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The Impact of Transportation Costs on Spatial Competition of Grain Buyers: An Iowa Case Study

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THE IMPACT OF TRANSPORTATION COSTS ON SPATIAL COMPETITION OF GRAIN BUYERS: AN IOWA CASE STUDY

Hotelling's classic model of spatial competition is adapted to estimate the impacts on grain price of the closure of one of three grain buyers on the Mississippi River in the vicinity of Scott County, Iowa. The customers of the buyer who is closing (River Gulf Grain Company) in Davenport, Iowa, are assumed to deliver their grain to a buyer in either Buffalo, Iowa, to the south or to a buyer in Clinton, Iowa, to the north. Calibration of Hotelling's framework to this situation leads to an estimated decline in grain bids of 1.5¢ per bushel for the buyer located in Clinton and by 2.5¢ per bushel for the buyer located in Buffalo. These estimates are based on an incremental transportation cost of 0.15¢ per mile between the seller's farm and the buyer. This price decline would reduce gross receipts of the farmers who currently deliver to Davenport by approximately \$264,000 per year. The effect of lower price bids on gross receipts of all area farmers would be approximately \$750,000 per year. Transportation costs would increase by an estimated \$75,000 for those farmers who would have to haul their grain farther because of the closure.

by Miguel A. Carriquiry and Bruce A. Babcock

INTRODUCTION

The impact of a reduction in the number of local buyers of grain has received little attention in the literature. More attention has been paid to increased concentration of grain buyers on a national scale. For example, when Cargill agreed to acquire Continental Grain in 1998, Hayenga and Wisner (2002) and USDA-ERS (1999) estimated the impact by measuring the change of concentration ratios nationally and regionally, but they did not estimate how decreased competition would affect prices or quantities. Concerns about a drop in local grain prices in Eastern Iowa arose when the city of Davenport told a local shipper, the River Gulf Grain Company, that its lease on riverfront property will not be renewed. The reason for non-renewal is that Davenport chose to use its riverfront property for new urban development.

If transportation costs are low relative to the market prices, then one would expect very little impact from reduced local competition because sellers would simply ship their product to the next closest buyer at no significant increased cost. However, transporting grain is costly relative to market prices. To ship 1,000

bushels of grain an additional 10 miles would cost a producer between \$10 and \$20, or between 1¢ and 2¢ per bushel. Because shipping grain is costly, the remaining local buyers in the area enjoy increased local market power. They can lower their bids marginally without losing all their customers because, even at the lower price, many of their customers would still find that the next best alternative price net of transportation costs would still be lower than the now-lower local price.¹ The extent to which the bid price can be lowered is limited, however. If local bid prices fall by too much, then local sellers will simply ship their grain farther away. And if one local buyer decides to lower price significantly, then the remaining local grain sellers would simply shift their business to the other local buyer(s).

The objective of this study is to estimate the impacts on local corn and soybean grain prices and transportation costs resulting from the closing of the River Gulf Grain Company. Currently local sellers have three main alternative buyers of grain: River Gulf Grain, in Davenport, Iowa, a buyer in Buffalo, Iowa, and a buyer in Clinton, Iowa. To estimate the impact of the closing of River Gulf the modeling approach first developed by Hotelling (1929) is adapted.

The Hotelling approach is used to calculate the equilibrium bid price with three buyers and compare it to the equilibrium price with two buyers. The degree of price decline is limited by a “residual buyer” located in Muscatine, Iowa (south of Buffalo).² The direct impact on farmers’ gross receipts of increased shipping costs resulting from the closing of River Gulf Grain is also estimated.

Not estimated in this study are other local impacts that would result from the closing. Such impacts would include the loss of economic activity associated with the loss of 19 jobs at River Gulf Grain, possible increased road deterioration from grain-hauling trucks, and increased waiting times by farmers to unload their grain at the remaining facilities. However, the adverse economic impact of the jobs lost at Davenport may be (at least partially) compensated by an increase in the number of jobs, or in the efficiency in capacity utilization at the remaining grain buyers, who will increase the amount of grain handled after the closure.

THE MODEL

The model employed to estimate the impacts of the closing of River Gulf Grain is an extension of Hotelling’s (1929) analysis of spatial competition. Hotelling’s line model is modified by increasing the number of firms (as in Economides (1993)), and by reversing roles in the sense that buyers are the players invested with market power (as in Zhang and Sexton (2001)) to capture the economic environment of the problem at hand.

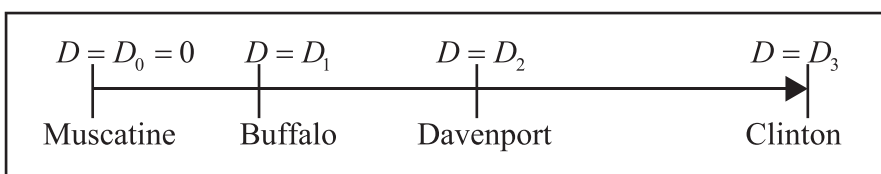
Suppose that the Mississippi River can be approximated by a straight line, with grain buyers being located at different points on the line. There are currently four grain buyers in the area (Muscatine, Buffalo, Davenport, and Clinton) that are considered. For notational

convenience, Muscatine, Buffalo, Davenport, and Clinton will be assigned numbers from 0 to 3, respectively. Muscatine is located at $D = 0$, and Clinton is located at the other end of the line. Figure 1 shows a diagram of the buyers’ locations.

Assume that the reality of grain availability in two dimensions can be mapped onto the one-dimensional line and that there is a fixed amount (normalized to one) of grain available in the area.³ Sellers incur transportation costs t per unit of grain per unit of distance to market their production. The type of “mill pricing” strategy is what we observe in practice. This implies that the price received by sellers (net of transportation costs per unit of grain) decreases linearly with the distance from the buyer. As noted before, it is precisely this transportation cost that gives buyers their market power. It is also assumed that the downstream market for grain is perfectly competitive.⁴ That is, grain buyers cannot influence the price they receive when they resell grain delivered from farmers. Thus, each unit (bushel) of grain has a value of p for all buyers. This does not mean, however, that all buyers will offer the same price.

Buyers choose their offer prices (p_i , $i = 0, \dots, 3$) simultaneously and independently. Each buyer competes directly only with its immediate neighbors. Given this information, the supply function for each buyer with linear transportation costs can be derived. It is assumed that the prices offered by any pair of contiguous firms is not so different (relative to transportation costs) to drive the supply of the low-price firm to zero or that agents use “no mill-price undercutting”⁵ conjectures when offering prices. This is a reasonable assumption, because all four firms are currently buying grain, indicating that some sellers are supplying them.⁶ It is further assumed that the reservation price of sellers (given by their next best alternative) and the costs of hauling

Figure 1: Location of Grain Buyers on the Mississippi River in Eastern Iowa



grain are not so high relative to the prices offered that some potential sellers in the market choose not to ship their grain to any of the buyers.⁷ In other words, it is assumed that all sellers will find it profitable to ship the grain to a buyer.

Sellers compare the net (of transportation cost) prices offered by the two nearest buyers in order to decide who to sell to. For example, a seller located at point $z_{i,i+1}$ in the interval $(i, i+1, i=0,1,2,)$ compares $p_i - t(z_{i,i+1} - D_i)$ against $p_{i+1} - t(D_{i+1} - z_{i,i+1})$. By assumption there is a seller $\hat{z}_{i,i+1}$ located in every interval $(i, i+1, i=0,1,2)$ that is indifferent between the two contiguous buyers. To make the seller indifferent, the following must be true:

$$p_i - t(\hat{z}_{i,i+1} - D_i) = p_{i+1} - t(D_{i+1} - \hat{z}_{i,i+1}).$$

That is, the net of transport costs price bids of the two closest buyers must be the same for the indifferent seller. Solving the equation just presented, the indifferent

seller in the interval $(i, i+1)$ is located at

$$\hat{z}_{i,i+1} = \frac{p_i - p_{i+1} + t(D_{i+1} + D_i)}{2t}.$$

Intuitively, if both buyers offer the same price, the indifferent seller will be located in the middle of the interval. A buyer will attract sellers that are farther away by increasing its bid price relative to its direct rival's bid price.

Thus, buyers located at D_0 and D_3 will receive all the grain that can be mapped to the interval $(D_0, \hat{z}_{0,1})$ and $(\hat{z}_{2,3}, D_3)$ respectively. The buyers located at the interior of the line, namely $D = D_1$, and $D = D_2$, will obtain the grain mapped to the interval $(\hat{z}_{0,1}, \hat{z}_{1,2})$ and $(\hat{z}_{1,2}, \hat{z}_{2,3})$ respectively. See Figure 2.

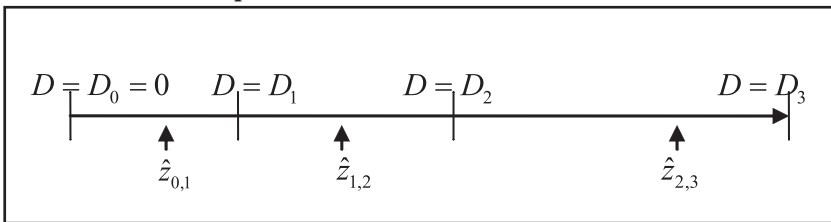
Since it is assumed that a fixed amount of grain is available, the locations of the indifferent sellers determine the proportion of the output that each buyer will obtain. The resulting

$$(1) \quad S_0(p_0, p_1) = \int_{D_0}^{\hat{z}_{0,1}} f(g) dg = F\left(\frac{p_0 - p_1 + t(D_0 + D_1)}{2t}\right) \text{ for } i=0$$

$$(2) \quad S_i(p_{i-1}, p_i, p_{i+1}) = \int_{\hat{z}_{i-1,i}}^{\hat{z}_{i,i+1}} f(g) dg = F\left(\frac{p_i - p_{i+1} + t(D_{i+1} + D_i)}{2t}\right) - F\left(\frac{p_{i-1} - p_i + t(D_i + D_{i-1})}{2t}\right) \text{ for } i=1,2$$

$$(3) \quad S_3(p_2, p_3) = \int_{\hat{z}_{2,3}}^{D_3} f(g) dg = 1 - F\left(\frac{p_2 - p_3 + t(D_3 + D_2)}{2t}\right) \text{ for } i=3$$

Figure 2: Location of Indifferent Sellers for Hypothetical Bid Prices and Transportation Costs



(proportional) supply functions are as follows: where $f(g)$ represents the density function of the grain mapped onto the line with $F(D_0) = 0$ and $F(D_3) = 1$. As one would expect, the amount of grain a buyer can obtain increases with his/her bid price and the distance to the closest rival buyer, and decreases with their (neighboring) rival's bid prices.

The distribution of corn and soybeans in eastern Iowa is relatively homogenous in space, indicating that a uniform distribution may be adequate to capture the distribution of grain in the line. The cumulative distribution function for this case is $F(g) = (g - D_0)/(D_3 - D_0)$ for $g \in [D_0, D_3]$. Clearly, this reality greatly simplifies the analysis, because closed form solutions for the equilibrium prices can be obtained. For situations in which this assumption is not valid, the analysis would require the use of numeric techniques. Also, extra care in the verification that the second order conditions hold and that the equilibrium in bid prices exists is warranted. Under a uniform distribution, the supply equations can be rewritten as:

Notice that when the grain is uniformly distributed, the proportion of the line (and not the locations) covered by a buyer determines the amount of grain the buyer obtains. For future reference, note that the supply functions for the firms located within the line (equation 2') indicate the area that will be covered by them in each direction. Notice that all buyers will obtain a positive grain amount only if $|p_{i+1} - p_i| < t(D_{i+1} - D_i)$, $i = 0, 1, 2$.^{8,9} That is, the difference in prices offered by two contiguous buyers is less than the difference in the transportation costs between them. Because all buyers are currently operating (receiving grain), attention will be restricted in the optimization to the continuous portions of the supply curves (see endnote 8). Applying a least-cost sharing rule, in the sense that farmers sell their product to the nearest buyer if more than one site offers the highest all-inclusive price (Wrede, 2003), it is easy then to verify that the prices derived below are an equilibrium under the conjectures assumed.¹⁰

$$(1)' \quad S_0(p_0, p_1) = \frac{p_0 - p_1 + t(D_1 - D_0)}{2t(D_3 - D_0)} \text{ for } i = 0$$

$$(2)' \quad S_i(p_{i-1}, p_i, p_{i+1}) = \frac{p_i - p_{i-1} + t(D_i - D_{i-1})}{2t(D_3 - D_0)} + \frac{p_i - p_{i+1} + t(D_{i+1} - D_i)}{2t(D_3 - D_0)} \text{ for } i = 1, 2$$

$$(3)' \quad S_3(p_2, p_3) = \frac{p_3 - p_2 + t(D_3 - D_2)}{2t(D_3 - D_0)} \text{ for } i = 3$$

Buyers' profits are given by:

$$(4) \quad \pi_0(p_0, p_1) = (p - p_0) \left(\frac{p_0 - p_1 + t(D_1 - D_0)}{2t(D_3 - D_0)} \right) \text{ for } i = 0,$$

$$(5) \quad \pi_i(p_{i-1}, p_i, p_{i+1}) = (p - p_i) \left(\frac{p_i - p_{i-1} + t(D_i - D_{i-1})}{2t(D_3 - D_0)} + \frac{p_i - p_{i+1} + t(D_{i+1} - D_i)}{2t(D_3 - D_0)} \right) \text{ for } i = 1, 2,$$

$$(6) \quad \pi_3(p_2, p_3) = (p - p_3) \left(\frac{p_3 - p_2 + t(D_3 - D_2)}{2t(D_3 - D_0)} \right) \text{ for } i = 3.$$

Equations 4 through 6 indicate that a buyer's total profits are the result of multiplying the units of grain the buyer is able to secure (given by the supply equations 1' to 3') by their per-unit

profit margin. Each buyer strives to maximize his own profits by choosing an offer price, given the prices offered by his rivals. First-order conditions for this problem are:

$$(7) \quad \frac{\partial \pi_0(p_0, p_1)}{\partial p_0} = \frac{-2p_0 + p_1 + p - t(D_1 - D_0)}{2t(D_3 - D_0)} = 0 \text{ for } i = 0,$$

$$(8) \quad \frac{\partial \pi_i(p_{i-1}, p_i, p_{i+1})}{\partial p_i} = \frac{-4p_i + p_{i-1} + p_{i+1} + 2p - t(D_{i+1} - D_{i-1})}{2t(D_3 - D_0)} = 0 \text{ for } i = 1, 2,$$

$$(9) \quad \frac{\partial \pi_3(p_2, p_3)}{\partial p_3} = \frac{-2p_3 + p_2 + p - t(D_3 - D_2)}{2t(D_3 - D_0)} = 0 \text{ for } i = 3$$

and the second-order conditions are satisfied. Rearranging the system of equations given by 7 through 9, the best response functions (on the restricted interval considered) are:

$$(10) \quad p_0 = \frac{p_1 + p - t(D_1 - D_0)}{2} \quad \text{for } i = 0,$$

$$(11) \quad p_i = \frac{p_{i-1} + p_{i+1} + 2p - t(D_{i+1} - D_{i-1})}{4} \quad \text{for } i = 1, 2,$$

$$(12) \quad p_3 = \frac{p_2 + p - t(D_3 - D_2)}{2} \quad \text{for } i = 3$$

indicating that each buyer will choose to increase its bid price if he believes a neighboring rival will do the same thing.

A non-cooperative price equilibrium for this model is the set of prices p_i^* , $i = 0, 1, 2, 3$ such that, given the price of its competitors, no seller can benefit from unilateral price deviations. The equilibrium is found by solving the system of equations 7 through 9. This is a non-singular linear system with four equations and four unknowns (prices). It can be shown (see the Appendix) to have the following solutions:

$$(13) \quad p_0^* = p - \frac{t}{15}(D_3 + 2D_2 + 8D_1 - 11D_0)$$

$$(14) \quad p_1^* = p - \frac{t}{15}(2D_3 + 4D_2 + D_1 - 7D_0)$$

$$(15) \quad p_2^* = p - \frac{t}{15}(7D_3 - D_2 - 4D_1 - 2D_0)$$

$$(16) \quad p_3^* = p - \frac{t}{15}(11D_3 - 8D_2 - 2D_1 - D_0)$$

Equations 13 through 16 show that equilibrium bid prices depend crucially on the location of the firms (which determines the distance between them), and on the per-mile cost of transportation. Thus, higher per-mile transportation costs and larger distances between firms, both indicating reduced spatial competition, would lead to lower equilibrium bids.

To evaluate the change in the equilibrium price if Davenport is closed, the previous exercise is repeated, removing point number two from the analysis. In equilibrium, the prices offered by the three remaining ports are:

$$(17) \quad p_0^{**} = p - \frac{t}{4}(D_3 + 2D_1 - 3D_0)$$

$$(18) \quad p_1^{**} = p - \frac{t}{2}(D_3 - D_0)$$

$$(19) \quad p_3^{**} = p - \frac{t}{4}(3D_3 - 2D_1 - D_0)$$

AN IOWA CORN AND SOYBEAN APPLICATION

Letting Muscatine be on the extreme of the line ($D_0 = 0$), Buffalo, Davenport, and Clinton are located at $D_1 = 18.95$, $D_2 = 29.5$, and $D_3 = 70.3$ miles (according to www.mapquest.com) from Muscatine, respectively.

With this information at hand, the price declines at the remaining three ports resulting from closing Davenport can be computed as $p_0^{**} - p_0^* = \frac{t}{60}(D_0 + 2D_1 + 8D_2 - 11D_3)$,

$$p_1^{**} - p_1^* = \frac{t}{30}(D_0 + 2D_1 + 8D_2 - 11D_3)$$

and $p_3^{**} - p_3^* = \frac{t}{60}(11D_0 + 22D_1 - 32D_2 - D_3)$. Table 1 presents the predicted price changes in cents per bushel for corn for different per bushel per mile costs of transportation (t). To illustrate, the first cell in Table 1 (Muscatine) is calculated by plugging-in the distances for the locations presented above to obtain

$p_0^{**} - p_0^* = -8.323t * 100 = -0.83$ cents/bushel for $t = \$0.001$ /bushel. The figure for Buffalo is $p_1^{**} - p_1^* = -16.646t * 100 = -1.66$ cents/bushel for $t = \$0.001$ /bushel.

The range of transportation costs in Table 1 was obtained from two sources. Baumel, McVey, and Gervais (1996) estimated that the variable cost per mile for a farmer-owned truck to haul a load of 970 bushels of corn was \$0.669, or \$0.00069 per bushel. This cost estimate was based on mid-1990s fuel, labor, and repair costs, which together account for approximately 77% of total variable costs. The price of fuel, as measured by the New York Mercantile Exchange December futures contract in 2003 (www.barchart.com), was approximately 50% higher than the same futures price in 1995. Average inflation rates for labor and repair over this period imply a transport cost of approximately

\$0.009 for corn and \$0.001 for soybeans, which is the lower end of the estimates in Table 1. Using a different method, Trimac Consulting Services (1999) estimated for Transport Canada that the variable cost per mile of hauling grain varied from \$0.0016 to \$0.0019 per bushel when converted into U.S. dollars using an exchange rate of Canadian \$0.75 to U.S. \$1.00. This serves as the upper range of the transport cost.

As expected, the price impact of closing a buying facility is sensitive to transportation costs. Over this range, a doubling of transportation costs doubles the decline in bids. It is difficult to obtain a precise estimate of transportation costs because it varies so widely among producers. The estimates used in Table 1 are based on the assumption that grain is hauled only one way, so if a farmer needs to travel an extra 10 miles to deliver grain, the actual distance traveled is 20 miles. These costs do not account for the cost of any additional waiting times to unload.

Table 1 shows that the price drop will be larger in Buffalo than in the other two ports. Davenport is about 10 miles from Buffalo, and about 40 miles from Clinton. The competition between Davenport and Buffalo therefore is expected to be more intense than competition between Davenport and Clinton. In the model presented here, Muscatine does not feel the pressure of Davenport's competition directly. Its adjustment is predicted to be milder than that of the direct competitors. The predicted price declines vary directly with transportation costs. If incremental shipping costs are 0.15¢ per bushel per mile, then price bids are estimated to decline by 1.2¢ in Muscatine, by 2.5¢ in Buffalo, and by 1.5¢ per bushel in Clinton (column 2 of Table 1).

After obtaining the equilibrium bid prices, the proportions of the line being covered by each buyer can be obtained from the supply equations

Table 1. Predicted Change in Bid Prices (Cents per Bushel) for Alternative Transportation Costs after Davenport Closure

	$t = \$0.001$	$t = \$0.0015$	$t = \$0.002$
Muscatine	-0.8	-1.2	-1.7
Buffalo	-1.7	-2.5	-3.3
Clinton	-1.0	-1.5	-2.0

1' through 3'. The results of the model indicate that Davenport is currently covering 25.8 miles (or 36.7%) of the line (see Table 2). This figure results from plugging equations 14 through 16 in equation 2' for $i = 2$ to obtain

$$S_2(p_1^*, p_2^*, p_3^*) = (15(D_3 - D_0))^{-1} \\ (7D_3 - D_2 - 4D_1 - 2D_0) * 100 = 36.7\%$$

(which represents 25.8 of the 70.3 miles long line). In 2002 Davenport purchased about 12 million bushels of corn and 4.1 million bushels of soybeans. This would indicate that if the grain is uniformly distributed over the line as assumed in the model, then the density of corn is roughly 462,000 bushels per mile, and that about 158,000 bushels of soybeans can be mapped to a mile of the line. According to the model, upon the exit of Davenport, Buffalo and Clinton will share the "space" left open. Buffalo will capture 80.7% of Davenport's area of influence, whereas Clinton will capture 19.3%. These percents are obtained by comparing the lengths of the line covered by Buffalo and Clinton in Davenport's direction before and after the closure. For Buffalo, the second term of equation 2', $\frac{p_1 - p_2 + t(D_2 - D_1)}{2t(D_3 - D_0)}$,

gives the proportion of the line covered by this buyer in the direction of Davenport for any pair of bid prices p_1 and p_2 before the proposed closure. Multiplying the previous expression by $(D_3 - D_0)$, which converts the proportions of the line to actual miles, and plugging-in the equilibrium bid prices, p_1^* and p_2^* (equations 14 and 15), Buffalo covered

$$\frac{p_1^* - p_2^* + t(D_2 - D_1)}{2t} = \frac{D_3 + 2D_2 - 4D_1 + D_0}{6} = 8.92$$

miles in Davenport's direction. After the closure, Clinton becomes Buffalo's closest buyer in Davenport's direction. Modifying the second term of equation 2' accordingly, by substituting Clinton's bid by Davenport's bid, and plugging-in the equilibrium price bids after the closure (given in equations 18 and 19), the length of the line covered by Buffalo in Davenport's direction (after converting proportions into miles) is given by

$$\frac{p_1^{**} - p_3^{**} + t(D_3 - D_1)}{2t} = \frac{5D_3 - 6D_1 + D_0}{8} = 29.73$$

miles. Therefore, the model predicts that Buffalo will capture $29.73 - 8.92 = 20.81$ miles or 80.7% of the 25.8 miles initially covered by Davenport. The difference between the numbers just presented and those in Table 2 for Buffalo account for the length of the line covered by this buyer in the direction of Muscatine before and after the closure of Davenport. The reader can verify this by plugging the equilibrium bid prices in the first term of equation 2' for $i=1$. A similar calculation (using equation 3') indicates that Clinton covered 16.65 miles and 21.63 miles before and after Davenport's closure respectively (see Table 2), which amount to an increase of $21.63 - 16.65 = 4.98$ miles or 19.3% of the 25.8 miles initially covered by Davenport.

Despite the fact that the model predicts that Buffalo would lower its price more than would Clinton, it will increase the area covered by a larger amount than would Clinton. This is again attributable to the geographical location of Davenport, which is relatively close to Buffalo. These increases in areas are represented by increases in the length of the line covered and are shown in Table 2.

Table 2. Length of the Line Covered by Each Buyer

	With River Gulf Grain		Without River Gulf Grain	
	Length covered (miles)	Proportion of Supply	Length covered (miles)	Proportion of Supply
Muscatine	9.4	13.3%	13.5	19.2%
Buffalo	18.5	26.3%	35.2	50.0%
Davenport	25.8	36.7%	-	-
Clinton	16.6	23.7%	21.6	30.8%

The financial impact for the area initially covered by Davenport is obtained by comparing the price paid by Davenport multiplied by its quantity purchased and the prices that the same amount of grain would receive after the Davenport closing in Buffalo and Clinton, weighted by the amounts absorbed by each of them. Let $p_2^*Q_2^*$ be the gross receipts obtained by the current sellers who deliver to Davenport. If Davenport is closed, Q_2^* will be shared between Buffalo (80.7%) and Clinton (19.3%). This implies that the gross receipts for the current Davenport sellers after River Gulf closes are $(0.807p_1^{**} + 0.193p_3^{**})Q_2^*$, where p_1^{**} and p_3^{**} are the equilibrium bid prices submitted by Buffalo and Clinton respectively after the closure of Davenport. The direct financial impact of closing Davenport is the difference between those two quantities, or $(0.807p_1^{**} + 0.193p_3^{**})Q_2^* - p_2^*Q_2^* = -10.93tQ_2^*$ dollars.¹¹ The price change for this region is thus $-10.93t$ dollars per bushel. For $t = \$0.001/\text{bushel}$, this change represents a $10.93 \times 0.001 \times 100 = 1.093$ cents per bushel decline (see Table 3). The estimates of the change in total receipts for the 12 million bushels of corn and 4.1 million bushels of soybeans delivered to Davenport in 2002 are reported in Table 3. To illustrate, the changes in gross receipts for corn and soybeans in this region

when $t = \$0.001/\text{bushel}$ are $-1.093 \times 12,000,000/100 = -\$131,160$, and $-1.093 \times 4,100,000/100 = -\$44,813$ respectively.

The direct financial impact for the region as a whole can be estimated by comparing total gross receipts for the region before and after the change. Differences in gross receipts are calculated by multiplying the predicted change in bid price (weighted average) by the total supply. This last quantity is inferred from the amount of corn and soybeans currently being shipped to Davenport (more on this below). The predicted average change in bid prices is $-11.38t$ dollars per bushel (details of this calculation are presented in the Appendix), or -1.138 cents per bushel for $t = \$0.001/\text{bushel}$. Table 4 presents the results.

Without more detailed data about current grain deliveries to Clinton and Buffalo, a more precise estimate cannot be made. However, note that the Table 4 estimates assume that 32.7 million bushels of corn and 11.2 million bushels of soybeans are affected by the lower bids. According to the National Agricultural Statistics Service of the United States Department of Agriculture's website (www.usda.gov/nass), Scott County alone produced an average of 18 million bushels of corn and 4.2 million bushels

Table 3: Predicted Change in Price and Total Receipts for Sellers of Corn and Soybeans That Currently Deliver to Davenport

	$t = \$0.001$	$t = \$0.0015$	$t = \$0.002$
Difference in gross receipts (cents per bushel)	-1.093	-1.639	-2.185
Difference in gross receipts for corn	-\$131,160	-\$196,680	-\$262,200
Difference in gross receipts for soybeans	-\$44,813	-\$67,199	-\$87,585
Total difference	-\$175,973	-\$263,879	-\$349,785

Table 4: Predicted Change in Price and Gross Receipts for Corn and Soybean Sellers in the Area Under Study

	$t = \$0.001$	$t = \$0.0015$	$t = \$0.002$
Difference in gross receipts (cents per bushel)	-1.138	-1.707	-2.276
Difference in gross receipts for corn	-\$372,126	-\$558,189	-\$744,252
Difference in gross receipts for soybeans	-\$127,456	-\$191,184	-\$254,912
Total difference	-\$499,582	-\$749,373	-\$999,164

of soybeans from 2000 to 2002. Thus, the Table 4 estimates seem reasonable because the area affected by lower bid prices consists of more than just Scott County. Clinton is located in Clinton County, which produced 29.9 million bushels of corn and 6.3 million bushels of soybeans in 2002; and Muscatine is located in Muscatine County, which produced 14.7 million bushels of corn and 3.6 million bushels of soybeans in 2002.

It might seem that the amount of production that would receive a lower price is being underestimated because the actual amount of grain produced in the region is much larger than that delivered to the three buyers. However, the number of affected bushels must be related to the aggregate amount of grain being delivered to Davenport. In 2002, 12 million bushels of corn were delivered to Davenport, which covered 25.8 miles, or 36.7% of the line. The model then predicts (by the assumption that grains are uniformly distributed along the line) that 32.7 million bushels of corn and 11.2 million bushels of soybeans will receive a lower price, which is 2.73 bushels affected for each bushel that was delivered to Davenport. As an example, the difference in gross receipts for corn in the area studied for $t = \$0.001/\text{bushel}$ is $-11.38 * t * 32,700,000 = -\$372,126$.

Strictly speaking, the change in gross receipts presented in Table 4 is not a welfare loss to the community, but a wealth transfer from the sellers to the buyers. In other words, the difference in gross receipts presented in Table 4 equals the

increase in buyers' profits.¹² However, after the closure of Davenport, farmers in its proximity will have to haul their grain farther. This entails higher costs for the farmer not captured by the change in gross receipts presented in Table 4. Of course, a portion of these costs will also benefit other sectors (e.g. gas stations and repair services) in the local economy. The next task is to estimate the direct increase in transportation costs that will be incurred by the current sellers to Davenport because of increased hauling distances.

INCREASED TRANSPORTATION COSTS

To estimate the effect of closing the Davenport buyer on the change in total transportation costs that must be incurred to transport grain to the neighboring buyers in Buffalo and Clinton, data on the geographical location and concentration of Davenport's current suppliers was used. That data was provided by the River Gulf Grain Company. The increased transportation costs are estimated by multiplying the average change in hauling distance by the number of bushels delivered by the cost per bushel per unit of distance.

The change in distance is estimated by assuming that each customer ships grain from the geographic center of that customer's zip code region. Then the distance to each potential buying point was calculated by entering the zip code and the address of all the potential

shipping locations (using mapquest.com). For simplicity, it is further assumed that each of River Gulf's customers in 2002 would choose to ship to the closest alternative buying point, hence an estimate of the extra number of miles each customer will need to haul its grain is obtained.

The available data indicate that 3,323 customers delivered grain to River Gulf Grain in 2002. Assuming that quantities of corn and soybeans currently delivered to Davenport are distributed uniformly among these customers, each customer is assumed to deliver 3,611 ($12,000,000/3,323$) bushels of corn and 1,234 ($4,100,000/3,323$) bushels of soybeans. Multiplying the amount of each product (corn or soybeans) that each customer delivers by the extra number of miles that customer needs to drive, and by the per-mile-bushel transportation rate an estimate for the additional transportation cost for that customer is obtained. Summing over all of Davenport customers yield the numbers presented in Table 5. To illustrate the calculations performed, the total number of extra miles that need to be driven after the closure of Davenport is 2,078.7. This figure was obtained through the procedure outlined in the previous paragraph. Using the assumption that the quantities of corn and soybeans are distributed uniformly among sellers, the additional transportation costs for the customers delivering to Davenport are $2,078.7 \times 3,611 \times 0.001 = \$7,506$ and $2,078.7 \times 1,234 \times 0.001 = \$2,565$ for corn and soybeans respectively and $t = \$0.001/\text{bushel}$.¹³

The reason why these transport cost estimates are small is that this method of calculating the change in distance results in a reduction in shipping costs for 61% of River Gulf's customers. That is, Davenport is farther away for these customers than is the next closest buyer. These customers must have had some other reason for shipping grain to River Gulf than simply shipping distance.

Table 6 reports the increased shipping costs for only the 39% of customers that would have an increased distance to ship their grain. The procedure to obtain the figures in Table 6 is the same as for Table 5, but summing only over the customers that would have an increased distance to ship their grain. The increased distance for these customers is 10,344 miles, implying an increase in transportation costs of $10,344 \times 3,611 \times 0.001 = \$37,352$ and $10,344 \times 1,234 \times 0.001 = \$12,765$ for corn and soybeans respectively and $t = \$0.001/\text{bushel}$. Subtracting the Table 6 estimates from Table 5 estimates shows the savings in shipping costs that would occur for those customers who reside closer to Clinton or Buffalo than to Davenport. The fact that many customers chose to ship their grain to Davenport even though one of the other buyers was closer indicates that River Gulf Grain must have offered some other benefit that overcame the increased travel costs. Two likely reasons are a stronger bid (which is consistent with the predictions of the model presented (see endnote 11) or a shorter waiting time to unload grain. The estimates made in this study do not account for

Table 5: Additional Transportation Costs for the Customers Trading With Davenport

	$t = \$0.001$	$t = \$0.0015$	$t = \$0.002$
Increased transport costs for corn	\$7,506	\$11,259	\$15,012
Increased transport costs for soybeans	\$2,565	\$3,848	\$5,130
Total additional transportation costs	\$10,071	\$15,107	\$20,142

Table 6: Additional Transportation Costs for Customers That Would Incur an Increase in Shipping Costs

	$t = \$0.001$	$t = \$0.0015$	$t = \$0.002$
Increased transport costs for corn	\$37,352	\$56,028	\$74,704
Increased transport costs for soybeans	\$12,765	\$19,147	\$25,529
Total additional transportation costs	\$50,117	\$75,175	\$100,233

the latter “hidden” benefit that would be affected if River Gulf Grain were to close.

CONCLUSIONS

Few estimates exist on the impact of local market power on buyers’ bids for grain. The potential closing of River Gulf Grain in Davenport, Iowa, provides an opportunity to apply existing spatial models to the problem of estimating the impacts of reducing the number of grain buyers in a local market from three to two. Hotelling’s line model of spatial competition was calibrated to model the impact of a decrease in grain-buying

competition on the Mississippi River. The key parameter in the model is the incremental cost of hauling grain. Estimates of this cost range between 0.1¢ to 0.2¢ per bushel per mile. Bids for grain by the remaining buyers in the local region are estimated to drop by between 0.8¢ and 3.3¢ per bushel given this range of transportation costs. This price decrease results in a decrease in gross revenue from grain of between \$499,582 and \$999,164 per year. Additional costs from the departure of River Gulf Grain include additional transportation costs of between \$50,117 and \$100,233 for those sellers who find that they will have to haul their grain a greater distance.

Endnotes

1. If one buyer lowers his or her bid by a small amount, only those sellers who were indifferent between selling to the one buyer or another buyer will change their decision about where to deliver their grain. This means that each buyer faces an upward sloping grain supply function.
2. It is implicitly assumed that illegal collusion between buyers does not occur.
3. This is just for notational convenience. Later, the current density for corn and soybeans will be used.
4. Zhang and Sexton (2001) argue that due to the high costs of transporting bulky and/or perishable products and a lower substitutability in consumers’ budgets, markets for farm products are likely to be narrower (in both products and geographic dimensions) than those of finished food products.
5. The term “no mill-price undercutting” is usually used in spatial models where sellers have market power (e.g. Novshek, 1980). Under these conjectures a firm takes the price of the other firms as given, but assumes that they will match any price cut that would drive them out of business (Martin, 2002). Applying the concept to the model presented, it is assumed that firms take the price of their rivals as given, but expect other firms to match any price that is high enough as to leave them with no supplies.

6. This condition also has to be satisfied in equilibrium. A firm facing no supply makes zero profits and hence has an incentive to increase its offer price. (See Tirole 1988). “No mill-price undercutting” conjectures have been defended on the grounds that they are the minimal departure from Nash conjectures (taking the actions of the other participants as given) that permit the existence of pure strategy equilibrium in prices and location in the basic Hotelling model (Novshek, 1980, Martin, 2002). Simply put, a pure strategy Nash equilibrium for the problem at hand is a vector of bid prices such that no individual buyer can increase his profits by unilaterally changing his bid.

7. For a discussion of models in which this does not hold, see Martin 2002, and the references therein.

8. When transportation costs are linear, the model is not well-behaved, in the sense that the supply functions are not continuous, and existence of equilibrium under standard Nash conjectures is not assured (e.g., Tirole 1988, or Martin 2002). In fact, for the distance between the cities considered it can be shown that a pure strategy equilibrium does not exist for Nash conjectures.

9. With only two firms, this condition must be satisfied in equilibrium (D’Aspremont, Gabszewicz, and Thisse, 1979). This also rules out the possibility of spatial arbitrage between the buying points.

10. For the two-firms case, D’Aspremont, Gabszewicz, and Thisse (1979) provide necessary and sufficient conditions for the existence of pure-strategy Nash equilibrium in prices. In the problem at hand, the fact that all the buyers under consideration face a positive supply lends support to the conjectures selected.

11. To see this, note that plugging-in the distances for the locations presented, equations 15, 18 and 19 indicate that $p_2^* = p - 25.78t$, $p_1^{**} = p - 35.15t$, and $p_3^{**} = p - 43.25t$. Replacing these equilibrium bid prices in the previous equation yields $(0.807p_1^{**} + 0.193p_3^{**})Q_2^* - p_2^*Q_2^* = (0.807(p - 35.15t) + 0.193(p - 43.25t) - (p - 25.78t))Q_2^* = -10.93tQ_2^*$

12. This point was raised by an anonymous referee and is gratefully acknowledged.

13. If this assumption does not hold, the formula is $t \sum_{j=1}^{3,323} (d_j * q_j)$, where d_j denotes the extra number of miles that customer j would need to drive after the closure of Davenport and q_j is the amount of corn or soybean owned by customer j .

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APPENDIX

Solving for the Equilibrium Price Bids When there are Four Firms Bidding

The system of equations 7 -9 can be written (after multiplying each equation by $2t(D_3 - D_0)$) in matrix form as

$$\begin{bmatrix} -2 & 1 & 0 & 0 \\ 1 & -4 & 1 & 0 \\ 0 & 1 & -4 & 1 \\ 0 & 0 & 1 & -2 \end{bmatrix} \begin{bmatrix} p_0 \\ p_1 \\ p_2 \\ p_3 \end{bmatrix} = \begin{bmatrix} t(D_1 - D_0) - p \\ t(D_2 - D_0) - 2p \\ t(D_3 - D_1) - 2p \\ t(D_3 - D_2) - p \end{bmatrix}$$

or $A^*P = B$. Since the matrix A is nonsingular it can be inverted to yield $P^* = A^{-1}B$ which equals

$$\begin{bmatrix} p_0^* \\ p_1^* \\ p_2^* \\ p_3^* \end{bmatrix} = -\frac{1}{45} \begin{bmatrix} 26 & 7 & 2 & 1 \\ 7 & 14 & 4 & 2 \\ 2 & 4 & 14 & 7 \\ 1 & 2 & 7 & 26 \end{bmatrix} \begin{bmatrix} t(D_1 - D_0) - p \\ t(D_2 - D_0) - 2p \\ t(D_3 - D_1) - 2p \\ t(D_3 - D_2) - p \end{bmatrix}$$

Equations 13 through 16 are obtained by carrying out the matrix multiplication just presented.

Predicted Change in Bid Prices for the Region

The average bid price change for the region is calculated as the difference in weighted average prices with and without the buyer in Davenport (River Gulf Grain). The weights are given by the proportion of the line covered by each buyer. Mathematically, the average equilibrium price for the region when River Gulf Grain is present is (making use of $D_0 = 0$) given by:

$$\bar{p}^* = \frac{z_0^*}{D_3} p_0^* + \left(\frac{(D_1 - z_0^*)}{D_3} + \frac{(z_1^* - D_1)}{D_3} \right) p_1^* + \left(\frac{(D_2 - z_1^*)}{D_3} + \frac{(z_2^* - D_2)}{D_3} \right) p_2^* + \left(\frac{D_3 - z_2^*}{D_3} \right) p_3^*,$$

which can be simplified to $\bar{p}^* = \frac{1}{D_3} (z_0^* (p_0^* - p_1^*) + z_1^* (p_1^* - p_2^*) + z_2^* (p_2^* - p_3^*) + D_3 p_3^*)$.

Similarly, the average equilibrium price without River Gulf Grain (or buyer number two in the current setting) is $\bar{p}^{**} = \frac{z_0^{**}}{D_3} p_0^{**} + \left(\frac{(D_1 - z_0^{**})}{D_3} + \frac{(z_1^{**} - D_1)}{D_3} \right) p_1^{**} + \left(\frac{D_3 - z_1^{**}}{D_3} \right) p_3^{**}$, or

$$\bar{p}^{**} = \frac{1}{D_3} (z_0^{**} (p_0^{**} - p_1^{**}) + z_1^{**} (p_1^{**} - p_3^{**}) + D_3 p_3^{**}).$$

Here, z_i^* (z_i^{**}) represent the number of miles to the right of firm $i = 0, 1, 2$ ($i = 0, 1$) covered by that buyer when River Gulf Grain is (is not) present. Therefore the average price change can be computed as the difference between these two quantities $\Delta \bar{p} = \bar{p}^* - \bar{p}^{**}$ or

$$\Delta \bar{p} = \frac{1}{D_3} (z_0^{**} (p_0^{**} - p_1^{**}) + z_1^{**} (p_1^{**} - p_3^{**}) + D_3 (p_3^{**} - p_3^*) - z_0^* (p_0^* - p_1^*) - z_1^* (p_1^* - p_2^*) - z_2^* (p_2^* - p_3^*)) = -11.38t$$

dollars per bushel.

Note that every expression within each interior bracket is a difference between two offer prices. Since those prices are linear in p (the net of processing and/or handling costs buyer's valuation for the product) the change in price for the region can be computed with the information available.