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Pricing in Vertically Integrated Network Switches

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Abstract

Many automated teller machine (ATM) networks are partially vertically integrated. A group of downstream retail banks own and operate the upstream network switch. The size of the group varies from network to network. The same situation exists in other network businesses, including airline computer reservation systems and credit card networks. A previous paper by McAndrews and Rob (1996) modeled the formation of such ownership structures. Here I take as parametric the size of the group that owns the upstream network, the monopoly structure of the upstream network switch, as well as the size of the downstream industry, all the members of which are connected to the switch. Given these assumptions I model the pricing and output behavior of the group of owners as the number of its members varies.

The analysis suggests that the more inclusive is the ownership group in a vertically integrated network, the more likely that the network adopts a flat fee (as a function of volume) pricing schedule. Second, the output of the downstream industry initially rises as the ownership group expands, but then contracts as the ownership group includes all of the downstream firms.

I. Introduction

Many established and emerging networks that process financial transactions, including credit card, automated teller machine (ATM), and point-of-sale (POS) debit networks, are typically owned by a number of their downstream customers. Previous work by McAndrews and Rob (1996) modeled the formation of such networks and generated predictions on concentration in the wholesale switch market and ownership by downstream bank customers. This paper takes as given the ownership structure and investigates the interaction between that structure and the pricing incentives of the wholesale switch.

These incentives are explored in a model in which a monopoly network switch serves many firms in a single market. The assumption of monopoly in the service provided by the network switch allows me to focus on the influence of the size of the ownership group on pricing. It is also empirically accurate over many sections of the country.¹ Alternative ownership structures, downstream market structures, and pricing equilibria are then explored for their effects on the prices charged in the switch service.

In particular, the industry is composed of a fixed number of downstream firms, n . They compete in setting output levels. A subgroup of these firms, consisting of k firms, where $0 \leq k \leq n$, owns and operates the switch. The owners are further distinguished in that they are Stackelberg leaders in the downstream output market. This assumption captures the fact that when there is a small group of firms that own and operate a network switch, they tend to be larger and more prominent firms in the downstream market. Examples of this include Bank of America in the early credit card industry, United and American Airlines in the computer reservation systems, and CoreStates Bank in the MAC ATM

¹See the allegations in the Department of Justice's complaint against Electronic Payment Services.

network in Pennsylvania, New Jersey, and Delaware. When $k = 0$, or when $k = n$, the downstream competition is perfectly symmetric. A firm outside the downstream industry owns the switch when $k = 0$.

The switch is operated in the interests of its owners. That means that the prices are set to maximize the sum of an owner's share of profits from the switch and all of its downstream profit. The wholesale prices are set in the first stage, the retail prices in a second stage. One might conjecture that, regardless of the number of firms in the ownership group, the upstream monopoly switch would be able to extract a fixed amount of profits from a downstream industry composed of a fixed number of producers, but that is not so. The nature of competition in the downstream industry changes with the changing number of firms in the ownership group, all of whom act as leaders. Furthermore, the interests of the owners change as their membership changes. Both of these considerations lead to a different pricing problem for each group of owners of the switch. Indeed, we will treat the problem as one that is parametric in the number of owners.

The next section of the paper reports some pricing data on ATM networks, the third section explores the model and its conclusions, and the fourth section concludes.

II. ATM Network Pricing

There are several fees associated with ATM network services. Typically networks charge member banks *switch fees*, and they may charge *fixed fees* for the basic service of providing the information processing necessary to relay authorization for a transaction from the cardholder's bank to the ATM. Networks also set *interchange fees* paid by cardholders' banks to machine-owning banks. Furthermore, banks may charge a *foreign fee* or a *transaction fee* to their cardholders for using ATMs. Finally, it is increasingly common for ATM owners to charge a *surcharge* to some who use their machines. For our purposes, we are going to focus on the switch fees and fixed fees that the networks

charge their customers for their services.

In Table 1 we report such fees for the ten largest ATM networks, as well as for an ATM network with a nonbank owner. I use data from the *Bank Network News* as well as a survey (McAndrews (1992)). I use data from 1992 because there was a greater variety of ownership structures at that time (since then, because of increasing consolidation in ATM networks, more of the networks have fairly widespread ownership). Table 1 displays the range of the per transaction switch fee, the range of any annual fees (if known), and the nature of the ownership, which I will categorize as nonbank owner, single bank owners, small group of owners, medium group of owners, large group of owners, all member ownership. The three middle categories are subjective. The medium group represents groups of owners that are relatively few, but who are especially large in the downstream banking market.

Table 1
Network Fees and Ownership Structure as of 1992

Network	Switch Fee Per Transaction	Fixed Fee (Annual)	Initiation Fee	Ownership
PULSE	\$.06	\$0	\$200	All Members
Yankee 24	\$.12	\$0	\$10-\$50 per ATM	All Members
Star System	\$.035-\$.08	\$1000 -\$2500	\$1500-\$2500	All Members
NYCE	\$.06-\$.13	\$0	\$0-\$20,000	Large Group
Exchange Accel	\$.12	\$6000	\$6000	Large Group
Money Station	\$.045-\$.15	\$2000	\$7500	Medium Group
Magic Line	\$.12	\$0	\$0	Medium Group
Honor	\$.02-\$.10	\$2000-\$125,000	\$2000-\$25,000	Small Group
MOST	\$.035-\$.14	\$0	\$600-\$100,000	Small Group
MAC	\$.05-\$.25	Unknown Card fees	\$5000 -\$25000	One Bank
MoneyMaker	\$.05	\$0	\$0	Nonbank

Table 1 does reveal some regularities. First, let us interpret a volume discount in the switch fee as being akin to a two-part price schedule. Then it seems that, except for the nonbank owner, the more exclusive the group of owners the greater is the range in the switch fee, and the more likely is there to be a fixed fee, and a relatively high initiation fee. The dichotomy is most clearly seen in the juxtaposition of PULSE and MAC. PULSE is owned by over 1000 member banks, while MAC was owned by a single bank in 1992. PULSE charged a flat switch fee of six cents, while MAC's switch fee ranged from 25 cents for the smallest banks to five cents for the largest, and had a large initiation fee. The Honor network, controlled by relatively few banks, had relatively high fixed fees when compared to PULSE, for example. This generalization is not exact, of course. The nonbank-owned network had a fee schedule similar to that of PULSE. It is notable that MoneyMaker was the 20th largest network, one-third the size of the tenth largest network, and probably faced more competition in its market than did the other networks listed. These data raise the question of the systematic link between the size of the ownership group and the pricing and output decisions of the network.

III. Modeling Network Pricing

The downstream industry is composed of n firms. They compete by setting their levels of output of retail transaction services, q_i , $i = 1, 2, \dots, n$. In the absence of any asymmetry in ownership of the network switch, that is, if none of the downstream firms owns the switch, or if all do, the levels of output are determined by the output levels associated with Cournot equilibrium levels of output. If k of the downstream firms own the switch, downstream outputs are determined by the $(n-k)$ nonowners acting as Cournot followers of the k Stackelberg leaders in output. The industrial structure of multiple, symmetric leaders and multiple, symmetric followers has been investigated by Sherali (1984) and by Daughety (1990). I adopt this structure to model the empirical regularity of larger, more prominent

firms often being in the ownership group of an upstream switch.

Market demand is linear: $P(Q) = \bar{A} + v(n) - bQ$; \bar{A} is a positive constant, $v(n)$ reflects the increased consumption value associated with the number of firms that participate in the network, b is a positive price, and Q is the sum of all n firms' outputs. Marginal cost of production is constant at $s > 0$; s is the price of one unit of the switching service--a necessary input into one unit of the output. This formulation is simplified further with the assumption that all participate in the network; for simplicity I set $b = 1$. Hence the demand curve can be rewritten as $P(Q) = A - Q$; where $A = \bar{A} + v(n)$, and profit for the individual firm is $\pi^i(q^i) = (A - Q)q^i$.

Output is determined at the downstream level by competition in output. If k firms are in the ownership group, say firms 1 through k , then q^1, q^2, \dots, q^k , are determined first (using the best-reply functions of the followers) and $q^{k+1}, q^{k+2}, \dots, q^n$ are determined after that and with the knowledge of the output levels of the leaders. It is standard that this method of competition yields the following levels of outputs (again see Sherali (1984) or Daughety (1990)):

$q^L = (A - s)/(k + 1)$; where q^L is the output of one of the k owners of the switch; and

$q^F = (A - s)/[(k + 1)(n - k + 1)]$; where q^F is the output of one of the $n - k$ nonowners of the switch.

When $k = 0$ or n , all the firms' outputs are the same and equal to $q = (A - s)/(n + 1)$. Q , the sum of the firms' outputs, is then equal to $Q = [(A - s)/(k + 1)][(n + nk - k^2)/(n - k + 1)]$.

These output levels yield the corresponding levels of profit for the firms.

$\pi^i(q^L) = [(A - s)/(k + 1)]^2(1/(n + k - 1))$, and

$\pi^i(q^F) = \{[(A - s)/(k + 1)](1/(n + k - 1))\}^2$.

With $k = 0$ or n , profits for all firms are the same and equal to

$\pi^i(q) = [(A - s)/(n + 1)]^2$.

Given these downstream outputs and profits, the switch will set its prices to maximize the profits

of its owners. We will denote the profit of a member of the joint venture by $\pi^{JV}(s)$. This objective is the one that McAndrews and Rob (1996) explored and is consistent with the joint venture structure of the enterprise. If there are no downstream owners, that is, if $k = 0$, the switch maximizes its profits.

The technology requires one unit of switch services for every unit of final output. Hence the profits derived from the switch are $\pi^S(Q) = (s - c)Q - F$ for single-part pricing; where c is fixed marginal costs (which I set equal to zero), and F is a fixed cost of setting up the switch. For two-part pricing the switch profits are $\pi^S(Q) = sQ + nT(s) - F$, where $T(s)$ is the fixed price, and s is the variable price.

We first investigate single-part pricing. A switch with k owners is operated to set prices to maximize $\pi^{JV}(s) = (1/k)\pi^S(Q) + \pi^i(q^L) = (1/k)(sQ - F) + \pi^i(q^L) = (1/k)\{s[(A - s)/(k + 1)][(n + nk - k^2)/(n - k + 1)] - F\} + [(A - s)/(k + 1)]^2(1/(n + k - 1))$.

The first-order conditions for the maximization of this expression yields a profit-maximizing single-part price given by

$$s^* = (a/2)\{[2nk + (n - 1)k^2 - k^3 + n + 2]/[2nk + (n - 1)k^2 - k^3 + n + 1]\}.$$

Under two-part pricing I first specify the level of the fixed price. Let the fixed price be equal to the profits of the nonowner firms, that is, let $T(s) = \pi^i(q^F)$. This is an extreme assumption, but it is qualitatively similar to one in which the fixed price is some proportion of the profits of the nonowners. The nonowners are a distinct market segment with smaller outputs than the larger owner firms (owner firms are assumed to be larger because they are leaders in the retail market). It is a common assumption that fixed fees are set at the level that makes the smaller demand segment indifferent to buying the product.

In the two-part pricing case the joint venture sets s to maximize

$$\pi_T^{JV}(s) = (1/k)[sQ + nT(s) - F] + \pi^i(q^L) - T(s) = (1/k)[sQ + T(s) - F] + \pi^i(q^L) - \pi^i(q^F) = (1/k)\{s[(A - s)/(k + 1)][(n + nk - k^2)/(n - k + 1)] - F\} + [(A - s)/(k + 1)]^2(n + nk - k^2)/(k(n + k - 1)^2).$$

Maximizing this expression with respect to s yields

$$s^{**} = (a/2) \{ [(n + nk - k^2)(k + 1)(n - k + 1) + 2(n + nk - k^2)] / [(n + nk - k^2)(k + 1)(n - k + 1) + (n + nk - k^2)] \}.$$

Some relationships among the variables can be found analytically. First, let $F = 0$, and treat k as a continuous variable. Examining the variation in Q as the number of owners change, leads to $\text{sgn}(\partial Q(s)/\partial k) = \text{sgn}(A - s)(n - 2k)$.

So for fixed s , Q increases in k when $k < (n/2)$ and decreases in k as k grows larger. Furthermore, as $k \rightarrow n$, $s^* \rightarrow (A/2)(n^2 + n + 2)/(n^2 + n + 1)$, and $s^{**} \rightarrow (A/2)(n^2 + 3n)/(n^2 + 2n)$. Hence at $k = n$, we have that $s^* < s^{**}$ for all $n \geq 3$. In addition, $\text{sgn}(\partial s^*/\partial k) = \text{sgn}(A/2)(-2n - 2(n - 1) + 3k^2)$; this is a quadratic in k , therefore s^* initially is decreasing in k (at $k = 0$ the expression is negative), but for large k , s^* is increasing in k . This fact reinforces the conclusions regarding the change in output associated with increasing k : prices fall and subsequently rise in k ; this reinforces the tendency for output to rise and subsequently fall in k . Similarly for s^{**} . Examining s^{**} , one finds that

$\text{sgn}(\partial s^{**}/\partial k) = \text{sgn}-(A/2)(n - 2k)$. Hence for $k < (n/2)$ the price falls, and for $k > (n/2)$ the price rises.

Result 1: For both pricing mechanisms, there is a tendency for prices to fall and output to rise as the number of owners grows, and then for these trends to reverse themselves.

This result follows Sherali's and Daughety's results on the output behavior of an industry as the number of leaders in the industry increases. They showed that, for a canonical demand and cost system, the output of the industry rises in the number of leaders up to some threshold, after which industry output falls back. The case of no leaders and the case of an all leader industry yield identical outputs.

Here, we see that the same incentives are at work. The same rise and subsequent fall in output is seen. Consequently, the upstream monopolist has a reduced incentive to extract profits from the downstream industry when the ownership group consists of about half of the industry, because of the countervailing incentive to increase output as a downstream retail-market leader. As a result, prices fall

as the downstream industry's output rises (and k rises to $n/2$). Thereafter, prices again rise (and output falls) as the incentives of the upstream monopolist to extract the profits available from the downstream industry, and the incentives of an increasingly sizable group of leaders, tend in the same direction. The profits of each of the joint venturers fall monotonically as the ownership group grows and the share of upstream profit that any individual member can claim is diluted by the increased membership.

Looking at profits, notice that, when $k = n$, for a fixed price \underline{s} , $\pi^{JV}(\underline{s}) = \underline{s} (A - \underline{s})/(n + 1) + [(A - \underline{s})/(n + 1)]^2 = \pi_T^{JV}(\underline{s})$. Given, however, that $s^* < s^{**}$ (that is, the single-part price is lower than the variable fee part of the two-part price schedule), for $k = n$ (and when $n \geq 3$), we have that $\pi^{JV}(s) > \pi_T^{JV}(s)$. In other words, the profits available to the industry when all firms own the upstream switch are greater under single-part pricing. This contrasts with the case when $k = 1$, for example, where, for all n , $\pi^{JV}(s) < \pi_T^{JV}(s)$.

Result 2: As the proportion of the downstream industry that owns the switch grows, single part pricing, initially less profitable, becomes more profitable than two-part pricing.

The intuition for this result follows from the changing incentives of the ownership group. Under two-part pricing, as the ownership grows more inclusive, less weight is placed on the downstream profit of the owner-member because the fixed-fee is increasingly "taxing" away these downstream profits. In the extreme case in which all of the members of the industry are owners, no weight is placed on downstream profits (the fixed fee exactly cancels out any downstream profit because all owners are "followers" as well as "leaders"), and the industry posts the same prices as would a third-party owner. This results in prices that are "too high" relative to the cartel profit-maximizing price--the problem of a double margin has reasserted itself in full. Under single-part pricing, this "zero-weighting" of the downstream profit doesn't occur. Hence, when a large percentage of the industry are owners, single-part pricing becomes more advantageous. In this case, the single-part price is lower than the variable-fee

part of the two-part prices--there is less of a double-margin being extracted. This allows the group of owners to come slightly closer to the cartel price and, therefore, to prefer this type of pricing.

This result leads to the conclusion that one should expect the more widely owned ATM networks to rely more on single-part pricing. This is in broad accord with the evidence presented in section 2 of this paper.

To illustrate the effect of changes in k on the levels of s^* , s^{**} and $T(s^{**})$, I numerically solved the model for $A = 20$ and for various levels of n . Table 2 reviews the levels of s^* , s^{**} , $T(s^{**})$, $\pi^i(q^L)$, $\pi^i(q^F)$, and profits of a joint-venture member for $n = 10$, as k varies from 0 to 10. One can interpret the level of s^* to be in cents, in which case it is in the same range as the fees reported in Table 1.

Table 2

**Prices, Outputs, and Profits Under Single-Part and Two-Part Pricing
As the Number of Owners of the Upstream Switch Varies**

k	s^*	$\pi^i(q^F)$	$\pi^{JV}(s)$	Q	s^{**}	$T(s^{**})$	$\pi_T^{JV}(s)$	Q
0	13.3	.36	80.8	6.06	10.83	.69	90.27	8.33
1	10.8	.21	96.4	8.7	10.47	.22	99.09	9.04
2	10.3	.12	49.2	9.25	10.35	.12	49.74	9.28
3	10.2	.09	33.0	9.45	10.30	.09	33.21	9.39
4	10.17	.07	24.82	9.54	10.27	.07	24.9	9.44
5	10.14	.07	19.8	9.58	10.27	.07	19.9	9.45
6	10.12	.07	16.5	9.59	10.27	.07	16.6	9.44
7	10.12	.09	14.21	9.56	10.30	.09	14.23	9.39
8	10.12	.13	12.436	9.50	10.35	.12	12.436	9.28
9	10.15	.24	11.03	9.34	10.47	.22	11.01	9.04
10	10.17	.78	9.86	8.84	10.83	.69	9.7	8.33

The results are qualitatively similar for $n = 8, 20$, and 50 . Several features are notable. First,

downstream ownership results in prices no higher than when ownership is by an outside firm (this is seen by comparing the cases $k = 0$, with all other rows). The only cases in which prices are the same are in the two-part pricing case, when $k = n$. This effect of partial vertical integration is important: partial vertical integration, even with only one member of the downstream industry as owner of the switch, reduces the problem of the double margin that is extracted with the outside owner of the switch. Prices fall and output rises significantly as the industry moves from outside ownership of the switch to one downstream owner of the switch. Cartel profit maximization would direct the switch to price at $s^* = \$0.10$. Significant ownership by downstream firms goes some distance toward this goal: with an outside firm owning the switch, the fee is $\$0.133$, while with six owners the fee is set at $\$0.1012$. As the number of owners rises, however, downstream profit receives increasing weight in the objective function of the switch operation, and prices creep back up, while output falls.

Second, prices generally fall and output rises until about half of the downstream group are owners. After that, with an increasingly inclusive ownership group, prices rise and output falls. Finally, profits for the ownership group are higher under single-part pricing for $k = 9$ and $k = 10$.

IV. Conclusion

This paper has presented a model of the pricing behavior of a partially vertically integrated network. It adopted a short-run approach in which the membership of the network is fixed, as is the ownership group. Using a rather restrictive set of assumptions on demand and cost, I generated two main conclusions regarding the behavior and performance of the networks. The first conclusion concerns the relationship between the number of owners and the output of the network. Initially there is an output gain as the group of owners becomes more inclusive. After the ownership group gets too large, prices rise, and output falls. In this case the joint venture is “overinclusive.” The term

overinclusive is used in the antitrust literature on joint ventures (Balto (1995), for example), but I believe this is the first model in which a decrease in output is clearly associated with a joint venture's increasing in size.

The second conclusion concerns the relationship between the form of pricing mechanism, and the structure of ownership. The more inclusive the ownership, the more likely is the network to be characterized by single part pricing. If volume discounts are interpreted as similar to two-part pricing, this would then translate into the larger the ownership group, the flatter the fee schedule. This is in broad agreement with pricing data reviewed on networks.

The model and the conclusions reached here are not general conclusions; they are exemplary in the sense that they are an extended example of what can occur under some, but not all, circumstances. The example was not constructed to be unusual, and therefore, the conclusion, while not general, should not be dismissed as a special case either. The second, and more important, conclusion, reflects Daughety's (1990) finding that output increases in the number of Stackelberg leaders in an industry up to a point, after which output declines with further increases in the number of leaders. He too uses a linear demand and cost model. The finding in this paper shows that further upstream market power by the leaders does not upset that conclusion. It is unlikely that more general demand and cost curves would reverse that conclusion either.

The long-run effects of ownership structure on pricing, output, and network size are clearly important, as is the notion of network competition. This paper is a first attempt to investigate the links among these factors.

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