A Study on Regulatory Policies in the International Telephone Markets

Theory and Empirical Evidence

by

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Abstract

The provision of international telephone calls requires a settlement arrangement between countries in traffic exchanges. A call-termination charge, or "settlement rate", is paid from the call-initiating country to the terminating one. Around 1980, the U.S. government attempted to improve efficiency by unilaterally introducing competition into its domestic market, supplemented with rules on carriers designed to avoid an unfavorable position in settlement negotiations with other countries. In particular, the FCC required all U.S. carriers to act collectively when negotiating settlement rates with foreign carriers and apply a Proportional Return Rule (PRR) to share foreign settlement income in accordance with their market shares of outbound. The dissertation tries to evaluate the FCCs policies and identify the factors that can derive the market efficiency.

Chapter 2 analyzes a scenario that competing carriers in a country jointly determine a uniform settlement rate for foreign incoming traffic. Under the PRR,, an increase in domestic competition reduces retail prices but also increases net settlement payments to other countries. Moreover, fixing the level of retail competition, the PRR cannot reduce retail prices, but increases the U.S.'s net settlement payments, contrary to the FCC's intent.

Chapter 3 discusses two other scenarios. The first one is that carriers from two countries choose settlement rates in a cooperative fashion of Nash bargaining. The equilibrium settlement rate is lower than the one under non-cooperative regime. The second model, multiple routes relaxes the Uniformity requirement. When there are multiple routes to exchange traffic between two countries, or there is competition at the settlement services, the retail competition can steer the market outcomes toward the efficient level.

Chapter 4 empirically examines the above theoretical predictions. I constructed a measurement of the intensity of the PRR for each international route in each year. I found empirical evidence that the rule did increase both the settlement rates and the net settlement payments made by the U.S. carriers. However, the rule's effect toward the retail price is unclear, possibly due to the model specification and the endogeneity issues. The empirical finding suggests that a multiple-route model matches the data better than the one with uniformity requirement.

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Chapter 1

Introduction

The completion of an international telephone call involves two major components: a domestic carrier collects the call and a foreign counterpart terminates the call by delivering it to the receiver. Access to the foreign carrier's network is an essential and complementary input for the domestic service provider. A service payment, often called a settlement rate, is made from the domestic to the foreign carrier. Moreover, international telephone calls typically flow in both directions and a carrier often provides both originating and terminating services, and thus derives two sources of revenues: retail and settlement revenues. As a major part of a carrier's marginal cost in providing international telephone services, the settlement rate can significantly affect the carrier's profit and consumer benefits, as well as overall efficiency in this market.

The U.S. was the first one in the world that introduced domestic competition into its international telephone market when the MCI entered to compete with the incumbent, AT&T in the late 1970's. To respond to this change and especially the potential harm from foreign monopoly carriers, the U.S. Federal Communications Commission (FCC) has revised its policies toward the international telephone markets several times. The major sets of the policies are following.

1. The International Settlements Policy (ISP) in 1987.

   The ISP was initially developed to prevent anticompetitive behavior on U.S.-international routes at a time when, in most countries, telephone service was provided by a monopoly carrier.

   > "The FCC established the policy to create a unified bargaining position for U.S. carriers because foreign carriers with monopoly power could take advantage of the presence of multiple U.S. carriers by whipsawing or engaging in anticompetitive behavior. Whipsawing generally involves the abuse of market power by a foreign carrier or a combination a carriers within a foreign market that is intended to play U.S. carriers against one another in order to gain unduly favorable terms and benefits in arrangements for exchange of traffic." [FCC, 1999]

   The ISP contains three elements, in a hope to ensure a competitive playing field among carriers which might eventually reduce the settlement rates and calling prices:

   (a) *"Uniformity"*. U.S. carriers all must be offered the same effective rate and same effective date (nondiscrimination). This means that if a foreign carrier offers a U.S. carrier a reduced settlement rate starting on a given date, it must offer that same rate to all U.S. carriers beginning on the same date.

(b) *"Proportional Return Rule (PRR)"*. U.S. carriers are entitled to a proportionate share of return U.S.-inbound traffic based upon their proportion of U.S.-outbound traffic. This means, for example, that if U.S. carrier traffic on the U.S.-France route accounts for 15% of the U.S. carriers traffic to a French carrier, that French carrier must send 15% of its calls to the U.S. through the U.S. carrier.

(c) *"Reciprocity"*. Settlement rates for U.S. inbound and outbound traffic are symmetrical (i.e., the accounting rate is divided 50-50 between the U.S. carrier and the foreign carrier).

2. 1997 Benchmarks Policy

International settlement rates are the most important component of the marginal cost of international telephone service. However, after implementing the ISP for nearly a decade, the FCC observed that international calling rates remained high, in spite of the fact that technological advances and competition were causing U.S domestic rates to fall. The agency started to realize that these rates remained high because in many countries, competition was non-existent or insufficient to drive settlement rates down to cost-based levels. In an effort to drive settlement rates closer to cost, the FCC exercised its jurisdiction over U.S. carriers in 1997 and prohibited them from paying inappropriately high rates to foreign companies to the detriment of U.S. consumers. Specifically, the FCC established its benchmarks policy with the goal of reducing above-cost settlement rates paid by U.S. carriers to foreign carriers for the termination of international traffic, where market forces had not led to that result. The benchmarks policy requires U.S. carriers to negotiate settlement rates at or below benchmark levels set by the Commission in its 1997 Benchmarks Order. The Benchmarks Order divided countries into four groups based upon economic development levels as determined by information from the ITU and World Bank. As such, the following benchmark rates apply:

(a) Upper Income - 15¢

(b) Upper Middle Income - 19¢

(c) Lower Middle Income - 19¢

(d) Lower Income - 23¢

3. 2004 International Settlements Policy Reform

In the 2004 ISP Reform Order, the FCC reformed its rules to remove the ISP from U.S.-international routes for which U.S. carriers have negotiated benchmark-compliant rates after observing retail competition existed in major other countries.

> "Lifting the ISP on those routes allows U.S. carriers greater flexibility to negotiate arrangements with foreign carriers. The Commission found that doing so would encourage market-based arrangements between U.S. and foreign carriers that would further our long-standing policy goals of greater competition in the U.S.-international market and more cost-based rates for U.S. consumers. A carrier that seeks to add

> a route to the list of routes exempt from the ISP may do so by filing an effective accounting rate modification showing that a U.S. carrier has entered into a benchmark-compliant settlement rate agreement with a foreign carrier that possesses market power in the country at the foreign end of the U.S.-international route that is the subject of the request." [FCC, 2004]

In order to examine the effectiveness of the FCC's policies that govern the negotiation behaviours of U.S. carriers and understand the factors that could fundamentally restrict the markups at the settlement services, this dissertation proposes several variations of bilateral oligopoly models to study the interactions among retail competition, the FCC's policies and settlement rate determinations between two countries. Each model tries to capture the features of different bilateral market structures in the international telephone networks and relevant FCC's policies. In particular, the focus of studies is on the FCC's "uniformity" requirement and the PRR, at which the previous literature had overlooked (see Einhorn [2002] for a review of the early literature).

Chapter 2 assumes that the "uniformity" requirement is imposed on the carriers of both countries that exchange international telephone traffic. Under this structure, all the carriers in one country face a same set of settlement rates for outgoing and incoming telephone traffic. Furthermore, it uses a non-cooperative game approach to model the settlement rate determination. That is, all the carriers in one country jointly determine a settlement rate for the incoming traffic from the other, in anticipation of the same behaviour of their counterparts. After the settlement rates are determined, the same country carriers compete in their retail markets, and the incoming traffic which represents a source of income is divided among the carriers according to the PRR.

The PRR makes retail competition more intensive. However this PRR effect is neutralized through inflated settlement rates. The equilibrium retail prices and traffic volumes are unaffected by incoming traffic division rules. The market outcome with retail competition in both countries is still less efficient than the integrated monopoly outcome. We also examined how retail competitiveness affects the net settlement payment between the two countries.

Chapter 2 also studies a scenario of settlement determination between a competitive country and a monopoly country. If each competitive carrier individually negotiates a settlement term with the monopolist, this is an approximation of the "whipsawing" that caused the FCC to restrict carriers' behaviour in negotiations with foreign carriers. Interestingly, by comparing the sub-game perfect equilibriums before and after those requirements, it is found that FCC's policies may not reduce the U.S.'s net settlement payments to other countries. Indeed, there is a good chance that the policy can worsen the imbalances.

Chapter 3 contains two alternative models to capture other possibilities in settlement rate determination and discusses the differences in the market efficiency. The first one modifies the model in Chapter 2 by instead assuming carriers from two countries choose settlement rates in a fashion of Nash bargaining. This modification is out of the concern that the interconnected carriers provide complementary services to each other and a cooperative behaviour is possible. The equilibrium Nash bargaining rate is lower than the one under non-cooperative regime. The second model, multiple routes, in this chapter is developed based on the relaxation of "Uniformity" requirement. When there are multiple routes to exchange traffic between two countries, or there is competition at the settlement services at each country, the retail competition can steer the market outcomes toward the efficient level where the calling price is equal to the real marginal cost of delivering a call from caller to receiver.

In the last section of this chapter, I highlight the major theoretical findings in the Chapters 2 and 3, and discuss how the model predictions are able to fit the actual market outcomes by using the U.S. data. Specifically, the discussion associates the changes in the U.S. collection rate and net settlement payment with the changes in both bilateral market structures and FCC's policies.

Chapter 4, using the annual data from 1992 to 2003 covering 42 countries that exchanged telephone traffic with the U.S. carriers, tries to empirically examine the theoretical predictions provided in the early chapters. Specifically, whether the PRR in the FCC's set of regulatory polices yields an outcome that is contrary to its initial purpose of reducing both the settlement rate and net settlement payment. To do so, I constructed a measurement of the intensity of the rule for each international route that connects the U.S. with another country in each year. I found empirical evidence that the rule did increase both the settlement rates and the net settlement payments made by the U.S. carriers. However, the rule's effect toward the retail price is unclear, possibly due to the model specification and the endogeneity of the settlement rates and retail prices. Also, the theory from the Chapter 2 shows that, under the requirement of "uniformity" among the U.S. carriers, an increase in their retail competitiveness incurs an increase in the settlement rate and the net settlement payment paid by those carriers, although the retail price falls. Using the Herfindahl-Hirschman Index (HHI) to proxy the retail competitiveness in both the U.S. and other countries markets, the empirical findings are against the predictions based on the "uniformity" requirement. Alternative theory of multiple routes is proposed at the end and it matches the empirical results.

Chapter 2

Non-cooperative settlement rates and proportional return rule[1]

2.1 Introduction

The completion of an international telephone call involves two major components: a domestic carrier collects the call and a foreign counterpart terminates the call by delivering it to the receiver. Access to the foreign carrier's network is an essential and complementary input for the domestic service provider. A service payment, often called a settlement rate, is made from the domestic to the foreign carrier. Moreover, international telephone calls typically flow in both directions and a carrier often provides both originating and terminating services, and thus derives two sources of revenues: retail and settlement revenues. As a major part of a carrier's marginal cost in providing international telephone services, the settlement rate can significantly affect the carrier's profit and consumer benefits, as well as overall efficiency

[1]This chapter is based on a co-authored work with Guofu Tan at the University of Southern California.

in this market. Figure 2.1 shows average retail prices and settlement rates in the U.S. from 1964 to 2002. During this period roughly 50% of the total revenues collected from domestic consumers were paid to foreign countries in order to obtain their cooperation in terminating calls.

Figure 2.1 also shows the trend of retail prices. The sharp drop in the late 1970's might be largely due to the entrance of MCI into this market which was previously monopolized by AT&T. At this point, the U.S. market was opened up for competition and we have observed shrunken differences between collection rates and settlement rates paid by the U.S. carriers after the MCI's entry. One would also expect that the huge progress in networking technology led to lower operating costs and might benefit consumers through even lower calling rates.[2] However, these pro-competitive factors seemed to stop functioning and did not bring in large price drops until the mid-1990's, as the figure illustrates relatively stable average consumer prices between the mid-1980's and mid-1990's.[3]

Figure 2.2 plots the total retail revenues, settlement payouts and receipts in year 2000 dollar from exchanging traffic with other countries. The gap between payout and receipt is called *net settlement payment*, represented by the shaded area in the figure. For example, the U.S. net settlement payment to all other countries in 1996 was about 6.4 billion dollars, 40% of total billed revenue in that year. Not surprisingly, this substantial outflow

[2]For example, Cave and Donnelly [1996] provide the estimates of per-minute cost of using trans-Atlantic cable, $2.53 in 1956, $0.04 in 1988 and $0.02 in 1992.

[3]We are aware of the fact that the average prices and settlement rates are also affected by the proportions of different U.S.-foreign routes in the total traffic volumes. However, the retail prices and settlement rates at the major U.S.-foreign routes do show similar trends as in the Figure 2.1.

created international disputes until more balanced payments appeared in recent years.

These observations motivate us to attempt to understand international telephone markets. We address the major characteristics of this industry and study their interactions: bilateral market structures of retail competition, incoming traffic division rules for competing carriers in each country, and settlement rate determination regimes. The essential question is whether market liberalization policy had helped to improve efficiency, and to what degree, in this industry. When efficiency cannot be achieved due to unavoidable market power, we wonder whether market outcome can be improved through documented government involvements, especially the polices by the Federal Communications Commission (FCC).

In this Introduction, we will start with a review of relevant literature[4], historical changes in this industry and government policies in the U.S. The three major events in the U.S. market marked in Figure 2.1 are particularly discussed. The second subsection describes our approach to the above issues and our main findings.

2.1.1 Background and literature

■ **Bilateral monopoly.** The literature on international telephone industry started with the case that both ends of an route are monopolistic. This had been the basic picture of the U.S.-foreign interconnections prior to 1980. Even now, international telephone businesses in many countries are still

[4]Einhorn [2002] provides an extensive review of literature on international telephone markets.

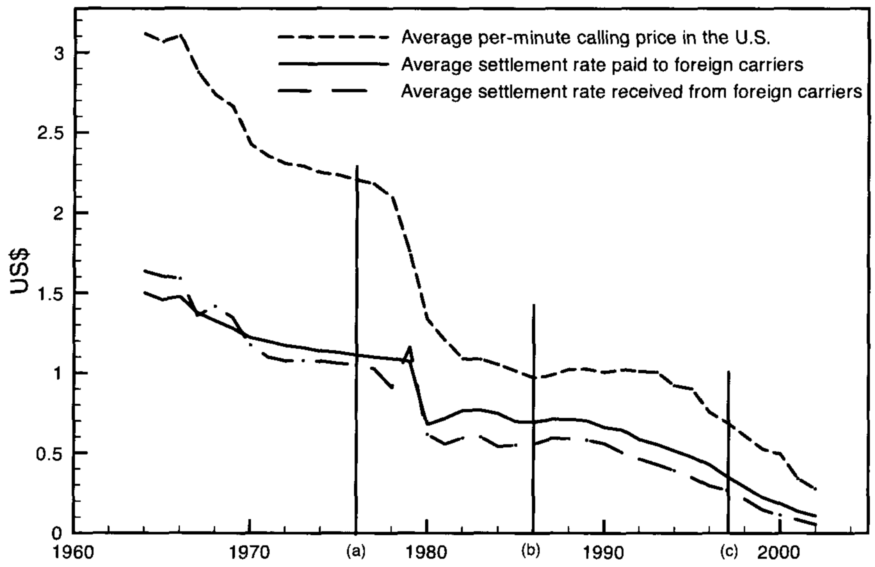

Figure 2.1: Average Retail Prices and Settlement Rates in the U.S. (1964–2002)

(a) MCI entered long-distance telephone market in 1976.

(b) The U.S. FCC implemented the International Settlement Policy in 1986.

(c) The U.S. FCC implemented the Benchmark Policy in 1997.

Source: Blake and Lande [2004]

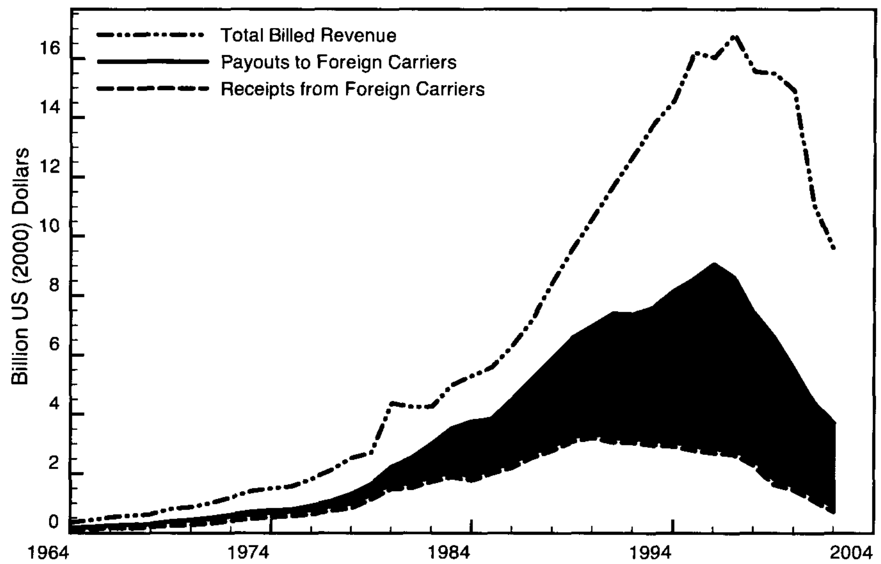

Figure 2.2: The U.S. International Telephone Market 1964–2002: Billed Revenue, Settlement Payouts and Receipts
Source: Blake and Lande [2004]

monopolized by single national carriers.

Carter and Wright [1994] have studied this bilateral monopoly structure. They consider both non-cooperative and collusive mechanisms for settlement rate determination. If the two monopolists set their settlement rates non-cooperatively, the equilibrium settlement rates are always well above the marginal cost of termination service. Calling prices in both countries are then elevated after double-marginalization. Given that both monopolists provide complementary inputs to each other and there is no retail competition between them, explicit collusion over settlement rates (that maximize their joint profit) can decrease settlement rates to marginal costs, which in turn benefits consumers. Cave and Donnelly [1996] use a Nash bargaining approach to model the settlement negotiation between the two bilateral monopolies, under the assumption that the threat-points are their profits under non-cooperative settlement rates. The rates under Nash bargaining are somewhere between the non-cooperative rates and the collusive rates; the carriers' profits under Nash-bargaining are also between the corresponding non-cooperative and collusive levels.

■ **Oligopoly v.s. monopoly.** Starting from the 1980's, while all other carriers remained monopolistic, the U.S. government unilaterally allowed new entrants into its domestic market, hoping this market liberalization could bring in welfare gains. However, the potential gain from competition could be offset by inflated settlement rates. For instance, suppose carriers can freely negotiate the settlement terms, which include (i) the rate charged for traffic initiated by each carrier, and (ii) the allocation of incoming traffic from the monopolistic carrier among the competing carriers, while the competing carriers' outgoing traffic must be all terminated by the monopolist. Competing carriers not only strive for caller subscriptions, but also foreign traffic terminations. These carriers must then accept whatever terms the monopolist brings forth, as there is no alternative means of terminating their international traffic, and rejecting the terms might result in no business. Both the U.S. carriers and the FCC deemed the unequal positions in exchanging traffic to be the reason for high settlement rates paid by competing carriers and hence their high consumer prices (Johnson [1989] and FCC [1999]).

This concern arising from the traffic exchanges with a foreign monopoly calls for government intervention in settlement negotiations. In 1987, the FCC initiated its International Settlements Policy (ISP),[5] intended to prevent foreign monopoly carriers from engaging in "whipsawing", or playing U.S. carriers against each other. The ISP consists of three major components: 1) *Uniformity*: all the U.S. carriers must pay the same settlement rate for the outbound traffic on the same route; 2) *Reciprocity*: the U.S. carriers must receive the same rate for terminating inbound traffic from a foreign country as the rate paid for outbound traffic; 3) *Proportional Return Rule (PRR)*: traffic from a foreign country is allocated among the U.S. carriers in exact proportion to their shares of outbound to that country.

These requirements tie up the competing carriers' interests and let them behave as a single entity while negotiating settlement terms with the foreign monopolists. More importantly, they remove Bertrand-type competition in providing termination service to other countries.

[5]See FCC [1999] and FCC [2002] for detailed description.

In 1997, the FCC put strong downward pressure on settlement rates by releasing its *Benchmark Order* FCC [1997]. Within a prescribed transition period, the order requires all U.S. carriers to negotiate settlement rates to be less than or equal to 15¢ for upper income countries, 19¢ for upper- and lower-middle income countries, and 23¢ for lower income countries. This order appears to be successful in bringing down settlement rates and end-user calling rates[6], as illustrated in Figures 2.1 and 2.2.

Several papers have discussed the international telephone agreement and the ISP's effects in this particular structure. Yun, Choi, and Ahn [1997] assume that Uniformity and Reciprocity are imposed on the settlement rates for the traffic flows between two countries. The carriers compete *a la Cournot* in the retail markets. They find that retail competition induces competing carriers to voluntarily choose high settlement rates. However, they do not consider the Proportionate Return Rule. Instead, they suppose that the foreign inbound traffic is evenly divided among domestic carriers, a traffic division rule that we call the Equal Sharing Rule in this paper. Wright [1999] incorporates the PRR in his discussion and uses Nash-bargaining among carriers to solve the reciprocal settlement rates. His numerical results support Yun, Choi, and Ahn [1997]'s findings. Galbi [1998] and Rieck [2000] study the effects of PRR and notice a price reduction created by the PRR. As a competing carrier's share of terminating inbound traffic, which represents a cost deduction to the carrier, is linked with its market share in the retail market, the carrier competes in retail price more aggressively.

[6]Cowhey [1998] and Stanley [2000] are good sources to understand the background of Benchmark Order.

The retail price could possibly even fall below the social marginal cost of providing telephone service (switching cost plus the settlement rate), hence a welfare loss to the country. This leads them to doubt the desirability of the PRR in allocating inbound traffic.

■ **Bilateral oligopoly.** Since the late 1990's, most other countries have liberalized their domestic markets to competition. In the FCC's practice, shown in FCC [1999] and FCC [2004], when the country that interconnects with the U.S. carriers is considered to be competitive, the ISP is removed from the negotiation of settlement agreements among the carriers. It implies that the international telephone carriers from both sides can freely choose their business partners and allocate the traffic. The FCC claimed that if the ISP were still imposed upon these routes, Uniformity and Reciprocity requirements might facilitate the collusion among carriers to sustain a 'high' settlement rate and 'high' retail price FCC [2002].

Even though most countries have by now introduced competition into their retail markets, research on bilateral oligopoly structure is scant.

2.1.2 Overview of the models and results

Our main objective is to provide a framework and analyze the interactions among bilateral market structures, traffic division rules and the settlement rate determination in this industry. Moreover, our work fills a gap in the telecommunication literature, which neglects the international aspects to the industry. For example, Armstrong [1998] and Laffont, Rey, and Tirole [1998] particularly focus on access charges and competition in local telecommunication networks, which have a different structure than international networks.

We model domestic product market competition in a *Cournot* fashion, with necessary modifications to incorporate the features of international telephone markets, such as two-way interconnections and incoming traffic division. Our modeling approach can also encompass various types of bilateral market structures, such as monopoly, oligopoly and perfect competition. Although the access charge literature tends to apply price competition model with differentiated products, such as Armstrong [1998] and Laffont, Rey, and Tirole [1998], this approach may easily run into problem with discontinuity in the profit functions. This may generate further problems for deriving equilibria in the multiple-stage game. This is one reason that their focus has largely been on the competition between carriers, instead of the endogenous choice of regulatory policy toward the carriers. Also, another advantage of the *Cournot*-type models is that they provide direct framework for fitting aggregated data for empirical work on this market. See, for example, Madden and Savage [2000].

We consider two possible rules for dividing incoming traffic among participating carriers, and combinations of them. One is the Proportionate Return Rule mentioned before. This rule has been adopted in practice, but not yet received enough attention in the academic literature, especially with regards to its impact on settlement rate determination. Under this traffic allocation regime, the domestic market price is linked with foreign market outcomes, even if the two countries have independent demands. Early studies have identified the downward pressure on retail price caused by the PRR. When establishing the settlement rates, carriers' preferences for the rates should be affected by their anticipation of the price effect. The other traffic division rule, which we call the Equal Sharing Rule (ESR), prescribes the incoming traffic to be *equally* divided among the participating domestic carriers. Possibly, governments collect the foreign settlement payments and equally distribute them among domestic carriers, regardless of their relative retail performances. The ESR is the traffic division rule studied in Yun, Choi, and Ahn [1997] and Madden and Savage [2000].

What is the mechanism behind settlement rate determination among carriers? There has been no clear answer in the literature on network interconnections, where the attention is primarily on the relationship between access charge levels and downstream competition (see Armstrong [1998] and Laffont, Rey, and Tirole [1998]). Typical treatments include collusive determination, Nash bargaining and non-cooperative games. Access to one's network is complementary to the other network, and their interconnection is an important tool to resolve network externalities. This feature supposedly calls for a cooperative approach in modelling the settlement agreements among interconnecting carriers, for example collusive determination or Nash bargaining. Collusive determination, however, involves side-payments which are likely to be illegal and its enforceability is always a question. Nash bargaining has its advantages. For example, a Nash bargaining solution does not involve side-payments among the bargaining parties and all the parties are better off under the solution than *status quo* (Paretian property). But the drawbacks of this cooperative approach, including justifiable specification of bargaining powers/threat points and the difficulty of deriving analytical solutions, limit its applications. Given these considerations, we will mainly apply a non-cooperative approach toward the determination of settlement rates. Above all, the individual rationality shown under this approach can guide us nicely in understanding the market outcomes and evaluating government policies.

Another issue remains to be clarified. Reciprocity in the International Settlement Policy simply requires a common settlement rate for both directions of traffic. However, the FCC has not firmly enforced this rule, as seen in Spiwak [1998]. Figure 2.1 also shows obvious gaps between the two settlement rates, paid and received by the U.S. carriers, over time. Nevertheless, the economic rationale behind reciprocity is unclear, since it does not respond to differential demand and cost structures across countries, and it is generally not in the interests of carriers Cave and Donnelly [1996]. Accordingly, we will not assume the reciprocity requirement in this paper.

In the next section we describe our model and two benchmarks. In Section 2.3, we analyze the case in which regulation in each country requires its domestic carriers behave collectively in setting a uniform settlement rate for inbound traffic and uses a combination of ESR and PRR to split incoming settlement payments. We find that due to the well-known double marginalization problem, the equilibrium outcome with retail competition in both countries is still less efficient than that of an integrated monopoly. In choosing settlement rates for inbound flow, carriers' gain from settlement income always dominates their loss in retail competition brought by the PRR. In equilibrium, retail prices and call volumes are thus unaffected by incoming traffic division rules, although equilibrium settlement rates under the PRR exceed those under the ESR.

In Section 2.4, we analyze the scenario of foreign monopolist "whipsawing" competing carriers. The FCC imposed the ISP in 1986 because it believed "whipsawing" was the reason for above-cost settlement rates and high net settlement payments by the U.S. carriers. We then compare the equilibrium net settlement payments in a "whipsawing" game with those in non-cooperative game of settlement rates in Section 2.3. We then provide a condition by which the policies can be effective in reducing net settlement payments. The findings help understand the impact and effectiveness of the FCC's policies. Both the unilateral introduction of competition and the PRR requirement toward domestic carriers are possible reasons for the worsening net settlement payments from the U.S.

Section 2.5 summarizes and discusses the major findings in this chapter. All the proofs are collected in the Appendix.

2.2 Model

The call termination service in the destination country is an essential and complementary input for international telephone operators. It is costly for an international telephone operator to build its own national networks in foreign countries, and countries have regulations that limit the operations of foreign operators. These restrictions require the operators in two countries to reach a 'trade' agreement on providing termination services to each other. A call-termination charge, often referred to as a "settlement rate", is paid from the call-initiating carrier to the terminating one.

When setting the settlement rates, carriers will also consider the impact of rates on retail competition in the other country, which in turn affects the traffic volumes from that country and their settlement payments. In this sense, this market has the feature of a standard vertical structure: upstream input suppliers and downstream manufacturers. In one direction of an international telephone call, the call terminating carrier is upstream to the call initiating carrier. Complicating this two-way communication network, an international telephone carrier plays as an upstream supplier in one direction but downstream in the other direction of traffic flow. Therefore, a typical carrier has two sources of profits, one from the retail market and another from offering the termination service to foreign counterparts. As we will see, traffic division rules can link the two directions of traffic flows or the two markets, hence the retail and input pricing decision of carriers and consumer welfare are much different than the results under a standard one-way vertical relation.

■ **Demands and costs.** There are two countries, A and B. Consumers in each country want to make phone calls to the other country. The inverse demand in A is given by $P_A(X)$ and in B is given by $P_B(Y)$, where X and Y are total outgoing call volumes from the respective countries. Call volumes are measured in minutes, while retail prices and settlement rates are per-minute charges. Country A has m identical international telecommunication carriers, and B has n identical carriers. The carriers from different countries, however, can have different operation costs. In country j $(= A, B)$, each carrier incurs marginal (per-minute) cost c_j to initiate an outgoing call, and d_j to terminate an incoming call. We assume $P_A(X)$ and $P_B(Y)$ to be decreasing and twice continuously differentiable. Moreover, we make four assumptions, which will be maintained throughout the rest of paper.

Assumption 2.1

$P_A'(X) < 0$, $2P_A'(X)+P_A''(X)X < 0$ *and* $P_B'(Y) < 0$, $2P_B'(Y)+P_B''(Y)Y < 0$.

This assumption is widely used in analyzing firms' retail behavior. It guarantees interior solutions for the monopoly solution and a Cournot-Nash equilibrium.

Price elasticities of demand for outgoing calls are defined as

$$\varepsilon_A = -\frac{P_A}{P_A' X}, \qquad \varepsilon_B = -\frac{P_B}{P_B' Y}.$$

We also define the following elasticities of the slope of demand functions

$$\eta_A = \frac{P_A'' X}{P_A'}, \qquad \eta_B = \frac{P_B'' Y}{P_B'}.$$

Under Assumption 1, $\eta_j > -2$ for $j = A, B$.

Assumption 2.2

$$\lim_{X \to 0} \left[P_A(X) + P_A'(X)X \right] > c_A + d_B;$$

and

$$\lim_{Y \to 0} \left[P_B\left(Y\right) + P_B'\left(Y\right)Y \right] > c_B + d_A.$$

Assumption 2 implies that an integrated monopolistic operator across two countries will provide retail and termination services. In short, operation in this market is profitable.

We need one more assumption about the demands and costs to assist the analysis. We define two functions, $\phi_A(X)$ and $\phi_B(Y)$ as the following equations (2.1) and (2.2). Assumption 2.3 is about their curvatures.

$$\phi_A(X) = (P_A(X) - c_A - d_B)X + \frac{1}{m}P'_A(X)X^2; \tag{2.1}$$

$$\phi_B(Y) = (P_B(Y) - c_B - d_A)Y + \frac{1}{n}P'_B(Y)Y^2. \tag{2.2}$$

Assumption 2.3 *Both $\phi_A(X)$ and $\phi_B(Y)$ are strictly concave.*

Assumption 2.3 is satisfied with common demand functions such as linear, constant elasticity and exponential demand functions. The reasons why we adopt this assumption will become clear in Section 2.3. Indeed, functions ϕ_A and ϕ_B will provide some convenience in deriving the equilibrium conditions.

■ **Two benchmarks.** Under the demand and cost specifications in our model, the real marginal cost of providing a minute of call from country A to B is $(c_A + d_B)$, and $(c_B + d_A)$ for the other calling direction. If the market of two countries is operated efficiently, retail calling rates should be equal to the real marginal costs, i.e., $P_A = c_A + d_B$ and $P_B = c_B + d_A$. We refer to this set of price levels as the *Social Efficiency Benchmark.*

At the other extreme, if the international telephone service is operated by a single company which owns the facilities in both countries, or all the carriers from both countries behave collusively, we refer to the outcome under this regime as the *Monopoly Benchmark.*

The monopoly profit from each direction of the traffic flow is denoted as

$$M_A(X) = (P_A(X) - c_A - d_B)X, \quad M_B(Y) = (P_B(Y) - c_B - d_A)Y$$

When either the cross-country monopolist or all the carriers collusively make the operation decisions, it is equivalent to choosing the traffic flows X and Y to maximize their joint profit, $\Pi_A(X,Y) + \Pi_B(X,Y)$. This joint profit is the same as $M_A(X) + M_B(Y)$, because the settlement payments are nothing more than internal transfers in the coalition. The traffic flows in both directions are thus X^M and Y^M given by

$$X^M = \arg\max M_A(X), \quad Y^M = \arg\max M_B(Y),$$

which are both positive interior solutions by Assumption 2.1.

This monopoly outcome can also be represented as

$$\frac{P_A^M - c_A - d_B}{P_A^M} = \frac{1}{\varepsilon_A}, \quad \frac{P_B^M - c_B - d_A}{P_B^M} = \frac{1}{\varepsilon_B},$$

where $P_A^M = P_A(X^M)$ and $P_B^M = P_B(Y^M)$.

■ **Timing of the game.** Our bilateral oligopoly model always follows a two-stage game. The first stage is the settlement rate determination. Carriers from both countries choose settlement rates for the two directions of the traffic. In the second stage (retail segment), given the settlement rates determined in the earlier stage, carriers in the same country compete in *Cournot* fashion for outgoing traffic, with each choosing the size of call volume that it wants to carry over to the other country. The markets in both countries clear and settlement incomes are shared by carriers according to pre-defined division rules, which will be specified later in this section.

Our analysis of rate determination starts with a non-cooperative game of settlement rates between two countries. This game and the market structure are illustrated in Figure 2.3. Carriers in the same country join together to form a union and choose a settlement rate for the traffic from the other country, maximizing the union's total profit. Under this setup, call-initiation carriers pay the same settlement rate for the termination service offered by the carrier union in the destination country. Let r be the settlement rate chosen by the union of carriers in country A for the traffic initiated in country B, and s be the rate chosen by carriers in B for the traffic coming from country A.

We also want to rule out the unlikely cases where settlement rates are too low (below termination costs) and too high (such that it is not possible to provide the service for originating carriers). Define $\bar{r}$ and $\bar{s}$ to be the upper bounds of settlement rates such that

$$\begin{aligned}
\bar{s} &= \lim_{X\to 0}\left[P_A(X) + P_A'(X)X\right] - c_A, \\
\bar{r} &= \lim_{Y\to 0}\left[P_B(Y) + P_B'(Y)Y\right] - c_B.
\end{aligned}$$

Under Assumption 2.2, $\bar{r} > d_A$ and $\bar{s} > d_B$. The ranges of settlement rates for our concern are then formally stated in the next assumption.

Assumption 2.4 *The settlement rates charged for traffic from country B are $r \in [d_A, \bar{r}]$; the settlement rates charged for traffic from country A are*

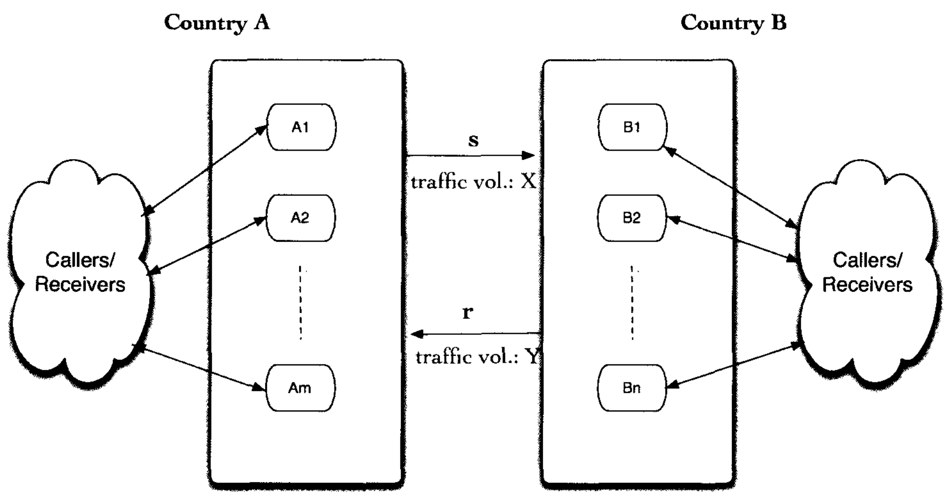

Figure 2.3: Non-cooperative Game of Settlement Rates

$s \in [d_B, \bar{s}]$.

■ **Incoming traffic division rules.** We consider two possible incoming traffic division rules among carriers. One is the Equal Sharing Rule (ESR) which equally allocates the settlement revenue among the domestic carriers. The other one, the Proportional Return Rule (PRR), allocates the revenue according to each carrier's proportion of outgoing traffic. We also consider a combination of the two rules. Let α be the portion of A's incoming traffic that is subject to the Proportional Return Rule and β for the same purpose in country B.

The profit function of a carrier i in country A is

$$\begin{aligned} \pi_{Ai} = \quad & (P_A(X) - c_A - s)\, x_i + \\ & \left[\alpha \frac{x_i}{X}(r - d_A)Y + (1-\alpha)\frac{1}{m}(r - d_A)Y\right] \end{aligned} \tag{2.3}$$

where x_i is the volume of outgoing calls initiated by carrier i and $X = \sum_{i=1}^{m} x_i$; $(r - d_A)Y$ represents the total settlement profit to be divided among the m carriers. The first term in (2.3) is the retail profit collected from domestic customers, after paying s per-minute for the termination service by B's carrier(s). The next two terms in the brackets are the income from settling B's incoming traffic, in which the former one is the profit from settling traffic subject to the PRR and the later one is from settling traffic under the ESR. This specification is flexible to encompass possible division rules and facilitate the analysis of optimal choice of division rules. Without ambiguity, we can use α to represent the traffic division rule adopted for A's carriers.

Similarly, the profit function of carrier j in country B is

$$\pi_{Bj} = \quad (P_B(Y) - c_B - r)\, y_j + \left[\beta \frac{y_j}{Y}(s - d_B)X + (1-\beta)\frac{1}{n}(s - d_B)X\right] \tag{2.4}$$

where y_j is the outgoing volume initiated by this carrier j and $Y = \sum_{j=1}^{n} y_j$. The total settlement profit from terminating A's traffic is $(s - d_B)X$ which is shared among the n carriers by the rule β.

The total profits in each country can then be written as

$$\Pi_A = (P_A(X) - c_A - s)X + (r - d_A)Y \tag{2.5}$$

$$\Pi_B = (P_B(Y) - c_B - r)Y + (s - d_B)X \tag{2.6}$$

■ **Organization of analysis.** Section 2.3 analyzes the non-cooperative rate setting regime. We then model a scenario of "whipsawing" in Section 2.4. "Whipsawing" refers to the case where a competitive country exchanges traffic with a monopolistic country. In our model, this corresponds to the case in which $m > 1$, $n = 1$ and there is no binding rule governing the bargaining behavior of those competing carriers in country A. Or, each carrier in A individually sets the settlement term with the sole provider of settlement service in B. Next, in Section 3.2, we modify the non-cooperative rate-setting behavior in Section 2.3 using a Nash bargaining game. Instead of choosing the settlement rates that are individually optimal, the two carrier unions agree on a pair of rates to maximize the Nash product of their profits.

Lastly, in Section 3.3, we allow several carrier unions in each country. Each union in one country forms an alliance with a union in the other country. The traffic initiated by one union is terminated by the other union in the same alliance. Their settlement terms are determined non-cooperatively by the two unions.

2.3 Non-cooperative game of settlement rates

This section derives and analyzes the equilibrium when carriers in one country non-cooperatively choose settlement rates for the other. We will begin with the extreme case whereby both sides of the market apply the equal sharing rule for incoming traffic division, i.e., $\alpha = \beta = 0$. This case can serve as a baseline for us to better understand how the proportional return rule affects the market outcomes, such as the traffic volumes between countries and the settlement rates.

2.3.1 Equal sharing rule

When both countries apply the ESR as their incoming traffic division rules, i.e., $\alpha = 0$ and $\beta = 0$, the settlement payments are divided among the carriers by exogenously fixed ratios. Each of A's carriers receives a $\frac{1}{m}$ share of B's payment and each of B's carriers receives a $\frac{1}{n}$ share of A's payment. Looking at the profit functions (2.3) and (2.4), we can easily see that the decisions in the first and second stages of the game are independent of each other for the same country. Foreign traffic inflow plays no role in a carrier's retail decisions. Thus the game is similar to a standard vertical relation in which a monopolistic manufacturer supplies essential components to downstream competing firms. Many of our insights can be gained from looking at one direction. For example, A's carriers provide outgoing call service to their customers, and B's carriers jointly supply settlement service to A's competing carriers. In standard IO language, A's carriers are downstream firms and B's are upstream. Since B's carriers jointly choose the settlement rate (input price), they behave as a monopolist in this direction of traffic flow.

We solve the game by backward induction. Fixing settlement rates (r, s), the retail decision of a typical carrier i in country A is given by

$$\max_{x_i} \left[(P_A(X) - c_A - s)x_i + \frac{1}{m}(r - d_A)Y \right]. \tag{2.7}$$

The total outgoing volume $X(s)$ is then implicitly determined by aggregating the first order conditions of (2.7) from $i = 1$ to m,

$$(P_A - c_A - s) + \frac{1}{m}P_A'X = 0. \tag{2.8}$$

By Assumption 1, condition (2.8) describes the retail *Cournot*-Nash equilibrium in this country. Transforming (2.8), we can reach another representation,

$$(s - d_B)\,X = (P_A - c_A - d_B)\,X + \frac{1}{m}P_A'X^2 \tag{2.9}$$

The left-hand-side of (2.9) is the total settlement profit to country B, or the profit of upstream monopolist in a standard vertical relation. Its right-hand-side is the function $\phi_A(X)$ defined in (2.1). In another word, the upstream profit can be equivalently expressed by a downstream equilibrium property, without having the choice variable s explicitly in it.

Similarly, country B's retail equilibrium in the second stage of game is given by

$$(r - d_A)Y = \phi_B(Y)$$

which implicitly determines a function $Y(r)$.

In the first stage of game while carrier unions choose settlement rates, because $\alpha = 0$ and $\beta = 0$, the profit-maximization decisions can be reduced into the maximization of settlement profits,

$$\begin{aligned} \arg\max_r \Pi_A(r, s) &= \arg\max_r (r - d_A)Y(r) \\ \arg\max_s \Pi_B(r, s) &= \arg\max_s (s - d_B)X(s). \end{aligned}$$

Both of $X(s)$ and $Y(r)$ are monotone by Assumption 2.1. Therefore, we can equivalently represent the settlement rate decisions as choosing the sizes of incoming traffic volumes,

$$\max_r (r - d_A)\, Y(r) \Longleftrightarrow \max_Y \phi_B(Y),$$

and

$$\max_s (s - d_B)\, X(s) \Longleftrightarrow \max_X \phi_A(X).$$

Assumption 2.3 is sufficient to guarantee unique solutions of (X, Y), so then the solutions of settlement rates (r, s). By the definition of ϕ_A and Assumption 2.2, we can show that

$$\begin{aligned}\phi_A'(0) &= \lim_{X\to 0}\frac{\phi_A(X)-\phi_A(0)}{X}\\ &= \lim_{X\to 0}\left[P_A(X)-c_A-d_B+\frac{1}{m}P_A'(X)X\right]\\ &> 0;\end{aligned}$$

and similarly,

$$\phi_B'(0) > 0.$$

Therefore, positive maximizers X^* and Y^* can be found by,

$$\phi_A'(X^*) = 0, \quad \phi_B'(Y^*) = 0. \tag{2.10}$$

Proposition 2.1 formally describes the equilibrium when both countries apply the ESR. The proof follows from the above discussion.

Proposition 2.1 *When both countries apply the Equal Sharing Rule to divide the incoming traffic, there exists a subgame perfect equilibrium in which the settlement rates* (r^*, s^*) *are determined by*

$$r^* - d_A = \frac{\phi_B(Y^*)}{Y^*}, s^* - d_B = \frac{\phi_A(X^*)}{X^*}$$

where traffic volumes (X^*, Y^*) *are given by (2.10). At these rates, the equilibrium total outbound volumes are equal to* X^* *and* Y^**, respectively.*

This subgame perfect equilibrium determines a pair of settlement rates $\{r^*(n), s^*(m)\}$ and outgoing traffic volumes $\{X^*(m), Y^*(n)\}$, all as functions of respective number of carriers. The number of carriers in our model can be interpreted as the retail competitiveness. Corollary 2.1 provides the comparative statics for this equilibrium.[7]

Corollary 2.1 *In the subgame perfect equilibrium described in Proposition 2.1,*

$$\frac{dX^*}{dm} > 0, \frac{dY^*}{dn} > 0 \tag{2.11}$$

and,

$$sign\left[\frac{dr^*}{dn}\right] = sign\left[-\frac{d\eta_B}{dY}\right] \tag{2.12}$$

$$sign\left[\frac{ds^*}{dm}\right] = sign\left[-\frac{d\eta_A}{dX}\right] \tag{2.13}$$

where $\frac{d\eta_A}{dX}$ *and* $\frac{d\eta_B}{dY}$ *are evaluated at the equilibrium volumes* X^* *and* Y^*.

The comparative statics (2.11) shows that an increase of degree of retail competitiveness increases the volumes of outgoing calls, but it has no effect on the level of incoming calls by Proposition 2.1. When the final demand of international calls in one country has monotonic η and there is a change in retail structure in this country (number of firms in our model), results (2.12) and (2.13) predict the response of settlement rate charged by the other country. In particular, if a country's, say A's demand is in the form of $X(p_A) = z_1(z_2 - p_1)^{z_3}$, where z's are parameters, the corollary predicts that the settlement rate s paid by this country is unchanged to its number

[7] In a remotely related paper, Tyagi [1999] investigates how input price of a monopolistic supplier is affected by competitiveness of downstream manufacturers in a one-way vertical relation under a slightly different set of assumptions on demand and cost.

of carriers m.[8]

However, the competitiveness of one country has no effect on the rate that it charges to the other country. For example, a change in m does not affect A's choice of settlement rate r, because the inflow Y has no effect on the retail equilibrium X in country A. This critically depends on the adoption of ESR in both countries and it no longer holds when the PRR is used in either country.

2.3.2 Proportional return rule

This subsection examines the equilibrium for all possible pair of traffic division rules in two countries. Given incoming traffic division rules $\{\alpha, \beta\}$ and settlement rates $\{r, s\}$, the optimal traffic volume decision of carrier i in country A is given by the first-order condition of (2.3),

$$(P_A - c_A - s) + P_A' x_i + \alpha \frac{X - x_i}{X^2} (r - d_A) Y = 0. \tag{2.14}$$

There is a similar formula for B's individual carrier. After denoting

$$\kappa_A = \alpha \frac{m-1}{m}, \text{ and } \kappa_B = \beta \frac{n-1}{n}, \tag{2.15}$$

we can express aggregate first-order conditions in the two countries as

$$\phi_A(X) - (s - d_B)X + \kappa_A(r - d_A)Y = 0 \tag{2.16}$$

$$\phi_B(Y) - (r - d_A)Y + \kappa_B(s - d_B)X = 0 \tag{2.17}$$

[8] It is easy to get this result by solving differential equation $d\eta_A/dX = 0$.

where $\phi_A(X)$ and $\phi_B(Y)$ are defined in (2.1) and (2.2), respectively.

Under Assumptions 1 and 2, equation (2.16) gives the retail volume X in A and it is unique, fixing s and B's settlement payment $(r - d_A)Y$. Similar results hold for (2.17). Unlike previous subsection, the quantities here are not monotone in rates. The immediate question is whether (2.16) and (2.17) can jointly determine a (unique) pair of positive (X, Y),[9] which is answered in the following Lemma 2.1.

Lemma 2.1 *Given any pair of* (r, s) *that satisfy Assumption 2.4, equations (2.16) and (2.17) jointly determine a unique pair of strictly positive* (X, Y).

From (2.16), X is increasing in α and non-decreasing in Y. Since the retail price P_A is inversely related to the total outgoing volume X, the PRR exerts a downward pressure on the retail price, because a carrier's share of this settlement revenue is determined by its retail market share x_i/X. The larger the revenue, the more the carrier is willing to increase its traffic level in order to capture a higher market share, thus lower retail price in equilibrium. Consumers benefit from the application of PRR if settlement rates are fixed. Roughly speaking, the size of the foreign market, Y, affects the domestic retail price through the PRR. Unlike the case in Section 3.1, the outgoing traffic volume X is a function of both s and r when $\alpha > 0$. This effect creates an interesting problem when choosing settlement rate r: a larger settlement revenue decreases the retail profit because of more intense competition for incoming traffic. Carriers are facing a trade-off between these two sources

[9] There is a trivial solution to the equations system (2.16) and (2.17), $\{X = 0, Y = 0\}$. However, by the first-order condition (2.14), the two traffic volumes cannot be both zero simultaneously. This trivial solution is from our transformation of the FOCs.

of incomes. The next lemmas will gradually investigate this trade-off and support a characterization of the equilibrium in Proposition 2.2.

We shall also observe that, given any degree of retail competition $\{m, n\}$ and traffic division rules $\{\alpha, \beta\}$, there is always a pair of settlement rates to recover output levels back to monopoly benchmarks (X^M, Y^M). We first explore some properties of $X(r, s)$, $Y(r, s)$ and the settlement incomes.

Lemma 2.2 *Given* (κ_A, κ_B),

(i) $X(r, s)$ *is independent of* r *if* $\kappa_A = 0$, *and single-peaked in* r *if* $\kappa_A > 0$.

(ii) $Y(r, s)$ *is independent of* s *if* $\kappa_B = 0$, *and single-peaked in* s *if* $\kappa_B > 0$.

Denote the total settlement income in country A as $I_A(r, s) = (r - d_A)Y(r, s)$, B's as $I_B(r, s) = (s - d_B)X(r, s)$. The choice of settlement rate r for B's traffic is to maximize the industry profit in A given by

$$\Pi_A(r, s) = (P_A - c_A - s) X(r, s) + I_A(r, s);$$

while s is chosen by B's carrier union to maximize

$$\Pi_B(r, s) = (P_B - c_B - r) Y(r, s) + I_B(r, s).$$

Lemma 2.3 *Given* (κ_A, κ_B),

(i) A*'s total settlement income* $I_A(r, s)$ *is single-peaked in* r *and*

$$\arg\max_r \Pi_A(r, s) = \arg\max_r I_A(r, s).$$

(ii) B's total settlement income $I_B(r,s)$ is single-peaked in s and

$$\arg\max_s \Pi_B(r,s) = \arg\max_s I_B(r,s).$$

So the maximization of industry profit is equivalent to the maximization of settlement income, which is just a part of the total profit. Each carriers' union is seemingly maximizing settlement income when choosing a settlement rate, without considering its impact on the domestic retail market. The reason can be explained as following. As the settlement income increases, so does the outgoing traffic volume because of the PRR effect in retail market. This causes outflow traffic volume to divert from its monopoly retail level even further[10]. The retail profit is therefore decreasing in settlement revenue. But it decreases *always* less than the settlement revenue increases, shown in the proof for Lemma 2.3. Let $R_A(X) = (P_A(X) - c_A - s)X$ be the retail profit of union A and treat X as a function of I_A, $X(I_A)$. These results can be summarized as, along the aggregated first order condition (2.16),

$$\frac{dR_A(X)}{dX} < 0, \quad \frac{dX}{dI_A} > 0,$$

and

$$-1 < \frac{dR_A(X)}{dX}\frac{dX}{dI_A} < 0.$$

Therefore, this trade-off between retail profit and settlement income is dominated by the change in the latter. This holds true even if the level of retail

[10]This monopoly retail level is different to the Monopoly Benchmark defined before. Here we refer to the level of $\arg\max_X (P_A(X) - c_A - s)X$, where settlement rate s is given. Obviously, when $m > 1$, this level is always exceeded.

profit is larger than the settlement profit. Given this understanding, we can smoothly derive the equilibrium of this game of settlement rates in Proposition 2.2. Some important properties of this equilibrium are provided in the Corollaries 2.2 to 2.4.

Proposition 2.2 *Given a pair of traffic division rules (α, β), if the carriers within a country jointly set the non-cooperative settlement rates for the other country, there exists a sub-game perfect equilibrium, in which the settlement rates (r^*, s^*) are given by*

$$r^* - d_A = \frac{1}{(1 - \kappa_A \kappa_B)\, Y^*} \left[\kappa_B \phi_A(X^*) + \phi_B(Y^*)\right] \tag{2.18}$$

$$s^* - d_B = \frac{1}{(1 - \kappa_A \kappa_B)\, X^*} \left[\phi_A(X^*) + \kappa_A \phi_B(Y^*)\right] \tag{2.19}$$

where X^* and Y^* are determined by equation (2.10). At these settlement rates, the equilibrium outbound volumes are equal to X^* and Y^*, respectively.

Corollary 2.2 *At the subgame perfect equilibrium,*

(i) the equilibrium volume (X^*, Y^*) is independent of (α, β);

(ii) settlement rates r^* and s^* are non-decreasing in α and β, respectively;

(iii) Given β, the equilibrium $\Pi_A(\alpha, \beta)$ is decreasing in α. Given α, the equilibrium $\Pi_B(\alpha, \beta)$ is decreasing in β.

Proposition 2.1 is indeed a special case of the Proposition 2.2 by taking $\alpha = 0$ and $\beta = 0$. The equilibrium traffic (X^*, Y^*) is surprisingly not influenced by the division rules. However the corresponding settlement rates are generally different. The application of the PRR in one country induces both countries to increase the settlement rates.

In this game of settlement rates, a settlement rate is the tool to adjust the level of inflow traffic. For instance, we look at the optimal choice of r by A's carriers. Lemma 2.3 shows that their best reaction is characterized by the optimal level of settlement income $I_A(r, s)$. Although the curvature of $I_A(r, s)$ is also affected by both (α, β) and (m, n), its optimal level is always achieved at the level of Y^*, an inflow level which is independent of the competition and demand in country A, and the settlement rates (r, s). Thus, we can implicitly represent the best-response of A's carrier union as

$$Y(r, s) = Y^*.$$

It means that whatever the rate s chosen by B, the best interest of A's carriers' union is to keep the level of inflow Y at Y^*. Similarly, the best-response of B's union in choosing settlement rate s is given by

$$X(r, s) = X^*.$$

In sum, the equilibrium outgoing traffic volumes are kept to be (X^*, Y^*) and they are invariant to (α, β).

However, the equilibrium settlement rates are increasing in both α and β. Take country A, a higher α induces a higher outflow to country B by the PRR effect in retail competition. If $\beta > 0$, this larger inflow to country

B creates more intense competition among B's carriers in its retail market. In turn, B's outflow Y to country A increases if settlement rates do not adjust to the change of α. But A's carriers as a whole would like to keep this traffic volume at Y^*. The only way is to choose a higher settlement rate r to restrict the retail competition among B's carriers. A similar idea can explain the reason for $\partial r^*/\partial\beta \geq 0$.

When the retail structures (m and n) are fixed, consumer surplus in this market is invariant to the incoming traffic division rules, because the surplus is defined on the traffic volumes or retail prices which are unaffected by (α, β) in equilibrium. Therefore, when the division rule is changed, the social surplus of a country (sum of consumer surplus and industry profit) change in the same direction of the changes in industry profits. In the light of Corollary 2.2 (*iii*), if each country (either union of carriers or government) can choose the incoming traffic division rule before carriers' unions non-cooperatively decide settlement rates, the ESR is the dominant strategy for either country. (ESR, ESR) is then the dominant strategy equilibrium in this policy game. In another word, the ESR Pareto-dominates the PRR.

Corollary 2.3 *At the subgame perfect equilibrium,*

(i) if $\beta = 0$*, then* $\partial r^*/\partial m = 0$*. If* $\beta > 0$*, then* $\partial r^*/\partial m > 0$*;*

(ii) if $\alpha = 0$*, then* $\partial s^*/\partial n = 0$*. If* $\alpha > 0$*, then* $\partial s^*/\partial n > 0$*.*

Corollary 2.3 presents an linkage between retail competition and PRR in affecting the choices of settlement rates. An increase of competition in country A can induce more outflow to country B. If country B applies the

PRR to divide this inflow, the competition among B carriers will in turn drive up its outflow to country A. Remember that A's most desirable level of inflow is Y^*. In order to avoid exceeding this level, the best strategy is to increase the settlement rate charged on inflow traffic and offset the PRR effect in country B. If country B does not use PRR, the competitiveness in country A does not affect the output level Y. So this rate r is unaffected by a change of competition in A.

We also like to know the exact levels of these equilibrium traffic volumes. One method is to compare them with the benchmarks that we set in the Section 2.2. After manipulating the expression (2.10) for subgame perfect equilibrium, the equilibrium in two countries can be shown in the familiar price-cost markup formula,

$$\begin{aligned} \frac{P_A - c_A - d_B}{P_A} &= \frac{1}{\varepsilon_A}\frac{m+2+\eta_A}{m}, \\ \frac{P_B - c_B - d_A}{P_B} &= \frac{1}{\varepsilon_B}\frac{n+2+\eta_B}{n}. \end{aligned} \tag{2.20}$$

Remember that $\eta_j > -2$, $j = A, B$. We can then state Corollary 2.4.

Corollary 2.4 *The equilibrium volumes (X^*, Y^*) are always below the corresponding monopoly benchmark, and they are approaching the benchmark as $m \to \infty, n \to \infty$.*

This market outcome is indeed unpleasant: the introduction of competition in retail segment cannot improve the market efficiency to much extent; it is even worse than the extreme monopoly situation. The benefit of retail competition is largely offset by the double marginalization of settlement services. Even if the friction at retail segment is removed ($m, n \to \infty$), the outcome can only be at the levels of monopoly benchmark.

Going back to the Figure 2.1, the major period that the PRR and collective settlement negotiation were required extends from the mid-1980's till the late 1990's. Comparing the trends before and after, this period shows relatively stable retail prices and settlement rates. However, people have seen enormous improvements in telecommunication networking technology and more providers competing in international services since 1980's. All these factors seem to not have brought retail prices down and not have benefited consumers to the level that they could enjoy, until 1997 when the U.S.'s FCC put a strong hand into the carriers' settlement negotiation by imposing rate caps. Our analysis provides plausible reasons to explain this inefficient market outcome.

2.4 A model of "whipsawing" and net settlement payments

After deriving the equilibrium of the game of settlement rates in a general bilateral oligopoly framework, we want to examine the desirability of the FCC's policy in this market. A natural criterion is the consumer surplus, or simply the retail price in our setting. The other is the net settlement payments between two countries in exchanging international telephone traffic. The attention over this inflating payments from the United States to all other countries is an important reason for the U.S. regulatory body, FCC to examine its involvement into this market.

The initial purpose of settlement rates was to compensate carriers for providing call-termination services. However, the market power of those terminating carriers usually diverts the rates largely from their marginal costs and affect market efficiency. These large mark-ups, in particular to a country like the U.S., which always has tremendous net outflows of traffic, also mean a huge and 'unfair' transfer of domestic welfare to foreign countries.

As described in the historic overview of international telephone industry in Section 1, starting from MCI's entrance in the late 1970's until the mid-1990's, the U.S. market had always been a competitive one facing monopolistic carriers in most of other countries. This bilateral market structure has caught particular attentions to FCC, because

> "...in negotiating settlement rates, foreign monopoly carriers could pit competing U.S. carriers against one another, exploiting the fact the U.S. carriers unwilling to pay settlement rates demanded by foreign carriers would lose business on those routes to higher-bidding U.S. competitors, as there are no alternative means of terminating international traffic. This practice, known as *'whipsawing'*, can drive up the cost to U.S. carriers of terminating international traffic to foreign markets, and hence, the prices paid by U.S. consumers." [FCC, 1999]

The fast-growing net settlement payments can be observed in Figure 2.2, by taking the difference between the payouts and receipts.

The International Settlement Policy, described in Section 1, was the government's first reaction toward this worry. The Policy requires all U.S.

carriers to pay and accept the same settlement rate when exchanging traffic with the same destination country; and all the inbound traffic should be allocated through the Proportional Return Rule. What we discussed in Section 2.3 is a good approximation of this Policy. To evaluate the policy effect, we also need a characterization of the outcome when the U.S. carriers are whipsawed.

We amend the existing model to build-in the structure of "whipsawing". Suppose country A has $m > 1$ identical carriers and B has one monopolist. The demands, costs and retail structure still follow the features set forth in Section 2.2. In the first stage of the game, however, each A's carrier individually negotiates a settlement term with the monopolistic carrier B. Figure 2.4 illustrates this settlement structure with an example of $m = 2$.

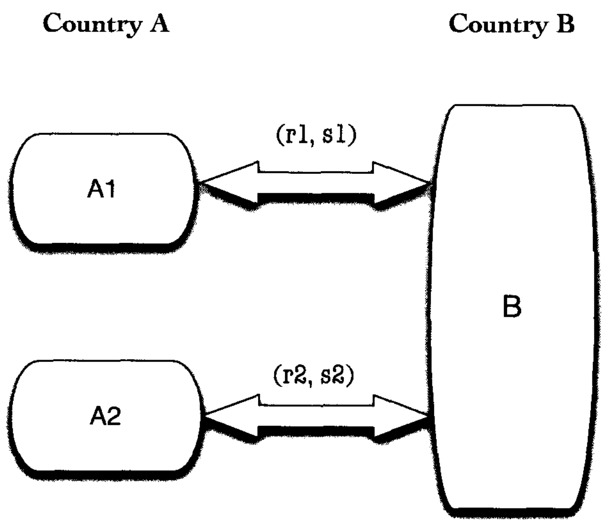

Figure 2.4: Game of "Whipsawing"

There is no binding rule governing the settlement term. Therefore, we consider all possible outcomes and denote settlement terms between carrier A_i and carrier B as $\{(r_i, y_i), (s_i, x_i)\}$. r_i is the settlement rate charged by A_i for B's traffic and y_i is B's traffic volume terminated by A_i; s_i is the settlement rate charged by B to terminate A_i's traffic x_i. The total traffic volumes are

$$X = \sum_{i=1}^{m} x_i, \quad Y = \sum_{i=1}^{m} y_i.$$

The profit functions are

$$\pi_{Ai} = (P_A(X) - c_A - s_i)x_i + (r_i - d_A)y_i$$

$$\Pi_B = \sum_{i=1}^{m} [(P_B(Y) - c_B - r_i)y_i + (s_i - d_B)x_i]$$

The termination services offered by competing carriers in country A are assumed to be homogenous. This is plausible because the termination service is mainly an interconnection agreement between the long distance carriers and local networks in this country. The access to local networks is usually open to other networks with regulated access charges. This is the case particularly in the U.S. and most other countries. Therefore, we would expect carrier B to extend its monopoly power and let competing carriers to play Bertrand type of game while choosing settlement terms. The equilibrium of this whipsawing game is given in Proposition 2.3.

Proposition 2.3 *When $m > 1, n = 1$ and carriers in A individually negotiate the settlement terms with carrier B, there exists a sub-game perfect* *equilibrium, in which the settlement rates* (r_i, s_i) *are given by*

$$r_i = d_A, \quad s_i = \phi_A(X^*)/X^* + d_B, \quad i = 1, \dots, m$$

where $X^* = \arg\max \phi_A(X)$. *At these settlement rates, the equilibrium outbound volumes are equal to* X^* *and* Y^M, *respectively.*

The Bertrand-type competition among A's carriers in providing termination service to the monopolist B reduces the settlement rate r to its marginal cost d_A. While choosing settlement rates s_i for A's carriers, B has no incentive to exclude any A's carrier that charges the lowest r_i ($r_i = d_A$ in equilibrium), or sign an exclusive contract with a single carrier in A. This then makes the scenario in A similar to the case that A's carriers apply ESR to divide their incoming traffic. The equilibrium settlement rate s is thus same as that level in Proposition 2.1, or a special case in equation equation (2.19) taking $\kappa_A = 0$.

In the equilibrium of this whipsawing game, both the monopolistic carrier and the consumers in country B are better off, compared to the game in Section 2.3, because $Y^M > Y^*$ and $r^* > d_A$. When there is a change in m in country A, the settlement rate s in this "whipsawing" game moves analogously in the direction shown in Corollary 2.1, i.e.,

$$\text{sign}\left[\frac{ds}{dm}\right] = \text{sign}\left[\frac{d\eta_A}{dX}\right] \text{ evaluated at } X^*.$$

The equilibrium outflow of country A in this game is the same as the outcome in the previous one (Proposition 2.2), and the settlement rate paid by those carriers is equal to the one shown in Proposition 2.1. So the retail price and consumer surplus in this country are unaffected by this change of settlement determination mode.

Net settlement payment can be seen as the profit transfer between the two carrier groups. This net payment from A to B is

$$NP = sX - rY.$$

From the results in Proposition 2.2 and Proposition 2.3, we can express the equilibrium net settlement payments under the two regimes in terms of their equilibrium traffic volumes.

In the game of whipsawing, the net settlement payment is

$$\begin{aligned} NP^{Before}(m) &= s^*X^* - d_A Y^M \\ &= [\phi_A(X^*) + d_B X^*] - d_A Y^M. \end{aligned}$$

In the game of non-cooperative settlement rates, the net settlement payment is both affected by (m, n) and (α, β),

$$\begin{aligned} NP^{After}(m, n; \alpha, \beta) &= s^*X^* - r^*Y^* \\ &= \left[\frac{1-\kappa_B}{1-\kappa_A\kappa_B}\phi_A(X^*) + d_B X^*\right] \\ &\quad - \left[\frac{1-\kappa_A}{1-\kappa_A\kappa_B}\phi_B(Y^*) + d_A Y^*\right], \end{aligned}$$

where κ_A and κ_B are defined in (2.15). Specifically, when $n = 1$,

$$NP^{After}(m) = [\phi_A(X^*) + d_B X^*] - [(1 - \kappa_A)\phi_B(Y^*) + d_A Y^*]$$

Proposition 2.4 *Both $NP^{Before}(m)$ and $NP^{After}(m, n; \alpha, \beta)$ are increasing in m; $NP^{After}(m, n; \alpha, \beta)$ is increasing in α.*

An intuition behind Proposition 2.4 follows. If country A becomes more competitive, its retail price falls and a larger outflow resultes. In either regime, country B can receive a higher settlement income even if keeping its charge s unchanged. Its settlement payment rY is unchanged with respect to m because of its monopoly position in termination service.

We would also like to know whether the FCC's involvement is effective in bringing down the net settlement payments, through the restrictions of carriers negotiation. The difference of two net payments is

$$\begin{aligned} \delta(m) &= NP^{Before}(m) - NP^{After}(m) \\ &= (1 - \kappa_A)\phi_B(Y^*) + d_A(Y^* - Y^M) \end{aligned}$$

The policy is effective if $\delta > 0$.

Since the equilibrium payout from A to B is unchanged in the two regimes, this difference is independent of the demand in country A. But the effectiveness is affected by two policy parameters in the country A, κ_A and d_A.

The condition critically depends on the size of d_A. In the extreme but 'unlikely' case, $d_A = 0$, the policy is always effective, no matter which country is interconnected with. If d_A is relatively large then the policy may not be effective in bringing down net payments. The major component of d_A is the (regulated) access charge to local telephone networks. We thus observe a link between the policies toward local networks and international markets.

κ_A contains both information on competitiveness (m) and incoming traffic division rule (α). The competitiveness in this country (m) affects the difference only through the application of the PRR in the regime studied in Section 2.3. δ is negatively related to κ_A. Thus, any positive κ_A only makes the policy less effective. In the best case case of $\kappa_A = 0$ (or $\alpha = 0$), we can show that

$$\delta = r^* Y^* - d_A Y^M. \tag{2.21}$$

A sufficient condition for the policy to be *ineffective* is the δ in (2.21) to be negative. Estimates of these relevant variables can thus provide helpful information in predicting the policy outcomes.

Although we cannot exactly determine the sign of δ, the fact that δ is decreasing in m does provide us some knowledge on the trend of net payments. In some sense, even if the government policy plays a role in reducing net payments, the effect can be weakened by an increase of m.

δ is decreasing in α, too. At the limit as $m \to \infty$, we know both Y^M and Y^* are unchanged. Thus,

$$\lim_{m \to \infty} \delta = (1 - \alpha)\phi_B(Y^*) + d_A(Y^* - Y^M)$$

which is still decreasing in α. When $\alpha = 1$, it is negative, because $Y^* < Y^M$. If $\alpha = 0$, δ is unaffected by the demand and competition in A. These exercises lead us to conclude that the proportional return rule is indeed another source of increase in net payments.

A casual observation from Figure 2.2 tells that the U.S. net settlement payments had been increasing significantly throughout the 1980's till the mid-1990's. In this section, we have provided two plausible explanations for this trend. One is that the U.S. market became increasingly competitive during this period (Proposition 2.4). The other reason is that those competing carriers divided the inbound traffic using the PRR which may even worsen the payments in equilibrium.

The drops of both settlement payouts and receipts after mid-1990's may be largely due to two reasons. Around 1997, the U.S. firmly implemented the Benchmark Policy, by which the settlement rates are capped. Also starting roughly around that time, more countries have begun to break down monopolies in their international telephone markets. This competition effect fits to another interpretation of Proposition 2.4: the net payment $NP^{After}(m, n)$ is decreasing in n, because $-NP^{After}$ by this definition is the net settlement payment from B to A. Although the balance of settlement payments can hardly be achieved because of the differentials in demands and costs across countries, the removal of asymmetric competitions is helpful to mitigate these international disputes.

2.5 Conclusion

This chapter proposed a bilateral oligopoly model to study the international telephone markets. In equilibrium, traffic volumes and settlement rates are influenced by both the organization of rate determination and inbound traffic division rules, as well as retail competitiveness.

When domestic carriers have to behave collectively in setting uniform settlement rates and determine settlement rates non-cooperatively, the PRR makes retail competition more intensive. However this PRR effect is neutralized through inflated settlement rates. The equilibrium retail prices and traffic volumes are unaffected by incoming traffic division rules. The market outcome with retail competition in both countries is still less efficient than the integrated monopoly outcome. We also examined how retail competitiveness affects the net settlement payment between the two countries.

We next studied a scenario of settlement determination between a competitive country and a monopoly country. If each competitive carrier individually negotiates a settlement term with the monopolist, this is an approximation of the "whipsawing" that caused the FCC to restrict carriers' behavior in negotiations with foreign carriers. Interestingly, by comparing the sub-game perfect equilibriums before and after those requirements, we found that FCC's policies may not reduce the U.S.'s net settlement payments to other countries. Indeed, there is a good chance that the policy can worsen the imbalances.

2.6 Appendix: Proofs in Chapter 2

2.6.1 Proof of Corollary 2.1

Look at the traffic direction $B \to A$ and let $\theta = 1/n$. The equilibrium volume is given by $\phi'_B(Y(\theta);\theta) = 0$. This gives

$$\frac{dY}{d\theta} = -\frac{(2P'_B + P''_B Y)Y}{\phi''_B(Y)} < 0 \tag{2.22}$$

because of Assumptions 2.1 and 2.3. Or, $\frac{dY}{dn} > 0$.

The second-stage retail outcome is given by

$$r(Y;\theta) = P_B(Y) - c_B + \theta P'_B(Y)Y. \tag{2.23}$$

This also tells us

$$\frac{\partial r}{\partial Y} = (1+\theta)P'_B + \theta P''_B Y. \tag{2.24}$$

Therefore, differentiating (2.23) by θ at the equilibrium, we can find out

$$\begin{aligned}
\frac{dr^*}{d\theta} &= \frac{dr^*}{dY}\frac{dY}{d\theta} + P'_B Y \\
&= [(1+\theta)P'_B + \theta P''_B Y]\frac{dY}{d\theta} + P'_B Y \\
&= -\frac{\theta(P'_B Y)^2}{\phi_B(Y)''}\frac{d\eta_B}{dY}
\end{aligned}$$

by using the fact that

$$\frac{d\eta_B}{dY} = -\frac{1}{(P'_B)^2}[P'_B P''_B + P'_B P'''_B Y - (P''_B)^2 Y].$$

Thus, at the equilibrium, $d\eta_B/dY$ has the same sign as $dr^*/d\theta$, or the opposite sign of dr^*/dn.

The proof for the other set of results can be followed by the same logic.

2.6.2 A Lemma

The inequalities in Lemma 2.4 are useful for later analysis.

Lemma 2.4 *If (2.16) holds,*

$$(s - d_B) - \phi'_A > (s - d_B) - \frac{\phi_A}{X} > 0$$

If (2.17) holds,

$$(r - d_A) - \phi'_B > (r - d_A) - \frac{\phi_B}{Y} > 0$$

Proof. From equation (2.16),

$$\frac{\phi_A}{X} - (s - d_B) + \kappa_A \frac{(r - d_A)\,Y}{X} = 0$$

The concavity of ϕ_A and $\phi_A(0) = 0$ imply that $\phi'_A < \frac{\phi_A}{X}$. Also, $\kappa_A \frac{(r-d_A)Y}{X} \geq 0$. So,

$$\phi'_A - (s - d_B) < \frac{\phi_A}{X} - (s - d_B) = -\kappa_A \frac{(r - d_A)\,Y}{X} \leq 0$$

The claim follows. Analogue in country B can be shown similarly. ■

2.6.3 Proof of Lemma 2.1

By definition, $0 \leq \kappa_A, \kappa_B < 1$. If $\kappa_A = 0$, denote the solution to (2.16) as X_0, which is positive and unaffected by Y. Similarly, we can find Y_0 by

(2.17) when $\kappa_B = 0$. Therefore, (X_0, Y_0) is a unique pair of solution when $\kappa_A = \kappa_B = 0$.

When $\kappa_A > 0$, from (2.16) we can get

$$Y = \frac{(s - d_B) X - \phi_A (X)}{\kappa_A (r - d_A)},$$

and then, applying Lemma 2.4,

$$\frac{dY}{dX}|^A = \frac{(s - d_B) - \phi'_A}{\kappa_A (r - d_A)} > 0, \tag{2.25}$$

$$\frac{d^2Y}{dX^2}|^A = \frac{-\phi''_A}{\kappa_A (r - d_A)} > 0.$$

Similarly, by (2.17), we can find out the shape of Y as function of X, also by Lemma 2.4, if $\kappa_B > 0$,

$$\frac{dY}{dX}|^B = \frac{\kappa_B (s - d_B)}{(r - d_A) - \phi'_B} > 0, \tag{2.26}$$

$$\frac{d^2Y}{dX^2}|^B = \frac{\kappa_B (s - d_B)}{\left[\phi'_B - (r - d_A)\right]^2} \phi''_B < 0.$$

Therefore when $\kappa_A > 0$ and $\kappa_B > 0$, the reaction curve $X(Y)|^A$ from (2.16) and the reaction curve $Y(X)|^B$ from (2.17) are both strictly concave in $(X > 0, Y > 0)$ space, or the former one implies that Y is strictly convex in X. (2.16) also implies the reaction curve intersects the point $(X_0, 0)$, and the curve by (2.17) intersects $(0, Y_0)$. Thus, the difference $Y(X)|^B - Y(X)|^A$ is concave, and $Y(X_0)|^B - Y(X_0)|^A > 0$. It is then sufficient to show the existence and uniqueness of the solution if

$$\frac{dY}{dX}|^{B} < \frac{dY}{dX}|^{A}, \tag{2.27}$$

or the difference is strictly decreasing. Multiply both sides of (2.27) by X/Y,

$$\begin{aligned}\frac{dY}{dX}|^{A} \cdot \frac{X}{Y} &= \frac{(s-d_B)-\phi'_A}{\kappa_A(r-d_A)Y}X = \frac{(s-d_B)-\phi'_A}{(s-d_B)X-\phi_A}X \\ &= \frac{(s-d_B)-\phi'_A}{(s-d_B)-\frac{\phi_A}{X}} > 1.\end{aligned}$$

The last inequality follows from Lemma 2.4. Similarly, we can show

$$\frac{dY}{dX}|^{B} \cdot \frac{X}{Y} < 1$$

Hence, the claim in (2.27).

2.6.4 Proof of Lemma 2.2

The comparative statics of $X(r,s)$ and $Y(r,s)$ is given by differentiating (2.16) and (2.17) simultaneously with respect to r and s.

$$\Gamma\begin{pmatrix}\frac{\partial X}{\partial r}\\ \frac{\partial Y}{\partial r}\end{pmatrix} = \begin{pmatrix}-\kappa_A Y\\ Y\end{pmatrix}, \Gamma\begin{pmatrix}\frac{\partial X}{\partial s}\\ \frac{\partial Y}{\partial s}\end{pmatrix} = \begin{pmatrix}X\\ -\kappa_B X\end{pmatrix}, \tag{2.28}$$

where

$$\Gamma = \begin{pmatrix} \phi_A' - (s - d_B) & \kappa_A(r - d_A) \\ \kappa_B(s - d_B) & \phi_B' - (r - d_A) \end{pmatrix}.$$

By equations (2.16) and (2.17), and the inequalities in Lemma 2.4, we can show that $|\Gamma| > 0$. We only give the proof of $X(r, s)$'s property. $Y(r, s)$'s property can be obtained similarly.

By (2.28),

$$\frac{\partial X}{\partial r} = -\frac{\kappa_A Y}{|\Gamma|} \phi_B'(Y). \tag{2.29}$$

Clearly, if $\kappa_A = 0$, $\frac{\partial X}{\partial r} = 0$.

Let $\kappa_A > 0$. By the Cramer's Rule and Assumption 2.3, the comparative statics in (2.28) gives

$$\frac{\partial Y}{\partial r} = \frac{Y}{|\Gamma|} \left[\phi_A' - (1 - \kappa_A \kappa_B)(s - d_B)\right] < \frac{Y}{|\Gamma|} \left[\frac{\phi_A}{X} - (1 - \kappa_A \kappa_B)(s - d_B)\right],$$

where the term in the bracket, by (2.16) and (2.17), is

$$\begin{aligned} \frac{\phi_A}{X} - (1 - \kappa_A \kappa_B)(s - d_B) &= \frac{\kappa_A}{X} \left[\kappa_B(s - d_B)X - (r - d_A)Y\right] \\ &= -\frac{\kappa_A}{X} \phi_B(Y). \end{aligned}$$

Therefore,

$$\frac{\partial Y}{\partial r} < -\frac{\kappa_A Y}{X|\Gamma|} \phi_B(Y), \tag{2.30}$$

Fixing s and Y^* defined by $\phi_B'(Y^*) = 0$, (2.16) and (2.17) jointly determine $X(s)$ and $r_0(s)$, given by

$$(r_0 - d_A) Y^* = \phi_B (Y^*) + \kappa_B (s - d_B) X \tag{2.31}$$

and

$$\phi_A (X) - (1 - \kappa_A \kappa_B)(s - d_B) X + \kappa_A \phi_B (Y^*) = 0 \tag{2.32}$$

The left-hand-side of (2.32) is strictly concave and strictly positive at $X = 0$ when $\kappa_A > 0$. Therefore, (2.32) determines an unique $X(s)$. Henceforth equation (2.31) gives an unique $r_0(s)$.

From (2.30), because $\phi_B(Y^*) > 0$,

$$\frac{\partial Y}{\partial r}\Big|_{r=r_0(s)} < 0.$$

Plus the uniqueness of $r_0(s)$, we can assert that when $r < r_0(s)$, $Y > Y^*$ and $\phi_B'(Y) < 0$; when $r > r_0(s)$, $Y < Y^*$ and $\phi_B'(Y) > 0$.

Therefore, looking at (2.29), when $r < r_0(s)$, $\frac{\partial X}{\partial r} > 0$; when $r > r_0(s)$, $\frac{\partial X}{\partial r} < 0$. In sum, X is single-peaked in r.

2.6.5 Proof of Lemma 2.3

We only need to show part (i). Part (ii) can be obtained similarly. If $\kappa_A = 0$, the statement is true obviously.

Let $\kappa_A > 0$. Examining (2.28), we can find out

$$\frac{\partial I_A}{\partial r} = \frac{Y}{|\Gamma|} \left[\phi_A' - (s - d_B)\right] \phi_B'(Y) \tag{2.33}$$

The first term $\frac{Y}{|\Gamma|}$ is positive and the second term $\left[\phi'_A - (s - d_B)\right]$ is negative by Lemma 2.4. Applying the proof of Lemma 2.2, $I_A(r, s)$ is shown to be single-peaked in r.

Define $R_A = (P_A - c_A - s)X$ and $I_A = (r - d_A)Y$. We can re-write condition (2.16) as

$$X = f_A\left(\kappa_A I_A(r, s), s\right);$$

or, X is expressed as a function of both settlement income I_A and settlement rate s.

Let

$$M_A(X) = (P_A(X) - c_A - d_B)X.$$

Thus,

$$\phi_A(X) = M_A(X) + \frac{1}{m} P'_A X^2,$$

and

$$\phi'_A < M'_A.$$

Condition (2.16) implies, when there is an infinitesimal change in I_A,

$$\left[\phi'_A - (s - d_B)\right] dX + \kappa_A dI_A = 0.$$

Notice that $R_A = M_A - (s - d_B)X$. Therefore,

$$\begin{aligned} dR_A &= M'_A dX - (s - d_B)dX \\ &> \left[\phi'_A - (s - d_B)\right] dX \\ &> -\kappa_A dI_A, \end{aligned}$$

and

$$d(R_A + I_A) > (1 - \kappa_A)dI_A.$$

A's joint profit is $\Pi_A = R_A + I_A$. While choosing settlement rate r, its first order condition is

$$\frac{\partial \Pi_A}{\partial r} = \left(\frac{\partial R_A}{\partial X}\frac{\partial X}{\partial I_A} + 1\right)\frac{\partial I_A}{\partial r} > (1 - \kappa_A)\frac{\partial I_A}{\partial r}.$$

Thus,

$$\frac{\partial R_A}{\partial X}\frac{\partial X}{\partial I_A} + 1 > 0.$$

Given $I_A(r, s)$ is single-peaked in r, this means that

$$\arg\max_r \Pi_A(r, s) = \arg\max_r I_A(r, s).$$

2.6.6 Proof of Proposition 2.2

By Lemma 2.3 and equation (2.33), the best-response of A's carriers is to choose r such that $\phi_B'(Y(r, s)) = 0$, or $Y(r, s) = Y^*$. Similarly, the best response of B's carriers is implicitly given by $X(r, s) = X^*$. Therefore, the Nash equilibrium is jointly determined by $Y(r^*, s^*) = Y^*$ and $X(r^*, s^*) = X^*$. The equilibrium traffic volumes are then X^* and Y^* in A and B, respectively.

Equations (2.18) and (2.19) can be found by solving (2.16) and (2.17) simultaneously.

2.6.7 Proof of Corollary 2.2

Part (i) is directly from the result of Proposition 2.2. Part (ii) can be obtained by straightforwardly from (2.18) and (2.19).

The industry profit in A is

$$\begin{aligned}\Pi_A(\alpha,\beta) &= (P_A - c_A - d_B)X - (s - d_B)X + (r - d_A)Y \\ &= (P_A - c_A - d_B)X + \frac{1}{1-\kappa_A\kappa_B}\left[(\kappa_B - 1)\phi_A + (1-\kappa_A)\phi_B\right]\end{aligned}$$

We compare the industry equilibrium profits between α and α' with $\alpha > \alpha'$, given any β. By the result in Proposition 2.2, the equilibrium X and Y are independent of (α,β). Thus, the difference is

$$\begin{aligned}\Delta\Pi_A &= \Pi_A(\alpha,\beta) - \Pi_A(\alpha',\beta) \\ &= \frac{1}{1-\kappa_A\kappa_B}\left[(\kappa_B - 1)\phi_A + (1-\kappa_A)\phi_B\right] \\ &\quad -\frac{1}{1-\kappa'_A\kappa_B}\left[(\kappa_B - 1)\phi_A + (1-\kappa'_A)\phi_B\right] \\ &= \left[\frac{1}{1-\kappa_A\kappa_B} - \frac{1}{1-\kappa'_A\kappa_B}\right](\kappa_B - 1)\phi_A \\ &\quad +\frac{m-1}{m}\phi_B(\alpha-\alpha')(\kappa_B - 1) \\ &< 0\end{aligned}$$

The comparison of industry profits in country B can be found by the same fashion.

2.6.8 Proof of Corollary 2.3

Note that

$$(r - d_A)Y^* = \frac{\kappa_B \phi_A(X^*) + \phi_B(Y^*)}{1 - \kappa_A \kappa_B}$$

and Y^* is independent of m. If $\beta = 0$, $\kappa_B = 0$ and $\partial r / \partial m = 0$. When $\beta > 0$, $(1 - \kappa_A \kappa_B)$ is non-increasing in m. Therefore,

$$\text{sign} \frac{\partial r}{\partial m} = \text{sign} \frac{d\phi_A(X^*; m)}{dm}$$

and, by the envelope theorem,

$$\frac{d\phi_A(X^*; m)}{dm} = \phi_A' \frac{\partial X}{\partial m} + \frac{\partial \phi_A}{\partial m} = -\frac{P_A' X^2}{m^2} > 0$$

Symmetric results for $\partial s / \partial n$ can be obtained similarly.

2.6.9 Proof of Proposition 2.3

There are two steps to show the equilibrium.

1. Determination of $\{r_i, y_i\}$.

Since the termination services by all A's carriers are homogeneous, B can route all its traffic to the carrier A_i which charges the lowest rate, r_i. Under the Assumption 2.4, the Bertrand competition among A's carriers over settlement income drives the equilibrium rate to be $r_i = r = d_A$. Thus, under this structure, the traffic initiated by B is Y^M. Carriers in A terminate equal amount of traffic from B, i.e., $y_i = \frac{1}{m} Y$.

2. Determination of $\{s_i, x_i\}$.

Given s_i, the traffic initiated by A_i is given by

$$x_i = \arg\max_{x_i} \pi_{Ai}.$$

Its FOC gives

$$P_A' x_i^2 + (P_A - c_A - d_B)x_i = (s_i - d_B)x_i.$$

The monotonicity between x_i and s_i lets us find out the optimal s_i by looking at x_i instead, i.e.,

$$\begin{aligned} & \max_{s_i} \sum (s_i - d_B)x_i \\ \Leftrightarrow \quad & \max_{x_i} \sum \left[P_A' x_i^2 + (P_A - c_A - d_B)x_i \right]. \end{aligned}$$

- It can be shown that the symmetric result $s_i = s$ is optimal for B;
- In the equilibrium, A's traffic is given by $\phi_A'(X^*) = 0$, same as the volume found in the Proposition 2.2. The rate s^* is given by $s^* - d_B = \phi_A(X^*)/X^*$.

2.6.10 Proof of Proposition 2.4

We know $X^*(m) = \arg\max_X \phi_A(X; m)$. By the envelope theorem,

$$\frac{d\phi_A(X^*(m); m)}{dm} = -\frac{1}{m^2} P_A'(X^*)(X^*)^2 > 0.$$

Also, $\frac{dX^*}{dm} > 0$ because the Assumption 2.1 gives

$$\frac{\partial^2 \phi_A(X)}{\partial X \partial m} = -\frac{X}{m^2}(2P'_A + P''_A X) > 0.$$

Both Y^M and Y^* are unaffected by m, so is $\phi_B(Y^*)$. Thus, when $n = 1$,

$$\frac{dNP^{Before}(m)}{dm} = \frac{d\phi_A(X^*)}{dm} + d_B \frac{dX^*}{dm} > 0;$$

and

$$\frac{dNP^{After}(m, n = 1)}{dm} = \frac{d\phi_A(X^*)}{dm} + d_B \frac{dX^*}{dm} + \frac{d\kappa_A}{dm}\phi_B(Y^*) > 0,$$

because

$$\frac{d\kappa_A}{dm} = \frac{\alpha}{m^2} > 0.$$

The monotonicity of $NP^{After}(m, n; \alpha, \beta)$ to m is generally true for any n by adding the facts

$$\frac{\partial}{\partial m}\left[\frac{1 - \kappa_B}{1 - \kappa_A \kappa_B}\right] > 0,$$

and

$$\frac{\partial}{\partial m}\left[\frac{1 - \kappa_A}{1 - \kappa_A \kappa_B}\right] < 0.$$

It is straightforward to show the monotonicity of $NP^{After}(m, n; \alpha, \beta)$ to α.

Chapter 3

Nash bargaining settlement rates and multiple routes[11]

3.1 Introduction

This chapter extends the analysis in Chapter 2 by considering two different scenarios. Section 3.2 modifies the model in Chapter 2 by instead assuming carriers from two countries choose settlement rates in a fashion of Nash bargaining. This modification is out of the concern that the interconnected carriers provide complementary services to each other and a cooperative behaviour is possible. In Section 3.3, a model of multiple routes which relaxes the requirement of "Uniformity" and thus carriers in one country can choose different business partners in the other country.

The equilibrium outcomes of these models are compared with the benchmarks in section 2.2. The last section summarizes the findings. All proofs are collected in the Appendix.

[11]This chapter is based on a co-authored work with Guofu Tan at the University of Southern California.

3.2 Nash bargaining settlement rates

Both games in Sections 2.3 and 2.4 assume a non-cooperative behavior across countries and in each game, leading to the result that the equilibrium traffic volume from one country is independent of the market competition and demand of the other (Corollary 2.2 and Proposition 2.3). One may argue that the carriers should display certain degree of cooperation when negotiating the settlement rates, because their termination services are complementary to each other. This section analyzes this organization of rate determination. Carriers' unions cooperatively choose settlement rates *à la* Nash bargaining in the first stage of game, maintaining the structures of their downstream retail competition. We further assume that, if the carriers cannot reach an agreement, the interconnection is broken down. Or, the threat-points of both carrier unions in the Nash bargaining model are chosen to be zero. [12]

We borrow the characterization of retail markets from Section 2.3. Lemma 2.1 also implies that for any pair of positive volumes (X, Y), there exists a unique pair of (r, s) satisfying the retail equilibrium conditions (2.16) and (2.17), or

$$r - d_A = \frac{1}{(1 - \kappa_A \kappa_B)Y} \left[\kappa_B \phi_A(X) + \phi_B(Y) \right],$$

$$s - d_B = \frac{1}{(1 - \kappa_A \kappa_B)X} \left[\phi_A(X) + \kappa_A \phi_B(Y) \right].$$

Given these conditions in the second stage of game, we transform the profit

[12] We believe this zero-threat point assumption is realistic. In practice, if the interconnecting carriers fail to reach a settlement term or the negotiated settlement rates are very high, they usually route the traffic through a third country. In this case, the story becomes the negotiation between those carriers with the third country. On the other hand, traffic re-routed this way is only a very small portion of the total traffic in and out of the U.S.

functions (2.5) and (2.6) into

$$\Pi_A(X,Y) = \frac{(1-\kappa_A)\kappa_B}{1-\kappa_A\kappa_B}M_A(X) - \frac{1-\kappa_B}{1-\kappa_A\kappa_B}\frac{1}{m}P_A'X^2 + \frac{1-\kappa_A}{1-\kappa_A\kappa_B}\phi_B(Y),$$

$$\Pi_B(X,Y) = \frac{(1-\kappa_B)\kappa_A}{1-\kappa_A\kappa_B}M_B(Y) - \frac{1-\kappa_A}{1-\kappa_A\kappa_B}\frac{1}{n}P_B'Y^2 + \frac{1-\kappa_B}{1-\kappa_A\kappa_B}\phi_A(X).$$

This implies that to determine the Nash bargaining settlement rates it suffices to determine the levels of volumes under the Nash bargaining solution. The properties of prices can be obtained by the inverse relation between volumes and prices.

The objective function for Nash bargaining with zero-profit threat points and equal bargaining powers is given by the Nash product

$$N(X,Y) = \Pi_A(X,Y)\cdot\Pi_B(X,Y)$$

A Nash bargaining solution (X^N, Y^N) solves $\max N(X,Y)$. It is also the equilibrium volumes of the whole game with Nash bargaining settlement rates. Using the above transformation, Lemma 3.1 compares this outcome with the equilibrium under non-cooperative settlement rates regime (Proposition 2.2), and Lemma 3.2 contrasts it with the monopoly benchmarks.

Lemma 3.1 *At the Nash bargaining solution, the volume in each direction exceeds the volume when the rates are independently determined, i.e.,* $X^N \geq X^*$ *and* $Y^N \geq Y^*$.

Lemma 3.2 *At the Nash bargaining solution, the volume in one direction is weakly larger than its monopoly benchmark (and the originating firms make* *less profits than the firms in the other country) while the volume in the other direction is weakly lower than the corresponding monopoly benchmark.*

Consumers benefit from making calls in our model. We can therefore compare the welfare levels among these regimes.

The non-cooperative game of settlement rates between countries creates huge markups in settlement rates over the termination costs. This vertical inefficiency can be reduced by any degree of cooperation between players in this vertical chain. The monopoly benchmark corresponds to a case where there is no vertical externality in a manufacturer-retailers relation. Side payments between countries will be needed to fully resolve this externality in an international telecommunications network, unless the two countries are identical in demand, cost and competition. If this is the case, the Nash bargaining outcomes will be the same as the monopoly benchmarks.

After further restricting the demand functions in Assumption 3.1, we can derive the comparative statics of equilibrium volumes to changes in competitiveness in both countries, shown in Proposition 3.1. We shall note that this assumption is generally satisfied in applied research, such as linear demand, exponential demand and constant-elasticity demand.

Assumption 3.1 $\left[\frac{d(-P_A' X^2)}{dX}/M_A'(X)\right]$ *is monotone in* X *and* $\left[\frac{d(-P_B' Y^2)}{dY}/M_B'(Y)\right]$ *is monotone in* Y*, and they have the same sign.*

Proposition 3.1 *Given Assumption 3.1, when* $\alpha = \beta = 1$*, the Nash bargaining volume* X^N *increases in* m *and decreases in* n*;* Y^N *decreases in* m *and increases in* n*.*

Under the Nash bargaining regime, the outgoing traffic volume is increasing in the competitiveness in this country. This result is analogous to the equilibrium with non-cooperative settlement rates (Proposition 2.2). But the change to the competitiveness of the other country is different.

So far, we have derived equilibriums through altering bilateral market structures, traffic division rules and/or settlement determinations. Although each alternation also changes the welfare state, none can drive the market toward its efficient level. The equilibrium outflows are increasing in the degree of competition in its own country, i.e., X increases in m and Y increases in n. Therefore, if carriers can choose the settlement rates for traffic flows, the breakdown of a monopoly in the retail segment is one step toward market efficiency. However, it is not sufficient for market efficiency, because of the excessive markups in the settlement services and double-marginalization in the downstream sectors.

3.3 Multiple routes for international traffic

Sections 2.3 and 3.2 build on a structure where there is only a single route to transmit international traffic between countries. This section will analyze cases where bottlenecks at termination are removed through the introduction of many international routes between the two countries.

Suppose there are K international routes between the two countries. Any international call has to be transmitted through one of these routes, and each route is technically capable to connect any caller and receiver. Each end of a route is jointly owned by some of the carriers in that country.

Thus, all the carriers in one country are partitioned into K non-overlapping groups. A's partition is denoted as $\{M_1, ..., M_K\}$, with m_k representing the number of members in group M_k. Similarly, B's partition is $\{N_1, ..., N_K\}$ and n_k is the number of carriers in N_k. $\sum_{k=1}^{K} m_k = m$, $\sum_{k=1}^{K} n_k = n$. Carriers in M_k and N_k together form the route k for international telephone traffic, and each side of the route is responsible for terminating the traffic from the other. Members in M_k jointly choose a settlement rate r_k for the traffic initiated by carriers in N_k, and s_k is the rate chosen by carriers in N_k for traffic by M_k. All telephone traffic from N_k is settled by M_k, and the settlement payment is divided by group members according to a pre-determined division rule, either PRR or ESR. The traffic and payment from M_k to N_k follows a similar structure. Figure 3.1 shows this settlement structure with an example of $K = 2$.

After the settlement rates are chosen, a carrier i in M_k (N_k) chooses its outgoing traffic level x_{ik} (y_{ik}). Let X_k (Y_k) be the group outgoing volume by M_k (N_k),

$$X_k = \sum_{i=1}^{m_k} x_{ik}, \quad Y_k = \sum_{i=1}^{n_k} y_{ik};$$

the total international traffic is

$$X = \sum_{k=1}^{K} X_k, \quad Y = \sum_{k=1}^{K} Y_k.$$

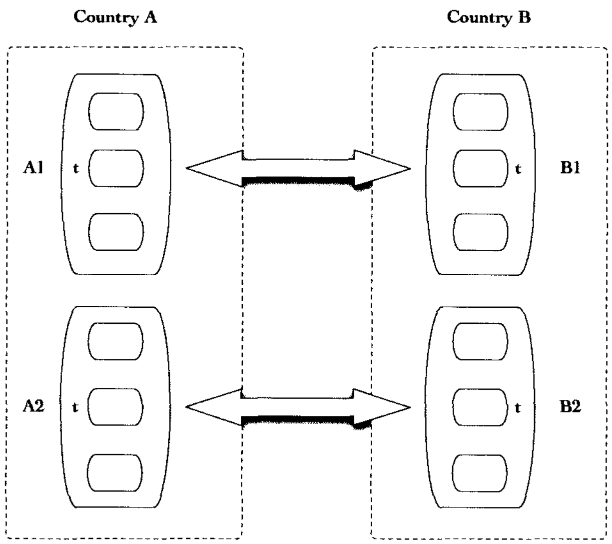

Figure 3.1: Multiple Routes for International Traffic

3.3.1 $K > 1$ and the ESR

Suppose that ESR is the only division rule agreed by *all* the groups for this subsection. The profit function of carrier i in group M_k becomes

$$\pi_{Aki} = (P_A - c_A - s_k)\, x_{ki} + \frac{1}{m_k}(r_k - d_A)\, Y_k.$$

Given the settlement rates (r_k, s_k), the carrier makes the retail decision following

$$\frac{\partial \pi_{Aki}}{\partial x_{ki}} = P_A' x_{ki} + (P_A - c_A - s_k) = 0;$$

the outgoing traffic of group M_k is given by

$$P_A' X_k + m_k (P_A - c_A - s_k) = 0 \tag{3.1}$$

The total traffic volume X can then be solved by

$$P_A' X + m (P_A - c_A) - \sum_{k=1}^{K} m_k s_k = 0 \tag{3.2}$$

When N_k sets s_k for M_k, it simply maximizes the settlement revenue from M_k , $(s_k - d_B)\, X_k$, or

$$X_k + (s_k - d_B)\frac{\partial X_k}{\partial s_k} = 0.$$

Proposition 3.2 describes the equilibrium for this game.

Proposition 3.2 *When there are K international routes and each group of carriers applies the ESR to divide incoming traffic among the group mem-*

bers, the equilibrium prices are given by

$$\frac{P_A - c_A - d_B}{P_A} = \frac{1}{\varepsilon_A} \frac{2(m+1) - \sum_{k=1}^{K}\left(m_k \frac{X_k}{X}\right) + \left[2 - \sum_{k=1}^{K}\left(\frac{X_k}{X}\right)^2\right]\eta_A}{m(m+1) - \sum_{k=1}^{K} m_k^2 + \left[m - \sum_{k=1}^{K}\left(m_k \frac{X_k}{X}\right)\right]\eta_A} \tag{3.3}$$

$$\frac{P_B - c_B - d_A}{P_B} = \frac{1}{\varepsilon_B} \frac{2(n+1) - \sum_{k=1}^{K}\left(n_k \frac{Y_k}{Y}\right) + \left[2 - \sum_{k=1}^{K}\left(\frac{Y_k}{Y}\right)^2\right]\eta_B}{n(n+1) - \sum_{k=1}^{K} n_k^2 + \left[n - \sum_{k=1}^{K}\left(n_k \frac{Y_k}{Y}\right)\right]\eta_B}$$

The equilibrium price in one country is affected by the partition structure of its carriers, but not by the structure of carriers in the other country. It is cumbersome to derive comparative statics and evaluate the impact of competition and the breakdown of bottlenecks for this general partition structure. We therefore resort to a symmetric partition of carriers. Suppose m and $m_k = t \geq 1$ are such that $m = tK$, or each group has t carriers. Therefore, at the symmetric equilibrium, $\frac{X_k}{X} = \frac{1}{K}$. The price-cost markup (3.3) simply becomes

$$\frac{P_A - c_A - d_B}{P_A} = \frac{1}{\varepsilon_A} \frac{1}{m} \frac{2(m+1) - \frac{m}{K} + \left(2 - \frac{1}{K}\right)\eta_A}{(m+1) - \frac{m}{K} + \left(1 - \frac{1}{K}\right)\eta_A}. \tag{3.4}$$

The special case $K = 1$ is indeed the result that we derived in equation (2.20). Also, by equation (3.2) and the symmetric condition $s_k = s$, we can find out the symmetric settlement rate s determined by groups in B,

$$\frac{s-d_B}{P_A}=\frac{1}{\varepsilon_A}\frac{1}{m}\frac{(m+1)+\eta_A}{(m+1)-\frac{m}{K}+\left(1-\frac{1}{K}\right)\eta_A}$$

Some properties of this symmetric equilibrium are given in Corollary 3.1.

Corollary 3.1 *Given the symmetric partition of carriers, $m=tK$, and all the groups apply the ESR to divide incoming traffic,*

(i) if m is fixed, both P_A and s decrease in K;

(ii) if K is fixed, both P_A and s decrease in m; if $K>1$, as $m\to\infty$, $P_A\to(c_A+d_B)$ and $s\to d_B$.

These results contrast sharply with the case of $K=1$ (Section 2.3). In this case, the bilateral downstream competition can only reduce the horizontal externality caused by the imperfection in domestic retail competition, while the vertical externality remains until competition is also introduced into the settlement service market. Whenever there is competition in the settlement service market ($K>1$), retail competition can drive the equilibrium prices toward our social efficiency benchmarks.

If only one country has retail competition and the other is monopolistic, settlement service competition is not feasible in our model. Unless the competitive country has a strong government which is also willing to push down the settlement rate, the efficient outcome cannot emerge through unilateral competition. Our results where $K=1$ shed some light in understanding the U.S. market from the mid-1980's to the mid-1990's when most other countries were monopolistic. In response to this unfavorable market structure, the U.S. government issued the Benchmark Order which essentially placed settlement rate caps on the carriers' settlement negotiation. Later on, as many other countries also introduced competition, multiple international telephone routes could be built. This development calls for the removal of the rigid requirements from government, especially the uniformity of settlement rates, since the collusive behavior of domestic carriers in negotiating settlement rates can be potentially anti-competitive. Carriers should be encouraged to find different business partners in the other country.

It is worthy to note that the market structure in this subsection is also similar to a standard vertical manufacturer-retailer structure, except for the bilateral flows of goods and that each firm plays both roles. When the incoming traffic is allocated according to the Equal Sharing Rule, its volume does not affect retail competition in domestic market, and the carriers only need to care about the total settlement revenue when choosing a settlement rate for the other country. Consider a standard vertical structure with one manufacturer and one retailer. No matter how small the market power enjoyed by the retailer, the presence of a monopolistic manufacturer can never move the retail price toward the real marginal production cost. When there are multiple manufacturers and retailers, different pricing behavior of the manufacturers can affect the outcomes differently. If they set the wholesale price collusively, consumers likely do not benefit from retail competition. If the wholesale price is set competitively among the manufacturers, efficient retail price becomes a possibility.

3.3.2 $K = 2$ and the PRR

The previous part derives the equilibrium when all groups use the ESR. If one group applies the PRR to allocate incoming traffic among the members, the complexity of deriving equilibrium grows substantially. Consider a simple case when $K = 2$ and all the four groups use the PRR. If group M_1 in country A decides to increase the settlement rate r_1 charged to its counterpart group N_1 in country B, intuitively the retail market share of N_1 and returning traffic to M_1 are reduced. Through the PRR, group members in M_1 have less incentive to compete in A's retail market and produce less outputs. The market share of M_1 is comparatively decreased. This places a first negative effect on group M_1. In country B, as N_1's retail marginal cost increased, N_2 can enjoy more market share and incur more traffic which is settled by members in M_2. Also through the PRR, members in M_2 are then willing to carry more outgoing traffic and this further squeezes the market share of M_1. This is the second negative effect to M_1 from increasing r_1. Overall, there is clearly a downward pressure on settlement rates in this market structure. In this subsection, we will specify a demand function to show an equilibrium which actually has inflated settlement rates, though the retail quantity also increases, compared to the case where all groups apply the ESR.

Suppose all the groups apply the PRR. A typical carrier's profit function is

$$\pi_{Aki} = (P_A - c_A - s_k)\, x_{ki} + \frac{x_{ki}}{X_k}\,(r_k - d_A)\, Y_k.$$

Given the settlement rates for all groups, the traffic volume X_k from group

M_k in country A is given by

$$P'_A (X_k)^2 + m_k (P_A - c_A - s_k) X_k + (m_k - 1)(r_k - d_A) Y_k = 0, \qquad (3.5)$$

and the total outgoing volume X is given by

$$P'_A X + m (p^A - c^A - d^B) - \sum_k m_k (s_k - d_B) + \sum_k (m_k - 1)(r_k - d_A) \frac{Y_k}{X_k} = 0.$$

By backward induction, at the rate-setting stage group k in A chooses r_k to maximize the joint profit of its members,

$$\begin{aligned} \pi_{Ak} &= (P_A - c_A - s_k) X_k + (r_k - d_A) Y_k \\ &= (P_A - c_A - s_k) X_k - \frac{1}{m_k - 1} \left[P'_A (X_k)^2 + m_k (P_A - c_A - s_k) X_k \right] \\ &= -\frac{1}{m_k - 1} \left[(P_A - c_A - s_k) Y_k + P'_A (X_k)^2 \right], \end{aligned}$$

where the second step is derived from the quantity equilibrium condition (3.5). The first order condition is

$$\begin{aligned} & P'_A X_k \left[\frac{\partial X_k}{\partial r_k} + \frac{\partial X_{-k}}{\partial r_k} \right] + (P_A - c_A - s_k) \frac{\partial X_k}{\partial r_k} \\ & + P''_A (X_k)^2 \left[\frac{\partial X_k}{\partial r_k} + \frac{\partial X_{-k}}{\partial r_k} \right] + 2 P'_A X_k \frac{\partial X_k}{\partial r_k} = 0. \end{aligned} \qquad (3.6)$$

Facing the difficulties to further derive useful results, we impose some restrictive conditions to simplify the analysis.

1. The two countries are symmetric in demand and technology.

2. Demand of call volume is linear in both countries, $P_A = 1 - X$, $P_B =$

$1 - Y$. Thus, $\eta_j = 0$, $j = A, B$.

3. The marginal operating costs are $c_A = c_B = c$, $d_A = d_B = d$.

4. There are two international telephone routes, $K = 2$.

5. The partition of carriers is also symmetric, with t members in each group. Thus, $m = n = 2t$.

This symmetric structure gives a symmetric equilibrium. Specifically looking at the outcome in country A, let X be the country's outgoing volume, and r be the settlement rate charged by every group in A. Denote $\bar{X} = 1 - c - d$, which is the traffic level at the social efficiency benchmark. The traffic initiated by each group is then $X/2$. In the symmetric equilibrium, $s = r$ and $Y = X$. Proposition 3.3 characterizes this symmetric equilibrium.

Proposition 3.3 *Under symmetric demand, cost and carriers' partition structure with* $K = 2$*, if all of the groups apply the PRR as their incoming traffic division rule, there exists* $\gamma \in \left[-\frac{3t+1}{t+1}, -2\right]$ *such that the symmetric equilibrium is given by*

$$\begin{aligned} \frac{\bar{X}}{X/2} &= 2 - \frac{2/t + \gamma}{t-1}, \\ \frac{r-d}{X/2} &= -\frac{t+1+t\gamma}{t-1}. \end{aligned} \tag{3.7}$$

Furthermore, γ *approaches* -3*, and* X *approaches* $\bar{X}$ *as* $t \to \infty$.

One implication of Proposition 3.3 is that once the retail competition is perfect (t approaches infinity), even if there are only two international routes, the outcome is still socially efficient. This is similar to the result when all groups use the ESR (Corollary 3.1). Maintain the same demand and cost structure but let all four groups apply the ESR, the equilibrium outcome is, from (3.4),

$$\left(\frac{\bar{X}}{X}\right)^{ESR} = 1 + \frac{3t+2}{2t^2+2t}$$

and compare it with (3.7). The result is shown in Corollary 3.2.

Corollary 3.2 *Under the demand, cost and carriers partition structure specified in this subsection, the equilibrium traffic volume when all groups use the PRR is higher than the level when all use the ESR.*

When each group of carriers use PRR to divide the incoming traffic from their corresponding group in the other country, the (indirect) competition at the settlement services restrict their intention to raise up the settlement rate charging their foreign counterpart, compared with the case when all carriers in a country form a single group. We know that the PRR intensifies the retail competition, this lowered rate essentially translate into a lowered retail price. Unlike the case with $K = 1$ where the traffic division rule has no effect on equilibrium volume or price, Corollary 3.2 shows that, when there is competition at the termination service, the PRR can increase the traffic level compared with the ESR, or decrease the retail equilibrium price.

3.3.3 Discussion

This subsection compares the equilibrium traffic volumes and settlement rates, based on a symmetric world with linear demand, identical technology, and symmetric partitions in the two countries. In addition, when $K = m = n$, each international route has two carriers, one from each country. This is a special case of $K > 1$ with the ESR as the only division rule among all groups. We can also calculate the outcome of this partition structure. Table 1 lists the equilibrium traffic volumes and settlement rates, and their limiting results where horizontal externality disappears, $m \to \infty$.

Table 1 Comparison of the Equilibria (as $m \to \infty$)

		$X/\bar{X}$	$(r-d)/\bar{X}$
$K=1$	ESR	$\frac{m}{2m+2} \to \frac{1}{2}$	$\frac{1}{2}$
	PRR	$\frac{m}{2m+2} \to \frac{1}{2}$	$\frac{m}{2}$
$K=2$	ESR	$\frac{m(m+2)}{m^2+5m+4} \to 1$	$\frac{2}{m+4} \to 0$, or $r \to d$
	PRR	$\frac{m(m-2)}{m^2-2m-4-m\gamma} \to 1$	$\frac{m(m+2+m\gamma)}{2(-m^2+2m+4+m\gamma)} \to 1$, or $r \to 1-c$
$K=m$	ESR	$\left(\frac{m}{m+1}\right)^2 \to 1$	$\frac{1}{m+1} \to 0$, or $r \to d$

As the notations in the last subsection, $\bar{X}$ represents the efficient outcome $(1-c-d)$, and $\gamma \in \left[-\frac{3m+2}{m+2}, -2\right]$.

$X/\bar{X} = \frac{1}{2}$ corresponds to our monopoly benchmark, and $X/\bar{X} = 1$ corresponds to the social efficiency benchmark. The efficiency of international telephone market relies on two types of competition, retail competition and settlement service competition. The case $K = m$ generates the highest traffic level among all five cases in Table 1. When the retail competition structure is fixed, an increased provision of international routes creates higher traffic levels, thus higher efficiency gains.

Efficient traffic levels do not always come with cost-based settlement rates ($r = d$). The particular traffic division rule also affects the level of rates. Whenever the PRR is adopted in these cases, the settlement rates tend to be very high. However the traffic levels are not worse off, due to the intensive retail competition under the PRR. This indicates that the level of settlement rates itself does not sufficiently reflect the efficiency of the market.

3.4 Discussions

This chapter discussed the structures of Nash bargaining settlement rates and multiple routes. Cooperation between complementary service providers can enhance market efficiency. When the requirement of collective rate-setting is relaxed, even if the settlement rate determination is still non-cooperative across countries, retail competition can steer the market outcomes toward the most efficient level where the calling price is equal to the real marginal cost.

Together with Chapter 2, the theoretical findings contribute to the understanding of the impact of the FCC's policies that were implemented in late 1980s. In this last section, we want to highlight them and illustrate how our models are able to fit the actual market outcomes by using the U.S. data. Specifically, we want to associate the changes in the U.S. collection rate and net settlement payment with the changes in both bilateral competitiveness and FCC's policies.

Recalling from Chapter 2, Figure 2.1 shows average retail prices (or collection rates) and settlement rates in the U.S. from 1964 to 2002. During this period roughly 50% of the total revenues collected from domestic consumers were paid to foreign countries in order to obtain their cooperation in terminating calls. Market power at the termination service would artificially raise up the settlement rate, henceforth the collection rate paid by consumers. Figure 2.2 plots the total retail revenues, settlement payouts and receipts in year 2000 dollar from exchanging traffic with other countries. The gap between payout and receipt is the *net settlement payment*, represented by the shaded area in the figure. At its largest amount, the U.S. net settlement payment to all other countries in 1996 was about 6.4 billion dollars, 40% of total billed revenue in that year. Not surprisingly, this substantial outflow created international disputes until more balanced payments appeared in recent years. This warrants a careful study of bilateral market structure and government policy toward restraining the power and protecting domestic welfare.

From the trends shown in these two figures and the FCC's policy changes, we divide the development of the international telephone markets into four periods and use a corresponding model to analyze the observed market outcomes.

■ The first period, before the 1980's, the industry was typically a bilateral monopoly structure, whereas the U.S. market was solely operated by AT&T. The early literature has discussed this market structure and it is nested in our model (by taking $m = n = 1$).

Our primary interest lies in analyzing the following periods. We try to explain the market outcomes of the second and third periods by our model of bilateral oligopoly and "whipsawing" model. The model of multiple-route is designed for the fourth period in international telephone market.

■ We refer the second period to be the one after the MCI's entrance and before the FCC implemented its International Settlement Policy in 1986. The period started with a sharp drop in the U.S. retail price. This drop might be largely due to the entrance and the direct competition between AT&T and MCI. At this point, the U.S. market was opened up for other entrants and we have observed reduced markups between collection rates charged and settlement rates paid by the U.S. carriers. This observation agrees with our theoretical prediction about the effect of (domestic) retail competitiveness. No matter the foreign market, more intense retail competition results in lower retail price in equilibrium.

One would expect that the huge progress in networking technology led to lower operating costs and might benefit consumers through even lower calling rates.[13] However, these pro-competitive factors seemed to stop functioning and did not bring in large price drops until the mid-1990's, as the Figure 2.1 illustrates relatively stable average collection rates between the mid-1980's and mid-1990's.

The bilateral structure in this period was typically with the U.S. side being competitive and the other side monopolistic. Without restriction on

[13]For example, Cave and Donnelly [1996] provide the estimates of per-minute cost of using trans-Atlantic cable, \$2.53 in 1956, \$0.04 in 1988 and \$0.02 in 1992.

the foreign monopoly power or a cooperation among the U.S. carriers, the foreign monopolist could "whipsaw" the competing U.S. carriers and extend its market power to the U.S. market through unequal settlement terms.

Out of the fear that the domestic welfare was being transfered abroad in the form of net settlement payments and prevailing consumer price did not reflect the potential from domestic competition, the FCC initiated a set of rules to govern the settlement negotiation in 1987, in a hope to bring down the settlement rate and collection rate. Those rules were briefly described in the Introduction.

■ The years between 1987 and 1997 is deemed to be the third period in our analysis of the international telephone markets. The major feature in this period was still that competing U.S. carriers exchanged traffic with monopoly carriers in other countries. Nonetheless, the U.S. carriers were subject to the FCC's requirement of uniform settlement rates and PRR for incoming traffic division.

To analyze these two periods, we first presented a model of bilateral oligopoly. When domestic carriers collectively set uniform settlement rates and determine settlement rates non-cooperatively, we found that the PRR makes retail competition more intensive. However, our model of bilateral oligopoly predicted that this retail effect is neutralized through inflated settlement rates. The equilibrium retail prices and traffic volumes are unaffected by incoming traffic division rules. The market outcome with retail competition in both countries is still less efficient than the integrated monopoly outcome.

We next studied a scenario of settlement determination between a competitive country and a monopoly country. If each competitive carrier individually negotiates a settlement term with the monopolist, this is an approximation of the "whipsawing" that caused the FCC to restrict carriers' behavior in negotiations with foreign carriers. Interestingly, by comparing the sub-game perfect equilibriums before and after those requirements, we found that FCC's policies may not reduce the U.S.'s net settlement payment to other countries. Instead, there is a good chance that the policy can worsen the imbalance. Figure 2.2 showed that the net settlement payment from the U.S. had been climbing up over the years in 1980's and the early 1990's. Its increase even accelerated in the late 1980's when PRR was imposed upon the U.S. carriers. Our prediction seems to be compatible with the data.

To further examine our theoretical prediction on the connection between net settlement payment and retail competitiveness in both ends of an international route, we collected the annual data on 42 countries that exchanged international traffic with the U.S. carriers, from TeleGeography [1993-2004], ITU [1999] and ITU [2004], for the period 1992–2003.[14] From the market shares of major carriers in those countries, we calculated three indices to capture the market competitiveness, namely the Herfindahl-Hirschman Index (HHI), the market share of the largest carrier ($CR1$) and the market

[14]These countries, categorized by their geographic locations, are: *Africa:* Egypt, Nigeria, South Africa; *Asian-Pacific:* Australia, China, Hong Kong, India,Indonesia, Japan, New Zealand, South Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand; *Eastern Europe:* Czech Republic, Hungary; *Middle East:* Israel; *West Hemisphere:* Canada, Costa Rica, Honduras, Mexico, Argentina, Brazil, Chile, Colombia, Ecuador, Venezuela; and *Western Europe:* Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom.

share the largest two carriers ($CR2$).

The FCC's International Bureau publishes the operation data of the U.S. carriers (*http://www.fcc.gov/ wcb/iatd/intl.html*). From it, we calculated the average collection rate, average settlement rate and net settlement payment paid by U.S. carriers to those 42 countries, as well as the HHI and CR's of the U.S. market in exchanging traffic with those countries.

All the monetary variables are deflated and converted into the constant U.S dollar by using the Consumer Price Index (base year 2000). Table 3.1 presents the average collection rate, average settlement rate paid by the U.S. carriers, the net settlement payment from the U.S. to those 42 countries and three indices for market concentration of the U.S. and the average foreign country. Figures 3.2, 3.3 and 3.4 plot them for a comfortable reading of those data.

The data about market competition before 1990's is either unavailable or incomplete. One characteristic of the market, however, is certain. While the U.S. market was gradually moving into a competitive structure since late 1970's, with HHI and $CR1$ in 1992 reaching 5446 and 70.3, respectively, almost all the other countries were still monopolistic.[15]

The net settlement payment by U.S. carriers dropped by 21% in the 1997. Comparing with the average change rate of 0.44% (which represents an increase in net settlement payment) in the previous years, we would treat this as a year of structural change. We relate this change to two facts happening in that year. First one is that the U.S. FCC started to implement the

[15]Our data shows that, in 1992, the HHIs of Australia, Chile, Korea, Philippine and United Kingdom are 9608, 6801, 6788, 8920 and 6436, respectively. All the other countries were monopolized, with HHI being 10000 and $CR1$ 100.

Benchmark Policy which prescribes the settlement rate caps for the negotiation across carriers. The second, as shown by the changes of foreign HHI and $CR1$, the foreign market, in average, significantly increased its domestic competition in their international telephone markets. The noticeable feature is that the previously dominant carriers quickly lost their market shares since the year.

■ Finally, in the years following the Benchmark Policy, the yearly average settlement rates are generally falling below the prescribed caps (\$0.15 for upper income countries, \$0.19 for middle income countries and \$0.23 for lower income countries). Our multiple-route model tries to explain this phenomenon. When the foreign country is competitive and FCC removed the collective bargaining requirement onto the U.S. carriers, multiple routes for transmitting telephone messages become feasible. Although the facility-based carriers don't necessarily compete directly at providing the settlement service in our model, the retail competition is able to translate into the competition at that segment. We showed that this multiple route feature is sufficient to drive down both the settlement rate and retail price toward the socially efficient level.

Overall, although the discussion in this section is not based on rigorous empirical analysis, we see our theoretical predictions well match those casual observations on the relations among retail prices, settlement rates and net settlement payments in different stages of the market development. Our findings help understand the impact of the FCC's policies that were implemented in late 1980s. These results also support the FCC's initiation of Benchmark Orders (settlement rate caps) in the late 1990's, because the previous restrictions on carriers cannot bring down settlement rates and enhance the market efficiency through carriers' voluntary actions. We identify that the efficiency gain from retail competition cannot be realized unless competition is also introduced at settlement service. This calls for the breakdown of carriers' coalition within a country when the other side of an international route is also competitive.

The models studied here can serve as a backbone for several extensions. For example, international roaming service shares similar features as international telephone. Specifically, when a subscriber travels outside the network of her carrier, the carrier needs to pay to access the traveler destination's network. We still see a huge markup in roaming charges which implies the market efficiency needs to be recovered. Also, in a study of the international telephone markets, demand specifications can consider the feature of substitutability/complementarity between the two directions of calls. Carriers' pricing strategies and settlement rate choices may differ in these environments, and so may the policy considerations. We have provided several theoretical predictions that were not found in the previous literature: the PRR plays a role in maintaining high settlement rates and worsening the net settlement payments; this traffic division rule has different effects on the final markets when the settlement rate determination regimes are changed. It will be highly valuable to empirically verify them in a structural framework.

Table 3.1: Comparison of U.S. and Foreign Market Competitiveness

Year	US Collection Rate (US$)	Settlement Rate (US$)	Net Settlement Payment (B. US$)	US *HHI*	Foreign *HHI*	US *CR*1	Foreign *CR*1	US *CR*2	Foreign *CR*2
1992	0.99	0.56	2.02	5446	9624	70.3	97.6	91.5	100.4
1993	0.96	0.50	2.16	4625	9365	62.2	95.8	87.6	99.6
1994	0.86	0.44	2.16	4554	9111	60.1	93.9	88.7	98.4
1995	0.80	0.38	2.14	4106	8999	54.3	93.1	86.3	98.0
1996	0.65	0.31	2.05	3790	8823	50.2	91.9	83.1	97.4
1997	0.59	0.23	1.62	3229	8380	44.7	88.8	75.9	95.5
1998	0.54	0.20	1.39	2978	7438	42.9	82.4	71.5	93.0
1999	0.48	0.15	1.43	2542	6588	36.8	75.6	65.1	90.1
2000	0.44	0.12	1.22	2245	5784	33.0	69.4	58.7	85.7
2001	0.29	0.09	0.86	2231	5264	30.9	65.4	60.4	82.8
2002	0.24	0.08	0.92	2083	4538	30.1	59.1	57.8	78.8
2003	0.18	0.07	0.94	1887	4154	26.0	55.1	50.9	77.2

Sources: own calculation.

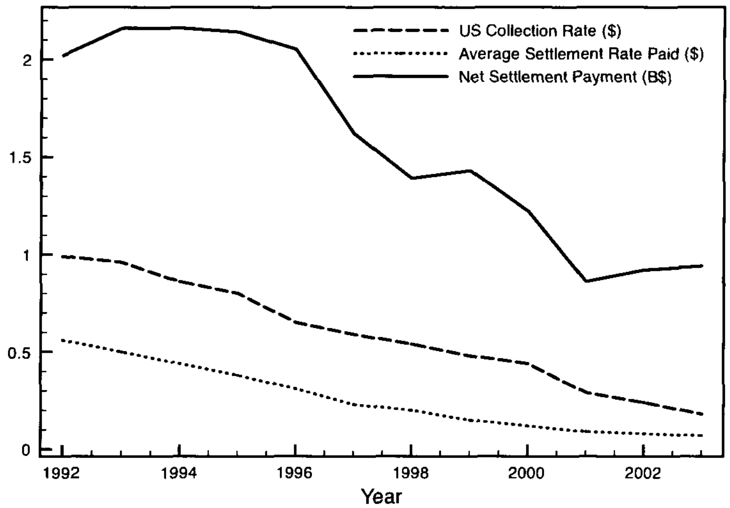

Figure 3.2: U.S. collection rate, settlement rate and net settlement payment (1992–2003)

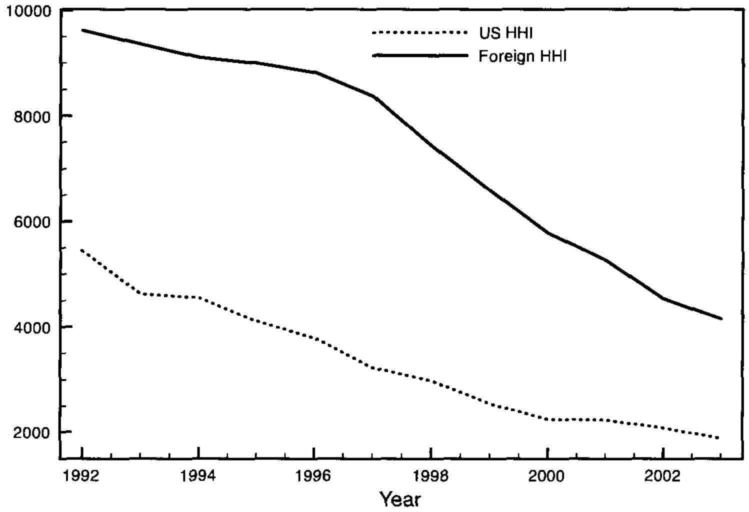

Figure 3.3: HHIs of the U.S. and average foreign country

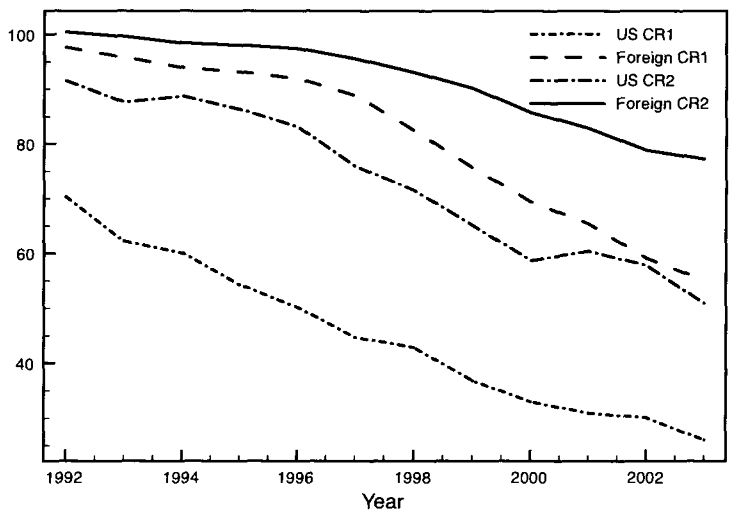

Figure 3.4: $CR1$ and $CR2$ of the U.S. and average foreign country

3.5 Appendix: Proofs in Chapter 3

3.5.1 Proof of Lemma 3.1

Any (X, Y) with either $\Pi_A < 0$ or $\Pi_B < 0$ cannot be optimal. Our attention is then restricted to the region with $\Pi_A \geq 0$ and $\Pi_B \geq 0$.

The first order condition of Nash bargaining problem with respect to X is

$$\begin{aligned}\frac{\partial N}{\partial X} &= \left[\frac{(1-\kappa_A)\kappa_B}{1-\kappa_A\kappa_B}\frac{dM_A}{dX} - \frac{1-\kappa_B}{1-\kappa_A\kappa_B}\frac{X}{m}(2P'_A + P''_A X)\right]\Pi_B \\ &\quad + \Pi_A \frac{1-\kappa_B}{1-\kappa_A\kappa_B}\phi'_A(X).\end{aligned}$$

Proposition 2.2 shows that $X^* < X^M$, which implies

$$\frac{dM_A}{dX} > 0 \text{ for } X < X^M, \text{ and } \phi'_A(X) > 0 \text{ for } X < X^*.$$

It follows that for any (X, Y) with $X \leq X^*$,

$$\frac{\partial N}{\partial X} \geq 0.$$

Similarly, we can obtain

$$\frac{\partial N}{\partial Y} \geq 0$$

for any (X, Y) with $Y \leq Y^*$.

3.5.2 Proof of Lemma 3.2

From the proof of Lemma 3.1, we can then restrict the discussion to the set of volumes with $X \geq X^*$, $Y \geq Y^*$, $\Pi_A \geq 0$, and $\Pi_B \geq 0$.

Moreover, note that

$$\phi'_A(X) = \frac{dM_A}{dX} + \frac{X}{m}(2P'_A + P''_A X).$$

It follows that

$$\begin{aligned}(1-\kappa_A\kappa_B)\frac{\partial N}{\partial X} &= \frac{dM_A}{dX}[(1-\kappa_A)\kappa_B\Pi_B + (1-\kappa_B)\Pi_A] \\ &\quad +(1-\kappa_B)\frac{X}{m}(2P'_A + P''_A X)(\Pi_A - \Pi_B).\end{aligned}$$

Similarly,

$$\begin{aligned}(1-\kappa_A\kappa_B)\frac{\partial N}{\partial Y} &= \frac{dM_B}{dY}[(1-\kappa_B)\kappa_A\Pi_A + (1-\kappa_A)\Pi_B] \\ &\quad +(1-\kappa_A)\frac{Y}{n}(2P'_B + P''_B Y)(\Pi_B - \Pi_A).\end{aligned}$$

Thus, at any interior (optimal) solution,

$$\frac{dM_A}{dX}\frac{dM_B}{dY} \leq 0.$$

3.5.3 Proof of Proposition 3.1

When $\alpha = \beta = 1$, the Nash bargaining problem is equivalent to the optimization problem

$$\max_{X,Y} U(X,Y;m,n) = u_A u_B \tag{3.8}$$

where

$$u_A = (n-1)M_A(X) + g_A(X) + nM_B(Y) - g_B(Y),$$

$$u_B = (m-1)M_B(Y) + g_B(Y) + mM_A(X) - g_A(X),$$

$$g_A(X) = -P_A'X^2, \quad g_B(Y) = -P_B'Y^2$$

Lemma 3.3 *At the Nash bargaining solution, Assumption 3.1 implies that* $dY^N/dX^N < 0$. *This means that as* m *or* n *changes, the Nash bargaining volumes* X^N *and* Y^N *change in opposite directions.*

Proof. The first order conditions of maximization problem (3.8) are

$$\left[(n-1)M_A'(X) + g_A'(X)\right] u_B + \left[mM_A'(X) - g_A'(X)\right] u_A = 0$$

$$\left[nM_B'(Y) - g_B'(Y)\right] u_B + \left[(m-1)M_B'(Y) + g_B'(Y)\right] u_A = 0$$

It follows that

$$\frac{mM_A'(X) - g_A'(X)}{(n-1)M_A'(X) + g_A'(X)} = -\frac{u_B}{u_A} = \frac{(m-1)M_B'(Y) + g_B'(Y)}{nM_B'(Y) - g_B'(Y)},$$

or equivalently,

$$\frac{M_A'(X)}{(n-1)M_A'(X) + g_A'(X)} = \frac{u_A - u_B}{u_A} = \frac{M_B'(Y)}{nM_B'(Y) - g_B'(Y)},$$

which can be also rewritten as

$$n - 1 + \frac{g_A'(X)}{M_A'(X)} = \frac{u_A}{u_A - u_B} = n - \frac{g_B'(Y)}{M_B'(Y)}.$$

Therefore, at $X = X^N, Y = Y^N$

$$\frac{g'_A(X)}{M'_A(X)} + \frac{g'_B(Y)}{M'_B(Y)} = 1. \tag{3.9}$$

Differentiating both sides of (3.9) with respect to m or n and noticing the monotonicity of g'_j/M'_j ($j = A, B$) by Assumption 3.1, we can show the claim. ■

The proof strategy to show $dX^N/dm > 0$ can be loosely described as follows. Differentiating both sides of the first FOC wrt m yields

$$U_{XX}\frac{dX}{dm} + U_{XY}\frac{dY}{dm} + U_{Xm} = 0.$$

We have previously shown that $U_{XY} > 0$ at the optimal solution. The second order condition of the maximization problem implies $U_{XX} < 0$ at the optimal solution. Lemma 3.3 tells that dY/dm and dX/dm have the opposite signs. Therefore, if we can show $U_{Xm} > 0$ at the optimal solution, then it follows that $dX/dm > 0$ and $dY/dm < 0$.

Note that

$$\begin{aligned} U_{Xm} &= [(n-1)M'_A(X) + g'_A(X)]\,[M_A(x) + M_B(y)] \\ &\quad + M'_A(x)[(n-1)M_A(X) + g_A(X) + nM_B(Y) - g_B(Y)]. \end{aligned}$$

Lemma 3.4 *At the Nash bargaining solution,*

$$(n-1)M'_A(X) + g'_A(X) > mM'_A(X) - g'_A(X).$$

Proof. Assume not. So,

$$(n-1)M_A'(X) + g_A'(X) \leq mM_A'(X) - g_A'(X).$$

Note that from the FOC

$$[(n-1)M_A'(X) + g_A'(X)]u_B + [mM_A'(X) - g_A'(X)]u_A = 0$$

we observe

$$[(n-1)M_A'(X) + g_A'(X)][mM_A'(X) - g_A'(X)] < 0.$$

It follows that

$$(n-1)M_A'(X) + g_A'(X) \leq 0 \leq mM_A'(X) - g_A'(X),$$

which implies

$$(n-1)M_A'(X) \leq -g_A'(X) < 0, \quad \text{and} \quad mM_A'(X) \geq g_A'(X) > 0.$$

A contradiction. Hence,

$$(n-1)M_A'(X) + g_A'(X) > mM_A'(X) - g_A'(X).$$

■

We therefore have,

$$(m-n+1)M_A'(X) - 2g_A'(X) < 0.$$

Next, note that

$$\begin{aligned} u_A &= (n-1)M_A(X) + g_A(X) + nM_B(Y) - g_B(Y) \\ &= (n-1)\sigma + \delta, \end{aligned}$$

$$\begin{aligned} u_B &= (m-1)M_B(Y) + g_B(Y) + mM_A(X) - g_A(X) \\ &= m\sigma - \delta, \end{aligned}$$

where

$$\sigma = M_A(X) + M_B(Y), \quad \delta = g_A(X) + M_B(Y) - g_B(Y).$$

We can then rewrite the FOC as

$$\sigma\left[2m(n-1)M_A'(X) + (m-n+1)g_A'(X)\right] + \delta\left[(m-n+1)M_A'(X) - 2g_A'(X)\right] = 0$$

or

$$\delta = -\sigma\frac{2m(n-1)M_A'(X) + (m-n+1)g_A'(X)}{(m-n+1)M_A'(X) - 2g_A'(X)}.$$

We can also rewrite

$$
\begin{aligned}
U_{Xm} &= \sigma[(n-1)M_A'(X) + g_A'(X)] + M_A'(X)[(n-1)\sigma + \delta] \\
&= \sigma[2(n-1)M_A'(X) + g_A'(X)] + M_A'(X)\delta \\
&= \sigma\left(2(n-1)M_A'(X) + g_A'(X) - f_A'(X)\frac{2(m(n-1)M_A'(X) + (m-n+1)g_A'(X)}{(m-n+1)M_A'(X) - 2g_A'(X)}\right) \\
&= -2\sigma\frac{[(n-1)M_A'(X) + g_A'(X)]^2}{(m-n+1)M_A'(X) - 2g_A'(X)} \\
&> 0.
\end{aligned}
$$

3.5.4 Proof of Proposition 3.2

We only need to show the equilibrium in country A. The one for country B can be obtained similarly. Given the partition structure and settlement rates determined in the first stage, the volumes X_k and X are given by

$$
\begin{aligned}
P_A'X_k + m_k\left(P_A - c_A - s_k\right) &= 0 \qquad (3.10) \\
P_A'X + m\left(P_A - c_A\right) - \sum_{k=1}^{K} m_k s_k &= 0
\end{aligned}
$$

The comparative statics w.r.t. s_k are

$$
\begin{aligned}
\frac{\partial X}{\partial s_k} &= \frac{m_k}{(m+1)P_A' + P_A''X} \qquad (3.11) \\
\frac{\partial X_k}{\partial s_k} &= \frac{m_k}{P_A'}\frac{(m+1-m_k)P_A' + P_A''(X - X_k)}{(m+1)P_A' + P_A''X} \qquad (3.12)
\end{aligned}
$$

When N_k sets s_k for M_k, the maximization of settlement revenue $(s_k - d_B)X_k$ gives

$$
X_k + (s_k - d_B)\frac{\partial X_k}{\partial s_B} = 0
$$

By (3.11) and (3.12),

$$X_k + (s_k - d_B)\frac{m_k}{P'_A}\frac{(m+1-m_k)P'_A + P''_A(X - X_k)}{(m+1)P'_A + P''_A X} = 0 \tag{3.13}$$

Equation (3.10) also tells that

$$P'_A X_k + m_k(P_A - c_A - d_B) = m_k(s_k - d_B)$$

So, (3.13) becomes

$$X_k + \frac{P'_A X_k + m_k(P_A - c_A - d_B)}{P'_A}\frac{(m+1-m_k)P'_A + P''_A(X - X_k)}{(m+1)P'_A + P''_A X} = 0$$

The summation over $k = 1, \ldots, K$ gives

$$X + \sum_{k=1}^{K}\left[\frac{P'_A X_k + m_k(P_A - c_A - d_B)}{P'_A}\frac{(m+1-m_k)P'_A + P''_A(X - X_k)}{(m+1)P'_A + P''_A X}\right] = 0$$

By the definition of ε_A and η_A, we can transform it into the format of price-cost-markup.

3.5.5 Proof of Corollary 3.1

Rewrite the symmetric equilibrium in country A,

$$\frac{P_A - c_A - d_B}{P_A} = \frac{1}{\varepsilon_A}\frac{1}{m}\frac{2(m+1) - \frac{m}{K} + \left(2 - \frac{1}{K}\right)\eta_A}{(m+1) - \frac{m}{K} + \left(1 - \frac{1}{K}\right)\eta_A}$$

$$\frac{s - d_B}{P_A} = \frac{1}{\varepsilon_A}\frac{1}{m}\frac{(m+1) + \eta_A}{(m+1) - \frac{m}{K} + \left(1 - \frac{1}{K}\right)\eta_A}$$

Fix m and Let $K_1 < K_2$. Under the same X, or P_A, we can find out that

$$\frac{2(m+1)-\frac{m}{K_1}+\left(2-\frac{1}{K_1}\right)\eta_A}{(m+1)-\frac{m}{K_1}+\left(1-\frac{1}{K_1}\right)\eta_A} > \frac{2(m+1)-\frac{m}{K_2}+\left(2-\frac{1}{K_2}\right)\eta_A}{(m+1)-\frac{m}{K_2}+\left(1-\frac{1}{K_2}\right)\eta_A}$$

Therefore, the equilibrium volume when $K = K_1$ must be lower than that under $K = K_2$, or the price is higher. By the similar idea, we can show that s is decreasing in K and part (ii) of the corollary. The limiting result is obvious.

3.5.6 Proof of Proposition 3.3

From traffic volume equilibrium condition (3.5), we define

$$\begin{aligned}(s_k - d_B)X_k &= (P_A - c_A - d_B)X_k + \frac{1}{m_k}P_A'(X_k)^2 + \frac{m_k-1}{m_k}(r_k - d_A)Y_k \\ &\equiv f_k^A(X_k, Y_k, X_{-k}, r_k)\end{aligned}$$

where X_{-k} refers to the total volume generated by the other group, i.e., $X_{-k} = X - X_k$. Similarly, we let

$$(r_k - d_A)Y_k = f_k^B(X_k, Y_k, Y_{-k}, s_k)$$

The comparative statics of traffic volume changes with respect to r_k can be solved by

$$\Phi \begin{pmatrix} \frac{\partial X_k}{\partial r_k} \\ \frac{\partial Y_k}{\partial r_k} \\ \frac{\partial X_{-k}}{\partial r_k} \\ \frac{\partial Y_{-k}}{\partial r_k} \end{pmatrix} = \begin{pmatrix} -\frac{m_k - 1}{m_k} Y_k \\ Y_k \\ 0 \\ 0 \end{pmatrix}$$

where,

$$\Phi = \begin{pmatrix} \frac{\partial f_k^A}{\partial X_k} - (s_k - d_B) & \frac{\partial f_k^A}{\partial Y_k} & \frac{\partial f_k^A}{\partial X_{-k}} & 0 \\ \frac{\partial f_k^B}{\partial X_k} & \frac{\partial f_k^B}{\partial Y_k} - (r_k - d_A) & 0 & \frac{\partial f_k^B}{\partial Y_{-k}} \\ \frac{\partial f_{-k}^A}{\partial X_k} & 0 & \frac{\partial f_{-k}^A}{\partial X_{-k}} - (s_{-k} - d_B) & \frac{\partial f_{-k}^A}{\partial Y_{-k}} \\ 0 & \frac{\partial f_{-k}^B}{\partial Y_k} & \frac{\partial f_{-k}^B}{\partial X_{-k}} & \frac{\partial f_k^B}{\partial Y_{-k}} - (r_{-k} - d_A) \end{pmatrix} \tag{3.14}$$

Similarly, we can find out the comparative statics of volumes with respect to the changes of other three settlement rates.

After imposing the symmetric demand, cost specification and the symmetric equilibrium conditions, let $\beta = 1 - \left(\frac{3}{2} + \frac{1}{t}\right) X - c - r$. At the symmetric equilibrium, the equation (3.5) becomes

$$r - d = t\bar{X} - \left(t + \frac{1}{2}\right) X, \tag{3.15}$$

and (3.14) becomes

$$\Phi = \begin{pmatrix} \beta & \frac{t-1}{t}(r-d) & -X/2 & 0 \\ \frac{t-1}{t}(r-d) & \beta & 0 & -X/2 \\ -X/2 & 0 & \beta & \frac{t-1}{t}(r-d) \\ 0 & -X/2 & \frac{t-1}{t}(r-d) & \beta \end{pmatrix}$$

Also,

$$\begin{aligned} \frac{\partial X_k}{\partial r_k} &= \mathcal{C}\left[\left(\left(\frac{t-1}{t}\right)^2 (r-d)^2 - \beta^2\right)(\beta + r - d) \right. \\ &\quad \left. + \left(\frac{Q}{2}\right)^2 (\beta - (r-d))\right] \qquad (3.16) \\ \frac{\partial X_{-k}}{\partial r_k} &= \mathcal{C}\left(\frac{X}{2}\right)\left[\left(\frac{X}{2}\right)^2 - \beta^2 - \left(\frac{t-1}{t}\right)^2 (r-d)^2 \right. \\ &\quad \left. -2\beta(r-d)\right] \qquad (3.17) \end{aligned}$$

where $\mathcal{C}$ is a common term which will be eliminated later. At the symmetric equilibrium, (3.6) becomes

$$\left(\beta - \left(1 - \frac{1}{t}\right)X\right)\frac{\partial X_k}{\partial r_k} - \frac{X}{2}\frac{\partial X_{-k}}{\partial r_k} = 0. \qquad (3.18)$$

Define $\gamma = 2\beta/Q$. By the definition of β and (3.15), we can find out that

$$\begin{aligned} \frac{\bar{X}}{X/2} &= 2 - \frac{2/t + \gamma}{t-1}, \qquad (3.19) \\ \frac{r-d}{X/2} &= -\frac{t+1+t\gamma}{t-1}. \qquad (3.20) \end{aligned}$$

Dividing (3.18) by $(X/2)^4$ and applying equations (3.16), (3.17) and (3.20) results in

$$\left(2+5t-t^2-6t^3\right)+\left(-8t^3+9t^2+7t+2\right)\gamma$$
$$+t\left(4t^2+4t+5\right)\gamma^2+2t^2\left(t+1\right)\gamma^3=0 \tag{3.21}$$

which describes the symmetric equilibrium outcome in term of γ, independently of the demand and cost parameters. There are three roots to (3.21) and Lemma 3.5 points out the correct one for equilibrium. Based on it, equation (3.19) gives us the diversion of equilibrium output from the social efficiency and completes the proof.

Lemma 3.5 *One root of the equation (3.21) is within* $\left[-\frac{3t+1}{t+1},-2\right]$, *one is within* $[-1,0]$, *and the third one is within* $[0,2]$. *The first root is the correct one for the symmetric equilibrium, and it approaches to* -3, *as* $t\to\infty$.

Proof. *Evaluating equation (3.21) at* $\gamma=-\frac{3t+1}{t+1}$ *gets*

$$-\frac{t\left(2t^3-3t^2+1\right)}{\left(t+1\right)^2}<0$$

and at $\gamma=-2$, *it is* $10t^3-19t^2+11t-2>0$. *Therefore, there is one root in* $\left[-\frac{3t+1}{t+1},-2\right]$. *By similar way, we can find out the regions within which the other two roots fall into.*

The non-negativity of price requires that $\frac{\bar{X}}{X}>1$, *or* $\gamma<-\frac{2}{t}<0$. *Therefore the positive root is ruled out. The non-negativity of settlement rate requires* $\gamma<-\frac{t+1}{t}<-1$. *So, only the root within* $\left[-\frac{3t+1}{t+1},-2\right]$ *is the one for us. The limiting result can be found by dividing equation (3.21) with* t^3.

■

3.5.7 Proof of Corollary 3.2

Re-label the volume in equation (3.19) as $\left(\frac{X}{\bar{X}}\right)^{PRR}$. The difference between equilibrium volumes under PRR and ESR is

$$\begin{aligned}
\Delta &= \left(\frac{X}{\bar{X}}\right)^{PRR} - \left(\frac{X}{\bar{X}}\right)^{ESR} \\
&= \frac{2\,(t-1)}{2t-2-\frac{2}{t}-\gamma} - \frac{2\left(t^2+t\right)}{2t^2+5t+2} \\
&= -\frac{2t^2\,(3t+t\gamma+1+y)}{\left(-2t^2+2t+2+t\gamma\right)(3t+2)}
\end{aligned}$$

By Lemma 3.5, we can find out that $\left(-2t^2+2t+2+t\gamma\right) < 0$ and $(3t+t\gamma+1+y) > 0$. Therefore, $\Delta > 0$.

Chapter 4

Empirical evidence

4.1 Introduction

The international telephone markets in the United States have undergone several stages of regulatory changes since the late 1970's, when the monopoly position of AT&T started to be eroded away through the entrance of MCI and subsequently other carriers. Along with the changes, two major economic factors forced the Federal Communication Commission (FCC) to consider a modification to its existing policy. The first is the market power of those facility-based telephone carriers in both the U.S. market and the foreign countries. The second is the policy effectiveness, whether its ongoing policy can constrain the behaviours of those dominant carriers in providing their call initiation services to callers and call termination services to call-initiating carriers, to the benefit of the U.S. consumers. (FCC 1987, 1997, 1999, 2002 and 2004) In this paper, I will try to empirically test the effects of those policies, in particular the introduction to competition and the Proportional Return Rule, whether these unilateral efforts at the U.S. side could limit the markup in settlement services offered by the foreign carriers.

4.1.1 Market structure and the FCC's policies

A critical feature in the structure of international telephone markets lies in the fact that the telephone traffic flows in two directions, while in a standard vertical relation, goods or service typically flow in a single one. This difference is because the completion of an international telephone call involves two major components. A domestic carrier collects the call, and a foreign counterpart terminates the call by delivering it to the receiver. The access to the foreign carrier's network is an essential and complementary input for the domestic service provider, and a service payment, often called settlement rate, is made from the domestic to the foreign carrier. Since international telephone calls typically flow in both directions, a facility-based carrier normally provides both originating and terminating services and hence has two sources of revenues: retail and settlement revenues. Furthermore, as a major part of carriers' marginal cost in providing international telephone service, the settlement rate can affect efficiency and consumer benefits to a large extent.

One reaction toward high international long distance price by the government is to introduce competition into the domestic retail market. This started with the entrance of MCI in the late 1970's. Until the mid-1990's, those competing U.S. carriers mainly dealt their traffic exchanges with foreign monopoly carriers in most of the other countries in the world. This asymmetry in the bilateral market structures creates possible harm to the U.S. callers if a foreign carrier can leverage its domestic market power and let the US carriers compete each other in the settlement negotiations. For example, the U.S. carriers might have to pay a high settlement rate to the foreign carrier in order to deliver the U.S. outgoing traffic, and charge a low rate for terminating incoming traffic from the foreign carrier, because the foreign monopoly controls the essential access to its national network and the termination service provided by the U.S. carriers is basically homogeneous to foreigners.

Since the mid-1990's, most other countries gradually started to liberalize their domestic markets to competition, allowing more than one facility-based carriers to directly exchange traffic with the U.S. carriers. This break-down of bottleneck at the foreign ends gives a possible rise of multiple routes for a U.S.-initiated call to reach the destination. This interconnection structure inherently enhances the bargaining position of the U.S. carriers and enables them to negotiate favorable settlement agreements, prominently, lowered settlement rates.

Besides the changes in the bilateral market structures between the U.S. and the other countries, the U.S. FCC has been constantly revising its policies toward the carriers conducts in their agreements of traffic settlement. The major parts of the policies include the *International Settlement Policy* (ISP) implemented in 1987, *Benchmark Policy* in 1997 and the *Flexibility Order* in 2002.

The ISP consists of three major components: 1) *Uniformity*: all the U.S. carriers must pay the same settlement rate for the outbound traffic on the same route; 2) *Reciprocity*: the U.S. carriers must receive the same rate for terminating inbound traffic from a foreign country as the rate paid for outbound traffic; 3) *Proportional Return Rule (PRR)*: traffic from a foreign country is allocated among the U.S. carriers in exact proportion to their shares of outbound to that country.

The Benchmark Policy in 1997 requires, within a prescribed transition period, all the U.S. carriers to negotiate settlement rates to be less than or equal to 15¢ for upper income countries, 19¢ for upper- and lower-middle income countries, and 23¢ for lower income countries. Since 2002, when the country that interconnects with the U.S. carriers is considered to be competitive, the ISP is removed from the negotiation of settlement agreements among the carriers. It implies that the international telephone carriers from both sides can freely choose their business partners and allocate the traffic. The FCC claimed that if the ISP were still imposed upon these routes, Uniformity and Reciprocity requirements might facilitate the collusion among carriers to sustain a 'high' settlement rate and 'high' retail price FCC [2002].

Figure 4.1 shows average retail prices and settlement rates in the U.S. from 1964 to 2002. Although we have observed the sharp decreases of calling prices in the recent years, the actual effectiveness of those FCC policies is unclear, whether the policies are effective in bringing the calling prices, or the price drop is due to other factors, for example, a lower marginal cost from technology progress. In order to study the policy effects, basically, we need to separate out the contribution of technology changes and the policy impacts onto the firm behaviours while explaining the pricing trends in the international telephone markets.

Furthermore, the Proportional Return Rule, as I will illustrate formally in the section 2.2, has a mixed effect onto the overall efficiency in the market. When a settlement rate is fixed, the carriers that are subject to the PRR

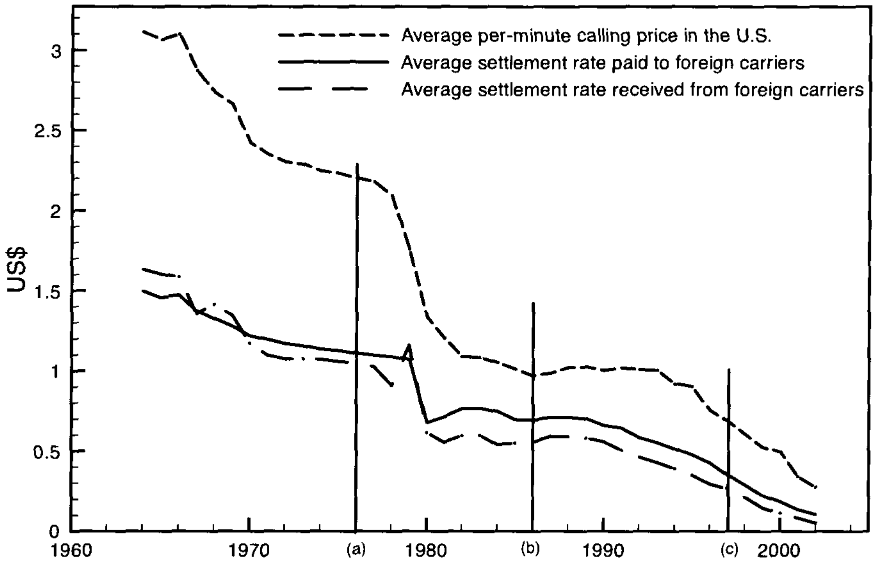

Figure 4.1: Average Retail Prices and Settlement Rates in the U.S. (1964–2002)

(a) MCI entered long-distance telephone market in 1976.

(b) The U.S. FCC implemented the International Settlement Policy in 1986.

(c) The U.S. FCC implemented the Benchmark Policy in 1997.

Source: Blake and Lande [2004]

in incoming traffic division will engage in an intensive retail competition, because each one is keen to grab a big share of settlement payments from the foreign inflows. However, from the perspective of a foreign carrier which provides the settlement service for the U.S.-initiated traffic and which decides the settlement rate to maximize its settlement income, the application of PRR at the U.S. side may generate a traffic level higher than its desired (or settlement income-maximizing) level. The foreign carrier may then utilize a high settlement rate to offset the U.S. carriers incentive in their retail competition. To the U.S. carriers which compete in retail market, a high level of settlement rate is able to alleviate their retail competition. If those carriers can coordinate with each other, the settlement rate can then act as a collusive device for the U.S. carriers. This feature is also found in the literature of local network interconnection, such as Armstrong [1998] and Laffont, Rey, and Tirole [1998]. The overall effect of PRR toward the calling prices then becomes questionable and warrants a careful study.

As in many other applications, the efficiency in international telephone markets is usually measured by their retail prices and input prices, hereby the settlement rates. [16]

Additionally, the Net Settlement Payments are always used as another measure to evaluate the market outcomes in the U.S. market. The U.S. is usually a net outflow country, and an above-cost settlement rate not only results in a high calling price paid by the U.S. consumers, but also incurs a

[16] The physical marginal cost of providing the international telephone calls is believed to be at a tiny scale and can be neglected. For example, Cave and Donnelly [1996] provide the estimates of per-minute cost of using trans-Atlantic cable, $2.53 in 1956, $0.04 in 1988 and $0.02 in 1992. The recent rapid progress in routing technology can surely bring down the number even further.

large amount net settlement payments to the foreign countries. For example, the U.S. net settlement payment to all other countries in 1996 was about 6.4 billion dollars, representing 40% of the total billed revenue in that year. These net settlement payments were deemed as a welfare transfer out of the U.S., and naturally created a vast concern and debates over the government policies, see the cited FCC documents, Johnson [1989] and Galbi [1998]. The major effort by the FCC to narrow down the traffic imbalance was the implementation of International Settlement Policy which includes the PRR and the Benchmark Policy [17] afterwards.

4.1.2 Literature

There are several empirical research papers on the international telephone markets related to my theme here. Madden and Savage [2000] provided a simultaneous four-equation model, motivated by the theoretical framework in Yun, Choi, and Ahn [1997], to explain the U.S. calling prices to foreign countries, correspondent foreign calling prices to the U.S., outgoing call volume and incoming call volume. Specifically, the paper assumes an equal division rule among the U.S. carriers in routing foreign incoming traffic and settlement rates to be exogenous. The endogenous variables, calling prices and calling volumes are identified through the assumption of Cournot equilibrium and the 3SLS. Other independent variables to capture cost differences include the distance between countries, telecommunications labor produc-

[17] One noticeable fact about the Benchmark Policy is that the settlement rate caps chosen by the FCC are well above any measure of the per-minute operation cost of providing international telephone services. The recent progress in both the bilateral market structures might the actual economic reason behind the sharp drops in the settlement rates and henceforth the calling prices. This is also examined in Ju and Tan [2007].

tivity (lines per employees), and percentage of digitization in the network. They also include three independent variables related to market competitiveness, namely dominant carrier's market share, combined private ownership shares and combined number of pairwise carriers. The paper is the first structural model to empirically study the markets, although the results are somewhat inconsistent, for example, one supply equation is estimated to be downward slopping.

Two issues that are overlooked in the paper may result in the inconsistency. The first is their assumption on the exogeneity of settlement rates. Since the rates are one kind of input prices charged by the players in the market, it is natural to believe that a fluctuation in the final demand or the routing cost would induce the traffic-exchanging carriers to re-negotiate a new set of settlement rates. The second issue is related to the FCC's policy, the PRR. The paper's sample period is 1991–94 when the rule was clearly implemented. Termination of incoming traffic is a profit source for the U.S. carriers, and it may become quite significant when the volume is large. The PRR relates a carrier's this profit to its retail performance. Whether the rule has any real effect on the markets is still unanswered in the empirical literature. The theoretical predictions in Ju and Tan [2007] about the PRR's impact on settlement rates is always positive, that is, the PRR would induce the carriers to choose a high settlement rates, no matter the determination regime is non-cooperative, collusive or through Nash-bargaining. The effect toward retail prices is mixed. If the carriers non-cooperatively choose settlement rates for each other, the PRR has no effect on the retail prices. But it can lower the prices if carriers use Nash-bargaining.

To provide an empirical perspective toward the determination of settlement rates, Wright [1999] collected 167 calling partners with the U.S. in 1980–1996 to explain the settlement rates as a (linear) function of pairwise differences in GDP per capita, distance between countries, foreign land area, foreign population, the share of outgoing calls from the U.S. carried by AT&T competitors, and a dummy for the allowed foreign competition. All these factors are assumed to be exogenous. The paper corrects each year-by-year equation for heteroscedasticity and uses three estimation techniques in the pooled analysis: standard OLS with time dummies, a panel regression that allows for individual and time dummies, and a random effects model that assumes that country intercepts are drawn from a common distribution. Wright argues in his theoretical model and gets identified in the empirical part that income difference between countries drives up the settlement rates. As to the market competitiveness, the empirical findings refute his conjecture that settlement rates would increase with the U.S. domestic competition. The problem might be from the simultaneity between the competitiveness and the rates, or possible specification issue on the settlement determination regimes.

Lee [2004] went even further in studying the settlement rate determination by a two-step approach. In the first step, he estimated profit functions of carriers from the observed equilibrium prices and calling volumes. Secondly, he fitted the estimated profit functions into a Nash bargaining model to identify the bargaining power function. His focus in on the collective bargaining requirement in the FCC's policy, by which all the U.S. carriers are required to jointly negotiate settlement terms with foreign counterparts. His counterfactual experiment showed that independent negotiation between a U.S. carrier and a foreign monopolist would result in a lower settlement rate and henceforth retail calling price. However, he forgot that when the competing U.S. carriers did not join together as a group in negotiating settlement terms, the foreign monopolist would have another strategy, "whipsawing" to let them accept unfavourable terms to the disadvantage of U.S. consumers.

4.1.3 Outline

The literature, to my knowledge, has done little about the PRR's effect which is unclear to people. The main objective of this paper is to empirically examine whether the market competitiveness and the PRR could limit the market power of telephone carriers and bring positive effects toward the market efficiency.

In the next section, I will provide a model which is based on Ju and Tan [2007], to illustrate the theoretical connections among the retail prices, settlement rates, competition and the PRR. The testing hypotheses are then put forward. Section 4.3 will summarize the data sources and basic statistics of major variables. I will also introduce a method to measure the scale of PRR in the U.S. market. The estimation results are reported in section 4.4, whilst the section 4.5 contains the conclusions and direction for future research.

4.2 Model and testing hypotheses

The model applied in this section is a simplified version of Ju and Tan [2007]. The major difference is that I take the inflow from foreign country as exogenous. However, this simplification is sufficient to provide the major insights.

4.2.1 Theoretical model

Consider two countries, A and B interconnected to provide international telephone services for the consumers in both countries. We can think of A as the U.S. and B as another country. To focus the attention on the U.S. side, I hereby assume that the U.S. market and policies have no impact toward the foreign demand, and thus take the incoming traffic flow from country B as exogenous. The total settlement payments from B to A is written as F.

The inverse demand for making a call from A to B is given by $P(X)$, where X is A's total outgoing call volumes, and $P(X)$ satisfies the "regularity" assumptions[18]. Country A has m identical international telephone carriers and the operation costs for both initiating and terminating calls are assumed to be zero for the reason of simplicity. The number m can be treated as a measure of competitiveness in the market.

There are two stages in the game. The first stage is settlement rate determination. Carriers in both countries decide a settlement rate s for the outgoing traffic from country A. I consider two determination regimes. One

[18] It is decreasing and twice continuously differentiable. Moreover, $2P'(X)+P''(X)X < 0$.

is the Stackelberg such that the carrier(s) in B chooses a settlement rate s to maximize its settlement income, sX. The other regime is Nash bargaining by which the carriers in both countries maximize the Nash product of their industry profits. In the second stage, A's carriers compete *à la* Cournot for outgoing traffic, with each choosing the size of call volume x_i that it wants to carry over to the other country. The market clears and settlement income F is shared by carriers according to a pre-defined division rule which is specified next.

The settlement payment F is shared by A's carriers according to two basic rules: the Equal Sharing Rule (ESR) which equally allocates F among the m carriers; and the PRR which allocates F according to each carrier's proportion of outgoing traffic, i.e., retail market share x_i/X. Let α be the portion of F that is subject to the PRR; the rest, $(1-\alpha)F$ is then shared through ESR.

The profit function of a carrier i in country A is

$$\pi_i = [P(X) - s]x_i + \left[\alpha \frac{x_i}{X} F + (1-\alpha)\frac{1}{m} F\right], \tag{4.1}$$

where the total outgoing traffic volume $X = \sum_{i=1}^{m} x_i$. The first term in (4.1) is the retail profit collected from domestic callers who subscribe to carrier i. The two terms enclosed in the large brackets represent the income that the carrier i obtains from settling B's traffic. The first one is the profit from settling traffic subject to the PRR and the second is from the traffic under the ESR.

The total industry profit in country A is

$$\Pi = (P(X) - s)X + F; \tag{4.2}$$

and its net settlement payment to country B is

$$NP = sX - F. \tag{4.3}$$

The subgame perfect equilibrium of the game is solved by backward induction. In the second stage of retail competition, given the settlement rate s, aggregating the first-order condition of (4.1) over all the m carriers results in

$$sX = \phi(X) + \kappa F, \tag{4.4}$$

where

$$\phi(X) = P(X)X + \frac{1}{m}P'(X)X^2,$$

and

$$\kappa = \alpha\frac{m-1}{m}.$$

It is easy to verify that, at this stage of the game,

$$\frac{\partial X}{\partial s} < 0, \text{ and } \frac{\partial X}{\partial \alpha} > 0. \tag{4.5}$$

In words, the retail price is increasing in the settlement rate and decreasing in the scale of PRR.

Stackelberg settlement rate

Consider first the Stackelberg settlement rate which is chosen by the carriers in country B to maximize their settlement income sX. By (4.4), the decision to find an optimal settlement rate s is equivalent to the one choosing an X to achieve the same objective,

$$\max_s sX \Leftrightarrow \max_X \left[\phi(X) + \kappa F\right].$$

Subsequently, A's equilibrium outgoing traffic volume X^* is given by

$$\phi'(X^*) = 0,$$

which is independent of α and increasing in m,

$$\frac{\partial X^*}{\partial m} > 0, \text{ and } \frac{\partial X^*}{\partial \alpha} = 0. \tag{4.6}$$

Given the monotonicity result in (4.5), we can find out that the Stackelberg settlement rate s^* has the following properties [19],

$$\frac{\partial s^*}{\partial m} > 0, \text{ and } \frac{\partial s^*}{\partial \alpha} > 0. \tag{4.7}$$

By the properties shown in (4.6) and (4.7), we can find out that the net settlement payment is also increasing in both the competitiveness (m) and

[19] This result comes from differentiating the optimality condition $\phi_X(X(s), m) = 0$,

$$\phi_{XX}\frac{\partial X}{\partial s}\frac{\partial s}{\partial m} + \phi_{Xm} = 0.$$

Since $\phi_{XX} < 0$, $\phi_{Xm} > 0$ and $\partial X/\partial s < 0$, one can obtain the result.

the degree of PRR (α),

$$\frac{\partial NP^*}{\partial m} > 0, \text{ and } \frac{\partial NP^*}{\partial \alpha} > 0. \tag{4.8}$$

Nash bargaining settlement rate

Nash bargaining is another possible modelling method for settlement rate determination. Suppose the carriers in each country form a group and the two industry groups negotiate over the settlement rate s. Their target is to maximize the Nash product,

$$V(s) = \Pi(X; s) \cdot sX. \tag{4.9}$$

By the condition (4.4) which describes the outcome in the retail stage, the maximization of (4.9) can be equivalently expressed as

$$\max_X \ln\left(P(X)X - \phi(X) - \kappa F + F\right) + \ln\left(\phi(X) + \kappa F\right). \tag{4.10}$$

Its first-order condition characterizes the Nash bargaining outgoing volume X^N, and henceforth the Nash bargaining settlement rate s^N by the monotonicity (4.5),

$$\frac{[P'(X^N)X^N + P(X^N)] - \phi'(X^N)}{\Pi(X^N)} + \frac{\phi'(X^N)}{s^N X^N} = 0. \tag{4.11}$$

One finding that is directly implied by (4.11) is about the relative level of X^N,

$$X^* < X^N < X^M,$$

where X^M is given by $P'(X^M)X^M + P(X^M) = 0$, a monopoly output level.

Differentiating (4.11) by κ, since the concavity of $\ln V(X)$, we can find out that

$$\frac{\partial X^N}{\partial \kappa} > 0,$$

which implies that

$$\frac{\partial X^N}{\partial \alpha} > 0. \tag{4.12}$$

By the same method of comparative statics, there is also a monotonic result about the degree of competitiveness,

$$\frac{\partial X^N}{\partial m} > 0. \tag{4.13}$$

Again, through the conditions (4.4) and (4.5) in retail stage, the Nash bargaining settlement rate r^N has the following properties,

$$\frac{\partial r^N}{\partial m} > 0 \text{ and } \frac{\partial r^N}{\partial \alpha} > 0. \tag{4.14}$$

A set of similar results about the net settlement payment can be derived by the properties in (4.12), (4.13) and (4.14),

$$\frac{\partial NP^N}{\partial m} > 0, \text{ and } \frac{\partial NP^N}{\partial \alpha} > 0. \tag{4.15}$$

4.2.2 Hypotheses

The above model generates three sets of testing hypotheses on the settlement rates, calling prices in the U.S. and the net settlement payments made by the U.S. carriers to other countries.

1. Settlement rate, by (4.7) and (4.14):
   (a) The settlement rates is increasing in the degree of competitiveness in the U.S.
   (b) The settlement rate is increasing in the scale of PRR.
2. Calling price, by (4.6), (4.13) and (4.12):
   (a) The U.S. calling price is decreasing in the degree of competitiveness.
   (b) The U.S. calling price is decreasing in or unaffected by the scale of PRR.
3. Net settlement payment, by (4.8) and (4.15):
   (a) The net settlement payment is increasing in the degree of competitiveness in the U.S.
   (b) The net settlement payment is increasing in the scale of PRR.

The major feature of the theoretical findings and the hypotheses put forward here is the doubt toward the effectiveness of PRR. The unilateral competition at the U.S. side creates a mixed welfare outcome: on one hand, it benefits the U.S. consumers through a lowered calling prices; on the other, the competition among the U.S. carriers further enhances the market power at the foreign side and boosts their net settlement payments.

4.3 Data

4.3.1 Description

To examine the market outcomes in the U.S. international telephone industry, I collected the annual data on 42 countries that exchanged international traffic with the U.S. carriers, for the period 1992–2003. This is an unbalanced sample of 449 observations in which some countries only cover part of the sample period. These countries are divided into six regions by their geographic locations,

- *Africa:* Egypt, Nigeria, South Africa;
- *Asian-Pacific:* Australia, China, Hong Kong, India,Indonesia, Japan, New Zealand, South Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand;
- *Eastern Europe:* Czech Republic, Hungary;
- *Middle East:* Israel;
- *West Hemisphere:* Canada, Costa Rica, Honduras, Mexico, Argentina, Brazil, Chile, Colombia, Ecuador, Venezuela;
- *Western Europe:* Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom.

The FCC, International Bureau publishes the operation data of the U.S. carriers (*http://www.fcc.gov/ wcb/iatd/intl.html*). The focus in the paper is those facility-based carriers which provide both call-initiation and call-termination services. For each carrier connecting with each foreign country in one year, the related variables include number of outgoing minutes, revenue collected from U.S. callers, payouts to foreign carriers, incoming minutes that are terminated by this carrier, and receipts from foreign carriers. I then calculated the average price that the U.S. consumers paid to call each country in each year, average settlement rate that the U.S. carriers paid to the other country, the Herfindahl-Hirschman Index (HHI) in the U.S. retail markets and the net settlement payments.

The variables for retail markets in all the foreign markets are obtained from TeleGeography [1993-2004], ITU [1999] and ITU [2004]. They include the average calling price to the U.S., and the market shares of major carriers in those countries (I can then calculate the HHI in them).

Through ITU [1999], ITU [2004], WDI [2007] and ComTrade [2007], I obtained the yearly average exchanges rates, internet users (per 1,000 people), total population, consumer price index, real GDP per capita, percentage of digital main line and the total trade volumes with the U.S.

All the monetary variables are deflated and converted into the constant U.S dollar by using the Consumer Price Index (base year 2000) and yearly average exchange rates. The retail prices and settlement rates are measured by per 3-minutes. Table 4.1 shows the summary statistics of the variables.

Table 4.1: Summary statistics

x	Definition	Mean	Std Dev	Corr(x,P)	Corr(x,R)
P	average calling price in the U.S., per 3-min	0.15	0.10	1	0.91
R	average settlement rate paid by U.S. carriers, per 3-min	0.07	0.07	0.91	1
HHI	HHI in the U.S. retail market	3868	835.95	0.62	0.60
HHI_F	HHI in the foreign retail markets	7140	2888.42	0.67	0.64
P_F	average calling price in the foreign countries, per 3-min	3.12	2.20	0.72	0.77
NP	U.S. net settlement payments (million)	10.44	21.23	0.11	0.23
GDP	U.S. GDP per capita	31880	2403.00	-0.80	-0.75
GDP_F	GDP per capita in foreign countries	15180	11389.90	-0.36	-0.46
ΔGDP	$GDP - GDP_F$	16700	11166.95	0.20	0.31
$size$	product of U.S. and foreign country population	22700	60382.88	0.16	0.26
$internet$	U.S. internet users per 1,000 people	260.20	195.54	-0.78	-0.73
$internet_F$	internet users per 1,000 people in foreign countries	121.7	158.86	-0.63	-0.61
$digit$	U.S. network digitization (%)	82.54	13.90	-0.80	-0.75
$digit_F$	foreign network digitization (%)	83.5	21.23	-0.66	-0.66
$trade$	trade volume between U.S. and foreign (billion)	36.27	64.20	-0.29	-0.24

Sources: FCC, TeleGeography [1993-2004], ITU [1999], ITU [2004], WDI [2007] and ComTrade [2007].

4.3.2 Market concentration

Two measures of market concentration are widely applied in the literature, namely the concentration ratios (CR) and Herfindahl-Hirschman Index (HHI). This subsection briefly illustrates the trends in the U.S. market by using these two measures.

Figure 4.2 shows the trends of four *Concentration Ratios* ($CR1, CR2, CR3$ and $CR4$) from the calculation of market shares in initiating outgoing minutes, after aggregating all the calls to foreign countries in the sample in a year. All the ratios have a clear downward trend, although the leading 3 carriers generally take over more than 90% of the market shares. Specifically, the $CR1$ curve shows the declining market position of AT&T in this market.

Turning to the Herfindahl-Hirschman Index (HHI), Figure 4.3 illustrates the index by using both markets shares in outgoing minutes and incoming minutes, for all calls between the U.S. and the rest of the sample countries. The trends indicated by the HHIs also confirm the deconcentration within this market over the years. The two HHIs largely coincide with each other before the year 2002 which might be due to the implementation of *Proportional Return Rule*, a part of the International Settlement Policy. In 2002, this rule was largely relaxed when the U.S. carriers exchanges traffic with non-dominant foreign carriers. This relaxation became possible because major other countries started to introduce domestic competition in the late 1990's and the number of non-dominant carriers started to climb up.

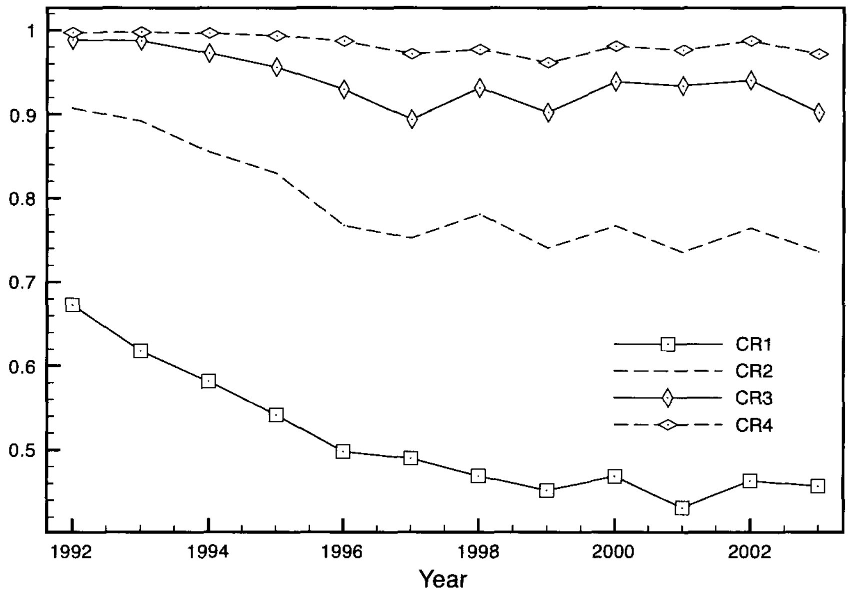

Figure 4.2: Yearly Average Concentration Ratios in the U.S. Retail Market

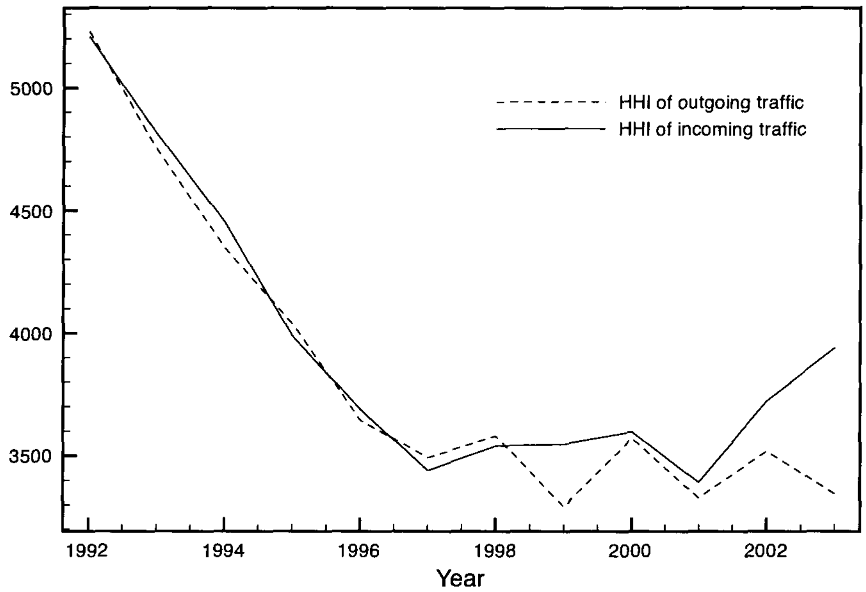

Figure 4.3: HHIs of Outgoing Traffic and Incoming Traffic in the U.S. Market

4.3.3 Measurement of the Proportional Return Rule

It is tricky to capture the variations in the implementations of PRR across different international telephone routes and over time. A simple method to describe the PRR is using a time proxy, which is zero for the years before 1998 (when the rule started to relax) and one otherwise. Clearly, this may forgo precious information embedded in the data.

The PRR was required by the FCC when the U.S. carriers exchanged their traffic with foreign dominant carriers. Henceforth, if all the traffic is subject to the PRR, an U.S. carrier's share in outgoing minutes should be equal to its share of terminating incoming minutes. The rule started to be relaxed in 1998 on the conditions that the interconnecting foreign carrier is not dominant and the negotiated settlement rates are below the corresponding settlement benchmarks. Even during the period when the PRR was firmly required, however, there were always deviations to different degrees, as shown in the data, i.e., an U.S. carrier's share in outgoing minutes to a country does not equal its share in terminating incoming minutes from that country. Many reasons could cause the differences. One is from accounting. Settlement rates usually change many times a year, so do the market shares of carriers. This may result in a discrepancy in the two shares at yearly average level even if the PRR were implemented precisely. The other reason is that many traffic (both incoming and outgoing) were exempted from the FCC's PRR requirement, for example, the traffic through the private lines or internet protocol.

For any reason, rational carriers would take into account of this discrep-

Table 4.2: Measurement of Proportional Return Rule

x	Mean	Median	Std Dev	Min.	Max.	Corr(x,P)	Corr(x,R)
prr	0.92	0.98	0.18	-0.98	0.99	0.30	0.25

Source: own calculation.

ancy when they make retail pricing decisions, likely in the way how the parameter α in the theoretical model adjusts the carriers' behaviours. In this paper, I propose to use the correlation coefficient between the shares of outgoing minutes and shares of incoming minutes of all the carriers serving a destination country to proxy the scale of PRR on that route in a particular year. For example, in a year, the route between the U.S. and Britain was served by six carriers at the U.S. side. Each one has a share in the total outgoing minutes to Britain and a share in settling the incoming minutes from Britain. The correlation coefficient between the series of shares in outgoing minutes and the series of shares in incoming minutes is treated as the intensity of PRR among those carriers on this route. Table 4.2 provides the basic statistics of this measurement.

An OLS regression the *prr* on the *year* gives that, with standard errors in the parenthesis,

$$\begin{array}{ccccc} prr & = & \underset{(0.02)}{1.05} & - & \underset{(0.002)}{0.02} \quad (year - 1991) \end{array} \tag{4.16}$$

There is a significant downward trend in *prr*, a 2% decrease in average per year. This does match the industry facts, such as the proliferation of private lines, voice over internet and possibly more important, the introduction of market competition in other countries.

4.4 Empirical results

This section uses the data described above to investigate the determinants of settlement rates, retail prices and the net settlement payments in the U.S. market. The choices of "exogenous" variables are motivated by the theme of this research and the literature. The results are discussed in the following.

4.4.1 Settlement rates

One of the key predictions in the model is that an intense application of PRR could raise the settlement rates. This is confirmed in the regression model 1 and 4, shown in the Table 4.3. Through calibrating the effect of PRR, one can find that, fixing all the other factors and switching the incoming traffic division from the PRR to an equal sharing rule (with $PRR = 0$), the average settlement rate would decrease by roughly 3.5 cents per 3-minute, which is about the half of the average settlement rate in the sample period.

The coefficients of the market concentrations (HHIs) are generally positive, which implies that concentrated bilateral markets would lead to a high settlement rate, or, bilateral competitive structure would benefit the U.S. with a low settlement rate. This is in contrary to what the model predicts. One possible reason, among many others, is that the model is built upon an assumption that the settlement rate is chosen by, or negotiated with a single foreign entity. If the situation is switched to multiple routes whereby, for example, many carriers in a foreign countries can provide the termination service for U.S. traffic. The routes are essentially competing with each other by settlement rates. This bilateral competition structure may induce the settlement rates to be reduced in those less concentrated markets.

Several other predictors are worth mentioning. "GDP difference" between countries always displays a significant and positive sign, as shown in the Table 4.3. This also confirms the finding in Wright [1999] that settlement rates are increasing in the income disparity, even though his sampling period is 1980-1996 when the bilateral market structure was mainly competition at the U.S. side and monopoly at the foreign side. The trade volume between two countries has a negative effect toward the settlement rate level. This is interesting because a high trade volume usually incurs a high demand for international phone calls. Possible reasons include that the cooperative behaviours of carriers across countries in negotiating settlement rates, and fierce competition for those high-demand routes in the domestic market. One can notice that a higher percentage of network digitization can also bring down the settlement rates, since, intuitively it is an indicator of marginal costs in handling telephone traffic. Between Model 2 and 3, the sign of Internet coverage changes when the variable Year is added. This might be due to the following reason. Within the years of my sample, the Internet coverage has been growing always. This may create a mutli-collinearity problem in the regression. This once again shows the impact of internet development to the traditional telephone network.

Table 4.3: Settlement rate regressions

	Model 1	Model 2	Model 3	Model 4
Constant	$-1.31E-01^*$	$5.89E-02^*$	$2.53E-01^*$	$-9.22E-02^*$
	$(1.70E-02)$	$(1.91E-02)$	$(3.03E-02)$	$(1.85E-02)$
US HHI	$2.93E-05^*$	$7.08E-06^*$	$3.12E-06$	$3.31E-05^*$
	$(3.05E-06)$	$(2.93E-06)$	$(3.08E-06)$	$(2.79E-06)$
PRR	$3.85E-02^*$	$-4.90E-03$	$7.64E-03$	$3.45E-02^*$
	$(1.32E-02)$	$(1.13E-02)$	$(1.10E-02)$	$(1.20E-02)$
Foreign HHI	$6.84E-06^*$	$5.90E-06^*$	$4.11E-06^*$	$7.71E-06^*$
	$(1.21E-06)$	$(9.93E-07)$	$(8.26E-07)$	$(1.06E-06)$
Trade	$-8.87E-14^*$	$-3.52E-14^*$	–	–
	$(3.73E-14)$	$(3.08E-14)$		
ΔGDP	$1.07E-06^*$	$2.17E-06^*$	$1.66E-06^*$	$4.06E-07^*$
	$(2.08E-07)$	$(1.87E-07)$	$(1.73E-06)$	$(2.35E-07)$
Internet	$-1.17E-07^*$	$2.77E-07^*$	–	$-8.64E-08^*$
	$(3.76E-08)$	$(4.10E-08)$		$(3.42E-08)$
Year	–	$-1.59E-02$	–	–
		$(1.09E-03)$		
Digit	–	–	$-2.69E-03^*$	–
			$(2.21E-04)$	
Digit_F	–	–	$-3.91E-04^*$	–
			$(1.27E-04)$	
Asia	–	–	–	$-2.81E-02^*$
				$(1.03E-02)$
E. Europe	–	–	–	$-5.02E-02^*$
				$(1.26E-02)$
M. East	–	–	–	$2.28E-02$
				$(1.70E-02)$
W. Hemis.	–	–	–	$-6.47E-02^*$
				$1.08E-02$
W. Europe	–	–	–	$-6.74E-02^*$
				$(1.08E-02)$
R^2	0.57	0.71	0.70	0.66
Adj. R^2	0.56	0.71	0.70	0.65

Standard errors are in parenthesis.
$*$ represents that the estimate is significant at 5% level.

4.4.2 Retail prices

The prediction concerning retail competitiveness on equilibrium prices is invariant to the settlement rate determination methods. No matter it is Stackelberg or Nash bargaining, retail competition in the U.S. side always benefits the callers with a reduced price. The PRR may or may not bring extra benefit toward the callers, as the competition-enhancing effect of the rule may be offset by a high settlement rate.

The empirical test of the determinants of retail price is tricky because of the endogeneity of both settlement rates and retail prices in this two-stage game. To preliminarily explore the patterns among major economic variables, Table 4.4 gives the regression results of retail prices in the U.S. on various factors. The first noticeable finding is that settlement rate is always a significant determinant of the retail price. A 1% increase in the rate would raise up the retail price by similar magnitude. This warrants the importance of the research into settlement rate determination, especially when there is large level of artificial markup in the settlement rate.

The market concentration measure HHIs in both the U.S and foreign markets have positive signs. This is consistent with the hypotheses in section 4.2.2. Competitive market, especially when competition exists in both sides of an international route, drives down the retail price, even though the settlement rate might move toward a different direction.

The degree of PRR, however, shows a different sign in the regressions of prices than the hypothesis derived from theoretical model. Settlement rate is likely to be an endogenous variable in the regression of retail price, because the carriers would take into account of the demand variation when they negotiate the settlement rate. I tried the two-stage least-square approach, by using network digitization percentage as instruments for the settlement rate. The result largely resemble the findings presented in Table 4.4, with positive signs on PRR and the rate.

Back to the figure 2.1, we can observe a (linear) time trend in the retail price and settlement rate in the sample period 1992–2003. This trend may represent some factors that are not controlled in the empirical models. And, the regression result shown in equation (4.16) also indicates that there is a same time trend in this measurement of PRR. Given this observation, another way to test whether the above finding about the PRR's effect is solid is to remove the time trend in retail price and regress the detrended price on a similar set of factors, as well as the detrended settlement rate. The result is shown in Table 4.5. The interested coefficient is then either significantly negative or insignificant, as the hypothesis.

In the Model 2 in Table 4.5, US HHI has a significant and negative sign which is different to that in Model 1. The change in the sign of HHI after adding settlement rate in explaining retail price might be due to the endogeneity issue. This once again confirm the endogeneity of settlement rate which has not properly been addressed yet in the empirical literature. However, the sign of bias is difficult to predict without a demand specification.

Once again, the trade volume is negatively correlated with the retail price. A probable reason is that a high-demand market would attract unproportionally more entrants to compete than those low-demand ones.

From the theory proposed in section 4.2, the effect of PRR toward the retail price depends on the attractiveness of the foreign settlement payment. I thus define the relative level of the foreign inflow and domestic outflow to be F/X, and a similar variable, $\alpha F/X$. The regression results of the two measure of inflow ratios on retail price and detrended retail price are shown in the Model 4 and 5 in Table 4.4 and Table 4.5. Both measures have significantly positive signs in determining (detrended) retail prices, while the theory predicts a different sign because, fixing other factors, larger inflow would induce intensive retail competition under the PRR. This puzzle also requires a further investigation into the data, as there may other factors to be controlled and the endogeneity of X in the pricing equation.

Table 4.4: Retail price regressions

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	$-7.83E-02^*$	$-6.19E-02^*$	$7.68E-02^*$	$-1.50E-02$	$4.65E-02^*$
	$(1.34E-02)$	$(1.47E-02)$	$(3.66E-02)$	$(1.11E-02)$	$(1.38E-02)$
PRR	$4.35E-02^*$	$3.85E-02^*$	$3.96E-02^*$	$1.89E-02^*$	–
	$(1.00E-02)$	$(1.01E-02)$	$(1.06E-02)$	$(9.46E-03)$	
Settlement rate	$1.12E+00^*$	$1.13E+00^*$	$1.13E+00^*$	$8.03E-01^*$	$7.83E-01^*$
	$(3.98E-02)$	$3.97E-02$	$3.91E-02$	$8.03E-01$	$4.18E-02$
US HHI	$1.38E-05^*$	$1.37E-05^*$	$8.32E-06^*$	$6.47E-06^*$	$4.28E-06^*$
	$(2.70E-06)$	$(2.68E-06)$	$(2.78E-06)$	$(2.47E-06)$	$(2.48E-06)$
Foreign HHI	$3.55E-06^*$	$3.81E-06^*$	$3.83E-06^*$	$4.62E-06^*$	$3.54E-06^*$
	$(7.76E-07)$	$(7.78E-07)$	$(8.33E-07)$	$(7.30E-07)$	$(7.64E-07)$
log(Trade)	–	–	$-4.57E-03^*$	–	–
			$(1.48E-03)$		
ΔGDP	–	$-5.11E-07^*$	–	–	–
		$(1.97E-07)$			
Inflow ratio	–	–	–	$9.48E-01^*$	–
				$(9.48E-02)$	
Inflow ratio * PRR	–	–	–	–	$8.17E-01^*$
					$(9.03E-02)$
Year	–	–	–	–	$-3.49E-03^*$
					$(8.36E-04)$
Size	–	–	$-7.58E-08^*$	–	–
			$(3.34E-08)$		
Asia	$3.20E-02^*$	$2.81E-02^*$	–	–	–
	$(8.60E-03)$	$(8.68E-03)$			
E. Europe	$6.26E-02^*$	$6.13E-02^*$	–	–	–
	$(1.08E-02)$	$(1.08E-02)$			
M. East	$2.08E-02$	$1.35E-02$	–	–	–
	$(1.40E-02)$	$(1.42E-02)$			
W. Hemis.	$-7.16E-03$	$-8.48E-03$	–	–	–
	$9.40E-03$	$9.36E-03$			
W. Europe	$2.92E-02^*$	$2.02E-02^*$	–	–	–
	$(8.86E-03)$	$(9.47E-03)$			
R^2	0.88	0.89	0.86	0.89	0.89
Adj. R^2	0.88	0.88	0.86	0.89	0.89

Standard errors are in parenthesis.
* represents that the estimate is significant at 5% level.

Table 4.5: De-trended retail price regressions

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	$3.21E-01^*$	$4.66E-02^*$	$-1.00E-02^*$	$3.22E-01^*$	$3.24E-01^*$
	$(5.19E-02)$	$(1.60E-02)$	$(1.87E-02)$	$(4.84E-02)$	$(4.85E-02)$
PRR	$-2.33E-03$	$-4.90E-02^*$	$-5.53E-03$	$-1.58E-02$	–
	$(1.48E-02)$	$(1.38E-02)$	$(1.61E-02)$	$1.39E-02$	
US HHI	$9.04E-06^*$	$-7.65E-06^*$	$2.20E-06^*$	$-2.31E-06$	$-3.18E-06$
	$(3.44E-06)$	$(3.58E-06)$	$(4.02E-06)$	$(3.52E-06)$	$(3.50E-06)$
Foreign HHI	$3.70E-07$	$-2.66E-06^*$	$8.19E-06^*$	$-2.62E-06^*$	$-2.77E-06^*$
	$(1.05E-06)$	$(1.07E-06)$	$(1.21E-06)$	$(1.02E-06)$	$(1.02E-06)$
log(Trade)	$-1.60E-02^*$	–	–	$-1.42E-02^*$	$-1.47E-02^*$
	$(2.03E-03)$			$(1.92E-03)$	$(1.89E-03)$
ΔGDP	$9.20E-07^*$	–	–	$1.32E-06^*$	$1.38E-06^*$
	$(2.43E-07)$			$(2.33E-07)$	$(2.31E-07)$
Size	$3.09E-07^*$	–	–	$2.50E-07^*$	$2.52E-07^*$
	$(4.62E-08)$			$(4.39E-08)$	$(4.39E-08)$
Settlement rate	–	$6.27E-01^*$	–	–	–
		$(4.87E-02)$			
De-trended	–	–	$-5.15E-01^*$	–	–
Settlement rate			$(7.88E-02)$		
Inflow ratio	–	–	–	$7.64E-01^*$	–
				$(9.58E-02)$	
Inflow ratio	–	–	–	–	$7.54E-01^*$
* PRR	–	–	–	–	$(9.61E-02)$
R^2	0.29	0.34	0.17	0.38	0.38
Adj. R^2	0.28	0.33	0.16	0.37	0.37

Standard errors are in parenthesis.
* represents that the estimate is significant at 5% level.

4.4.3 Net settlement payments

The net settlement payments to other countries made by the U.S. carriers have been a contentious issue in both the design of relevant economic policy and the political debates internationally. The imbalance of traffic especially happen to be among the routes between the U.S. and many developing countries. The net payment is deemed to be an unfair welfare transfer at the U.S. side, while the receiving countries likely think it as an reasonable subsidy to buy the telecommunication technology from those developed countries.

Table 4.6 tries to tell a story behind the imbalanced trade of termination services. Consistent with theory prediction, the intensity of PRR at the U.S. side worsens the net payment made by the U.S. carriers. A direct counterfactual analysis implies that, fixing all the other factors, net settlement payment could be almost doubled when switching from an equal sharing division rule (with $PRR = 0$) to the PRR (with $PRR = 1$).

The degree of competition at the foreign is shown to be an unimportant factor in determining the net payment. However, as the U.S. retail became less concentrated (lower HHI), the net settlement payment tends to reduce. This result is different to what the model predicts. Many possible reasons may contribute to the discrepancy and I will discuss it in the section 4.5.

It is worthwhile to discuss other factors in the regressions. Interestingly, a higher degree of network digitization in the U.S. also worsens the imbalance while the foreign side's network status would help to reduce it. This may be related to the marginal cost of termination service, which is translated into the settlement rate, after a markup, at the foreign side. A lower rate would help the U.S. to reduce the payment. The development of internet is helpful, too, to the U.S. in reducing its deficit in the traffic exchange, shown by the negative signs of those coefficients in front of "internet". The internet has evolved into a substitute to international voice network and it can divert traffic that would be flowed through regular telephone lines. Or, the development of internet is beneficial toward a lowered marginal costs in delivering phone calls across nations. The total trade volume between two nations also plays a determinant role in the net settlement payment. The positive sign seems to suggest that the Americans tend to make more phone calls toward their large trading partners than vice versa. This may be from the fact that the U.S. calling price is generally lower than the other countries. The trading partners would have an incentive to arbitrage in order to satisfy their communication needs with a lower cost. The positive sign for "GDP difference" confirms the fact that a developing country tends receive a larger share of the U.S. carriers' retail revenue than those developed ones.

4.5 Concluding remarks

This paper is a first attempt in the literature to empirically test the effectiveness of the proportional return rule and the introduction of market competition in the U.S. international telephone industry. A theory based on Stackelberg model and Nash bargaining model of settlement rate determination is proposed and suggests that (1) the settlement rate and net settlement payment by the U.S. carriers are both increasing in the degree of market competitiveness in the U.S. and the scale of PRR in dividing the in-

Table 4.6: Log(net settlement payment) regressions

	Model 1	Model 2	Model 3
Constant	$1.37E+01^*$	$1.37E+01^*$	$2.40E+00^*$
	$(1.00E+00)$	$(3.47E-01)$	$(8.90E-01)$
PRR	$2.40E-03$	$6.95E-01^*$	$7.01E-01^*$
	$(3.59E-01)$	$(3.24E-01)$	$(2.95E-01)$
US HHI	$2.25E-04^*$	–	–
	$(1.02E-04)$		
Foreign HHI	$-1.36E-07$	–	–
	$(3.37E-05)$		
Trade	$6.80E-12^*$	$8.09E-12^*$	–
	$(1.07E-12)$	$(8.88E-13)$	
log(Trade)	–	–	$4.95E-01^*$
			$(3.63E-02)$
GDP difference	–	$5.17E-05^*$	$5.48E-05^*$
		$(5.25E-06)$	$(4.81E-06)$
Size	$4.84E-06^*$	–	–
	$(1.02E-06)$		
Digit	$1.78E-02^*$	–	–
	$(7.74E-03)$		
Digit_F	$-9.40E-03^*$		
	$4.11E-03$		
Internet[a]	$-8.00E-06^*$	$-6.31E-06^*$	$-6.61E-06^*$
	$(1.13E-06)$	$(7.24E-07)$	$(6.62E-07)$
R^2	0.34	0.42	0.51
Adj. R^2	0.33	0.41	0.51

Standard errors are in parenthesis.
$*$ represents that the estimate is significant at 5% level.
a: The variable "Internet" here is taken to be the multiplication of internet users per 1K people in the U.S. and the foreign country.

coming traffic among those competing U.S. carriers; and (2) the retail price is decreasing in those two factors.

The empirical findings support the predictions about the PRR's effects toward the settlement rate, retail price and net settlement payment made by the U.S. carriers. Fixing all the other factors and switching the incoming traffic division from the PRR to an equal sharing rule (with $PRR = 0$), the average settlement rate would decrease by roughly 3.5 cents per 3-minute, which is about the half of the average settlement rate in the sample period; and the change in the traffic division rule would cause the average net settlement payment out of the U.S to be almost halved. The retail prices may or may not be reduced by the application of PRR. These numbers shed a doubt toward the FCC's policy in requiring the PRR to divide incoming traffic among the domestic carriers, while leaving the settlement rate negotiation to the carriers themselves. A foreign monopoly carrier would prefer a high above-cost settlement rate for the sake of maximizing its settlement revenue; the U.S. carriers which are competing at the retail segment would also jointly agree with a high rate in order to soften their downstream retail competition, especially when the PRR is imposed.

The hypothesis with respect to the relation between retail competition and retail price is also accepted by the regression results, evidenced by the significant and positive coefficients in front of the HHIs. Decentralized U.S. market would cause the retail price to fall and the trend was further strengthened by the introduction of competition in the foreign markets.

The two hypotheses concerning the relations between retail competitiveness and settlement rate, as well as net settlement payment, are rejected with opposite signs. The equilibrium settlement rate charged by the foreign country and net settlement payments flow to that country in the theoretical model are both decreasing in the HHI in the U.S. market, while the empirical findings are the opposite (recall that lower HHI implies a higher degree of competitiveness in the market). Many facts could lead to this difference. At the theoretical side, the current model is built on an assumption that carriers in each country form a coalition in setting the settlement rate with the other country's coalition (or a monopolist). In practice, the FCC allows the U.S. carriers to freely negotiate separate settlement term with non-dominant foreign carrier, and the term needs not to abide by the PRR, while the traffic exchanges with those dominant carriers is required to follow the PRR. The existence of alternative international route naturally presents a competitive threat to the foreign dominant carrier which would thus limit its dominance at the settlement service. Intuitively, the domestic competition at both sides of a country-pair and the emergence of multiple routes put a downward pressure onto the settlement rate, because the settlement services offered by different carriers in one country can be deemed as close substitutes. Moreover, competition at the foreign side drives down its calling price and drives up its traffic volume to the U.S.[20] Henceforth, the traffic from and to the U.S. become more balanced, so does the net settlement payment. However, it is impossible to empirically identify the traffic volume that was

[20]This result can be obtained by considering a downward-sloping demand in the foreign market. The foreign market is modeled to have a fixed outflow in the paper for the reason of simplicity and to mainly illustrate the effect of PRR toward the settlement rate and the retail equilibrium in the U.S. market. Demands at different countries are assumed to be independent to each other, as literature has done. Competition at the foreign end would naturally improve the trade deficit of those U.S. carriers.

exchanged with non-dominant carriers in the available data.

In spite of this limitation, the "negative" results from the pooled data give rise to alternative modeling approach that can reflect the multiple routes, which is explored in the extensions in Ju and Tan [2007]. A simple version of the multiple-routes model is presented in the Appendix. Under modest condition, when there is competition of settlement services at the foreign end, an increase in the retail competitiveness at the U.S. side can reduce the average settlement rate paid by the U.S. carriers. Even under the model of multiple routes, the PRR's effect is the same as what this paper presents. That is, the application of PRR, even if it only exists among a subset of carriers, moves up the settlement rate and the net settlement payment. However, the empirical finding about the trend in net settlement payment toward the changes in HHI is not captured by this model, either.

Moving to the policy implication, the regression analysis suggests that a unilateral effort at the U.S. side (such as the PRR and encouraging domestic competition) is insufficient for the market to restrict the bottleneck power especially existed in the monopolized foreign market. The breakdown of bottleneck and competition in the settlement service at the foreign markets is a necessary factor to derive the settlement rate and retail price toward their efficient levels. When the foreign market power persists, the PRR may not be an ideal policy to protect the U.S. consumers and carriers.

The results hitherto show many interesting patterns in this market and evoke a deeper analysis into the data. A structural empirical framework to better account for the endogeneity will be particularly conductive in the future research.

4.6 Appendix

This appendix provides a simple model with competition at the foreign country and with multiple routes for international telephone interconnection. The purpose is to illustrate the following. The empirical findings which rejected the two hypotheses in the main text concerning the relations between retail competitiveness and settlement rate, as well as net settlement payment, may be supported by the fact that there is traffic flow outside the regulation of International Settlement Policy.

The basic model structure is shown in Figure 4.4. There are $m+1$ identical *Cournot* carriers in country A and two carriers in country B. The first carrier in country A interconnects with the first carrier in country B. The rest m carriers in A form a coalition and exchange their traffic with the second carrier in B.

The inverse demand in country A is taken to be in a simple functional form, $P(X) = 1 - X$. The settlement payments from the two carriers in B are denoted to be F_1 and F_2, respectively, and they are assumed to be fixed in the model. F_1 is received by the first carriers in A. F_2 is divided among the other m carriers accordingly to a pre-defined rule α, whereby portion α of F_2 is divided through the PRR and the rest portion, $1-\alpha$ is divided by the ESR among these carriers.

The game timing is similar to the Stackelberg model discussed in section 4.2. In the first stage, carriers in B choose s_1 and s_2, respectively, for the traffic flowed from their counterparts in A. In the second stage, all the $m+1$ carriers engage in a retail competition. The traffic initiated by carrier 1 is x_1

and the total traffic initiated by the rest m carriers is x_c. Thus, $X = x_1 + x_c$.

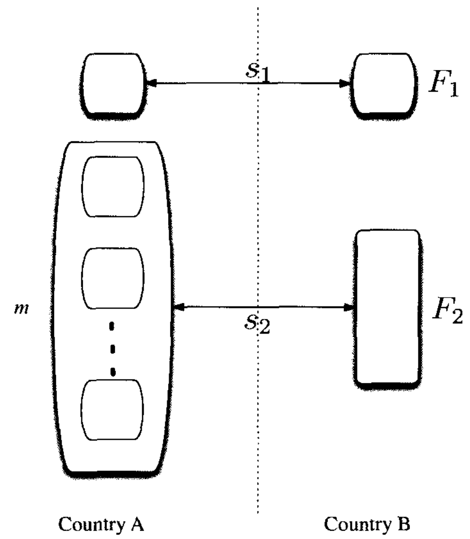

Figure 4.4: A Model of Multiple Routes

The carrier 1's profit function is given by

$$\pi_1 = (P - s_1)x_1 + F_1;$$

and the carrier $i = 2, \ldots, m+1$ has a profit function

$$\pi_i = (P - s_2)x_i + \left[\alpha \frac{x_i}{x_c} F_2 + (1-\alpha)\frac{1}{m} F_2\right].$$

In the second-stage, given the settlement rates s_1 and s_2, the first-order conditions of these carriers' decision result in

$$s_1 x_1 = P(X)x_1 - (x_1)^2, \tag{4.17}$$

$$s_2 x_c = \phi(x^c; x_1) + \kappa F_2; \tag{4.18}$$

where $\phi(x^c; x_1) = P(x_1 + x_c)x_c - \frac{1}{m}(x_c)^2$ and $\kappa = \alpha\frac{m-1}{m}$.

In the first stage of game, the choices of rates s_1 and s_2 by those two carriers in country B are equivalent to finding the equilibrium traffic volumes x_1 and x_c whose objectives are defined in the equation (4.17) and equation (4.18), respectively. After applying the explicit demand function $P(X) = 1 - X$, the equilibrium traffic volumes are

$$x_1 = \frac{m+2}{7m+8},\ x_c = \frac{3m}{7m+8} \text{ and } X = \frac{4m+2}{7m+8}.$$

Define the average settlement rate paid all the carriers in A be

$$\bar{s} = \frac{s_1 x_1 + s_2 x_c}{X}.$$

Skipping the detailed algebra, the relevant properties of this subgame perfect equilibrium, which are also empirical supported, include

$$\frac{\partial X}{\partial m} = \frac{18}{(7m+8)^2} > 0,$$

$$\frac{\partial \bar{s}}{\partial \alpha} = \frac{(m-1)(7m+8)}{2m(2m+1)} F_2 > 0,$$

and

$$\frac{\partial \bar{s}}{\partial m} = -\frac{3}{2}\frac{3\kappa F_2(7m+8)^2 - 5m^2 + 16m + 16}{(14m^2 + 23m + 8)^2}.$$

A sufficient condition $\kappa F_2 \geq 1$, which can be easily satisfied (thinking F_2 as a large number), implies that $\frac{\partial \bar{s}}{\partial m} < 0$.

The equilibrium net settlement payment in this model is

$$NP = s_1 x_1 + s_2 x_c - F_1 - F_2 = \frac{11m^2 + 17m + 8}{(7m+8)^2} + \kappa F_2 - F_1 - F_2.$$

Its derivative with respective to m is

$$\frac{\partial NP}{\partial m} = \frac{3(19m+8)}{(7m+8)^3} > 0.$$

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