Price Relationships in Processors’ Input Market Areas: Testing Theories for Corn Prices Near Ethanol Plants

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This study examines corn pricing in the vicinity of processing plants. We develop and test several price-distance models for cargo, insurance and freight (CIF) plant pricing in the presence of varying degrees of exporter competition, and for discriminatory free-on-board (FOB) pricing at the farm. The price-distance functions describing spatial prices near processing plants all depend on local transport costs. But the pricing system (CIF or FOB) and the extent of local competition define the level and spatial rate of change in prices. Estimations of an empirical price-location function for Iowa during the spring of 2003 suggest that prices near the plants of four conventional businesses conform to the CIF pricing model. But prices near producer-owned firms or farmer cooperatives failed to show any statistically significant effect on nearby prices. One plant had a price-distance function that resembled FOB pricing.

INTRODUCTION

Processing of grain into ethanol for motor fuel has become a major growth industry in the Midwest. The motivations behind the growth include public interest in creation of renewable energy, reducing dependence on imported oil, adding value to crop production, and promoting rural economic growth. The U.S. and some state governments have provided tax and financing incentives for investment in new ethanol processing plants. Increasing gasoline quality requirements, evolving clean air regulations, and a ban on

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the only other oxygen-enhancing additive, MTBE, are creating strong growth in demand for fuel ethanol. In the United States, corn used for ethanol is up nearly 505 million bushels from the early 1990s, and four new ethanol plants entered operation in 2003. In Canada, four new ethanol plants will likely be required to meet projected demand in 2005 (Canadian Renewable Fuels Association 2004).

Several economic issues are important to investors in these new plants: producers who will supply feedstock, other grain marketing firms that will compete with the new plants, and local governments seeking tax revenues. One key issue is the effect ethanol plants have on the geographic price surface for corn, the major raw material being used for the ethanol feedstock. This, in turn, has implications for the cost of producing ethanol at the plant, and the aggregate amount of value added to corn production in the plant’s supply area.

We report on a cross-section analysis of corn prices at 270 cities and towns in Iowa that empirically determines the impact of ethanol plants on the price surface. We also test alternative hypotheses about spatial price behavior when ethanol plants are present and foreign buyers represent a major alternative market for the corn.

THEORIES OF LOCAL MARKET AREA PRICING

The classic analysis of local market areas and prices for agricultural commodities considers point demand in a central place and uniformly distributed supply in the surrounding area. The central place is a local town market for the raw agricultural product (Von Thunen). Later, Losch recognized that the central place could also be a processing facility. In both analyses, farm prices form a “price cone,” with the highest farm price occurring at the central place and declining with more distant locations (Losch p. 37, 1954; Parr 2002). A more recent study of local agricultural prices also investigated the efficiency of markets in a developing country with limited infrastructure and high transport costs (Mwanuamo et al 1997).

Longer-run analyses identify economic forces influencing the location and size of the central place. For instance, Hsu 1997 considers the economic factors influencing the location of an agricultural processing plant, finding that increases in product demand encouraged the processing firm to locate closer to the central place and market. Also, Krugman (1991) shows that as manufacturing employment expands with growth in a developed economy, the real wage in manufacturing relative to agriculture tends to increase, inducing further urban population growth and more product demand in central markets. However, our analysis will take the size of the central market as given, and focus on short-run pricing for agricultural products in the surrounding market area.

In this section, we discuss alternative spatial models of corn price determination at the processing plant and in the surrounding market area for a surplus region. Two characteristics define the appropriate price determination model. First, we show that the point of ownership transfer influences the spatial distribution of prices. Usually, farmers transfer ownership at the processing plant and pay transport charges with cargo, insurance and freight (CIF) pricing. But producers may, instead, transfer ownership at the farm gate with free-on-board (FOB) pricing and allow the processor to pay transport charges. We consider both possibilities. Second, the particulars of the spatial relationship between the
local buyers and the export buyers helps define the distribution of prices. So we modify
the central place theory to account for the presence of international buyers and develop
testable econometric relationships.

**CIF Pricing**
The CIF pricing model builds on the classic spatial analysis. First, we review the basic
premises from the classic model that we retain in our analysis. Then we explain how the
presence of buyers for the international market changes the analysis in three cases.

In the classic analysis, the market for the farm good is located in town, and surround-
ing farmers deliver all of their supply to this market. The price at the central place is given
by the interaction of market supply and demand. The farmer pays the freight and sells
his product at the market in town (Chisholm, p. 15). Then farm price is determined as the
exogenous market price less transport cost to the market. Hence, the farm price decline
that occurs with distance from the town’s market matches the increasing transport cost.

When there is one product and one market, producers exit when the farm price falls
to the break-even point at minimum average variable costs ($C_0$). Hence, the distance
at which price equals minimum cost identifies a circular input market area boundary
($r^*$) defined by the producers’ break-even price. The direct route measure of distance
to the point of minimum average variable cost is a good approximation for the market
boundary because of the intense network of secondary roads in agricultural production
areas. We also assume an early stage of processing industry development, where firms
choose non-overlapping market areas (Greenhut et al 1987, p. 263).¹

A major difference between Von Thunen’s analysis and ours is that local buyers and
sellers must beat, or at least match, bids from foreign buyers. For illustration, consider
how a Japanese buyer’s bid (or his agent’s bid) in the local Iowa corn market changes for
locations near a processor’s market area. First, the Iowa bid price is the Tokyo price less
transport charges—the Tokyo price is determined on a highly integrated world market.²
Also, there are three components of transport costs: local truck transport to a train
terminal, unit train transport to a West Coast port and ship transport to Japan. It is
important that the price of a mile of transport services declines by nearly a factor of ten
as the mode of transport changes from truck, to train and to ship (Table 1).

The foreign buyer’s bid changes little for more distant sources near an Iowa processor
because his cost for the distance increase is small. If the Japanese buyer, for example, moves

<table>
<thead>
<tr>
<th>Table 1. Grain transport cost for a shipment from western Iowa to Japan, by component and total origin-destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Seattle-Yokohama</td>
</tr>
<tr>
<td>Omaha-Portland</td>
</tr>
<tr>
<td>Farm-Terminal</td>
</tr>
<tr>
<td>Total:</td>
</tr>
</tbody>
</table>

²Sources: Reliant Transportation Company, Lincoln, NE and Edwards and Smith.
the source from Iowa’s western border (Omaha) 25 miles eastward inside state, he will likely extend the low cost train component for a cost increase of 0.88 cents per bushel leaving other components unchanged. But the local processor extends his market area by an equal distance using the truck rate, which increases costs by nearly 6 cents per bushel. In fact, our hypothetical Tokyo buyer who extends the train component could move the location of his bid from the western border to the middle of the state (150 miles) and only reduce the Iowa bid by 5.3 cents/bu. In sum, the export market bid price is exogenous to the local corn market and changes slowly as location changes.

The proximity of the exporters’ bid to the local corn processing plant defines three types of local input pricing regimes. In case A, export facilities are located throughout the processors’ market area. This situation could be encountered as new ethanol plants locate in the north, central and west section of Iowa, because export facilities were operating throughout the area before processing facilities existed (Figure 1). In cases B and C, export facilities within the ethanol processors’ market area are sparse or do not exist. These cases could occur in the eastern and southern part of Iowa, which contains the mature (built circa 1980) segment of the state’s ethanol industry. Next, we discuss the spatial price relationships for each case and develop appropriate estimating relationships.

CIF Pricing

Case A
Suppose that a processor has recently located in what had been a grain export region. Then a dense network of exporting facilities throughout the processors’ market area is likely. Further, it is possible that farm prices throughout the market area are equal to the slowly changing export price (Figure 2a). Farmers are able to obtain the export price without transport charges at any location within the area because the export network is dense. Similarly, processors can bid grain away from export facilities at slightly above the export price throughout the input area. Hence, the farmer’s bid price will remain constant with distance from the plant.

Case B
Now there are no grain exporting facilities within the market area. But the processor uses grain up to the market area boundary. This situation could possibly emerge in areas where ethanol plant placements preceded large-scale exporting using unit train facilities. Alternatively, this pricing structure might emerge after a period when exporting facilities and the ethanol plant shared the same location but exporting profits were not sufficient to continue operation within the market area. However, export facilities on the circular boundary and beyond continue profitable operation. Finally, the processor might also procure grain from beyond the market area boundary during short-run periods of inventory accumulation or peak demand.

The dominant pricing relationship is likely with the processor paying the export price at the boundary and shipping it to the plant site. Further, suppose the processor pays everyone the same price at the plant site ($P_p$) when they deliver the grain. Then the price for a farmer $r$ miles from the plant ($P_f(r)$) is implicitly defined by the distance from the processor and transport costs ($t$),
Figure 1. Iowa grain facilities map
Case A: With exporters in local market

Case B: With exporters at the edge of local market and processor demand equal or greater than area supply

Case C: With exporters at the edge of local market and area supply exceeding processor demand

Figure 2. Farm price-distance functions under CIF pricing

\[ P_v = P_f(r) + tr \]

Further, competition will force the processor to match the exporter’s bid \( P_0 \) in order to obtain supply. When the exporter is located at the market boundary, at distance \( r^* \) from the plant, the minimum farm price for any given distance from the plant is the exporter’s bid price plus an allowance for transport to the boundary,

\[ P_f(r^*) = P_0 + t(r^* - r) \]

Substituting for the farm price in the site-price equation, the implied site price is the exporter price plus transport to the boundary,

\[ P_v = P_0 + tr^* \]

For the sake of exposition, we have the export price as exogenous and constant. However, subsequent empirical analysis can account for slowly changing export prices around the market boundary as distance from the foreign destination changes.

Figure 2B depicts the farm price-distance function. Notice that the market area, radius \( r^* \), is smaller than the market area for a one-commodity von Thunen market with the same site price, \( r' \). This occurs because the export price, not the lower average variable production costs, defines the market boundary.

For testable hypotheses about farm prices under CIF pricing, rearrange the equilibrium condition for a farm price equation that depends on distance from the plant,

\[ P_f(r) = \alpha_c - \beta_c r = (P_0 + tr^*) - tr \]

Thus a farm price-distance regression should identify the transport rate as the slope coefficient \( \beta_c \). Further, the intercept \( \alpha_c \) should equal the site price, or the sum of the exporter price bid plus transport from the market boundary.
Case C
Once again, there are no grain exporting facilities within the processor's market area. But now, grain is leaving the local market area for export. Here, the dominant pricing relationship is that farmers receive the export price at the boundary, but must subtract the freight charges for shipment from their location to the boundary. Now suppose that a farmer at distance \( r \) considers shipping his product to the export facility located at \( r^* \) because the processor is not able to match the net export bid to the farmer. Then the effective farm price is the export price less the transport to the border,

\[
P_f(r) = P_0 - t(r^* - r) \quad \text{or} \quad P_f(r) = \alpha_c + \beta_c r = (P_0 - tr^*) + tr
\] (2)

This farm price could hold throughout the local market area if the processor succeeds in buying at the farmers' opportunity cost within his active market area. In an econometric analysis, this pricing regime can be identified by a positively sloping farm price distance function that has a slope equal to the transport rate and a site price that is lower than the export price by the cost of transport to the market boundary (Figure 2C).

This positively sloped price line could arise when the ethanol plant is operating below capacity due to low demand. Alternatively, a restricted demand by corn processors could be a strategic choice aimed at monopsony management of corn input expenditures in the context of a CIF pricing scheme.

**FOB Pricing**

Although CIF pricing is the norm in local agricultural markets, FOB pricing could also arise when there is not strong external competition from exporters' bids. In fact, FOB pricing provides the processor a mechanism for practicing price discrimination in his input purchases, because he escapes the requirement that he pay all producers the same delivered site price. Instead, the processor may choose to negotiate a price at each supply point with surrounding farmers or local elevators and pay the transportation to the plant.

Now we develop a model of discrimination for a firm that consumes the input at one point and buys the product from geographically dispersed producers. Our analysis is parallel to an existing analysis of a firm that produces the output at one point and sells the product to geographically dispersed consumers (Greenhut et al 1987, pp. 116–20).

Consider the processor's profit for corn purchased from identical producers at distance \( r \) from the processing plant,

\[
\pi(r) = Rq(r) - rtq(r) - \text{TEI}(r) \quad \text{where} \quad \text{TEI}(r) = [C_0 + b q(r)] q(r)
\]

The first term in the profit function gives the revenues from sale; it consists of the product of revenues per unit of corn processed \((R)\) and the output of farms \( r \) miles from the plant \((q(r))\). The second term gives transport costs for corn purchased; it is the transport rate times the distance from the plant times production.

The third term indicates the total expenditure on the corn input at \( r \) miles from the plant \((\text{TEI}(r))\). For the sake of discrimination analysis, we assume there is a price-dependent supply curve that describes the relation between the farm supply price at distance \( r \) \((P_f(r))\) and the output forthcoming from that distance.
\[ P_f(r) = C_0 + bq(r) \]

Here \( C_0 \) gives the marginal cost of the most efficient land at the given distance \( (r) \) and the slope indicates the price increase necessary at distance \( r \) to attract a larger volume of corn to be sold to the processor at the distance \( r \). An upward-sloping farm supply could arise from a quality ordering of a farm’s land parcels if, say, some of his land was susceptible to flooding or erosion; if rising corn prices could induce more intensive land use and rising productivity; if on-farm feeding is diverted to market supplies; or if land is diverted from other crops (like soybeans) to corn.

A discriminating monopsonist maximizes profit at each buying point by choosing the purchase volume that maximizes profits. Differentiating the profit equation for \( q(r) \) yields the first-order condition (FOC),

\[ \frac{\partial \pi(r)}{\partial q(r)} = (R - rt) - \text{MEI}(r) = 0, \text{ where } \text{MEI}(r) = C_0 + 2bq(r) \]

Equivalently, the marginal revenue from increasing corn purchases at distance \( r \) equals the marginal expenditure on corn input. Rearranging the FOC gives the equilibrium condition

\[ R - rt = C_0 + 2bq(r). \]

The left side gives the processing revenue less transport expenditure per unit obtained from a distance of \( r \). The right side gives the usual marginal expenditure—it has the same intercept and twice the slope compared to the price-dependent supply curve.

The farm price equilibrium is shown graphically in Figure 3. Marginal revenue and marginal expenditure intersect giving a high value on the vertical axis and define the quantity that the processor will buy from farmers. The quantity in turn defines a price on the supply curve \( (P_f^d) \) that is considerably lower than the processor’s marginal revenue. Finally, FOB pricing is not consistent with a strong presence on the part of foreign buyers. A relatively low value for the exporter’s bid \( (P_0) \) is shown in the diagram; it is not sufficient to persuade the farmers to divert their output from the local processor.

For testable hypotheses about farm prices under FOB pricing, first rearrange the farm supply price equation to a quantity-dependent form and substitute into the FOC. The implied form for a regression specification is,

\[ P_f(r) = \alpha_d - \beta_d r = [C_0 + R]/2 - (t/2)r \]

Thus a negative relation between the farm price and distance from the processor holds. Further, a farm price-distance regression should identify one-half of the transport rate as the slope coefficient \( (\beta_d) \). Others have also noticed that the discriminator absorbs one-half of the freight (Greenhut et al 1987, p. 117). This is a testable hypothesis that distinguishes FOB pricing from CIF pricing.

The intercept \( (\alpha_d) \) is also amenable to interpretation. First, \( C_0 \) is the entry supply price for the most efficient production units. Also, the contribution of the first processing unit \( (N_0) \) is the revenue for the unit of corn processed less the price of the first unit, \( N_0 = R - C_0 \). Substituting for \( R \) gives a new parameterization of the intercept as the processors’ corn input price plus one-half of the initial processing margin,
Thus, the intercept, $\alpha_{d}$, is the low marginal cost for corn from the best land plus one-half of the initial processing margin—FOB pricing may lower the structure of prices if the processing margin is not large.

**ESTIMATION PROCEDURES**

Now we investigate corn pricing near operating ethanol plants in Iowa. For our preliminary study, we constructed a cross-section data set from a period when processors were operating and buying corn. In this fashion, we can focus on spatial aspects of the problem, instead of diverting our attention to the estimation of time series problems, such as market entry/exist or optimal inventory management.

Specifically, we constructed a cross section of corn prices in Iowa during the spring of 2003. We used corn price data at 270 towns in Iowa taken from the DTN (Data Transmission Network) commodity news service. End-of-day price reports were taken on Fridays during the last 3 weeks of April and the first week in May of 2003. The sample average price approximates each town's equilibrium corn price. These elevator prices are the prices paid to nearby farmers.

Iowa's ethanol plants were operating and procuring corn during the April–May 2003 period; ethanol prices and margins were favorable for plant operation; corn prices were moderate; and corn inventories were not unusually high. At this time there were nine operating ethanol plants at various locations throughout the state (Table 2).

**Two-Component Price Equation**

Some spatial data were included with the springtime corn price for each town $j(P_j)$. First, overall position of town $j$ in the state was measured using the horizontal or
Table 2. Threshold estimates of market area radii for ethanol plants operating in Iowa in April 2003

<table>
<thead>
<tr>
<th>Plant location (i)</th>
<th>Market radius $r^*_i$ (mi)</th>
<th>Capacity (mil. gal.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sioux Center</td>
<td>37.5</td>
<td>14</td>
</tr>
<tr>
<td>Marcus</td>
<td>50.0</td>
<td>40</td>
</tr>
<tr>
<td>Galva</td>
<td>43.8</td>
<td>18</td>
</tr>
<tr>
<td>Lakota</td>
<td>23.5</td>
<td>45</td>
</tr>
<tr>
<td>Clinton</td>
<td>50.0</td>
<td>160</td>
</tr>
<tr>
<td>Cedar Rapids</td>
<td>42.5</td>
<td>240</td>
</tr>
<tr>
<td>Eddyville</td>
<td>35.0</td>
<td>35</td>
</tr>
<tr>
<td>Muscatine</td>
<td>45.0</td>
<td>10</td>
</tr>
</tbody>
</table>

east–west distance ($x_j$) and the vertical or north–south distance ($y_j$) from a central Iowa town (Ames). Second, we identified the closest ethanol plant, indexed by $i$, and measured the distance between each town and the closest plant ($r_{ij}$)

The regression model specifies that the corn price consists of two components. First, a general spatial component is related to the overall position within the state and represents export-based bids on the local market. The general component of price ($P^0_j$) is a quadratic function of location

$$P^0_j(x, y) = \Theta_0 + \Theta_1 x_j + \Theta_2 x_j^2 + \Theta_3 y_j + \Theta_4 y_j^2 + \Theta_5 x_j y_j$$

which can fit any conic section (paraboloid, hyperbola, half-circle) with any orientation using relatively few parameters. The quadratic function is also amenable to linear estimation.

Second, a processor market area effect on corn price ($\Delta_j^i$) exists for towns sufficiently close to plant $i$

$$\Delta_j^i = \alpha_i - \beta_i r_{ij}$$

The local market effect can describe alternative CIF pricing schemes (Eq. (1) or (2)) or FOB pricing (Eq. 3), depending on the circumstances of a particular data set. Finally, add local market effects for all ethanol plants and define binary variables ($Z_{ij}$) for the boundaries of market areas to obtain

$$P_j = \sum_i (\alpha_i - \beta_i r_{ij}) Z_{ij} + P^i_0$$

and

$$Z_{ij} = \begin{cases} 
0, & r_{ij} \geq r^*_i \\
1, & r_{ij} < r^*_i 
\end{cases}$$

where $i =$ Sioux City, Marcus, Galva, Coon Rapids, Lakota, Clinton, Cedar Rapids, Eddyville, Muscatine. Eq. (4) can be estimated using conventional procedures, such as least squares.

Eq. (4) can estimate several types of spatial organization, depending on parameter values. An export-based area would have statistically significant values for the parameters of $P_0$ and the local market effects would be excluded. An emerging processing industry would likely have statistically significant parameters for both components, as processors initially choose mutually exclusive input market areas and the export industry remains in the area. Further, the parameters estimated for local market effects can be used in evaluations of market pricing. A mature processing industry would have statistically significant
and perhaps overlapping market areas, while the parameters for the \( P_0 \) component might not be important.

**Market Boundary Thresholds**

In the long run, the boundary for a market area \((r^*)\) reflects the balance of plant capacity and supply in the area around the plant (Gallagher et al 2003, p. 341). Integrating the function, \( q(r) \), the supply available to the plant is proportional to the area defined by a circle with radius equal to the maximum distance traveled to the plant,

\[
Q = \pi r^{*2} dy
\]

Consequently, the ratio of plant input capacity \((Q)\) to supply density \((dy)\) defines the boundary of the market area \((r^*)\):

\[
\sqrt{Q/(\pi dy)} = r^*
\]

However, estimates of the market boundary from cross-section price data are determined in the market. Market-based estimates of corn supply density may reflect reductions in available corn due to local feed demand on farms. Also, inventory management may dictate that purchases for a month deviate from their monthly proportion of annual capacity when prices are unusually low or high.

We used a sequential procedure for estimates of the market boundary thresholds. For each plant, we selected only those observations for towns that are closest to that particular plant. Next, we inspected a graph of the data for a preliminary estimate of the boundary’s location. Finally, we iterated over various choices for the magnitude of \( r_{ij}^{*} \) for the value that minimized the error sum of squares from the price-distance regression.

Generally speaking, multiple threshold estimation requires a joint grid search over all possible values for each threshold (Goodwin and Piggot 2001, p. 304). But sequential estimation of individual thresholds is likely equivalent when individual thresholds are statistically independent. The statistically significant price effects of the subsequent section are based on data from mutually exclusive spatial input market areas. Two statistically significant market areas in the center of the state are completely isolated. Further, three statistically significant market areas on the eastern border overlap only in an area where cash grain production is minimal and livestock are typically the dominant farm enterprises. Hence, the independence criterion is satisfied and sequential threshold estimation is likely justified for these cases.

**RESULTS**

This section presents threshold estimates for market boundaries, preliminary estimates of the price equation and tests of hypotheses about pricing in local market areas around ethanol plants.

**Market Area Estimates**

The market area estimates obtained by stepwise threshold estimation are shown in Table 2 and Figure 4. These estimates indicate that the processing industry is not fully developed in the sense of an interlocking grid of market areas. Instead, some market areas are completely separated (Eddyville and Lakota). Others are partly overlapping (Cedar Rapids,
Clinton and Muscatine). The remainder are clustered in mostly overlapping marketing areas in the northwest section of the State.

**Price Equation Estimates**

Least squares estimates of Eq. (4) used cross-section corn price data for Iowa in the spring of 2003. The market boundary estimates of Table 2 define the binary values ($Z_{ij}$’s) for the market areas of ethanol plants.

Results for the price equation (4) are shown in the left half of Table 3. Generally, the estimated coefficients have the anticipated signs. Further, the explanatory variables explain a high proportion of sample variation.

Specifically, all elements of the quadratic component have relatively high $t$-values, suggesting statistical significance. The estimated quadratic function, $P_0^e$, suggests that prices decline toward the center of the state and the north. Prices increase with movement from the center and toward the east or west, and the price increase is more pronounced approaching the eastern border (Figure 5).

Furthermore, the slope of the state component of prices matches the prices of the appropriate transport rates, supporting the notion of export-based pricing. For instance, consider the price change associated with a 1-mile eastward movement using Figure 6a and the transportation service prices from Table 1. From the western border, the state component of prices declines about $\$0.0004$/bu per mile corresponding to the unit train rate for additional distance to the west coast. Moving eastward from the center of the state, where $x = 0$, the state price component increases at the same unit train rate, reflecting transportation to barges on the Mississippi River. Near the eastern border, about $x = 130$, the state component of prices increases about $\$0.0012$/bu per mile corresponding to the truck rate for transport to the river.
Table 3. Price location regression for Iowa (t-values for coefficients are given in parentheses)\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>a. Unconstrained regression: General location component(^b)</th>
<th>b. Constrained regression: General location component(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant</strong></td>
<td>2.19189 (578)</td>
<td>2.19100 (678)</td>
</tr>
<tr>
<td>(X)</td>
<td>0.0003421 (6.66)</td>
<td>0.0003401 (0.66)</td>
</tr>
<tr>
<td>(X^2)</td>
<td>0.00000296 (5.29)</td>
<td>0.00000326 (6.81)</td>
</tr>
<tr>
<td>(Y)</td>
<td>-0.0005572 (10.75)</td>
<td>-0.00054926 (11.36)</td>
</tr>
<tr>
<td>(Y^2)</td>
<td>0.00000256 (3.22)</td>
<td>0.00000248 (3.38)</td>
</tr>
<tr>
<td>(XY)</td>
<td>-0.00000207 (2.80)</td>
<td>-0.00000221 (3.56)</td>
</tr>
</tbody>
</table>

|                  | Local market area component\(^c\)                          | Local market area component\(^c\)                          |
| (i)              | \(\alpha_i\) \(\beta_i\)                                 | \(\alpha_i\) \(\beta_i\)                                 |
| Sioux City       | 0.0391 (1.83) -0.00153 (1.64)                               |                                                             |
| Marcus           | 0.00403 (0.24) -0.00022395 (0.43)                           |                                                             |
| Galva            | 0.00816 (0.45) -0.00020821 (0.35)                           |                                                             |
| Coon Rapids      | 0.01608 (1.16) -0.0007538 (1.46)                            |                                                             |
| Lakota           | -0.02630 (1.37) -0.00089995 (0.77)                          | -0.02595 (1.37) -0.00091831 (0.79)                         |
| Clinton          | 0.06387 (2.35)                                              | 0.05796 (2.18)                                              |
| Cedar Rapids     | 0.11809 (4.95) -0.00342 (4.74)                              | 0.11611 (4.89) -0.00340 (4.89)                             |
| Eddyville        | 0.08949 (3.25) -0.00494 (4.55)                              | 0.08993 (3.28) -0.00494 (4.56)                             |
| Muscatine        | 0.03208 (1.04) -0.00219 (2.67)                              | 0.02780 (0.91) -0.00217 (2.66)                             |

|                  | Summary statistics                                         | Summary statistics                                         |
| \(\bar{R}^2\)    | = 0.6804                                                   | = 0.6818                                                   |
| \(\bar{S}\)      | = 0.0304                                                   | = 0.0303                                                   |

\(^a\)Estimated coefficients are based on Eq. (4), using Iowa town data from spring of 2003.
\(^b\)Variable definitions: \(X\) = east (+)/west(−) distance from Ames, near the state’s center.
\(Y\) = north (+)/south (−) distance from Ames, near the state’s center.
\(^c\)Parameter estimates refer to the intercept \((\alpha_i)\) and coefficient on the distance, in miles, from the processing plant \(i\) \((\beta_i)\).
Similarly, the price change associated with a 1-mile northward movement (Figure 6b) suggests a price decline. The rate of decline matches the unit train rate in the central part of the state, but the magnitude of the price decline increases toward the truck rate near the southern border.

Estimates of local market effects shed light on the spatial price relationships in local market areas. For instance, the plant distance variable has a negative slope coefficient, which conforms to Eqs. (1) and (3). Further, four of five significant local market effects have a positive intercept, suggesting that most ethanol plants tend to increase prices at the plant site. However, the intercept for one plant (Lakota) is negative, which suggests that the site price is below the export price just outside the plant’s market area.

Tests for the Existence of Local Market Areas
The first set of tests based on Eq. (4) uses F-tests for the significance of particular local market effects, taken one at a time (Table 4). To execute the F-test, we used the regression from Table 3a for the unconstrained sum of squares. Next, the constrained regression set the intercept and slope for a local market area at zero, i.e., $\alpha_i = \beta_i = 0$, to obtain the sum of squares under the null hypothesis that there is no local market effect. We calculated a test for each of the eight ethanol plants. The null hypothesis was accepted at the 5% confidence level for the plants at Sioux Center, Marcus, Galva, and Coon Rapids. The hypothesis was rejected at the 1% confidence level for the plants at Lakota, Clinton, Cedar Rapids, Eddyville and Muscatine.

The results show several interesting patterns. All plants without a local market effect were producer cooperatives or producer-owned firms that require corn delivery
Figure 6. (a) Slope of price surface at $Y$ of 0\(^1\). (b) Slope of price surface $X$ of 0\(^1\)

Variable definitions: $X$ = east (+)/west (-) distance from Ames, near the State's center.
$Y$ = north (+)/south (-) distance from Ames, near the State's center.
commitments of farmer-owners. In contrast, all but one of the plants with significant local market effects were conventional agribusiness firms that are more formally separated from farms by a market. A possible explanation is that due to supply contracts with farmers, the producer-owned firms can avoid bidding on the local market for corn supplies, whereas conventional firms cannot. These supply contracts are commitments of farmer-owners to allocate a specific number of bushels to the plant regardless of the price. Finally, one producer-owned plant has a statistically significant local effect that is negative, possibly due to monopsony pricing.

The spatial pattern of the market area estimates and preliminary tests are also interesting. Plants with statistically significant price effects tend to be in mutually exclusive supply areas; the Eddyville and Lakota market areas are completely surrounded by export bids according to the estimates. Similarly, price observations for Cedar Rapids Muscatine, and Clinton come mostly from mutually exclusive components of the supply area. These three plants are located near the Mississippi river on the eastern border, probably for convenience in exporting byproducts to Europe. There is an overlapping component of the supply areas for these three plants given by the shaded area in Figure 4. But this is not an intensive crop-producing area, and only 2 of the 43 price observations come from within the common area. The price-distance functions estimate a westward direction for the Cedar Rapids supply area, a northward direction for Clinton, and a southward direction for Muscatine.

Most of the plants with statistically significant market areas have few export facilities within their supply areas (Figure 1). Instead, export buyers tend to be located along the borders of the ethanol supply area. The borders are located along the Mississippi River and in central Iowa.

The four plants without statistically significant market area effects are clustered in the northwest section of the state, for convenient byproduct marketing to local feedlots. Further, the overlap of market areas for these plants is much more extensive and most price observations are in overlapping areas. The finding of uniform pricing in this area may occur because there are many export buyers within the supply area of the ethanol plant (see Figure 1). The multitude of grain export facilities matches the many small producers, and produces competitive pricing.

<table>
<thead>
<tr>
<th>Plant location (i)</th>
<th>$F$</th>
<th>Test status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sioux City</td>
<td>1.7958</td>
<td>Accept</td>
</tr>
<tr>
<td>Marcus</td>
<td>0.0979</td>
<td>Accept</td>
</tr>
<tr>
<td>Galva</td>
<td>0.1034</td>
<td>Accept</td>
</tr>
<tr>
<td>Coon Rapids</td>
<td>1.1047</td>
<td>Accept</td>
</tr>
<tr>
<td>Lakota</td>
<td>8.0863</td>
<td>Reject</td>
</tr>
<tr>
<td>Clinton</td>
<td>5.5614</td>
<td>Reject</td>
</tr>
<tr>
<td>Cedar Rapids</td>
<td>12.6084</td>
<td>Reject</td>
</tr>
<tr>
<td>Eddyville</td>
<td>11.4656</td>
<td>Reject</td>
</tr>
<tr>
<td>Muscatine</td>
<td>5.0771</td>
<td>Reject</td>
</tr>
</tbody>
</table>

Critical values for $F$-statistic: $F_c(2, 249) = 4.70$ for 1% confidence level. $F_c(2, 249) = 3.04$ for 5% confidence level.
The constrained regression in Table 3 jointly excludes local price effects unless the preliminary tests indicated statistical significance. Estimates of the overall price component and the significant local market effects remain. Further, the joint constraint provides a moderate improvement in the regression’s fit, increasing the adjusted $R^2$ and root mean square error. This regression is used as the reference for subsequent hypothesis testing.

Tests of CIF and FOB Pricing

The theoretical price-distance equations (1), (2) and (3) provide some guidelines for coefficient magnitudes if the model assumptions are true. Below we report some tests for the remaining market areas that have significant price effects.

The slope coefficient in the price-distance regression is definitive in identifying pricing behavior. Specifically, the slope equals the transport rate with competitive CIF pricing, and one-half of the transport rate with for discriminatory FOB pricing. The reference transport rate is given in Table 1 and reproduced in Table 5. This is a representative transport rate for semi-trucks on the short haul from a farm to a processing plant during the first half of 2003. The truck rate is based on a rate of $2.2/\text{truck/mile}$ and a capacity of 950 bushels of corn. The farm-to-plant observation for grain trucks is consistent with similar truck rates. For instance, a recent survey gives an average rate of $1.75/\text{truck/mile}$, ranging up to $2.3/\text{truck/mile}$, for livestock delivery to market (Iowa State University Extension Service). The ethanol haul rate is 30% higher than the average livestock rate, reflecting the shorter average haul distance for the ethanol plant.

The $t$-tests for the slope and intercept defined by the competitive pricing equation (1) are given in Table 5. Table 5a gives the slope test for the market areas with statistically significant local market effects. In Table 5a, the respective columns identify the market area, the slope estimate from the constrained regression of Table 3b, the actual transport rate or slope under competitive pricing, the estimated standard error of the slope estimate, the implied $t$-statistic, and the status of the $t$-test at 5% significance. The slope coefficient estimates tend to support the notion of competitive CIF pricing according to Eq. (1) for the plants at Cedar Rapids, Eddyville and Muscatine because estimated slope magnitudes are either equal or somewhat larger than the transport rate. In contrast, the slope for the Lakota plant rejects competitive CIF pricing.

The intercept tests for Eq. (1) are given in Table 5b. Here columns 2 through 4 give the constrained intercept and its components. Column 5 gives the estimated intercept coefficient. Column 6 gives the standard error of the intercept estimate. The last two columns give the calculated $t$-ratio and the status of the test. The hypothesis that the intercept gives transport charges from the boundary to the plant site is accepted for Cedar Rapids and Eddyville. The same hypothesis is rejected for Lakota, Clinton and Muscatine. The Clinton intercept estimate is not directly comparable, because small degrees of freedom precluded slope estimation. Nonetheless, the intercept dummy variable for Clinton suggests that there is a statistically significant local market area effect of about $0.05/\text{bushel}$; this does support the CIF pricing model of Eq. (1) in that prices are higher inside the local market area. The intercept hypothesis is rejected for Muscatine.

Generally, the estimated local market effects are not consistent with the pricing equation (2). Estimated distance coefficients are all negative, instead of positive, and all but one of the intercept coefficients are positive. The $t$-tests in Table 6 confirm that Eq. (2) should be discarded for our sample. All slope tests, and all but one intercept test suggest rejection of the null hypotheses.
Table 5. Tests for competitive CIF pricing with export points at local market area boundary (Eq. 1)

a. Slope test, Eq. (1): $\beta_i = -t$

<table>
<thead>
<tr>
<th>Plant location ($i$)</th>
<th>Distance regression slope estimate ($\beta_i$)</th>
<th>Actual transport cost $\beta_0 = -t$</th>
<th>Standard error of $\beta_i$ ($se(\beta_i)$)</th>
<th>$t$-value $t = \frac{\beta_0 - \beta_i}{se(\beta_i)}$</th>
<th>Test status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakota</td>
<td>-0.000918</td>
<td>-0.00232</td>
<td>0.00116</td>
<td>-1.20491</td>
<td>Reject</td>
</tr>
<tr>
<td>Cedar Rapids</td>
<td>-0.003412</td>
<td>-0.00232</td>
<td>0.000719</td>
<td>1.523015</td>
<td>Accept</td>
</tr>
<tr>
<td>Eddyville</td>
<td>-0.00494</td>
<td>-0.00232</td>
<td>0.00108</td>
<td>2.42963</td>
<td>Accept</td>
</tr>
<tr>
<td>Muscatine</td>
<td>-0.00218</td>
<td>-0.00232</td>
<td>0.000817</td>
<td>-0.16648</td>
<td>Accept</td>
</tr>
</tbody>
</table>

b. Intercept test, Eq. (1): $\alpha_i = tr^*$

<table>
<thead>
<tr>
<th>Plant location ($i$)</th>
<th>Actual transport cost $t$ ($$/bu/mi$)</th>
<th>Radius $r^*$ (mi)</th>
<th>Product $\alpha_0^*$</th>
<th>Estimated intercept $\alpha_i$</th>
<th>Standard error of $\alpha_i$</th>
<th>$t$-value $t = \frac{\alpha_0^* - \alpha_i}{se(\alpha_i)}$</th>
<th>Test status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakota</td>
<td>0.002316</td>
<td>23.5</td>
<td>0.054426</td>
<td>-0.026</td>
<td>0.01888</td>
<td>4.259852</td>
<td>Reject</td>
</tr>
<tr>
<td>Clinton</td>
<td>0.002316</td>
<td>55</td>
<td>0.12738</td>
<td>0.05796</td>
<td>0.02659</td>
<td>2.610756</td>
<td>Reject</td>
</tr>
<tr>
<td>Cedar Rapids</td>
<td>0.002316</td>
<td>42.5</td>
<td>0.09843</td>
<td>0.11611</td>
<td>0.02373</td>
<td>-0.745057</td>
<td>Accept</td>
</tr>
<tr>
<td>Eddyville</td>
<td>0.002316</td>
<td>35</td>
<td>0.08106</td>
<td>0.08993</td>
<td>0.02744</td>
<td>-0.32325</td>
<td>Accept</td>
</tr>
<tr>
<td>Muscatine</td>
<td>0.002316</td>
<td>55</td>
<td>0.12738</td>
<td>0.0278</td>
<td>0.03059</td>
<td>3.255312</td>
<td>Reject</td>
</tr>
</tbody>
</table>
Table 6. Tests for competitive CIF pricing with export points at local market area boundary, (Eq. 2)

a. Slope test, Eq. (2): \( \beta_i = +t \)

<table>
<thead>
<tr>
<th>Plant location (i)</th>
<th>Distance regression slope estimate (( \beta_i ))</th>
<th>Actual transport cost (( \beta_0 = +t ))</th>
<th>Standard error of ( \beta_i ) (se( \beta_i ))</th>
<th>( t )-value ( t = \frac{\hat{\beta}_i - \beta_0}{se(\hat{\beta}_i)} )</th>
<th>Test status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakota</td>
<td>−0.000918</td>
<td>0.00232</td>
<td>0.00116</td>
<td>2.79</td>
<td>Reject</td>
</tr>
<tr>
<td>Cedar Rapids</td>
<td>−0.003412</td>
<td>0.00232</td>
<td>0.000719</td>
<td>7.97</td>
<td>Reject</td>
</tr>
<tr>
<td>Eddyville</td>
<td>−0.00494</td>
<td>0.00232</td>
<td>0.00108</td>
<td>5.57</td>
<td>Reject</td>
</tr>
<tr>
<td>Muscatine</td>
<td>−0.00218</td>
<td>0.00232</td>
<td>0.000817</td>
<td>5.50</td>
<td>Reject</td>
</tr>
</tbody>
</table>

b. Intercept Test, Equation (1): \( \alpha_i = tr* \)

<table>
<thead>
<tr>
<th>Plant location (i)</th>
<th>Actual transport cost ( t ) ($/bu/mi)</th>
<th>Radius ( r* ) (mi)</th>
<th>Product ( \alpha_i^0 )</th>
<th>Estimated intercept ( \alpha_i )</th>
<th>Standard error of ( \alpha_i ) (se( \alpha_i ))</th>
<th>( t )-value ( t = \frac{\hat{\alpha}_i - \alpha_i}{se(\hat{\alpha}_i)} )</th>
<th>Test status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakota</td>
<td>0.002316</td>
<td>23.5</td>
<td>−0.05443</td>
<td>0.026</td>
<td>0.01888</td>
<td>−1.5</td>
<td>reject</td>
</tr>
<tr>
<td>Clinton</td>
<td>0.002316</td>
<td>55</td>
<td>−0.12738</td>
<td>0.05796</td>
<td>0.02659</td>
<td>−6.9</td>
<td>reject</td>
</tr>
<tr>
<td>Cedar Rapids</td>
<td>0.002316</td>
<td>42.5</td>
<td>−0.09843</td>
<td>0.11611</td>
<td>0.02373</td>
<td>−9.0</td>
<td>reject</td>
</tr>
<tr>
<td>Eddyville</td>
<td>0.002316</td>
<td>35</td>
<td>−0.08106</td>
<td>0.08993</td>
<td>0.02744</td>
<td>−6.2</td>
<td>reject</td>
</tr>
<tr>
<td>Muscatine</td>
<td>0.002316</td>
<td>55</td>
<td>−0.12738</td>
<td>0.0278</td>
<td>0.03059</td>
<td>−5.0</td>
<td>reject</td>
</tr>
</tbody>
</table>
Table 7. Slope and intercept test discriminatory FOB pricing, Eq. (3), Lakota Market Area

a. Slope test: \( (\beta = -t/2) \)

<table>
<thead>
<tr>
<th>Distance regression slope estimate ( (\beta_i) )</th>
<th>One half of actual transport cost ( (\beta_0 = -t/2) )</th>
<th>Standard error of ( \beta_i ) ( (se(\beta_i)) )</th>
<th>( t )-value</th>
<th>Test status</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.00092</td>
<td>-0.001158</td>
<td>0.00116</td>
<td>-1.789793</td>
<td>Accept</td>
</tr>
</tbody>
</table>

b. Intercept test

<table>
<thead>
<tr>
<th>Constrained intercept ( \alpha_0 = C_0 + \frac{1}{2}N_0 )</th>
<th>Actual Lakota intercept ( k = P_0 + \alpha_i )</th>
<th>Standard error of ( k ) ( (se(k)) )</th>
<th>( t )-value</th>
<th>Test status</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.165</td>
<td>2.133</td>
<td>0.01804</td>
<td>-1.77</td>
<td>Accept</td>
</tr>
</tbody>
</table>

Critical values for the \( t \)-statistic: \( t_c(247) = 1.64 \) for 10% confidence level and 2-tailed test; \( t_c(247) = 1.96 \) for 5% confidence level and 2-tailed test.

For Lakota, additional tests shown in Table 7 suggest a lowering of local prices below the price level, and perhaps discriminatory FOB pricing. The slope test of Table 7 does not reject the discriminatory pricing hypothesis, but the slope’s standard error is large and other null hypotheses (including zero) are not rejected either.

The intercept under the null hypothesis of FOB pricing in Table 7 depends on the anticipated processing margin, which can be expected to shift from year to year. Intercept tests using midrange values from the previous year for processing revenues do marginally accept the FOB pricing constraint \( \alpha_0 = C_0 + N_0/2 \). But some other calculations of the intercept under the null hypothesis of FOB pricing used smaller processing margin \( (N_0) \) estimates. Then the null hypothesis intercept was rejected. But this test suggested that the price-distance function was positioned even lower than FOB pricing would suggest. Overall, the estimates do suggest a lowering of actual prices below the competitive level, and perhaps discriminatory FOB pricing, which could result from contractual obligations of farmers to deliver corn to the plant regardless of price.

CONCLUSIONS

This study has investigated corn pricing in the vicinity of processing plants. We developed several conceptual price-distance models for CIF plant pricing in the presence of varying degrees of exporter competition and for discriminatory FOB pricing at the farm. With CIF pricing and corn shipment exhausting supplies in the local area, the farm price declines at the same rate that transport costs increase, and declines to the level of an export market-based bid at the boundary of the local market area. With CIF pricing, weak processor demand and surpluses within the local market area, the farm price increases at the same rate as transport costs and the site price is below the exporter price. With discriminatory FOB pricing, the farm price declines at one half of the rate that transport costs increase. Discriminatory FOB pricing may also lower the local price structure.

Estimations of an empirical price-location function for Iowa during the spring of 2003 suggest several interesting conclusions. Prices near the plants of four conventional
businesses conform to the CIF pricing model, so the farm price increases as one gets closer to the processing plants. In contrast, five of six producer-owned firms or farmer cooperatives failed to show any statistically significant effect on nearby prices. Most of these firms require a corn supply guarantee from producers as a condition of ownership of the processing plant. Perhaps the removal of these supplies removes the pressure for price increases near the plant. A second explanation for the absence or presence of local market areas concerns the proximity of exporter competition. Perhaps the early construction of ethanol plants in the eastern part of Iowa during the late 1970s and early 1980s, along with locations near the Mississippi River, discouraged development of corn-exporting facilities. In contrast, the market areas of the 2000’s plants are within a dense network of grain export facilities. After a decade of western plant operation, perhaps the density of exporting facilities will more closely resemble the east’s density.

One plant had a price distance function that resembled FOB pricing. The level of prices was reduced, compared to the surrounding area, and the price declined by less than the transport cost increase as distance from the plant increased. This plant, located in north-central Iowa, is remote in terms of access to export markets. Limited exporter competition may create an environment where discriminatory pricing is sometimes possible. The pricing pattern may also be related to contract obligations of farmer owners.

Our sample did not show CIF pricing with deficient demand anywhere. One explanation is that inventories were not excessive in our springtime sample. Another sample from a fall harvest period might display upward sloping price cones in a year with high supplies.

Clearly, threshold estimation used in conjunction with price-distance regressions has a place in the econometric analysis of commodity prices in space, because the geographic boundary where local and international buyers both compete can be identified. However, other methods and hypotheses still deserve investigation. For instance, future research might usefully verify price-distance relationships throughout the Corn Belt, in another time period, or over time. Also, simultaneous methods of threshold estimation may improve our understanding of local market pricing when clusters of plants have overlapping market areas, such as northwest Iowa. Finally, estimates of the general price component might be improved, using a derived demand price that subtracts ocean, rail and truck components of marketing costs at every location in the supply area from the appropriate foreign commodity price.

NOTES

1 When the processing industry has evolved to the most mature stage of development, other market area shapes may develop in the uniform plane. Specifically, an interlocking network of octagons is defined when adjacent processors compete on the boundary of a market area to procure supplies (Bressler and King 1970, p. 143–4).

2 Market integration is itself a testable hypothesis. Elsewhere, the extent of market integration is measured by the variance of residuals in a cross-section price regression relating prices in two markets. Statistical factors influencing integration are market transaction costs, information, volume and concentration (Goodwin and Schroeder 1991).

3 The grain-handling infrastructure in Iowa may be more dense than in some other North American grain production areas. Further, not all elevators are export facilities. There are approximately
1,000 elevator first-drop points for farmers’ grain. This works out to about 70 elevators per ethanol market area, using state average data and a typical plant area. The short haul (4 miles average) from farm to elevator likely occurs at very low costs using grain hoppers pulled by pickup trucks or tractors.

In turn, the output of farms at a distance \( r \) from the plant, or equivalently, the production in a ring at a given distance from the plant, is defined by the circumference of a circle at the given distance from the plant, the width of the ring, and the density of corn supply \( (dy) \):

\[
q(r) = \Delta Q = 2\pi r dy \Delta r
\]

In principle, any processing facility could induce a local “price cone.” However ethanol’s large scale sets it apart from other forms of corn processing. For instance, a large hog facility with four buildings and a 4,800 head inventory uses about 0.125 million bushel of corn annually. If this corn had been used for ethanol, it would have produced about 0.33 million gallons. Meanwhile, a typical ethanol plant has about 50 million gallons of annual capacity and uses about 19 million bushels of corn.

The sample mean price at a location has some measurement error relative to its population mean price, the latter being the ideal dependent variable for our regression. However, “measurement error on the dependent variable can be absorbed in the disturbance and ignored, as long as the regressor is measured properly” (Green 2000, p. 376).

Tsay (1989, p. 235) also suggests visual inspection methods for threshold estimation. He inspect a graph of the residuals from a linear regression against the variable with a possible threshold value. The largest residual should identify the threshold value.

In general, the statistical price function, Eq. (4), has intercept \( k = P_0 + \alpha_i \) in the Lakota market area. The standard error of \( k \), \( se(k) \), was calculated using the estimated state price component function with variances and covariances among \( X \), \( X^2 \), \( Y \), \( Y^2 \), \( XY \), and the Lakota intercept term, \( \alpha \). The formulas for the variance of a function (Greene 2000, p. 64, and Kmenta 1971, p. 444) of several variables was also used in this calculation.

REFERENCES


