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International telephony: a review of the literature

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Abstract

This paper reviews recent literature completed by research economists in the area of international telephony. Theoretical research principally entails how interconnected national carriers determine call prices, and how domestic competition, regulatory restrictions, and bypass affect call volume, routing, and rates. Applied research hinges around the complementarity of outgoing and incoming traffic between two nations, the two-part nature of a call (i.e. access and minutes), and the response of calling volume to prices, economic conditions, and demographic factors. Existing theory usefully identifies key market factors that bear upon policy-making. However, applied researchers have had difficulty measuring several important data items that are now at central stage. © 2002 Published by Elsevier Science B.V.

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1. Introduction

This review discusses theoretical and applied economic research in international telephony that was completed in the past decade. This research has focused principally upon economic factors that influence caller demand for switched services and the prices that these callers pay. Taken as a group, these factors include service costs, economic development, traffic complementarity, and demographic, geographic, and linguistic considerations.

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We shall review these papers with a particular eye to two important contemporary phenomena. Firstly, as new technologies have emerged, transport and switching costs have fallen. Secondly, governments are now negotiating lower interconnection rates in bilateral and multilateral arrangements. These factors together should greatly stimulate the demand for international calling.

On the upside, the papers impressively identify a slate of influential variables regarding pricing, competition, regulatory restriction, and bypass. They have real worth in policy discussions. On the downside, applied researchers cannot now quantify several key variables — such as technology, changing service options, and policy changes — that now affect caller behavior and carrier prices.

The paper is organized as follows. Section 2 reviews the institutions of international ratemaking and discusses recent reform initiatives. Sections 3 and 4 respectively discuss and summarize seven theoretical papers. Sections 5 and 6 discuss and summarize eight applied pieces. Reviewed articles were culled from scholarly books and journals or from promising unpublished research material. Material in the trade press is occasionally cited (but not reviewed) to provide the requisite institutional backup.

2. Institutional background

This section reviews the institutional background that must be assimilated by any researcher in the area of international telephony.

Switched international traffic between two countries can originate in either. Per the guidelines of the International Telecommunication Union (1992), every pair of interconnected carriers negotiates *accounting rates* that can be recovered from the originating end of the call. These rates are usually defined on a per minute basis in dollars, gold francs, or SDRs. They are rarely time-differentiated and do not reflect temporal differences in incremental capacity costs.

Once collected, accounting revenues are conventionally credited evenly to the two interconnected countries despite the fact that the outgoing carrier actually faces higher costs. The recipient half of an international minute is termed the *settlement rate*. No national carrier actually makes payment to a correspondent network unless its net traffic outflow to the partner is positive. Total settlement revenues owed are the product of the settlement rate times its net outflow of minutes.

The originating carrier bills callers with itemized *collection rates*. For calls to be profitable to originating carriers, collection rates to any country must minimally cover the actual origination and transport cost plus the prevailing international settlement rate. Collection rates can be subject to competition if two or more domestic carriers offer international service.

Regarding competitive activity, each US long-distance carrier may bilaterally negotiate a settlement rate with each respective foreign carrier. However, the

Federal Communications Commission's (1986) *international settlement policy* (ISP; formerly *uniform settlement policy*) now restrains these negotiations.

1. Equal rates: settlement rates for calls to any one nation must be equal for all US carriers.
2. Equal shares: settlement revenues on each international call must be split 50/50 with the foreign carrier.
3. Proportionate return: US carriers must share incoming revenue from a particular nation based on their respective outgoing settled shares to that nation.
4. No special concessions: no US international carrier may accept special concessions from a foreign carrier that has sufficient market power in the destination market to adversely affect competition in the US.

International call rates have greatly exceeded marginal cost. US consumers in 1999 paid an average of $0.49 per international minute, which actually represented a 62% decrease from 1990 (Federal Communications Commission, 1999). This amount can be compared unfavorably to the contemporaneous $0.13 per minute for domestic long-distance calls, which have only a slightly lower marginal cost. Including originating and terminating access charges paid to local exchanges that are not part of true marginal cost, the FCC estimated the actual incremental cost of international minutes to be $0.06–0.09. The major culprit here has been the inflated accounting rate.

Carriers and callers have increasingly avoided high accounting rates in a number of ways (Mason, 1998). Most importantly, retail carriers may route outgoing traffic over *international private lines* that are not subject to accounting and settlements rules. These arrangements may be one-way or two-way. The efficiency of these arrangements is enhanced by *optical and packet-switching*, which has greatly increased transport capacity and reduced unit costs of all calls. These retail carriers may also route international calls to wholesale carriers that offer voice-over-IP services (Stubbs, 1999). Additionally, private callers themselves can use *private networks* and *switched voice-over-IP telephony* that bypass both settlement and interconnection charges.

Carriers and callers may also use several forms of arbitrage to avoid high collection charges. Originating carriers may avoid high settlement rates to a particular nation by routing calls through a hub nation with more economic arrangements for final termination (called *refiling*). With *call-back* technologies, call originators may reverse the direction of their calls in order to obtain a lower collection rate. *Country direct* services enable US callers in a foreign country to call a US operator and reverse charges. Finally, parties in two countries may practice 'manual arbitrage' by deliberately originating telephone conversations in the low-price country.

There have been several important reform initiatives that have been undertaken

in the US since 1992. (For earlier history, see Johnson (1989) and Stanley (1991).) The ITU's Recommendation D.140 (International Telecommunication Union, 1992) called for cost-based, nondiscriminatory, and transparent accounting rates. A 1993 follow-up, Recommendation D.300R, established a method for determining these costs for designated country pairs based on crowflight distances and degree of digitization (International Telecommunication Union, 1993). Based on these guidelines, the FCC set forth settlement rate benchmarks for high, middle, and low income countries of 15, 19, and 23 cents per calling minute (Federal Communications Commission, 1996b, 1997) and established a 4-year compliance schedule that was activated in 1999.

In April, 1999, the Commission also eliminated its ISP for negotiations with nondominant foreign carriers and dominant carriers that maintained settlement rates at 75% or below of the Commission's relevant benchmark (Federal Communications Commission, 1999). This superseded the FCC's earlier Flexibility Order (Federal Communications Commission, 1996a) that allowed US long-distance carriers to bid competitively to terminate inbound traffic from foreign countries that provided effective competitive opportunities (Federal Communications Commission, 1995). By agreement, carriers in the European Union must offer access to domestic interconnect rates for calls between Member States, in parallel with the traditional accounting rate arrangements.

3. Theoretical papers

This section reviews seven recent theoretical papers involving international telephony. We pick up several themes from Section 2.

1. The sequence of rate-making: accounting and collection rates are set sequentially. Accounting rates can be set unilaterally, collusively, or through non-cooperative bargaining. Collection rates are set in monopoly markets, or in markets that are Bertrand or Cournot competitive.
2. Negotiating position: of two interconnected networks, the carrier with the net traffic outflow will have more incentive to lower accounting rates. Ceteris paribus, the gap between most preferred rates will widen with traffic imbalance.
3. Domestic competition: collection rates will fall toward marginal cost as domestic competition increases. This can lead to more calling and greater imbalance in US traffic.
4. Regulatory restrictions: if the FCC's ISP is effective, competitive providers may bargain less aggressively to terminate calls, increase accounting rates to offset collection losses that result under competition, and 'oversettle' outgoing traffic in order to increase termination credits that are based on settled outflow.
5. Settlements avoidance: call-back strategies and one-way incoming private lines

may actually increase traffic imbalances for the US and therefore lead to more foreign pressure to increase settlement rates.

To the greatest degree possible, we shall employ consistent notation, sometimes simplifying from the original. The subscripts $i = d,\ f$ $(j = f,\ d)$ designate domestic and foreign partners of a carrier pair and will be eliminated if clarity permits.

3.1. Hakim and Lu

In a relatively early paper, Hakim and Lu (1993) consider the implications of perfect arbitrage in an international market with two monopoly providers. They demonstrate that each carrier may willfully increase its collection rate to become a 'net call terminator' and therefore the recipient of all settlement revenues.

The two carriers unilaterally set settlement and collection rates in a two-stage sequential game. With perfect arbitrage, all calls originate in the nation with the lower collection rate, designated p. Profits in the low- (high-) rate country are $[sa - z]q(p)$ and $[p - sa - c]q(p)$, where a and s represent the accounting rate and settlement share, c and z represent origination and termination costs $(c > z)$, and $q(p)$ represents outgoing demand. If prices are equal, each country originates half the traffic and profits are $0.5[p - c - z]q(p)$.

The authors then show that each carrier may overprice collection in order to reverse traffic flow and avoid high origination costs c. This ratcheting stops only when both collection rates exceed accounting rate a. The authors derive a joint profit-maximizing solution of $a = p_m - c + z < p_m,\ \ s = 0.5$ where $p_m = \text{argmax}[p - c - z]q(p)$ to which symmetric providers could commit and maintain. Otherwise, side-payments would be necessary to maintain this.

That arbitrage may lead providers to seek to reverse traffic flow demonstrates just how important net traffic inflow is in determining a carrier's overall profitability. However, arbitrage calls of the kind described may now be a small component of international volume. More generally, outgoing traffic may repress or stimulate reverse traffic.

3.2. Carter and Wright

Carter and Wright (1994) consider the inefficiencies that result when monopoly carriers unilaterally set termination and collection rates. The authors demonstrate that collection rates may exceed monopoly prices and that settlement collusion can reduce these prices.

The two monopoly carriers play a two-stage noncooperative game where they sequentially set termination and collection rates t and p. Carrier profits are $R_i = p_i q_i(p_i) - C(q_i,\ q_j) + t_i q_j - t_j q_i$, where $C(q_i,\ q_j)$ represents a carrier's physical access costs, $q_i(p_i)$ represents outgoing demand, and p_i represents collection rate.

When unilaterally set, profit-maximizing termination rates are above marginal cost and collection rates are above monopoly levels. Therefore, both producers might actually benefit if they can collude to lower termination fees and avoid double marginalization. This would reduce collection rates as well.

The paper establishes that double marginalization is harmful when a carrier sets termination prices without accounting for negative externalities imposed on its interconnected partner. However, the paper suffers from the assumption that settlement rates are unilaterally set. Carriers now bargain non-cooperatively over these rate levels.

3.3. Cave and Donnelly

Cave and Donnelly (1996) modify the above model to incorporate noncooperative bargaining over settlement. Using notation from Hakim/Lu, profits for operator i are $[p_i - s_j a_j - c]q(p_i) + [s_i a_i - z]q(p_j)$. As in Carter/Wright, each provider first determines its unilaterally most preferred level of $t_i = a_i s_i$ that serves as a threat point in a Nash bargaining solution. In noncooperative bargaining, the carriers maximize the product of their incremental profits above 'threat point' levels. Each country's resulting settlement price is somewhere between its 'Carter/Wright amount' and its trading partner's preference (of 0 or z).

If not so constrained, settlement rates sa will be equal to one another and to termination cost z if and only if carriers are symmetric. Each collection rate in this case will be at its monopoly level. When settlement equality is otherwise enforced, the settlement outcome is between the two carriers' most preferred points; one carrier necessarily gains and the other loses from the constraint. Conflicts over accounting rates may then result when equality is enforced. These conflicts may worsen as traffic asymmetry increases. This issue arises particularly when relative income levels differ. (For example, see Cheong and Mullins, 1991; Ergas and Paterson, 1991.)

The paper is useful for several reasons. Firstly, the bargaining outcome is preferable to Carter/Wright. Secondly, the authors affirm that incremental cost pricing is not generally expected. Thirdly, the paper considers the consequences of traffic imbalance and the likelihood of settlements conflict between rich and poor nations.

3.4. Yun, Choi, and Ahn

Yun et al. (1997) introduce domestic competition to the Cave and Donnelly model. They demonstrate that domestic competition reduces collection rates. However, carriers with lower collection margins may favor higher accounting rates. 'Equal rate' rules may actually enable these carriers to achieve their desired increase.

We begin with two monopoly providers. Assuming linear demand functions and

equal origination and termination costs, carrier profits are $[A_i - Bq_i]q_i - c_i[q_i + q_j] + a[s_i q_j - s_j q_i]$. Assuming $s = 1/2$, carrier output $q_i = [A_i - c_i - a/2]/[2B]$ is inversely related to cost c_i and rate a.

More developed countries would have higher levels of demand A and lower costs c. The preferred accounting rate for carrier i is $a_i = 2[A_j - A_i + 2c_i - c_j]$. These ideal levels differ when A and c differ; one preferred rate exceeds combined cost $c_i + c_j$, and the other is below. Predictably, a carrier's preferred rate increases (decreases) with home c_i (correspondent c_j) and foreign A_j (home A_i). A similar discrepancy holds for surplus-maximizing governments, where preferred rates $a_i = 2[2(A_j - c_j) - 3A_i + 5c_i])$.

Introducing access competition, let m_i represent the number of (assumed identical) carriers in country i. Assuming ISP, all settlement rates equal $a/2$. Assuming Cournot competition, respective outgoing traffic levels are $m_i[A_i - c_i - a/2]/[(m_i + 1)B]$ and $m_j[A_j - c_j - a/2]/[(m_j + 1)B]$. Access competition reduces collection rates and increases national outflow.

Significantly, domestic competition that reduces collection rates also increases the incremental profit gain that results when caller demand increases. This increases the incentive for each competing carrier to attempt to increase settlement rate $a/2$. With more incoming traffic, the terminating network will press for higher rates as well.

3.5. Wright

In a theoretical prologue to econometric results discussed below, Wright (1999) modifies Yun/Choi/Ahn to consider the consequences of call reversal and incoming private lines. Wright has two procedural differences. Firstly, competing access providers set collection rates as differentiated Bertrand strategists. Secondly, first-stage accounting rates are restricted to their Nash bargaining solution.

When call-back systems are deployed, Wright observes that more switched calls will be initiated in the nation with the lower prices (i.e. US). With larger traffic inflow, foreign correspondents may push for higher settlement rates (see also Scanlan, 1996, 1998). A similar problem results when incoming calls to the US can be routed over private lines to avoid settlements, but outgoing calls cannot. Therefore, cost avoidance by some callers may actually lead to higher settlement charges for the remainder.

3.6. O'Brien

O'Brien (1991) shows how the FCC's ISP may weaken the US bargaining position. He demonstrates that 'equal rate' rules may actually limit the ability of US carriers to reward foreign compliance and consequently increase accounting rates. In contrast to previous authors, he predicts that competing US carriers would disfavor these rules.

There are two US domestic carriers ($i = 1, 2$) and a foreign monopolist. Let c, t_{iU}, and t_{iF} respectively represent outbound marginal cost, carrier i's charge for terminating traffic, and the termination price paid by carrier i. Originating demands for carrier i under monopoly and duopoly are $q_m(t_{iF} + c)$ and $q_i(t_{iF} + c, t_{jF} + c)$. Respective profits are $[p(q_m) - t_{iF} - c]q_m$ and $[p(q_i + q_j) - t_{iF} - c]q_i$. The foreign carrier facing US monopoly and duopoly earns $[t_{iF} - c]q_m$ and $[t_{1F} - c]q_1 + [t_{2F} - c]q_2$.

With US duopoly, each carrier in turn bargains with the foreign monopolist over its respective settlement rate. The monopolist first offers a settlement price to carrier 1 that can be accepted or countered. If not accepted, the monopolist may continue negotiations or begin talks with carrier 2. A carrier may begin service immediately after bilateral agreement is reached. O'Brien then demonstrates that second-round delay would harm both bargaining participants. Consequently, the second bargaining agreement would immediately follow the first.

Initially assuming no return traffic to the US, O'Brien uses backward induction to solve the model. Payoffs in each stage are set at Nash bargaining levels. When discrimination is permitted, carrier 2 has considerable bargaining power over t_{2F}. This is because the transition from domestic monopoly to duopoly lowers US collection prices, stimulates traffic outflow, and increases foreign profits. This prospective profit gain is a 'carrot' that should induce the foreign monopolist to consent to a reasonable deal. Because first-round carriers anticipate second-round outcomes, carrier 1 also enjoys bargaining leverage over t_{1F}.

If discrimination is not permitted, carrier 2 must accept the resulting rate t_{1F}. Lacking a second-round 'carrot', carrier 2 cannot arrive at an advantageous deal for itself; carrier 1 is hindered as well. O'Brien then demonstrates that accounting rates are necessarily higher under 'equal rate' rules. Indeed, the foreign carrier can obtain its most preferred price p^*, take-it-or-leave it, if discount rates are zero.

Introducing return traffic, O'Brien first allows t_{iU} and t_{iF} to differ (i.e. nonequal shares). Depending on whether $t_{1U} = t_{2U}$ is relaxed or enforced, the foreign monopolist again can have smaller or larger incentives to play for another take-it-or-leave it outcome on t_{iU}. This 'take it or leave it' outcome would be as low as feasible; i.e. marginal cost.

Assuming share equality ($t_{iU} = t_{iF}$), the relative sizes of incoming and outgoing traffic affect the bargaining outcome. If traffic inflow to the US were positive (e.g. telegraph), the foreign monopolist would be more concerned with the high magnitude of its outgoing payments. It would therefore press for a settlement price near marginal cost. However, if traffic outflow from the US were positive (e.g. telephone), the foreign monopolist would be more concerned with the profitability of incoming payments. It would then press for settlement prices near p^*. US carriers and their originating callers then are better (worse) off in the first (second) instance.

Though elegant, O'Brien's results may not be robust with regard to the assumptions underlying his bargaining model. His model bears a key prediction:

US telephone carriers should disfavor the 'equal rate' rule. This directly contradicts previous insights and might be reasonably tested.

3.7. Galbi

Galbi (1998) considers how the proportionate return rule affects how US carriers deploy settlements bypass. Under this rule, US carriers are credited with termination revenues based on their respective shares of settled outgoing traffic. As a result, they will perceive a reduction in the net marginal cost of settling an outgoing call. With this distorted price signal, each carrier may 'oversettle' calls, increasing caller costs overall. With higher inflow from the US, foreign carriers may attempt to push up accounting rates.

Government regulators in the model first set accounting rates a and shares s and carriers subsequently determine collection rates. Under proportionate return, return revenue is credited to domestic carriers based on their proportion of outgoing settled traffic. Net costs for domestic carrier $i = \{1, 2, \ldots, n\}$ are $C_i = [sa + c]f_iS_i + b[1 - f_i]S_i - [sa - z][f_iS_i/T_H]T_F$ where b represents unit bypass cost, f_i and S_i respectively represent the settled share and the traffic total (settled plus bypass) of carrier i, and $T_H = \Sigma\, f_iS_i$ and T_F represent total outgoing settled traffic from the home and foreign country. The terms f_iS_i and $f_iS_iT_F/T_H$ then represent the outgoing settled traffic and inflow credit of carrier i. Because transport costs c and z are assumed to be identical for all US carriers, total and marginal costs differ between carriers only because outgoing traffic levels f_iS_i and inflow credit differ.

Galbi differentiates C with respect to fS to show that marginal cost monotonically increases in traffic volume. Intuitively, the incremental effect of an increase in switched outflow f_iS_i upon inflow credit $f_iS_iT_F/T_H$ is greatest when f_iS_i is smallest. With a larger incremental credit per switched minute, the perceived marginal cost of the smallest carrier is less. A carrier switches traffic up to the point where marginal cost equals b.

Galbi then derives two interesting theorems. Firstly, for any inflow level T_F, there exists a threshold $L(T_F)$ such that all outflow f_iS_i below (above) $L(T_F)$ is routed over switched (bypass) routes that are (are not) subject to settlement. The smallest carriers will exclusively settle and the largest will exclusively bypass (and one carrier may do both). The threshold L also increases in bypass cost b, meaning that switching and settling is more likely when bypass is more costly.

Secondly, because net carrier costs are reduced by inflow credits, each home carrier underestimates the true marginal cost of settling traffic and will 'oversettle' traffic. As a consequence, national carriers as a group fail to minimize interconnection expenses. The foreign carrier also enjoys a larger traffic inflow from the US and seeks to boost accounting rates.

Regarding national preferences, Galbi demonstrates that even if $sa = b$, one country will prefer cost-based termination and the other will not (or the two may be perfectly indifferent). Quite interestingly, the former nation will *not necessarily*

be that with net traffic outflow. If the foreign carrier were monopolized, it would use exclusive bypass if $b < sa$, as would all return carriers, which would have no means of earning return revenue. However, the monopolist would continue to send settled traffic if it were a Stackelberg strategist and could stimulate return traffic.

Galbi's paper nicely confirms that rules that enforce proportionate return can affect carrier routing. Traffic outflow may be 'oversettled', to the economic advantage of a terminating foreign monopolist. This would justify direct FCC-jawboning with foreign providers.

4. Summary of theoretical papers

We conclude the theoretical review of Section 3 by summarizing how each paper addresses the items identified in our initial checklist. We shall identify each paper by the name of the first author. The reader may find Table 1 useful.

1. The sequence of rate-making: all models favor a two-stage game where accounting and collection rates are set sequentially. First-stage rates are set unilaterally in Hakim, both unilaterally and collusively in Carter, and exogenously (by governments) in Galbi. Noncooperative bargaining appears in Cave, Wright, and O'Brien. Second stage competitive equilibria for collection rates are Bertrand (Galbi, O'Brien, Wright) or Cournot (Yun).
2. Negotiating position: most papers show that traffic symmetry eliminates payments and therefore enables carriers to strike efficient bilateral settlement

Table 1
Theoretical summary

Sequence of ratemaking	
Accounting rates unilaterally set	Hakim, Carter
Accounting rates collusively set	Carter
Exogenous accounting rates	Galbi
Noncooperative bargaining for accounting rates	Cave, Wright, O'Brien
Second stage competition for collection rates	Galbi, O'Brien, Wright, Yun
Domestic competition	
Bilateral monopoly	Hakim, Carter, Cave
Domestic competition, one-side	Galbi, O'Brien
Domestic competition, two-side	Yun, Wright
Regulatory restrictions	
Share equality	Cave, Galbi, O'Brien
Rate equality	O'Brien
Proportionate return	Galbi
Settlements avoidance	
Call-back systems, incoming private lines	Wright
Carrier strategies for bypass	Galbi

agreements. Conflicts arise when traffic levels are asymmetric, perhaps from uneven development.

3. Domestic competition: Hakim, Carter, and Cave consider bilateral monopoly only. Galbi and O'Brien introduce US domestic competition. Yun and Wright have competition at two ends. Access competition has two effects. Firstly, it can depress collection rates and stimulate volume, benefiting both callers and foreign providers. Secondly, it may provide incentives for competing carriers to increase accounting rates.
4. Regulatory restrictions: papers frequently consider the implications of the FCC international settlements policy. Cave, Galbi, and O'Brien consider share equality, O'Brien explores rate equality, and Galbi examines proportionate return. These rules are found to hinder aggressive bargaining and reduce bypass. They may also offset the ability of domestic competition to reduce collection rates.
5. Settlements avoidance: Wright establishes that the US traffic imbalance increases when call-back systems and incoming private lines to the US are operative. Galbi points out that US carriers have incentives to 'oversettle' calls under proportionate return. Both effects would increase the tendency of the recipient nation to bargain for higher settlement rates.

5. Econometric papers

We now review eight econometric papers concerning international demand and call rates. Readers interested in earlier works are referred to Lago (1970), Yatrakis (1972), Rea and Lage (1978), and Schultz and Triantis (1982).

A few general concerns will frame our discussion.

1. The determinants of demand: call traffic between two nations depends on service and network variables (e.g. own-price, reverse price, number of access lines), the level of macroeconomic activity (e.g. real income or GDP, bilateral trade volume), and demographic and geographic factors (e.g. time zone difference, tourist volume, immigrant population, and common language).
2. The nature of calling: telephone calls are two-part goods with distinct prices for set-up and usage (Taylor, 1980). In two-stage budgeting, a caller first determines likely call length based upon prevailing minute charges. He calls if the anticipated value of the call exceeds the estimated price.
3. Types of calls: in order of ascending price, service categories include direct dial (DD), operator assisted station-to-station (SS), and operator assisted person-to-person (PP). Researchers can relate overall call volume to an aggregate price index, and market shares to relative service prices. Price coefficients on service shares and call volume can be combined to estimate total elasticities.

4. Data bases: data can be time series, cross-sectional, or pooled. Coefficients estimated from annual time series data are generally regarded to quantify short-run effects; coefficients derived from cross-sectional data provide long run counterparts. Results derived from pooled data bases evidently depend on the number of time series or cross-sections in the data base and may not be robust in different time periods and situations.
5. Traffic substitution or complementarity: traffic between two interconnected networks can be weak substitutes or complements (Larson et al., 1988). Cross-price and cross-income elasticities between two countries therefore can be weakly positive or negative.
6. Price effects: both accounting and collection rates have both exogenous and endogenous determinants — e.g. transport/termination costs and calling volume. Similarly, call volume depends upon endogenous collection rates. The resulting simultaneity issues involving volume and price may require advanced econometric modeling (e.g. 2SLS, 3SLS, FIML).
7. Changing parameters: response parameters are not necessarily constant over time or over different routes. Changing commercial mix, advancing technologies, growing consumer awareness, and new service options may strongly influence these parameters from year to year.
8. Nonmeasurability: important data are sometimes not measurable and key phenomena cannot be quantified. These would include private line capacity, call back systems, number of calling cards, hubbing arrangements, and internet usage.

5.1. Bewley and Fiebig

Bewley and Fiebig (1988) explain overall traffic and DD, SS, and PP market shares from Australia to each of 10 countries. The authors derive separate results for call volume and excess minutes.

Total call volume is regressed against the real average set-up price index, real GDP, call volume first difference, and a fourth-quarter dummy. Calling shares for DD, SS, and PP are regressed upon relevant price ratios, the lagged dependent variable, a fourth-quarter dummy, and number of DD subscribers. Excess minutes-of-use are regressed upon deflated GDP, call minute first difference, and a fourth-quarter dummy. Because the per minute price for all operator-assisted (OA) calls is the same across SS and PP, only one equation could be meaningfully estimated; the excess minute share for OA minutes is regressed upon relative price ratios, total excess minutes, the lagged dependent variable, and a fourth-quarter dummy.

The log-linear format is used throughout. Data are quarterly time-series cross-section from 1976:3 to 1983:1. Separate coefficients (except for price elasticity) are estimated for short and long hauls. The estimation technique is FIML.

The authors specify their price variables as follows. Respective per minute

charges for DD and OA calls are P_{DD} and P_{OA}. Assuming a 3-min minimum duration, set-up charges for SS and PP calls are $F_{SS} = 3P_{OA}$ and $F_{PP} = 3P_{OA} + S$, where S is a surcharge. With no minimum duration, DD set-up prices are $F_{DD} = kP_{DD}$, where k is econometrically fitted.

The authors estimate separate volume and share elasticities and combine their results to obtain composite elasticities. The composite price elasticities of long- (short-) haul calls with respect to P_{DD} and P_{OA} are -0.01 and -0.36 (-0.01 and -0.37). The price elasticities of long- (short-) haul minutes with respect to P_{DD} and P_{OA} are -1.02 and -1.47 (-1.34 and -1.14). Call volume is not very price-elastic, while excess minutes generally are.

Coefficients on deflated GDP in both volume and minutes equations are always significantly positive. First-differences in dependent variables in these equations are significantly negative (except long-haul minutes). Lagged dependent variables in the share equations are significantly positive, while DD subscriber numbers are insignificant.

The paper makes three advances. Firstly, it recognizes that call set-up and usage minutes have two distinct prices. Secondly, it uniquely models both total traffic and call market shares. Thirdly, the econometrics are very careful.

The paper's relevance suffers from its early time frame (1976–1983) and a meager list of dependent variables. It fails to consider substitution or complementarity between calling partners and does not consider if coefficients vary over time. As mentioned, results based on pooled data might not be particularly robust to the mixtures of time series and cross sections incorporated in the data set.

5.2. Appelbe et al.

Appelbe et al. (1988) explain the volume of outgoing billed minutes for customer dialed calls from each of six Canadian provinces to each of four US regions. Equations for return traffic are not estimated. Four sets of separate regressions are estimated for short- (0–800 miles) and long-haul traffic, for full-rate (08:00 to 18:00 h, Monday to Saturday) and discount (other hours) periods. Independent variables include deflated own-price index, access lines (residence, business, or total), return traffic, economic activity (i.e. provincial employment, retail sales, or exports), seasonality, and special events. A log-linear format is used. Data are quarterly time-series/cross-sectional for unspecified years. The estimation technique is pooled, generalized 3SLS.

Estimated coefficients on the economic variables and access lines differ by cross-section and are always significantly positive. Own-price coefficients (designated A_1) are significantly negative: -0.35 (full rate, short-haul), -0.43 (discount, short-haul), -0.38 (full rate, long-haul), and -0.45 (discount, long-haul). Corresponding coefficients on return traffic (A_2) are significantly positive — 0.42, 0.24, 0.47, and 0.40 — confirming return complementarities. Assuming equal

values of A_2 on unestimated US–Canada equations, resulting price elasticities will be $E_1 = A_1/[1 - A_2^2]$; i.e. -0.43, -0.45, -0.49, and -0.53.

The paper includes an impressive list of economic determinants. This paper rightly includes return traffic as an explanatory variable for outgoing volume. It strongly confirms complementarities, but would be more complete and accurate if return traffic were explicitly modeled. The list of independent variables is modest and the pooled time-series, cross-sectional data base might not be robust to its mixture.

5.3. Acton and Vogelsang

Acton and Vogelsang (1992) explain both incoming and outgoing billed minutes between the US and each of 17 European countries. In reduced form equations, independent variables include daytime tail block prices (deflated and US-converted) in both countries, telex prices, originating access lines, deflated GDP (for both countries), volume of bilateral trade, and sector employment (agriculture, restaurants/hotels, banking, manufacturing, and transportation). The authors use a log-linear format with dummy intercepts for each country. Data are pooled annual time-series, cross sectional data from 1979 to 1986. They adjust for heteroscedasticity and first-order autocorrelation.

Estimated own-price demand elasticities for US and foreign callers are -0.36 and -0.49 and significantly negative. Estimated return-price elasticities are insignificant, rejecting both substitution and complementarity. Coefficients on US outgoing telex prices are significantly positive, confirming some substitutability here. Coefficients on originating access lines and real GDPs (including correspondent) are significantly positive, while trade volume is insignificant. Employments in each sector pick up a positive significant coefficient, except transportation (insignificantly negative).

The paper is the first to model explicitly two-way traffic and includes an impressive list of economic variables. It is somewhat short on demographic and geographic factors (see Sandbach below). The authors do not include reverse traffic as an exogenous variable. Their consequent reduced form equations lead to strange results — correspondent GDP matters but ‘reverse prices’ do not. The authors explain the estimated insignificance of reverse price as a possible combination of offsetting price and income effects, but there are other plausible explanations for these results related to omitted variables and specification error; i.e. the telex price term may introduce multicollinearity, the daytime tail block is a simplistic price variable, and results may be confounded by pooling.

5.4. Hackl and Westlund

Hackl and Westlund (1995) explain levels of outgoing traffic minutes from Sweden to each of Germany, UK, US, Denmark, Norway, and Finland. Explanat-

ory variables are deflated own-price, bilateral trade volume, Swedish industrial production index (IPI), correspondent IPI, and seasonal dummies. The structural form is log-linear, which is close to optimal among estimated Box–Cox transforms. Data are pooled monthly time-series, cross-section from 1976 to 1990.

Coefficients on IPI and trade volume are significantly positive; the former variable is lagged for up to 6 months. The authors use *locally weighted curve fitting* (Cleveland et al., 1988) to allow own-price-elasticities to vary over time. Except for outbound traffic to the US, elasticity estimates continually increase and are uniformly near or above unity in 1990. By contrast, the demand elasticity for US-bound traffic diminishes over the interval and is near zero in 1990.

The piece is seminal for showing that demand elasticities vary over time, but that underlying causes are difficult to quantify. Unfortunately, future projections and forecasts based on historic time trends are suspect. This is particularly problematic here because the available data stop in 1990.

The model is evidently modest in other respects. The list of other variables is minimal. Correspondent prices, number of access lines, and demographic and geographical variables are unfortunate omissions. The results are based on pooled data and might not be robust.

5.5. Sandbach

Sandbach (1996) explains billed traffic minutes between seven European and 20 other nations. He models outgoing and incoming traffic on each of 140 routes. Exogenous variables include three price variables, originating plus terminating lines, per capita real GDP, common language dummy, number of time zone differences, the reciprocal of geographic distance, and a dummy for Germany–Turkey. The format is a complex mixture of log and level variables. Data are cross-sectional in 1995. The estimated technique is OLS.

The three price variables are own-price, the difference in collection prices (i.e. own minus reverse price), and a truncated ‘collection price’ difference that becomes positive only when it exceeds a threshold that is ‘best fitted’ ($0.90/min). The price differences presumably capture the possibility of arbitrage. All three price terms and the dependent variable are logged. The three respective price coefficients are significantly negative, negative and almost significant (at 5%), and insignificant.

The structural form is strange. As independent variables, only minutes, access lines, and GDP are ‘logged’, while the remaining variables are ‘leveled’. Coefficients on originating and terminating access lines, per capita deflated GDP, common language dummies, and the Germany–Turkey dummy are significantly positive. Effects of time zone differences and geographic distance are significantly negative.

The author makes two advances. Firstly, he includes many interesting demographic and geographic variables that affect the level of calling volume. Secondly,

he models price arbitrage. However, the three included price variables implicate multicollinearity; his arbitrage term $[P_{ji} - P_{ij}]$ would probably be significant if his threshold term were eliminated.

Problematically, heteroscedasticity and price endogeneity are not examined and the OLS estimation is therefore suspect. The functional form is ad hoc; right hand variables include logs, levels, and inverses. The author does not include return traffic or correspondent economic factors in any route equation. By including his reverse prices only in terms related to arbitrage, Sandbach does not consider more general substitution or complementarity

5.6. Garin Munoz and Perez Amaral

Garin Munoz and Perez Amaral (1996) explain outgoing international traffic from each of 50 provinces in Spain. The authors use two alternative dependent variables — per line deflated expenditure and traffic minutes. Explanatory variables include real own-price index, national gross value added, number of hotel stayovers by foreign tourists, number of foreign residents, and number of Spanish emigrants going abroad. The structural form is log-linear. Data are pooled annual time-series, cross-section in 1985–1989.

Estimated own-price (value added) elasticities in the two respective equations are -0.77 (0.63) and -0.57 (0.47). These elasticities exceed comparable results that one author (Perez Amaral et al., 1995) derived for interprovincial traffic in Spain (-0.13 and 0.46). Elasticities for tourism and foreign residents are significantly positive.

There are some intriguing variables dealing with tourism and immigration. This seems worthwhile, particularly major tourist countries such as Spain. The list of economic variables is modest. The authors do not include correspondent prices, return volume, or economic conditions. Results derived from pooled data may lack robustness.

5.7. Madden and Savage

Madden and Savage (2000) present a comprehensive model of volume and pricing based on two earlier approaches that we should first summarize. In the first, Madden and Savage (1998) use data for 27 US bilateral markets in 1985–1995. They regress (log-linear) US real per minute settlement rates on per minute investment cost of trans-Atlantic cable (+), correspondent area (+), time difference (+), lines/person (−), lines/employee (+), time (−), traffic volume (−), national income (−), and a 0–1 dummy if the foreign country permits incoming one-way private lines (−). The authors include two alternative measures of market concentration: dominant foreign carrier market share [+] or number of foreign carriers [−]. Estimated coefficients are significant and usually correctly signed (except time difference and lines/employee).

In the second, Madden et al. (2000) use data for 82 bilateral international markets (43 countries) in 1991–1995. They regress (log-linear) the ratio of outgoing to incoming minutes upon relative collection rates (−), real per capita income (+), private ownership market shares (+), share of partner trade aggregate (+), and two alternative measures of market concentration (dominant carrier market share [−] and number of facilities-based carriers [+]). When the price ratios exceed a certain level, a call reversion term is included for arbitrage. Except for trade shares, coefficients are significant and correctly signed.

Madden and Savage (2000) explain US collection rates, correspondent collection rates, outgoing call volume, and incoming call volume in a simultaneous four-equation model built up from theoretical principles. The authors actually report reduced form results for collection rates only. They include four independent variables that affect carrier costs and prices — telecommunications labor productivity (lines/employees), linear distance between national capitals, (real) per minute termination rates, and percent of main telephone lines served by digital switches. They also include three independent variables related to market structure — dominant carrier's market share of minutes, combined private ownership shares, and combined number of pairwise carriers.

The system is log-linear. The authors use pairwise pooled data between the US and 39 trading partners in 1991–1994. They estimate the model with 3SLS, using technical corrections for single equation autocorrelation, heteroscedasticity, and inter-equation covariance.

All four variables that reflect carrier costs pick up significant coefficients. The coefficient on labor productivity is sensibly negative and greater (in absolute value) for US outgoing traffic. Linear distance picks up a sensible positive coefficient that is roughly equal in the two equations. Settlement rates pick up a sensible positive coefficient that is considerably greater in the incoming equation. Finally, percent digitization picks up a puzzling positive coefficient in the outgoing equation and an insignificant one for incoming. The authors explain the puzzle as a short-run effect that may result if US local carriers raise collection rates to recover investment costs.

Regarding market share, the coefficient on dominant carrier share is significantly positive and considerably greater in the incoming equation. The coefficient on combined private ownership is significantly negative and greater in absolute value in the incoming equation. The authors contend that these relative competition effects result because competition can be more stimulatory in foreign countries that are first moving from monopoly. However, the coefficient on number of competitors is significantly (insignificantly) negative and greater in absolute value in the US outgoing equation. This result directly contradicts the market share effect.

The paper is the first econometric model that is built from a complete theoretical structure. It also models both two-way traffic volume and accounting rates consistent with that theory. The econometric analysis is very thorough.

However, the results are somewhat inconsistent. Firstly, the authors do not report equations for outgoing and incoming call volume. Secondly, some estimated market structure effects contradict one another. Thirdly, labor productivity is a very inappropriate surrogate for telecommunications productivity. Fourthly, the linear distance term involving mileage from Washington, DC fails to recognize the economic importance of the US West Coast, particularly with regard to Asia.

5.8. Wright

Wright (1999) explains US per minute settlement rates involving 167 calling partners in 1980–1996. He explains real (1985 prices) rates as a function of pairwise differences in per capita incomes, distance between countries, foreign land area, foreign population, the share of outgoing calls from the US carried by AT&T competitors, and a 0–1 dummy for the allowed foreign competition. The author estimates regressions on both a year-by-year and a pooled time series basis; the number of annual observations in each may differ by foreign partner. He corrects each year-by-year equation for heteroscedasticity and uses three estimation techniques in the pooled analysis — standard OLS equation 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.

Income differences are expected to reflect traffic imbalances that could increase settlement rates. Settlement rates are expected to increase with transport distance and foreign land area (i.e. transport and termination costs) and decrease with population (i.e. population density). Wright expects the coefficients on these cost variables to decline over time, reflecting advancing technology and improved scale. Reflecting his theoretical framework (see Section 3), Wright expects that settlement rates will increase as the share of AT&T competitors increases. The presence of foreign competition could increase or decrease rates, depending on whether foreign carriers can reach settlement arrangements outside of the FCC's international settlements policy.

In the annual equations, Wright regresses real settlement rates against six variables: income difference [+], transport distance [+], log (population) [−], log (foreign area) [−], the 0–1 presence of foreign competition (1993–1996 only), and an interaction between the foreign competition dummy and transport distance [−]. Coefficients for the first four independent variables are generally correctly signed and decline in magnitude (as expected). Terms involving foreign competition are not significant, perhaps reflecting the rarity of this event before 1996. In the pooled equation, the author augments the above six variables with four interactive variables: log (population)×time, log (foreign area)×time, distance×time, and distance×'non-AT&T share' of outgoing US calls. Settlement rates again increase with income difference; this effect diminishes with 'non-AT&T' market share and the presence of foreign competition. Distance, foreign popula-

tion, and land area pick up correct signs, though with diminished significance. The 0–1 dummy for foreign competition is now significantly negative.

Wright principally argues that accounting rate levels and traffic imbalances should be positively related to one another. More consistent with theory, he might have directly included as an exogenous variable the level of traffic imbalance itself instead of the difference in per capita income between the two nations. Coefficients could have been appropriately estimated with 2SLS, etc.

His pooled results refute his theoretical conjecture that settlement rates would increase with US domestic competition. The problem here may entail two simultaneous effects. In recent times, competition has increased while settlement rates have declined. Secondly, competition is more likely to have resulted along high-traffic routes to economically developed partners with relatively lower accounting rates.

6. Summary of econometric papers

We summarize the applied research as follows (also see Table 2).

1. The determinants of demand: the papers identify many good determinants of international calling volume. Explaining calling volume, Appelbe considers the most complete list of economic variables, including return traffic, access lines

Table 2
Econometric summary

Featured demand determinants	
Return traffic, access lines, macroeconomic factors	Appelbe
Bilateral trade volume, sectoral employments	Acton, Hackl
Common language and geographic distance	Sandbach
Tourism and foreign visits	Munoz
The calling process	
Separate prices for call set-up and minutes	Bewley
Separate elasticities for shares and volume	Bewley
Types of calls	
Direct dial, operator assisted station-to-station, person-to-person	Bewley
Data bases	
Pooled time-series/cross-sectional data	All except Sandbach
Traffic substitution or complementarity	
Includes return traffic	Appelbe
Includes correspondent rates	Sandbach
Includes correspondent economic data	Acton, Hackl
Price effects	
Own-price elasticity of call volume is between 0 and −1	All
Price elasticities increase	Hackl
Cross-price elasticities	Weak effects

(residence, business, total), and macroeconomic factors (employment, sales, and exports). Acton and Hackl introduce bilateral trade volume and sectoral employments. Sandbach is very thoughtful with demographic and geographic variables — common language, time differences, and geographic distance. Munoz considers tourism and foreign visits.

2. The calling process: with detailed data, Bewley recognizes that telephone calls are two-part goods with separate prices for set-up and usage minutes. The paper incorporates different equations for each. He also distinguishes price elasticities for service shares and overall volume.
3. Types of calls: Bewley recognizes that calling activity includes direct dial, operator assisted station-to-station, and person-to-person. The paper first regresses overall volume on the aggregate price index, and subsequently regresses call shares upon relative prices. The paper derives relevant elasticities by combining these results.
4. Data bases: except for Sandbach, all papers use pooled time-series/cross-sectional data. If estimated coefficients should properly differ in time series and cross sectional analysis, the pooled results may be specific to the mixture of time series and cross sections in the data sample.
5. Traffic substitution or complementarity: only Appelbe includes return traffic volume as an independent variable to explain the level of outgoing traffic. Preferring reduced forms, Acton and Hackl include correspondent economic data as exogenous variables. Sandbach considers correspondent rates in his arbitrage terms, but ignores more complex substitutions and complementarities between outgoing volume and incoming prices. Munoz and Bewley incorporate no correspondent data. No strong consensus supports the notion that outgoing and incoming calls are either complements or substitutes.
6. Price effects: most studies demonstrate that the own-price elasticity of call volume is significantly negative and between 0 and -1. US estimates in Acton and Vogelsang and Canadian estimates in Appelbe are between -0.36 and -0.53. Using early data, Hackl finds that demand elasticities in Europe are somewhat higher and possibly increasing. There is no strong support for cross-price elasticities being positive or negative.
7. Changing parameters: Hackl recognizes that demand parameters may change over time and models a time-dependent process. His data unfortunately end in 1990. He offers no explanation for differing trends on domestic and foreign price elasticities. Wright includes interactive terms involving time and cost factors. His estimated trends are sensible, though truncated in 1996.

7. Conclusion

We conclude this paper with some general observations about public policy and suggestions for future research.

Theoretical models make some important policy insights. Firstly, monopoly network providers have economic incentives to overprice both accounting and collection rates. Consequently, multilateral agreements to maintain settlement benchmarks and to introduce domestic and routing competition may be necessary to strengthen price discipline.

Secondly, the net recipient nation in any country pair will favor higher accounting rates; this is often a less developed nation that needs revenue to finance network buildout. If accounting rates are reduced, aid programs may be reasonably instituted to help offset revenue shortfalls. Econometric studies of price-elasticities may be useful in estimating expected revenue losses.

Thirdly, the FCC's international settlements policy discourages price competition. If equal rate rules are effective, domestic competitors may attempt to recover lost collection revenues by increasing the common settlement rates. US carriers subject to the proportionate return rule may actually oversettle international calls, thereby increasing caller costs and traffic imbalance.

Fourthly, apparently competitive strategies, such as call-back and one-way bypass, may actually increase traffic imbalance. Foreign carriers may then attempt to increase settlement rates, thereby raising collection rates paid by other US callers.

Researchers in future efforts may consider extensions that implicate new events and policy agendas. Firstly, theoretical frameworks such as Yun and Wright assume a market of oligopolistic competitors without recognizing the importance of a competitive fringe that is now growing rapidly. The competitive fringe should now be directly modeled in future research. Such modeling would be particularly timely, as the FCC (Federal Communications Commission, 2001) recently concluded that the statutory requirement that non-dominant common carriers file tariffs for their international interexchange services is no longer necessary due to the emergence of competition in the market for international services.

Secondly, as ISP rules are abandoned, carriers will increasingly compete with one another for the right to terminate incoming calls. Consequently, multilateral bargaining models are now relevant. Researchers previously could not quantify important technical factors that have improved transport or termination efficiency, new customer services that affect volume and price elasticity, and new calling and routing options that may divert traffic from settlements. Many of these are not available in the public domain. Given their present importance, their omission is particularly unfortunate. New data would be particularly useful, and would greatly improve the general applicability of future econometric results.

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