or the goal for U.S. carriers to maximize their revenues.

5.2 Two-Way Traffic with Both Constraints

Having by now destroyed any hope that the price discrimination constraint alone can prevent foreign telecommunications monopolies from extracting U.S. surplus, I show in this section that the USP may be effective when the 50-50 division of tolls is also enforced.

Under the independent demand assumption, it is reasonable to assume that the decisions to carry inbound and outbound traffic are made independently. In fact, there are numerous examples from all three service segments where certain U.S. carriers, at certain times, have been set up to originate but not terminate traffic. Hence, the natural benchmark from which to judge the effects of the USP has already been derived. Under free bargaining, the equilibrium charge for access to the U.S. network equals marginal cost ($a^U = c$), and the price paid by U.S. firms is that derived in Chapter 3 ($a^M = a^N$).

Turning to the regime where the USP is enforced, the 50-50 division of tolls introduces two complications in markets with two-way traffic. First, any change in the uniform access charge (one satisfying both constraints) affects not only each carriers revenues from inbound traffic, but also its own marginal cost of producing outbound calls. Therefore, each firm considers both the revenue effect on incoming calls and the effect on its own marginal cost when it negotiates the uniform access charge. Second, despite the 50-50 division the foreign monopolist can still threaten to reallocate U.S. bound traffic away from U.S. carriers refusing to accept its terms. Although this threat is also available when the 50-50 division is not enforced, it does not alter the effects of the price discrimination constraint because a^U is competed down to c in either regime. Under the 50-50 division, however, U.S. inbound traffic is profitable for all $a > c$. If the equilibrium uniform access charge turns out to be greater than marginal cost, then this threat will be important. The first task is to determine how this influences the equilibrium access charge under the USP.

With two-way traffic slightly more notation is needed. The inverse demand for calls originating overseas is F(y). The monopoly output of the foreign monopolist is y(a), where a is the uniform access charge. Each firm's total profit flow now includes the revenues received from overseas for inbound traffic. Let I(a) = (a - c)y(a) be the total net revenues received by U.S. firms for inbound traffic. Letting ρ_i be the fraction of U.S. bound traffic received by firm i, the monopoly and Cournot equilibrium profits of firm i are

$$(5.1) \qquad \tilde{\pi}_m(a) = \pi_m(a) + I(a)$$

and

$$(5.2) \qquad \tilde{\pi}_i(a,\rho_i) = \pi(a) + \rho_i I(a)$$

where π_m and π are the monopoly and Cournot equilibrium profits earned by firm i in the market for traffic originating in the U.S. The foreign monopolist's profits from agreeing to the uniform access charge with one firm, and with both firms are

$$(5.3) \qquad U_m(a) = F(y(a))\, y(a) - (a + c)y(a) + (a - c)x_m(a)$$

and

$$(5.4) \qquad U(a) = F(y(a))\, y(a) - (a + c)y(a) + (a - c)X(a)$$

where x_m is the monopoly output and X is the total Cournot equilibrium output in the U.S. $\tilde{\pi}_m$, $\tilde{\pi}_i$, U_m, and U are all assumed to be strictly concave in a.

Under the USP, the price set by the foreign monopolist when it *exercises price leadership* with both U.S. firms in production is

$$(5.5) \qquad a^{M*} \equiv \text{argmax } \{U(a) \mid a \geq c\}$$

The price each U.S. firm would unilaterally set if it were to receive all U.S. bound traffic is

$$(5.6) \qquad a^{U*} \equiv \text{argmax } \{\pi(a) + I(a) \mid a \geq c\}$$

I focus attention on situations in which firms always agree to carry two-way traffic. The requirement that the access charge be greater than marginal cost in both (5.5) and (5.6) reflects the assumption that carriers can refuse to accept unprofitable inbound traffic. While one can imagine carriers contemplating agreements to operate at less than marginal cost, this would create incentives for each carrier to reduce inbound traffic by blocking circuits or quality degradation. That is, such an agreement would be inherently unstable.

Bargaining Equilibrium

To see how the threat to reallocate U.S. bound traffic can be used by the foreign monopolist when the USP is enforced, let us return to the telegram game introduced in Chapter 3. At time zero one of the U.S. carriers, say firm 1, is randomly designated as the first to meet with the monopolist. Bargaining proceeds in the same way, except now the monopolist decides how to allocate U.S. bound traffic across U.S. firms. Suppose that the monopolist adopts the strategy of always allocating all this traffic to the first U.S. carrier to reach agreement. That is, in its meeting with firm 1, the monopolist threatens to take all of this traffic to firm 2 if it doesn't get the agreement it prefers. This threat to reallocate is credible, since the monopolist is indifferent between which firm carries its traffic in any equilibrium under the USP.

As before, attention is restricted to stationary equilibrium where each agent plans to offer the same price in every period. Let the foreign monopolist's offer be $a^*(\delta)$; let that of each U.S. firm be $\hat{a}(\delta)$. A necessary condition for these prices to be SSPE is that they solve

$$(5.7) \qquad g(a^*,\hat{a}) \equiv \underset{a \geq c}{\operatorname{argmax}} \; \pi(a) + I(a)$$

$$\text{s.t.} \quad (1 - \delta)\, U_m(a) + \delta\, U(a)$$

$$\geq \frac{\delta}{2}\left[(1 - \delta)\, [U_m(a^*) + U_m(\hat{a})] + \delta\, [U(a^*) + U(\hat{a})] \right]$$

$$(5.8) \qquad h(a^*, \hat{a}) \equiv \underset{a \geq c}{\text{argmax}}\ (1 - \delta)\, U_m(a) + \delta\, U(a)$$

$$\text{s.t.} \qquad (1 - \delta)\, \pi_m(a) + \delta\, \pi(a) + I(a) \geq \frac{\delta^2}{2} [\pi(a^*) + \pi(\hat{a})]$$

and

$$(5.9) \qquad a^* = h(a^*, \hat{a}), \qquad \hat{a} = g(a^*, \hat{a}).$$

To reflect the belief that bargaining costs are small relative to the discounted value of profits available I focus on the limiting equilibrium as $\delta \to 1$.

<u>Proposition 5.2</u>. Under the USP, there exists a SSPE to the telegram game in which $\lim_{\delta \to 1} a^*(\delta),\ \hat{a}(\delta) = a^{M*}$.

<u>Proof</u>: Since each carrier's profits are strictly concave, there is a compact, convex region over which the foreign monopolist and each U.S. carrier have a conflict of interest. By the theorem of the maximum (eg. Varian 1984, 327), h and g are continuous functions over this region. Hence, Brouwer's fixed point theorem implies that a solution to equations (5.9) exists, and therefore a SSPE exists. I now consider three possible cases that can occur, and demonstrate that there is a SSPE in which the monopolist exercises price leadership in each case.

Case 1: $a^{M*} > c$, $a^{U*} > c$. Suppose a^* converges to $\bar{a} \neq a^{M*}$. For the constraint in (5.7) to hold for δ close to one, it is clear that $\hat{a}$ also converges to $\bar{a} \neq a^{M*}$. Then, since $I(\bar{a}) > 0$ for all access charges between a^{M*} and a^{U*}, the monopolist can offer an access charge slightly more favorable to itself and still expect either U.S. carrier to accept. For, by rejecting, that carrier loses its entire profit from inbound traffic, which is greater than the loss due to accepting a slightly less favorable access charge. Hence, $a^*(\delta)$, $\hat{a}(\delta) \to a^{M*}$ in this case.

Case 2: $a^{M*} = c$, $a^{U*} > c$. The argument is similar to that in case 1. For all $\bar{a} > c$, there exists an offer slightly lower than $\bar{a}$ such that firm 1 accepts for fear of losing its inbound traffic.

Case 3: $a^{U*} = c$, $a^{M*} > c$. By arguments similar to those in cases 1 and 2, it is clear that $a^*(\delta)$ and $\hat{a}(\delta)$ do not converge to the interior of the interval between a^{M*} and a^{U*}. I construct an equilibrium in this case in which it converges to a^{M*}. Suppose that in every period the monopolist plans to offer

$$(5.10) \qquad \tilde{a}(\delta) \equiv \text{argmax } \{(1 - \delta)U_m(a) + \delta U(a) \mid a \geq c\},$$

and U.S. carriers each plan to offer $a'(\delta)$, given by $a'(\delta) = g(\tilde{a}(\delta), a'(\delta))$ (It is easy to verify that such an a' exists). These are SSPE offers if and only if $\tilde{a}(\delta) = h(\tilde{a}(\delta), a'(\delta))$.

Since the monopolist's profits are monotonic over the range relevant for bargaining, the constraint in (5.7) (which binds for δ close to one) implies that $a'(\delta) \to \tilde{a}(\delta)$ as $\delta \to 1$. Therefore, since $I(\tilde{a}(\delta)) > 0$ for all δ close enough to one,

$$(1 - \delta)\pi_m(\tilde{a}(\delta)) + \delta\pi(\tilde{a}(\delta)) + I(\tilde{a}(\delta)) > \frac{\delta^2}{2}[\pi(\tilde{a}(\delta)) + \pi(a'(\delta))]$$

for all such δ. That is, $\tilde{a}(\delta) = h(\tilde{a}(\delta), a'(\delta))$ for δ close to one, verifying that $\tilde{a}$ and a' are SSPE. Clearly, $\tilde{a}(\delta) \to a^{M*}$ as $\delta \to 1$. Q.E.D.

Contrary to the argument usually presented by the FCC, Proposition 5.2 argues that the USP *allows* the foreign monopolist to exercise price leadership. Intuitively, the threat to reallocate profitable U.S. bound traffic away from U.S. carriers refusing its terms is enough to give the foreign monopolist complete price setting power. Observe, however, that in case 2 the monopolist unilaterally sets the uniform access charge equal to marginal cost, while in case 1 it may set it significantly higher. This provides a preview of why the policy may either benefit or harm U.S. ratepayers.

The Price and Revenue Effects of the USP

The main utility of Proposition 5.2 is that it allows the effects of the USP to be studied by examining a simple constrained optimization problem. Whether the policy increases or decreases the access charge paid by U.S. carriers hinges on whether granting foreign monopolies price setting power yields an access charge higher or lower than a^N.

Under the USP the foreign monopolist solves

$$(5.11) \quad \max \{F(y(a))\, y(a) - (a + c)\, y(a) + (a - c)\, X(a) \mid a \geq c \}$$

Recognizing that y(a) is the optimal level of output for any a, the Kuhn-Tucker necessary conditions are

$$(5.12) \quad - y(a^{M*}) + X(a^{M*}) + (a^{M*} - c) \frac{\partial X(a^{M*})}{\partial a} + \lambda = 0,$$

$$\lambda \geq 0, \quad a^{M*} - c \geq 0, \quad \lambda(a^{M*} - c) = 0.$$

Since $\partial X/\partial a < 0$, the constraint binds ($a^{M*} = c$) whenever $X(a^{M*}) < y(a^{M*})$. Hence, the USP lowers the uniform access charge to marginal cost in markets where the net flow of traffic is inbound to the U.S. Interestingly, this is also the solution to the following second best problem: Maximize world welfare (the sum of producer and consumer surplus) subject to 1) monopoly pricing in the foreign country, 2) Cournot pricing in the U.S., and 3) making individually rational each carrier's decision to receive inbound traffic. Hence, there is a normative justification for the USP in markets where the net traffic flow is inbound to the U.S. Notice that the informational requirements for this policy are very weak. If demands are approximately independent all the FCC needs to do is observe whether the net traffic flow is inbound to the U.S. when the USP is enforced to the net traffic flow is inbound to the U.S. when the USP is enforced to determine whether the policy is having a beneficial effect. This test has already been carried out in the telex market.

For $X(a^{M*}) > y(a^{M*})$ the constraint in (5.11) no longer binds, and $a^{M*} > c$. Whether a^{M*} is higher or lower than a^N depends on the relative volumes of U.S. outbound and inbound traffic. To see this, introduce the shift parameter $\alpha \in [0,\infty)$ into the derived demand for access to the U.S. network by writing it as $y(a,\alpha)$, where $\partial y/\partial\alpha > 0$, $\partial^2 y/\partial\alpha^2 = 0$, and $y(a,0) = 0$. As α approaches zero, foreign outbound traffic falls to zero, and $a^{M*}(\alpha)$ approaches $a^L \equiv \text{argmax } \{(a - c)X(a) \mid a \geq c\}$. As α approaches infinity, foreign outbound traffic grows relative to U.S. outbound traffic, and a^{M*} approaches c. Since $c < a^N < a^L$, the continuity of y and U implies that for some α', $a^{M*}(\alpha') = a^N$. Since $a^{M*}(\alpha)$ is monotonically decreasing in α,[3] it follows that for all $\alpha < \alpha'$, $a^{M*}(\alpha) > a^N$.

Since final product price is an increasing function of the uniform access charge under Cournot competition, these conclusions can be summarized as follows.

<u>Proposition 5.3</u>. The uniform settlements policy reduces the price of U.S. service whenever, under the USP, the volume of traffic originating overseas, $y(a^{M*},\alpha)$, is greater than the volume originating in the U.S., $X(a^{M*})$. When $X(a^{M*}) > y(a^{M*},\alpha)$, the effects of the USP are

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[3]That is, $\partial a^{M*}/\partial\alpha = (\partial y/\partial\alpha)/U'' < 0$ by the sufficient second order condition to (5.11).

are uncertain. However, there exists α' such that for all $\alpha \in [0,\alpha')$ the USP raises the price of U.S. service.

Notice that when $X < y$ the USP also increases the revenues of U.S. carriers. This is because the charge for access to the U.S. equals marginal cost in either regime, while that paid by U.S. carriers in the unconstrained regime (a^N) is higher than that paid under the USP (c). On the other hand, there are some values of α for which the USP raises U.S. price but also raises the revenues of U.S. carriers. This follows because when $\alpha = \alpha'$, the USP raises the access charge paid U.S. carriers (from c to a^N) but leaves the charge they pay unchanged.

This is summarized as follows.

<u>Proposition 5.4</u>. The uniform settlements policy increases the revenues of U.S. carriers whenever, under the USP, the volume of traffic originating overseas is greater than the volume originating in the U.S. When $X(a^{M*}) > y(a^{M*},\alpha)$, the effects of the USP on U.S. revenues are uncertain. However, there exists $a'' < \alpha'$ such that for all $\alpha \in [0,\alpha'')$ the USP reduces U.S. revenues.

5.3 Policy Implications

These propositions give the policy maker some basis for judging the efficacy of the USP. In the telex segment, U.S. firms carry more inbound than outbound traffic in most foreign markets. Hence, Proposition 5.3 suggests that the policy reduces the price of final service; Proposition 5.4 suggests that it raises the revenues of U.S. carriers.

It is instructive to consider the important role of the 50-50 division of tolls in this result. In the unconstrained regime, Bertrand competition drives a^U down to marginal cost, while $a^M = a^N \in (c, a^L)$ because U.S. carriers have some bargaining power in determining the access charge they pay. Recall the effects of enforcing only the price discrimination constraint. Bertrand competition still drives a^U down to marginal cost, but the foreign monopolist now has more control over the price for access to its own network. This is the worst possible scenario -- the monopolist has more control over the price it charges, but no less control over the price it pays U.S. firms.

Adding the 50-50 division forces the monopolist to consider how raising the access charge affects its own marginal cost of outbound traffic. It effectively operates as a commitment by the FCC to retaliate by raising the charge for access to U.S. networks whenever the foreign monopolist raises the charge for access to its own. In setting the charge, the monopolist takes into account both changes in revenues from traffic inbound from the U.S. as well as the automatic retaliation of the U.S. When its own inbound traffic is unimportant relative to its outbound traffic, the foreign monopolist sets a low access charge to reduce its marginal cost. It is important to note, however, that only in the presence of the 50-50 division of tolls does this welcome result occur. This strongly recommends maintaining the

50-50 division in the telex market.

Interestingly, the decline in telex access charges from 1971 to the present closely follows a similar decline in satellite utilization charges. These charges are a major component of U.S. carriers' marginal cost.[4] In 1971 the per half-circuit charge fell from about $2400 per month to about $1800. It was constant throughout most of the 1970s, but then fell from $1800 to about $800 between 1977 and 1982. Access charges for service between the U.S. and CEPT countries followed similar patterns. They were initially set at $1.50, fell to $1.125 in 1971, and then declined as follows: July 1977, $1.05; July 1978, $.985; January 1981, $.69. Conditional on the 50-50 division of tolls, the revenue effects of these declines all favored the PTTs in the CEPT countries. Moreover, there were cases where certain U.S. carriers were threatened with the loss of U.S. bound traffic if their agreement could not be obtained. While it is not known whether these declines would have occurred in the absence of the USP, they are broadly consistent with the predictions of the telegram game.

The voice and telegraph segments of the market are different stories altogether. Proposition 5.3 suggests that the USP may raise the price of service in these markets, since the volume of traffic from the U.S. to the foreign country typically exceeds the volume flowing in

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[4]Satellite circuits are leased from *Comsat*, the U.S. signatory to the International Satellite Organization, from whom most international satellite circuits are obtained for telecommunications service. See Johnson (1987) for more details.

the opposite direction. The likelihood that it raises prices grows as U.S originated traffic grows relative to that originated overseas.

Recall the CEPT and COMTELCA telegrams discussed in Chapter 2. Both CEPT and COMTELCA had been trying to negotiate access charge increases in the telegraph market for quite some time before sending out those telegrams. Finally, each determined that the only way to effect the change was to threaten to terminate the operating agreements or to reallocate traffic away from U.S. carriers refusing to agree. Since the access charge increases were substantial, one might surmise that the volume of U.S. originated telegraph traffic was much larger than the volume flowing in the opposite direction. This was indeed the case. For service to the COMTELCA countries, U.S. originated traffic was over three times larger than traffic flowing in the opposite direction for all countries except El Salvador. Similarly, the volume of U.S. outbound traffic was double that of inbound traffic in many of the CEPT countries.

Again, these observations do not say whether a similar increase in access charges would have occurred in the absence of the USP. However, marginal operating costs almost certainly did not rise before the telegrams. And it appears that neither CEPT nor COMTELCA was exercising the price leadership power prior to the telegrams. If this is true, the telegrams, along with the disproportionate traffic flows are consistent with the view that both consortia recognized their price setting power in 1983 and exercised it.

In the *Order on Reconsideration* (FCC 1987), the FCC was careful to point out that "uniformity is not an end in itself." They state that "departures from uniformity are permissible if the particular departure does not conflict with [the] objectives [for fair treatment of U.S. carriers, and low rates for U.S. consumers]" (FCC 1987, 1118). The mechanism allowing non-uniformity to occur is simple. The carrier desiring to operate at a non-uniform rate applies to the Commission for a waiver of the policy, and if the Commission takes no action after some amount of time (60 days for telex and telegraph, 10 days for voice) the application is granted.[5]

While there are numerous examples of strong enforcement in telex (usually leading to lower access charges), the early indications are that the weaker stance adopted toward voice is being born out in practice. Indeed, between 1985, the year MCI and Sprint entered the voice market, and February 1987 the FCC received 37 applications for waiver of the USP for voice service to a total of 61 countries. None of those requests were opposed or even commented upon (FCC 1987, 1126).

If one takes the view that the burden of proof rests on policy makers for demonstrating the need for the USP, the *per se* approach adopted in telex and the *rule of reason* approach adopted in voice are consistent with the sharp predictions of the telegram game in telex, its ambiguous predictions in voice. This same view, however, would recommend a rule of reason approach in the telegraph market, an approach that does not seem to have been adopted there.

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[5]See Appendix A for a summary of the waiver procedure.

6. Conclusion

This dissertation argues that the uniform settlements policy, and more generally, forbidding third degree price discrimination can have adverse welfare consequences. It develops a model that endogenously determines the degree to which an upstream monopolist controls input prices. In international telecommunications, the uniform settlements policy is shown to reduce the price of outbound U.S. calls whenever, under the USP, the net flow of traffic is inbound to the U.S. However, the price of U.S. calls may increase if the difference between U.S. outbound and inbound traffic is positive and sufficiently large. Unfortunately, the model does not provide enough information to suggest how large the difference must be.

The bargaining model yielding these results is relatively general. In a world where firms bargain over the price of intermediate goods, upstream monopolists who cannot credibly refrain from bargaining with additional unsigned buyers cannot exercise price leadership when the time between successive offers is small. In contrast, forbidding price discrimination provides the monopolist with a credible commitment to refrain from bargaining with the last unsigned buyer. This results in higher equilibrium prices than when price discrimination is not forbidden.

Nevertheless, many simplifications were made, and many issues warrant further exploration. AT&T is likely to maintain a large market share in the voice market well into the future. This suggests that a model in which downstream firms differ in costs, perceived quality, or some other dimension of product differentiation may be more appropriate for analyzing the voice segment, at least during the transition to more symmetric rivalry. One could also relax the assumption that the number of U.S. carriers is fixed. The possibility of entry and the existence of large fixed costs in this market may constrain a foreign monopoly's ability (or its desire) to increase access charges in the regime where the USP is enforced. The assumption of independent demands is also quite restrictive. One might want to allow for interdependent demands that also incorporate international call externalities. My guess, however, is that this would significantly complicate the analysis of the bargaining model.

It is clear that there are many other ways that the model could be generalized in an attempt to better reflect the real world. But the main insight that I conjecture will turn out to be robust to many generalizations is the conclusion that forbidding price discrimination transfers at least some bargaining power to the foreign monopolist. Even when enforcing the USP benefits U.S. ratepayers (when U.S. firms carry more inbound than outbound traffic) the reason is that it transfers bargaining power to the foreign monopolist whose objectives happen to match those of U.S. ratepayers. In essence, the USP provides the foreign monopolist with 1) a credible commitment to refrain from bargaining with additional U.S. carriers after an initial access charge has been set, and 2) a credible threat to reallocate traffic away from U.S. firms refusing its terms. Together, these two effects may give the monopolist complete control over the uniform access charge. Whether the USP benefits or harms U.S. ratepayers depends on how closely the objectives of the foreign monopolist match those of U.S. ratepayers.

It does not appear that current FCC officials view the USP as operating in this manner. To the extent that the telegram game captures some of the important strategic features present in the international telecommunications market, my conclusions demonstrate how the strategic approach to bargaining can shed light on problems that previously were not well understood.

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Appendix A: Summary of the Uniform Settlements Policy

This appendix summarizes the current international settlements policy of the FCC as put forth in the *Report and Order, In the Matter of Implementation and Scope of the Uniform Settlements Policy for Parallel International Communications Routes* (FCC 1986) and the subsequent *Order on Reconsideration* (FCC 1987). Uniformity, when imposed, consists of precisely the two constraints discussed in the Introduction:

1) *the price discrimination constraint*, requiring that access charges paid or received by all U.S. carriers to or from a particular foreign monopoly must be equal, and

2) the *50-50 division of tolls*, requiring that the access charge paid by U.S. carriers to a particular foreign monopoly must be equal to the charge paid by that foreign monopoly to U.S. carriers.

Departures from uniformity may arise when a carrier's application to the FCC for a waiver goes unchallenged by the Commission. The regulatory requirements are more stringent in telex and telegraph than they are in voice; hence, waivers are more easily obtained in voice. The following is a description of the waiver procedures.

The Telex and Telegraph Procedure: The 60-day Semi-Automatic Grant

Each application to the Commission for waiver of the USP must contain:

1) A description of the existing agreement and the proposed new or modified agreement.
2) A projection of the revenue effect on the proponent carrier.
3) A projection of the overall revenue effect on the U.S. industry.
4) A statement as to whether changes in the methods of allocating return traffic among U.S. carriers were included in the negotiations leading to the change; and if so, to what effect.
5) A statement as to whether there was any attempt by the PTT(s) involved to secure concessions in the access charge through any measures (such as reallocations of return traffic or other special concessions) that would indicate whipsawing.

The application is placed on Public Notice, beginning a 60 day timetable. During the first 21 days, other carriers and/or the general public may file objections or comments. Thereafter, reply comments may be filed by the applicant within 10 days. In the remaining 29 day period, the Commission staff reviews the waiver application, any objections or comments, and the replies to those comments. The staff can raise objections either *sua sponte* or in response to the submitted filings. After 60 days, the Commission will either:

1) Take no formal action, in which case the application for waiver is deemed granted on the 61st day,

2) Write a staff letter requiring additional information,

3) Write a staff letter indicating that opposition was filed but that the filing was found to be without merit in which case the waiver is granted on the 61st day, or

4) Write a staff letter indicating that the waiver petition raises complex issues or is opposed, and thus must await formal action by order or letter rather than being automatically granted.

Voice Procedure

Any carrier intending to establish a non-uniform access charge must serve notice to that effect to the Commission at least 21 days prior to proposed effective date of the new charge. This notice must also be served on all carriers providing service to the point in question. Any carrier may submit an informal written protest of the intended action within 10 days of service of the notice. Absent a Common Carrier Bureau determination to the contrary, the new access charge becomes effective upon the proposed date.

Appendix B: Proofs for Chapter 3

Proof of Lemma 3.1. The proof follows a line of argument similar to that first adopted by Shaked and Sutton (1984).

Existence

Let m_t be the infimum of all the SPE payoffs received by the monopolist in any subgame (i.e. a subgame of this subgame) beginning at time t, when it is the monopolist's turn to make an offer. By By Property 3.3, π_i is strictly decreasing over the set $A_i(\bar{a}_j)$. Therefore, there exists a unique offer, a_t, such that $\pi_i(a_t,\bar{a}_j) = m_t$. Since the monopolist receives at least $U_i(a_t,\bar{a}_j)$ at time t, firm i can receive at most $\pi_i(a_{t-1},\bar{a}_j)$ at time t-1 when it offers, where $a_{t-1} = g(a_t,\bar{a}_j)$. Similarly, at time t-2 the monopolist can then receive at least $U_i(a_{t-2},\bar{a}_j)$ where $a_{t-2} = h(a_{t-1},\bar{a}_j)$. Note that the subgame (of this subgame) beginning at time t is identical to that beginning at time t-2. Therefore, $a_t = a_{t-2}$.

Now, in the preceding paragraph replace the word "infimum" with "supremum" and interchange the words "at most" with "at least". An identical argument then implies that m_t is also the supremum over all the SPE payoffs received by the monopolist in any subgame beginning at time t. Therefore, all SPE payoffs satisfy the equations of the preceding paragraph.

Given $\bar{a}_j$, define the map $Z: A_i(\bar{a}_j) \rightarrow A_i(\bar{a}_j)$ by

$Z(a,\bar{a}_j) \equiv h(g(a,\bar{a}_j),\bar{a}_j)$. By the theorem of the maximum (Varian 1984, 327), h and g are continuous, and therefore Z is continuous. The set $A_i(\bar{a}_j)$ is a compact and convex line segment. By the Brouwer fixed point theorem, Z has at least one fixed point. Let $S_i(\bar{a}_j)$ be the fixed point of Z. Then $S_i(\bar{a}_j)$ and $R_i(\bar{a}_j) \equiv g(S_i(\bar{a}_j),\bar{a}_j)$ are the SPE offers of the monopolist and firm i respectively, and it is easy to see that the accept/reject decisions in the Lemma are optimal given S_i and R_i.

Uniqueness

Note that $g(a,\bar{a}_j) = V_i(a,\bar{a}_j)$ and $h(a,\bar{a}_j) = V_{Mi}(a,\bar{a}_j)$ for all $a \in A_i(\bar{a}_j)$, where V_i and V_{Mi} are given in equations (3.11) and (3.12). By Property 3.5,

$$\begin{aligned} a' - a &> g(a',\bar{a}_j) - g(a,\bar{a}_j) \\ &> h(g(a',\bar{a}_j),\bar{a}_j) - h(g(a,\bar{a}_j),\bar{a}_j) \\ &= Z(a',\bar{a}_j) - Z(a,\bar{a}_j), \end{aligned}$$

which implies that Z is a contraction map. Therefore, S_i and R_i are the unique SPE offers to the subgame. Q.E.D.

<u>Verification of Property 3.6</u>. In any SPE, the constraint in problem (3.13) binds. For, if it didn't, firm i could reduce its offer, increasing its profits without violating the constraint. The constraint in problem (3.14) may or may not bind. If it doesn't,

then $S_i'(\bar{a}_j) = 0$, and Property 3.6 follows from Properties 3.3 and 3.4.

But suppose both constraints bind. Substituting equations (3.6) - (3.10) into the constraints yields

(B.1)

$$\frac{\delta(\alpha - 2S_i + \bar{a}_j - w)(2S_i - \bar{a}_j - c)}{6\beta} = \frac{(\alpha - 2R_i + \bar{a}_j - w)(2R_i - \bar{a}_j - c)}{6\beta}$$

and

(B.2) $$\frac{(\alpha - 2S_i + \bar{a}_j - w)^2}{9\beta} = \frac{\delta(\alpha - 2R_i + \bar{a}_j - w)^2}{9\beta}.$$

Differentiating this system with respect to $\bar{a}_j$, it is easy to verify that $S_i'(\bar{a}_j) = 1/2$. Since U is concave,

$$\frac{\partial^2 U}{\partial a_i^2} + \frac{\partial^2 U}{\partial a_j^2} S_i'(\bar{a}_j) = \frac{\partial^2 U}{\partial a_i^2} + \frac{1}{2}\frac{\partial^2 U}{\partial a_j^2} < 0,$$

and since $\partial\pi_i/\partial a_i = -(1/2)\,\partial\pi_i/\partial a_j < 0$,

$$\frac{\partial \pi_i}{\partial a_j} + \frac{\partial \pi_i}{\partial a} S_i(\bar{a}_j) = \frac{1}{4}\frac{\partial \pi_i}{\partial a_i} < 0.$$

These equations verify Property 3.6.

Appendix C: Proofs for Chapter 4

Property 4.1. In an interior symmetric equilibrium,

$$(C.1) \qquad P_y(ny)y + P(ny) - V_y(y,a) = 0.$$

Differentiating (C.1) with respect to n yields

$$(C.2) \qquad \frac{\partial y}{\partial n} = \frac{-y(P_{yy}\, y + P_y)}{\Delta},$$

where $\Delta = nP_{yy}y + (n + 1)P_y - V_{yy}$. By Assumption 4.3, $\Delta < 0$, and by Assumption 4.4, the numerator is positive. Hence, $\partial y/\partial n < 0$.

$\partial Y/\partial n$ is given by

$$(C.3) \qquad \frac{d(ny)}{dn} = y + n\frac{\partial y}{\partial n}$$

$$= \frac{nP_{yy}y^2 + (n + 1)\, P_y y - V_{yy}y - ny(P_{yy}y + P_y)}{\Delta}$$

$$= \frac{(P_y - V_{yy})y}{\Delta} > 0.$$

The derivatives $\partial x/\partial n$ and $\partial y/\partial n$ have the same sign since x is a normal input; similarly, $\partial X/\partial n$ has the same sign as $\partial Y/\partial n$.

Property 4.2. First, it is necessary to derive expressions for $\partial y_i/\partial a_i$ and $\partial y_i/\partial a_j$. Consider the maximization problems of firm i, and of the n - 1 firms other than i, each of which will be referred to as firm j in symmetric equilibrium. Imposing symmetry on firms other than i, the first order conditions for firm i and each j are

$$P_y(y_i + (n-1)y_j)\, y_i + P(y_i + (n-1)y_j) - V_y(y_i, a_i) = 0, \tag{C.4}$$

and

$$P_y(y_i + (n-1)y_j)\, y_j + P(y_i + (n-1)y_j) - V_y(y_j, a_j) = 0. \tag{C.5}$$

Differentiating with respect to a_i, imposing $y_i = y_j \equiv y$, and solving using Cramer's rule yields

$$\frac{\partial y_i}{\partial a_i} = \frac{V_{ya}\left[P_{yy}y(n - 1) + nP_y - V_{yy} \right]}{D}, \tag{C.6}$$

and

$$\frac{\partial y_j}{\partial a_i} = \frac{- V_{ya}\left[P_{yy}y + P_y \right]}{D}, \tag{C.7}$$

where $D = (P_y - V_{yy})(nP_{yy}y + (n + 1)P_y - V_{yy})$. It is easily seen that Assumptions 4.1 - 4.4 imply that $\partial y_i/\partial a_i < 0$ and $\partial y_i/\partial a_j > 0$.

Now, $\pi_{i,n}(\mathbf{a}) = P(y_i(\mathbf{a},n) + (n-1)y_j(\mathbf{a},n))y_i(\mathbf{a},n) - V(y_i(\mathbf{a},n),a_i)$. Differentiating with respect to a_i, imposing symmetry, and recognizing that y_i satisfies (C.4) at its optimal value yields

$$\text{(C.8)} \qquad \frac{\partial \pi_{i,n}}{\partial a_i} = P_y(n - 1)\frac{\partial y_j}{\partial a_i} y - x < 0$$

since $\partial y_j/\partial a_i > 0$.

Next, consider what happens to $d\pi_{i,n}/da$ as $n \to \infty$. Notice that as $n \to \infty$, $y, x \to 0$. For, if this were not the case then $Y = ny$ would be unbounded, contradicting Assumption 4.1. Totally differentiating $\pi_{i,n}$ with respect to a yields

$$\text{(C.9)} \qquad \frac{d\pi_{i,n}}{da} = [nP_y y + P - V_y]\frac{dy}{da} - x,$$

where dy/da is easily found to be $V_{ya}/[nP_{yy}y + (n + 1)P_y - V_{yy}]$. Since V_{ya} is bounded above zero (Assumption 4.2), $dy/da \to 0$. Thus, since the term in brackets is bounded and $x \to 0$, $d\pi_{i,n}/da \to 0$.

<u>Property 4.3</u>. Suppose $a_i = a$, and $\mathbf{a}_{-i} = (a,\ldots,a)$. By Property 4.1,

$$\text{(C.10)} \qquad U_{i,n}(a,\ldots,a) = (a - c)\,[X(a_i,\mathbf{a}_{-i}) - X(\mathbf{a}_{-i})] = 0$$

implies that $a = c$. Differentiating with respect to a_i yields

$$\text{(C.11)} \qquad \frac{\partial U_{i,n}(c,\ldots,c)}{\partial a_i} = x_i(c,\ldots,c) > 0.$$

<u>Property 4.4</u>. Differentiating $\pi_{i,n}$ with respect to n and substituting in (C.1) yields

$$\text{(C.12)} \quad \frac{\partial \pi_{i,n}}{\partial n} = \frac{P_y y^2 [P_{yy} y + 2P_y - V_{yy}]}{\Delta} < 0.$$

To verify the second part, suppose K = 0. Since $y \to 0$ as $n \to \infty$, it follows from (C.1) that

$$P(ny(a,n)) \to V_y(y(a,n),n) \to \frac{V(y(a,n),a)}{y(a,n)}$$

which implies that

$$\pi_{i,n} = \left[P(ny(a,n)) - \frac{V(y(a,n),a)}{y} \right] y - K \to -K < 0.$$

Since $\pi_{i,n}$ is continuous, it follows from the intermediate value theorem that, if there exists any n such that $\pi_{i,n} > 0$, then there exists N′(K,a) such that $\pi_{i,N'}(a,\ldots,a) = 0$.

<u>Proof of Proposition 4.6</u>. Suppose K = 0. For convenience let us recall equation (4.6) which characterizes equilibrium:

$$\text{(C.13)} \qquad \frac{\partial U_{i,N}(\mathbf{a}^0)}{\partial a_i} \pi_{i,N}(\mathbf{a}^0) + \frac{\partial \pi_{i,N}(\mathbf{a}^0)}{\partial a_i} U_{i,N}(\mathbf{a}^0) = 0.$$

Differentiating $U_{i,N}$, substituting from (C.8), and multiplying by $\Delta(P_y - V_{yy})/y^2$, the first term in (C.13) becomes

$$\text{(C.14)} \qquad \frac{[\Delta x + (a - c)V_{ay}]\ [P_y - V_{yy}]\ [P - W/y]}{y},$$

and the second term becomes

(C.15)

$$\frac{\left[-(n-1)V_{ya}yP_y(P_{yy}y + P_y) - \Delta x(P_y - V_{yy})\right] (a - c)[X(a,n) - X(a,n-1)]}{y^2} .$$

Now, suppose that as $n \to \infty$, $nx \to \bar{X}$, and $ny \to \bar{Y}$. Then it is straightforward to verify that

(C.16) $\Delta x \to P_y\bar{X},$

and

(C.17) $$\frac{(P - W/y)}{y} \to \frac{(P - V_y)}{y} = -P_y .$$

Moreover, since $X(a,n) - X(a,n-1) \to 0,$

(C.18) $$\frac{(a - c)[X(a,n) - X(a,n-1)]}{y^2} \to \frac{(a - c)\frac{\partial \bar{X}(a,n)}{\partial n}}{y^2}$$

$$\to \frac{(a - c)\frac{d\bar{X}}{d\bar{Y}}\frac{\partial \bar{Y}}{\partial n}}{y^2}$$

$$\to \frac{(a - c)\frac{d\bar{X}}{d\bar{Y}}(P_y - V_{yy})\bar{Y}}{ny^2[P_{yy}\bar{Y} + (1 + n)P_y - V_{yy}]}$$

$$\rightarrow \frac{(a - c)\frac{d\bar{X}}{d\bar{\bar{Y}}} (P_y - V_{yy})}{P_y\bar{Y}}$$

where dX /dY > 0 reflects how total equilibrium factor demand changes as total output changes. Substituting (C.16) - (C.18) into (C.14) and (C.15), adding them, and taking the limit as $n \rightarrow \infty$ yields

$$\text{(C.19)} \quad P_y\bar{X} + (a - c)V_{ya} + \frac{[P_yV_{ya}\bar{Y} + (P_y - V_{yy})\bar{X}](a - c)\frac{\partial\bar{X}}{\partial\bar{\bar{Y}}}}{P_y\bar{Y}} = 0.$$

Now, to demonstrate that price leadership does not occur in the limit, it must be demonstrated that $dU_n(a^0,\ldots,a^0)/da \rightarrow L > 0$. Note

$$\frac{dU_n}{da} = n\frac{\partial U_{i,n}}{\partial a_i}$$

$$= \frac{n[\Delta x + (a - c)V_{ya}]}{\Delta}$$

$$\rightarrow \frac{P_y\bar{X} + (a - c)V_{ya}}{P_y}$$

which is positive if and only if $P_y\bar{X} + (a - c)V_{ya} < 0$. Since the third term in (C.19) is strictly positive, it is, in fact, positive. Hence, price leadership does not occur in equilibrium under free bargaining in the limit as $n \rightarrow \infty$. Q.E.D.

Curriculum Vitae

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