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The Effect of Elevator Competition Upon Market Areas

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ABSTRACT

The purpose of this paper is to develop a theoretical model which determines the market boundary of a particular elevator based upon economic conditions. Specifically, a conceptual framework is developed which considers the production in a region, the prices offered by elevators, and assembly and shipping costs. Farmers are assumed to ship grain to the elevator offering the highest net price. Therefore, the boundary for a particular elevator's market area depends upon arbitrage conditions such that farmers are indifferent between shipping grain to various elevators. As a result, the model can be applied to study competition between elevators and the effect of such competition upon elevator bid prices. In particular, the model can be used to analyze policy implications of varying transportation rate structures upon interfirm elevator competition.

I. INTRODUCTION

Market area efficiency, the study of the optimal organization of an industry operating in spatial markets, has been an important and enduring research problem for agricultural economists. In recent years, several market area efficiency studies have been conducted to study the effect of recent changes in transportation technology and rate structures upon the restructuring of the country grain elevator system.[1] This research has primarily dealt with the optimum number, size, and location of marketing facilities. "Although such information may be of general value in formulating both public and private goals, the results are apt to be sterile in the absence of some central planning authority" (French 1977, p. 159). In other words, a major weakness of the market area efficiency models is the inability of the method to address the effects of change at the firm level.

The purpose of this paper is to develop a theoretical model which determines the market boundary of a particular elevator based upon economic conditions. Using arbitrage conditions, the model is applied to determine the market boundary and hence market areas of particular elevators in a region. The specific objectives are: 1) to briefly review the conceptual framework of assembly area models; 2) to develop a theoretical model to analyze assembly areas based upon economic considerations; and 3) to illustrate and identify potential applications of the method as a policy tool to evaluate competition between elevators.

II. CONCEPTUAL FRAMEWORK

Assembly areas have been estimated in most grain elevator market area efficiency studies using a model developed by French (Dooley). French assumed that processing plants operate at the origin of a circular supply region with a uniform, continuous production density (1960, p. 769.) The model states that total quantity supplied is equal to the product of area and production density, or:

(1) $Q = D\pi r^2$

where: Q = quantity of product handled;
D = density of supply per unit of area;
r = the radius of the circular supply area;
π = 3.1416.

Solving for r yields the average distance from the farm to the elevator,

(2) $r = Q^{1/2}(D\pi)^{1/2}$

While appropriate for grain industry market restructuring studies, the French model is not suitable for the firm level analysis of elevator competition. The French model assumes that the entire volume of grain for a supply region goes to one centrally located elevator. However, farmers are generally not bound to a single centrally located elevator within the supply region, but rather have options in their marketing of grain. For example, in seeking to maximize profits, farmers may bypass nearby small local elevators and haul grain directly to multiple-car rail elevators (MCRs) because of higher bid prices at the latter.

In this paper, elevator competition is added by including more than one elevator in the supply region. Thus, profitmaximizing farmers may choose among competing elevators when merchandising their grain. In such a framework, elevator pricing decisions endogenize the market boundary and hence, throughput to the economic model. Since economic variables such as bid prices and assembly costs are reflected in the model, explicit consideration of changing economic and legal conditions in the industry can be analyzed.

In recent years, there have been significant changes in several of the factors affecting elevator bid prices and farmer assembly costs. For example, MCRs have been able to expand their market areas because multiple-car and contract rail rates have lowered shipping costs for MCRs. Market areas also vary as assembly costs change. Farmer assembly costs of moving grain to elevators have fallen because new farm trucks have greater payload capacities and higher fuel efficiencies. Lower assembly costs may allow farmers to haul their grain to more distant elevators.

In the next section, a model is discussed which considers the effect that economic factors such as bid price and assembly costs have upon market areas. This model can be applied to analyze competition between elevators and the effect of such competition upon market areas, elevator margins, and elevator bid prices to farmers.

III. THEORETICAL MODEL

Assume, as with the French model, that the production of agricultural commodities is distributed uniformly over a geographic region. Elevators may not discriminate among farmers with bid prices. Thus, all farmers receive the same price offered by a particular elevator. Farmers are also assumed to ship their grain to the elevator offering the highest bid price net of a constant transport assembly cost per mile. Further assume that the elevator does not have a storage capacity constraint in the sense that they can serve all farmers in the relevant region.

Given these assumptions, the market boundary of an elevator is dictated by the elevator bid price, the distance the farmer ships to the elevator and the farmer's transport cost such that the farmer is indifferent between shipping to elevator i or any other elevator k.[2] The assembly area for an elevator depends upon farmer arbitrage conditions which are characterized by:

(3) $P_i - td_i = \bar{P}_k - td_k$ for all k

where P = the bid price at elevator i and elevator k;

d = the distance to elevator i and elevator k; and

t = linear transportation assembly cost.

Equation (3) holds only for farmer shipments emanating from the market boundary. For shipments off of the market boundary, the farmer's decision does not reflect indifference; rather it reflects a preferred alternative.

To complete the model, the elevator's decision framework is added. Without loss of generality, let the location of the set of elevators be denoted by a Cartesian coordinate system. Each elevator's location (l_i) can be represented by a coordinate pair, $l_i = (x_i, y_i)$. The ith firm's market area (M_i) is characterized by:

(4) $M_i = \{(x_i, y_i) \mid P_i - td_i \geq P_k - td_k\}$ for all k

Thus, the market area for the ith firm is the set of Cartesian coordinates such that each farmer within the area ships to the ith elevator. The market area boundary is characterized by the locus of points such that the farmer is indifferent between shipping to elevator i and any other elevator k. In other words, the boundary of the ith firm, $B(M_i)$, is a direct result of the farmer's arbitrage condition, or:

(5) $B(M_i) = \{(x_i, y_i) \mid P_i - td_i = P_k - td_k\}$ for all k

Given production is characterized by a distribution f(·) over the market area, the ith elevator's expected throughput, Q_i, is given by:

(6) $$Q_i = D\int_{\mu\epsilon M_i} d\mu$$

where D is production per unit area and M_i is the ith elevator's total market area. Given (4), (5), and (6), the price paid to farmers by each elevator represents the choice variable for an elevator seeking to maximize profits. In such a framework, the elevator trades off the benefits from a larger market area associated with a higher bid price against the cost of a lower margin.[3]

IV. MODEL APPLICATION

In this section, the spatial competition notion of market areas is illustrated with a hypothetical example. The model is applied to five cases to study the pricing behavior of one of the elevators in a fixed region as shipping costs, assembly costs, and the competing elevator's prices vary. Before discussing the results, the features of elevator competition in a fixed region are discussed.

Suppose that there are two elevators competing in a 100 square mile production region. Production points in the region are denoted by discrete Cartesian coordinate pairs (x, y) taking values in the set ($x = \pm 5$, $y = \pm 5$). Consequently, the production region is square with 121 discrete production points. Let elevator 1 be located at (-3.5, 0) and elevator 2 be located at (3.5, 0).

By equation (5), the market boundary is characterized by:

(7) $P1 - td_1 = P2 - td_2$

where: P_i is the elevator bid price offered to all farmers by elevator i = 1, 2;

t is the transportation cost per mile faced by all farmers; and

d_i is the distance from a given production point to elevator i.

In (7), there are several cases to consider. First, when both elevators offer the same bid price, the market boundary reduces to a perpendicular line equidistant between the two elevators. Second, if one elevator offers a price greater than the farmer's assembly cost between the two elevators, $\{|P1 - P2| > 7t\}$, then the entire region is serviced by the elevator with the highest price. In this case, the elevator is paying a price high enough relative to the other elevator to induce farmers to drive by the other elevator. Third, when the difference in elevator bid prices is less than the farmer's transportation cost but nonzero, the market boundary is a hyperbola bowing away from the highest paying elevator and intersecting the x-axis at x = (P1 - P2)/2t. Finally, the farmer's assembly cost also plays a critical role in this model. As t goes to zero, the market boundary at the limit is characterized by P1 = P2. In this case, farmers are indifferent between which elevator services them and a small change in price results in one elevator serving the entire region. On the other hand as t increases, elevator competition is "less intense" in the sense that elevator price changes have less of an impact on the farmers' selling decision. In short, the market boundary is the result of elevator pricing policies and assembly costs.

TABLE 1
Starting Values for Elevator 1's Pricing Problem

Variable	Abbreviation	Starting Value
Market Price	Pm	\$3.00/bushel
Elevator 1's shipping cost	T1	\$0.38/bushel
Elevator 2's shipping cost	T2	\$0.38/bushel
Farmer's assembly cost	t	\$0.01/mile
Elevator 2's margin	π2	\$0.10/bushel
Storage and handling costs	C2	\$0.15/bushel

At the outset, behavioral assumptions pertaining to the two elevators are made. There are several alternative pricing strategies available to elevators. In this case, it is assumed that one of the elevators follows a fixed price rule. In other words, this elevator (elevator 2) observes the terminal market price (Pm), and then determines its bid price to farmers (P2) by subtracting from Pm the shipping cost to the terminal market (T2), the related storage and handling costs (C2), and a fixed margin per bushel ($\pi 2$). Elevator 1 is assumed to be more aggressive in its marketing practices. Given elevator 2's bid price (P2), elevator 1 chooses its bid price (P1) so as to maximize its profits.

The algorithm used to solve elevator 1's pricing problem follows three steps. First, elevator 2's offering price, P2, is determined. Given P2, the minimum price elevator 1 can offer and still provide service (P1MIN) and the maximum price elevator 1 needs to offer such that it serves the entire region (P1MAX) are calculated. Second, the difference between the two prices (P1MAX - P1MIN) is divided by 100 to yield the step size of each search over all possible prices used in the algorithm. Third, profit for each step taken is compared to determine the maximum profit yielding price for elevator 1. As a starting point, a summary of the beginning values for the algorithm are presented in Table 1.

The effect of changing elevator 1's shipping cost to the terminal market is the first case investigated (Table 2). The beginning rate of 38 cents per bushel approximates the single car rate for moving wheat from Rosalia, Washington to Portland, Oregon, a distance of approximately 350 miles (Borris et al.). The rate for a 26-car shipment is about 30 cents per bushel. It is assumed that the 26 cent per bushel rate is reflective of a contract rate.[4]

The results suggest that as elevator 1's shipping costs are lowered, some of the savings are passed on to farmers (Table 2). Elevator 1's shipping costs fell 8 cents per bushel as it shifted from a single car to a multiple-car rail shipper (MCR). However, the savings are not completely passed on to farmers as elevator 1 retains some of the lower shipping costs in the form of a slightly higher margin. Some of the higher margin may be regarded as the return on investment for any equipment required to convert a country elevator to a MCR.[5] The difference in bid

TABLE 2
Elevator 1's Profit Maximizing Results With Varying Shipping Costs

Elevator 1's Shipping Rate (\$/bu)	Elevator 1's Bid Price (\$/bu)	Elevator 1's Profit[a]	Farmers Served by Elevator 1 N=121
.38	2.3714	6.5076	66
.35	2.3914	8.5004	79
.33	2.4114	10.4448	102
.30	2.4274	13.7312	112
.26	2.4274	18.2112	112

[a]Profit is an index which needs to be multiplied by the number of bushels moved. It is the margin per bushel multiplied by the number of farmers shipping to elevator 1.

TABLE 3
Elevator 1's Profit Maximizing Results with Varying Shipping Costs for Elevator 2

Elevator 2's Shipping Rate ($/bu)	Elevator 1's Bid Price ($/bu)	Elevator 1's Profit[a]	Farmers Served by Elevator 1 N=121
.38	2.3714	6.5076	66
.35	2.4014	4.5276	66
.33	2.4088	3.3660	55
.30	2.4192	1.9304	38
.26	2.4438	0.6026	23

[a]Profit is an index which needs to be multiplied by the number of bushels moved. It is the margin per bushel multiplied by the number of farmers shipping to elevator 1.

prices to farmers is 5.6 cents, while elevator 1 increased its margin by 2.4 cents per bushel. The number of farmers hauling grain to elevator 1 increased from 66 to 112 as the shipping rate fell to 30 cents per bushel.

The second case analyzed is analogous to the first, except that elevator 2's shipping costs are allowed to vary instead of elevator 1's. The results suggest that an elevator responds to its competitor becoming a MCR by paying a higher price to farmers (Table 3). Recall that the transport shipping savings realized by elevator 2 are completely passed on to farmers since elevator 2 practices a fixed pricing rule. As a result, elevator 2's bid price increased by 8 cents per bushel. There is a negative impact on elevator 1's market area, with the number of farmers served falling from 66 to 38. Elevator 1 reacts by increasing its bid price. However, its price does not increase as much as elevator 2's. For example, as elevator 2 moves from the single rate of 38 cents per bushel to the multiple-car rate of 30 cents per bushel, elevator 1 increases its offer price by only 4.8 cents per bushel.

The third case investigated considers changes in the terminal market price received by both elevators. The results suggest that changes in the market price are passed on completely by elevator 1 to the farmers (Table 4). In this case, elevator 1's pricing behavior is equivalent to elevator 2's fixed price rule. Profit margins, market area, and the number of farmers served are unaffected by varying the terminal market price. The only difference is the change in revenue received by farmers.

Allowing elevator 2 to change its fixed per bushel profit margin so as to vary elevator 2's offering prices to farmers is the fourth case investigated. This

TABLE 4
Elevator 1's Profit Maximizing Results With Varying Market Price

Terminal Market Price ($/bu)	Elevator 1's Bid Price ($/bu)	Elevator 1's Profit[a]	Farmers Served by Elevator 1 N=121
3.25	2.6214	6.5076	66
3.15	2.5214	6.5076	66
3.00	2.3714	6.5076	66
2.85	2.2214	6.5076	66
2.70	2.0714	6.5076	66

[a]Profit is an index which needs to be multiplied by the number of bushels moved. It is the margin per bushel multiplied by the number of farmers shipping to elevator 1.

TABLE 5
Elevator 1's Profit Maximizing Results With Varying Profit Margins for Elevator 2

Elevator 2's Profit Margin ($/bu)	Elevator 1's Bid Price ($/bu)	Elevator 1's Profit[a]	Farmers Served by Elevator 1 N=121
.13	2.3624	8.5004	79
.10	2.3714	6.5076	79
.07	2.4014	4.5276	66
.04	2.4188	2.8160	55
.01	2.4292	1.5504	38

[a]Profit is an index which needs to be multiplied by the number of bushels moved. It is the margin per bushel multiplied by the number of farmers shipping to elevator 1.

situation is similar to the case in which elevator 2's shipping costs decreased. The results suggest that elevator 2 becomes more competitive as it lowers its profit margin (Table 5). Once again, elevator 1 responds to an increase in competition by increasing its offer price to farmers and allowing its market area to shrink.

The final competitive situation analyzed considers the farmer's assembly cost. The results suggest that when farmer transport costs are low, the pricing decisions of the aggressively marketing elevator 1 are more sensitive than when transport costs are high (Table 6). In other words, elevator 1 must offer a higher incentive to attract grain when assembly costs are high. On the other hand, only a slight increase in elevator 1's price is necessary when assembly costs are low. Indeed, elevator 1 effectively prices elevator 2 out of the market when transport costs in this example fell to 0.4 cents a mile.

V. SUMMARY AND CONCLUSIONS

The pricing policy of an aggressive marketing elevator has important ramifications upon market areas. The results of the hypothetical example sug-

TABLE 6
Elevator 1's Profit Maximizing Results With Varying Farmer Assembly Costs

Farmer Assembly Cost ($/mi)	Elevator 1's Bid Price ($/bu)	Elevator 1's Profit[a]	Farmers Served by Elevator 1 N=121
.0130	2.3709	5.3994	66
.0100	2.3707	6.5538	66
.0075	2.4010	6.6264	96
.0065	2.4010	7.0441	102
.0060	2.4044	7.3427	112
.0040	2.3980	8.1720	121[b]
.0010	2.3770	11.2530	121[b]

[a]Profit is an index which needs to be multiplied by the number of bushels moved. It is the margin per bushel multiplied by the number of farmers shipping to elevator 1.
[b]Reflect elevator 1 serving the entire region.

gest than an elevator's bid price will increase when it becomes a multiple-car shipper because profits increase as it passes on some of its lower outbound shipping costs to farmers. Bid prices will also rise when a competitor becomes a MCR shipper as the single car shipper uses higher prices to maintain some of its market area. Similarly, an elevator will also raise its bid price in response to lower margins by a competitor. An elevator's market area and profitability does not vary with changes in the terminal market price because each elevator changes its bid price by the same amount. Finally, assembly costs are an important determinant of an elevators market area. Increases in the farmer's assembly costs limit the effectiveness of using bid prices to expand the market areas of elevators.

While the results seem plausible, it is important to remember that this research analyzes a hypothetical case. A weakness of the analysis is the failure to consider other factors such as elevator storage capacity constraints or the element of risk in pricing. Nevertheless, the model provides a useful framework for analyzing elevator pricing and market area decisions for a fixed region. Policy-makers may find the model useful when analyzing how the benefits and costs of lower transportation rates are allocated among shippers, railroads, and farmers. As the next step, the model will be applied to study the effect of rail contract rates upon elevator bid prices and market areas.

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ENDNOTES

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1. For example, see Fuller et. al. (1981); Harris,; Hilger, McCarl, and Uhrig; Ladd and Liffereth; and Martin, Devine, and Kulshreshtha.
2. This type of approach is analogous to the spatial equilibrium models for firms selling products (See Greenhut, Norman, and Hung for an in-depth review).
3. For further detail about the model see Wilson and Dooley.
4. Rail industry officials suggest that close to 50 percent of the nationwide grain traffic moves under contract rates.
5. In 1984, the average investment cost of upgrading a single car elevator to a multiple-car elevator in Washington was approximately $200,000 (Casavant and Dooley).