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Measuring the Impact of Ethanol Plants on Local Grain Prices

Kevin McNew and Duane Griffith

A considerable number of farmer-owned ethanol plants have been built in the past few years, with many more planned. In part, farmers' investment in ethanol plants is an attempt to increase grain prices in their local market. We examined this issue by estimating the impact on local grain prices of twelve ethanol plants that opened from 2001 to 2002. We find that these new ethanol plants increased local grain prices, but the impact was not uniform around the plant. Markets downstream from a new plant, where prices tend to be higher, experienced a smaller price impact from the ethanol plant. On average across plants, corn prices increased by 12.5 cents per bushel at the plant site, and some positive price response was felt 68 miles away from the plant.

There are few areas of agriculture that have witnessed such consistent and robust growth as the U.S. ethanol industry. Since 1980, U.S. ethanol production has increased 13% per year and in 2003, production was up an astonishing 32% (Renewable Fuels Association 2004).

Ethanol, which is mostly produced from corn, is used as a gasoline additive. The ethanol industry began in the 1970s as escalating oil prices led to concerns about national energy security. At the time, fuel ethanol was considered an attractive gasoline extender that could reduce U.S. dependence on foreign oil. Even today, energy security concerns have many policymakers favoring expanded ethanol use (Lugar and Woolsey).

By the 1980s and 1990s, environmental policies began to shape the course of the ethanol industry. The Clean Air Act Amendments of 1990 required that gasoline be reformulated with one of two oxygenates—ethanol or methyl tertiary butyl ether (MTBE). Although MTBE has historically been the oxygenate of choice, this will likely change as MTBE has been found to contaminate ground and surface water. As of 2003, eighteen states had policies to limit or ban the use of MTBE in the near future.

Along with environmental policies, other federal policies have stimulated ethanol production and use. Since 1978, ethanol has been exempt from the Federal

■ *Kevin McNew and Duane Griffith are associate professors, respectively, in the departments of Agricultural Economics and Economics, Montana State University.*

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Excise Tax on gasoline and various states have enacted ethanol tax credits to promote its use (Rask). Likewise, a series of federal, state, and local policies have been enacted to encourage investments in ethanol plants. The U.S. Senate introduced the Fuels Security Act of 2003 that would require ethanol use to double in the next decade.

With such favorable policies, it is not surprising that ethanol production and the number of ethanol plants have increased significantly. Recently, U.S. farmers have shown considerable interest in ownership of ethanol plants. In 2003, ten of the thirteen new ethanol plants under construction were farmer-owned cooperatives, and numerous additional plants are in the planning phase (Renewable Fuels Association 2003).

Two reasons potentially motivate farmers' interest in ethanol plant ownership. First, the outlook for increasing ethanol demand combined with a history of declining real grain prices means ownership of an ethanol plant could generate profits. Second, many believe that the existence of a plant will boost local grain prices, thereby providing indirect returns to farm ownership of the plant even if the plant earns zero profit (Hayworth).

While numerous case and feasibility studies exist that provide an assessment of the expected profit potential (e.g., Sparks Companies and Kansas State University; Herbst et al.; Fruin and Halbach; Outlaw et al.), no research has considered the impact of ethanol plants on local corn prices. This is especially problematic since the ethanol industry appears to be highly competitive with no significant entry barriers. Thus, above-normal profits are not likely to be sustainable.[1] As such, the indirect returns of owning the plant through higher corn prices may be a vital component to the financial payoff to farmers who own a plant.

We developed a model of spatial equilibrium that illustrates the impact on regional prices from introducing an ethanol plant. This model serves as a useful framework for empirically estimating the impact of the twelve corn-based ethanol plants that opened between 2001 and 2003.

A Model for Opening an Ethanol Plant

The U.S. grain distribution system comprises farms, storage elevators, and transportation networks involved in moving grain from production areas to domestic and overseas markets. Because transportation costs are one of the largest components of grain marketing costs, the system plays an important role in grain commodity price on several levels. First, costly transportation leads to declining prices as one moves away from demand centers. Second, shocks to demand, supply, or transportation costs can induce shifts in trade patterns and lead to differential impacts on farm-level and terminal market prices (McNew 1996; Fackler and Goodwin). This latter scenario is consistent with the opening of a new ethanol plant. The introduction of a new demand source for grain can induce shifts in trade patterns as well as adjust the spatial characteristics of prices around the plant.

A graphical representation of a spatial model is presented in this section (see the Appendix for a mathematical treatment of the problem). The model is patterned after the agents-on-links spatial equilibrium model, which assumes that production occurs along a line segment (i.e., the links). The links contain demand

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centers at various points (see e.g., Faminow and Benson; Dahlgren and Blank for applied examples in agriculture).[2]

Assume initially that there is one demand center, which we also refer to as a terminal market, located at the end of a line segment measured in distance $d \in [0, 1]$. Grain production is assumed to occur uniformly along this line segment with total production assumed to be exogenous and fixed for the purposes of this analysis. Grain is shipped to the terminal market located at $d = 1$ and producers receive a net price at their location adjusted for transportation costs, which is assumed to be proportional to the distance shipped.

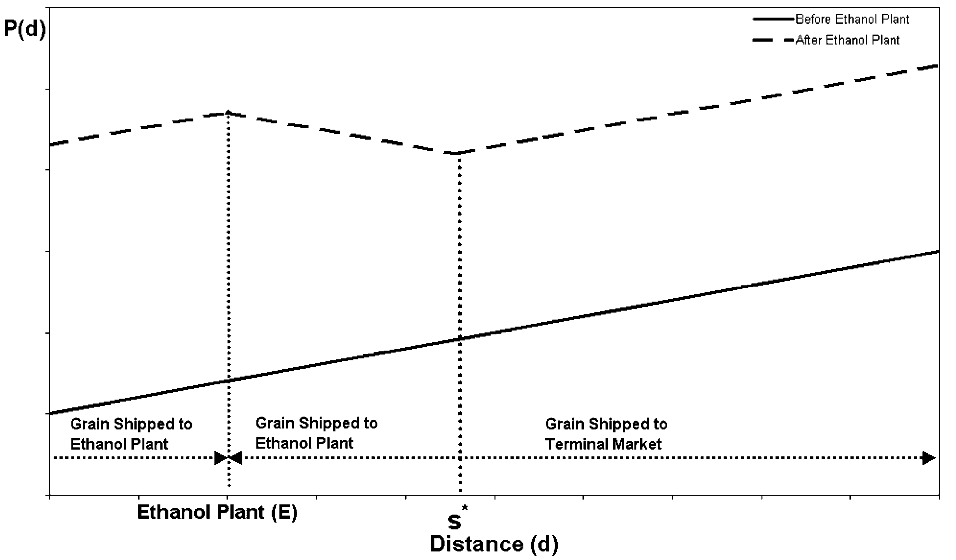
Assuming all grain is shipped to the terminal market, the price at any location d can be expressed in terms of the terminal market price, P^{T}, and the per unit cost of shipping, r:

$$P(d) = P^{\mathrm{T}} - r(1 - d). \tag{1}$$

Prices continuously increase as one moves closer to the terminal market (d approaches 1) with the transportation rate r dictating the slope of the price surface. This is illustrated graphically in figure 1, with the linear line labeled "Before Ethanol Plant."

Suppose that an ethanol plant opens at some exogenously determined point $E \in [0, 1)$. This plant brings a new grain demand source to the market and can potentially alter shipping patterns. In this model, it can be shown that a boundary between the ethanol plant and the terminal market exists, which delineates the two demand markets. This point, s^*, signifies the spatial boundary of grain shipments to the ethanol plant and the terminal market. Producers located along the line segment $d^{\mathrm{E}} \in [0, s^*]$ will ship grain to the ethanol plant while producers along $d^{\mathrm{T}} \in (s^*, 1]$ will ship to the terminal.

Figure 1. Impact on spatial price surface from an ethanol plant



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As a result of the new ethanol plant, grain prices increase along the entire line segment, but the price impact varies spatially across three distinct regions. First, producers who continue to ship to the terminal market (i.e., $d^T \in (s^*, 1])$, still receive a positive price impact as a result of the ethanol plant. This is because demand for grain from the ethanol plant reduces the amount of grain shipped to the terminal market. Thus, prices increase even in areas that do not ship to the plant as a result of lower grain supplies reaching the terminal.

Prices for producers that ship to the plant increase even more because of lower transportation costs. Before the ethanol plant, producers around the plant had to ship grain to the far away terminal market. With a nearby plant, their shipping costs are lowered, which translates into higher regional prices for these producers. However, not all producers shipping to the plant save equally on shipping costs so the price impacts around the plant vary.

For example, those producers "upstream" from the plant (i.e., in a low-priced region relative to the plant) will see the largest impact because they enjoy the greatest transportation cost savings. This region is depicted in figure 1 by the area to the left of the plant site, E. All upstream producers have the same price impact from the plant because each producer reduces shipping costs by the amount $r(1 - E)$, which is the cost of shipping from the ethanol plant to the terminal market. A producer located upstream from the plant at point $d_0 < E$, for example, would incur a shipping cost of $r(1 - d_0)$ to the terminal market. After the plant opens, however, shipping costs are $r(E - d_0)$, so the transportation cost savings is $r(1 - E)$, which is the same for all producers (i.e., does not depend on d_0).

For producers who ship to the plant but are on the downstream side, the transportation costs savings diminish as the distance from the plant increases. This is because producers in this region must ship grain back to the plant and therefore they do not receive the full transportation cost savings of upstream producers. The further away from the plant, the higher the cost of back hauling, and the lower the price impact from the new plant.

In what follows, we develop a spatial econometric model that estimates the regional impact on grain prices from opening ethanol plants. Our econometric work is motivated by this simple spatial model, which suggests that the impacts will vary depending on whether the locations are upstream or downstream from a new plant, as well as what the distance from the plant is.

Data and Methodology

Daily local corn price data were obtained from the Cash Grain Bids Data Service for March 2000 through March 2003. This unique dataset contains over 2,000 U.S. corn markets. Because our interest is on the local impact of an ethanol plant opening, we converted daily cash prices to basis values using nearby CBOT corn futures prices for the same time period. The basis, defined as the local cash price less the futures price, is more likely to be influenced by local supply and demand conditions, transportation costs, and storage costs relative to the cash price, which is influenced by not only these local forces but also by national and global shocks. Daily basis values for each market were averaged by month, yielding 37 monthly observations per market from March 2000 to March 2003.

Over this same time period, thirteen corn-based ethanol plants began operations (table 1). Not surprisingly, the plants are mostly in the Midwest ranging

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Table 1. New ethanol plants and number of corn markets

Plant Location	Start-Up Date	Plant Capacity (Million Gallons per Year)	Number of Markets in 150-m Square Area
Craig, MO	February 2001	20	28
Wentworth, SD	September 2001	45	37
Sioux Center, IA	December 2001	14	61
Rosholt, SD	January 2002	18	33
Galva, IA	March 2002	18	96
Big Stone City, SD	July 2002	45	35
Stanley, WI	July 2002	15	8
Coon Rapids, IA	August 2002	45	109
Lena, IL	August 2002	40	38
Watertown, SD	September 2002	45	35
Caro, MI	November 2002	45	2
Lakota, IA	November 2002	45	83
Monroe, WI	November 2002	40	34

geographically from Missouri in the southwestern section of the Cornbelt to Michigan in the Upper Midwest. Data on each plant including the start-up date and the plant capacity were obtained through the Renewable Fuels Association press releases.

Although the cash grain price dataset contains over 2,000 U.S. markets, we considered only those markets in the analysis that reported corn prices over the sample period and were within a 150-mile square area centered on a new ethanol plant. This process allowed us to consider a definite market impact area for each plant. Since several plants opened nearly simultaneously (e.g., two plants per month opened in July 2002 and August 2002; three plants in November 2002), it was necessary to define the market area for each plant so that the price impact could be identified. In essence, we assumed that the price impact of each plant is contained in the 150-mile square region centered on the plant.[3] Table 1 provides a summary of the number of markets contained in each plant region. Because of the lack of markets within the Caro, MI plant region, it was excluded from the analysis, leaving 316 cash markets and 12 ethanol plants.

To quantify the impact of an ethanol plant opening, it would be empirically appealing to compare prices before and after a plant opens. Any differences in prices could then be attributed to the plant opening. However, in practice, other economic factors also influence prices over time, thus making a direct comparison of before and after prices problematic. Our approach is to model prices using a spatial econometric model that accounts for economic forces that influence local prices. We attribute remaining variation in prices to the opening of an ethanol plant.

Few empirical studies have constructed economic models of grain basis. Early research by Tilley and Campbell found that exports and U.S. stocks of wheat influenced hard red winter wheat basis from the Louisiana Gulf. In production

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areas, McNew (1994) found local production and transportation rates impact local prices. As such, we estimated a model of spatial basis variation, which accounts for changes in national and local production as well as transportation rates (see the Appendix for equations (A2)–(A9)):

$$
\begin{aligned}
(2) \qquad B_{it} = {} & \alpha_0 H_t + \sum_s \alpha_{1s} h_{st} + \sum_s \sum_k \alpha_{sk} M_k + \sum_{e=1}^{12} R_{ie} \big[\delta_e E_{et} + \beta_{e1} X_{ei} + \beta_{e2} Y_{ei} \\
& + \beta_{e3} X_{ei} Y_{ei} + \beta_{e4} X_{ei}^2 + \beta_{e5} Y_{ei}^2 + \beta_{e6} X_{ei}^2 Y_{ei} + \beta_{e7} X_{ei} Y_{ei}^2 \\
& + \gamma_{e1} r_t X_{ei} + \gamma_{e2} r_t Y_{ei} + \gamma_{e3} r_t X_{ei} Y_{ei} + \gamma_{e4} r_t X_{ei}^2 + \gamma_{e5} r_t Y_{ei}^2 \\
& + \gamma_{e6} r_t X_{ei}^2 Y_{ei} + \gamma_{e7} r_t X_{ei} Y_{ei}^2 \big] + e_{it}
\end{aligned}
$$

where B_{it} is the basis for market i in time period t, H_t is U.S. corn production, and h_{st} is corn production in state s for market i. Both U.S. and state-level corn production are in million bushels and are the same values from October through September, coinciding with the beginning of the harvest period in October.[4] Seasonality in basis is modeled with state-level dummy variables for the month of the year (M_k). The term R_{ie} is a dummy variable signifying that market i is within the 150-mile region of an ethanol plant, indexed by $e = 1, 2, \ldots, 12$ for the twelve plants in our sample.

Within each region, we estimated a basis surface utilizing the distance from each plant, where X_{ie} is the east–west distance in miles that market i is from plant e and Y_{ie} is the north–south distance that market i is from plant e. A negative (positive) value for the (X_{ie}, Y_{ie}) coordinate indicates that market i is northwest (southeast) of plant e. We estimated a second-order quadratic expansion using the (X_{ie}, Y_{ie}) coordinates to capture the spatial variation inherent in basis. In addition, it seems likely that the basis surface will change depending on the cost of transportation. We used the U.S. average retail diesel price, r_t, as a proxy for grain trucking costs. Thus, the diesel price r_t interacting with the distance measures (X_{ie}, Y_{ie}) allows for the price surface to adjust depending on transportation rates. Finally, the term E_{et} is a dummy variable signifying that ethanol plant e is open in period t. As such, the coefficient on this term (γ_e) represents the average price change in region R_e after the ethanol plant has opened.

While equation (2) provides an estimate of the average impact in a plant region, it provides little evidence about the variation of the plant's impact over space. Indeed, the theoretical reasons outlined above suggest that such impacts will vary depending on whether a market is upstream or downstream from a plant. In particular, downstream markets are likely to see less impact than upstream markets.

To examine this possibility, we first need to categorize each market as upstream or downstream from a specific plant. We chose a relatively simple and intuitive approach by comparing basis values between a market and the plant site. Specifically, we define U_{ie} and D_{ie} as a dummy variable that signifies whether market i is upstream or downstream from plant e, as:

$$
\begin{aligned}
U_{ie} &= 1 \quad \text{if } \; B_i \leq B_e \\
&= 0 \quad \text{o.w.}
\end{aligned}
$$

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$$D_{ie} = 0 \quad \text{if} \;\; B_i \leq B_e$$
$$= 1 \quad \text{o.w.}$$

That is, if the basis in market i is less than or equal to the basis at the ethanol plant, the market is considered upstream from the ethanol plant. We utilized the average basis values for March 2000 through January 2001 to make this computation since the first plant in the dataset opened in February 2001.

Along with whether a market is upstream or downstream, the distance from the plant likely influences the size of the plant's impact. As such, we also utilized the Euclidian distance from the plant, defined as

$$d_{ie} = \sqrt{X_{ie}^2 + Y_{ie}^2}.$$

Utilizing our definition of upstream and downstream along with distance to a plant, we modified equation (2) by replacing $\delta_e E_{et}$ with:

$$E_{et}[\delta_e' + \delta_U' U_{ie} d_{ie} + \delta_D' D_{ie} d_{ie}]. \tag{3}$$

The remainder of the model is as outlined in equation (2). Equation (3) now provides several important estimates of a plant's impact. First, the coefficient δ_e' represents the price impact at the plant site (where $d_{ie} = 0$). Second, the slope coefficients, δ_U' and δ_D', represent the change in price moving upstream or downstream from the plant. The theoretical arguments outlined above suggest that these slope coefficients would satisfy $\delta_U' = 0$ and $\delta_D' < 0$. That is, upstream markets should experience the same impact as the plant site itself, while downstream market prices should decay as distance from the plant increases. Indeed, the term δ_e'/δ_D' measures, in miles, the distance of the price impact. Downstream markets that are greater than δ_e'/δ_D' miles from the plant will have no price impact.

Finally, the empirical model specified in equations (2) and (3) is likely to have spatial autocorrelation in the errors. That is, for a given time period, any two markets i and j will likely have positive correlation ($E[e_{it}e_{jt}] > 0$), which violates the assumptions of least-squares regression. Advances in spatial econometrics provide a framework for dealing with this problem. Anselin provides a maximum likelihood method for a general regression model of the form:

$$y = X\beta + e$$
$$e = \lambda W_e + u$$
$$u \sim N(0, \sigma^2 I)$$

where y is a vector of dependent variables and X represents the data matrix containing explanatory variables. W is a known spatial weight matrix and the parameter λ is a coefficient on the spatially correlated errors analogous to the serial correlation problem in time-series models. The weight matrix W quantifies the spatial aspect of the data by signifying which observations are linked. There are numerous means of constructing a spatial weights matrix, with the appropriate method being primarily an empirical matter.[5]

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We utilize a distance-based binary method to construct the spatial weight matrix, such that the elements of the W matrix are defined as:

$$
\begin{aligned}
W_{ij} &= 1 \quad \text{if } d_{ij} \leq 50 \\
W_{ij} &= 0 \quad \text{if } d_{ij} > 50 \qquad (4) \\
W_{ii} &= 0.
\end{aligned}
$$

Thus, any two markets (i, j) that are within 50 miles of each other are assumed to have positively correlated errors.[6]

Results

The model of spatial basis variation given by equation (2) was estimated using maximum likelihood methods subject to our choice of the spatial weight matrix specified in equation (4). For space reasons, we do not present the estimated coefficients on the state-level seasonal dummies, although they were significant and exhibited typical seasonality patterns prominent in grain prices. Table 2 presents all other estimated parameters. The spatial autocorrelation parameter λ was statistically significant as expected, indicating the importance of accounting for spatial autocorrelation in the errors.

As expected, production at the national and state levels tends to influence basis levels with higher production leading to a lower basis. The U.S. corn production negatively impacts basis at a local level. For example, a 500-million bushel increase in U.S. corn production, a magnitude that is consistent with year-to-year variation in the last five years, would cause basis levels to decline by 2.5 cents per bushel. Also, decreases in state-level production caused basis levels to increase in eight of the nine states. The exception was Illinois, which showed a positive response from state-level production. The measures of distance from the plant, as given by the (X, Y) coordinates and the transportation cost, r, showed significant impacts on basis within each plant region. However, not all coefficients were significant and the significance of coefficients was not uniform across plant regions. This suggests that basis variation over space is not uniform. That is, basis levels may increase/decrease more in the north–south directions, relative to east–west directions.

All twelve plant regions showed higher prices after the plant opened. The parameter estimate for the variable E_{et} measures the average change in basis within the 150-mile square region of each plant. All of the estimated parameters for E_{et} are highly significant and positive, although considerable variation exists across regions. At the low end, the Monroe, WI region experienced a 1.5-cent improvement in the basis while the Rosholt, SD region had a nearly 12-cent increase in the basis. On average, these twelve plant regions had a 5.9-cent increase in the basis.

Given that the opening of ethanol plants appears to have raised corn basis levels within a region, an empirically interesting issue is to identify the nature of the price impact depending on distance and location relative to the plant. Equation (3) augments the plant dummy variable E_{et} to include a measure of distance from the plant and whether a market is upstream or downstream. The hypothesis from the theoretical model is that upstream markets should have identical impacts while

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Table 2. Estimated impacts of ethanol plant openings in each plant region

	Prod. Coeff.		MO-Cr.	SD-We.	SD-Ro.	IA-Si.	IA-Ga.	SD-Bi.	WI-St.	IA-Co.	IL-Le.	SD-Wa.	IA-La.	WI-Mo.
U.S.	−0.005**	X	0.67	1.07	−4.25**	1.09*	−1.98**	1.12	−2.54**	2.59**	−0.36	−0.43	−2.67**	2.76**
IL	0.041**	Y	5.52**	−1.12	−4.19**	0.28	1.45*	0.75	1.45	0.98*	0.18	0.27	0.01	1.37*
IA	−0.002*	X^2	5.07**	3.54*	−3.91	−4.97**	2.90**	−1.40	1.76**	8.97**	−19.5**	−0.81	5.27**	17.0**
KS	−0.136**	Y^2	6.08**	−4.96**	−15.9**	−1.22	−4.32**	−4.51**	1.05	−2.57**	1.56	−10.4	0.51	−5.46**
MN	−0.007**	XY	21.8**	−11.3**	4.20	−7.67**	0.70	4.60	−2.83**	−1.38	−32.4**	−5.96	1.95	−6.78
MO	−0.001	X^2Y	13.6**	0.99	37.1**	−3.98	−12.5**	3.35	−7.60**	−0.94	27.0**	0.61	7.73**	10.2
NE	−0.051**	XY^2	17.1**	11.1**	−17.4	−10.8*	9.93**	−6.76	−7.81*	10.97**	64.7**	9.49	−2.56	10.5*
ND	0.136**	Xr	−0.12	−0.44	0.70*	−0.27*	−0.20	−0.08	−0.14**	−0.28**	0.04	0.05	0.06	−0.60**
SD	−0.052**	Yr	0.27	0.25	−0.64*	−0.04	−0.03	0.53*	0.22	−0.23	−0.42**	−0.64	−0.42**	0.35*
WI	−0.118**	X^2r	−1.50**	0.35	−1.41	−0.12	−0.56**	−0.58	−0.58*	−1.54**	−0.48	−1.68	−2.19**	−0.02
		Y^2r	−0.28	0.27	−0.74	0.14	−0.24	−0.75*	1.19	−0.23	−1.73**	−0.42	−0.63**	−0.33
		Xyr	−0.39	−0.71*	1.99	−0.14	0.54**	−0.18	2.18	0.15	−0.58	−0.27	0.02	2.27*
		X^2Yr	−0.61	1.05	−1.92	1.54	−0.38	−2.52*	−8.91	−0.02	2.69	3.55	−1.77**	−5.70**
		XY^2r	0.19	0.42	3.65	−1.74	−0.11	−1.93	−6.52	−0.96*	−0.83	0.01	2.77**	−2.56*
		Plant open (E_t)	7.26*	6.49**	11.89**	4.16**	4.51**	3.81**	6.83**	4.76**	9.52**	6.48**	3.63**	1.53**

Note: $R^2 = 0.8687$, the spatial error coefficient $\lambda = 0.467$ and has a p-value of 0.001.
*Significant at the 5% level.
**Significant at the 1% level.

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Table 3. Estimated price impact at the plant, and downstream/upstream impacts

Plant	Intercept	Slope-Downstream	Slope-Upstream	Price Impact from Plant (Miles)
Craig, MO	6.09 (0.036)	0.1466 (0.126)	−0.1515 (0.287)	*
Wentworth, SD	12.33 (0.001)	−0.2089 (0.001)	0.0504 (0.301)	59.0
Rosholt, SD	13.45 (0.001)	0.1024 (0.148)	0.1964 (0.101)	*
Sioux Center, IA	11.01 (0.001)	−0.1086 (0.001)	−0.0074 (0.714)	101.4
Galva, IA	5.59 (0.001)	0.0283 (0.316)	−0.0607 (0.016)	92.1
Big Stone City, SD	9.75 (0.002)	−0.2348 (0.001)	−0.010 (0.909)	41.5
Stanley, WI	10.95 (0.001)	−0.1405 (0.082)	0.0015 (0.877)	77.9
Coon Rapids, IA	10.88 (0.001)	−0.2422 (0.001)	−0.0214 (0.455)	44.9
Lena, IL	19.33 (0.001)	−0.2278 (0.029)	−0.0244 (0.792)	84.9
Watertown, SD	14.34 (0.001)	−0.1750 (0.042)	0.1333 (0.203)	81.9
Lakota, IA	4.63 (0.001)	0.0031 (0.926)	0.0740 (0.109)	*
Monroe, WI	6.70 (0.007)	−0.2124 (0.017)	0.0293 (0.245)	31.6

Note: $R^2 = 0.884$, the spatial error coefficient $\lambda = 0.439$ and has a p-value of 0.001.
*Impact distance is not defined when slope coefficients are positive or insignificant.

downstream markets should experience a declining price impact as distance from the plant increases.

Table 3 presents the results of equation (3) for the plant impact, and downstream/upstream impacts. All other coefficients were similar to those presented in table 2 and are not reported. The intercept column in table 3 signifies the price impact at the plant site (in cents per bushel), while the upstream/downstream slope terms measure the change in price depending on the miles away from the plant.

The estimated price impact at the plant site is given by the intercept coefficient. For the twelve ethanol plants, the estimated price impact at the plant site was positive and statistically significant. Unlike the price impact measure reported in table 2, which measures the average over the 150-mile plant region, the intercept estimate in table 3 provides a direct measure of the impact at the plant site. In general, impacts at the plant site are greater than those for the 150-mile region impacts, suggesting that the price increase is spatially concentrated around the plant. Price impacts at the plant sites ranged from 4.6 cents in Lakota, IA, to a high of 19.3 cents in Lena, IL. On average across the twelve plants, the price was 12.5 cents higher at the plant site.

In addition to significant impacts at plant sites, the slope coefficient estimates in table 3 indicate the presence of asymmetric downstream and upstream impacts around the plant. From our theoretical model, the null hypothesis of the plant impact is that $\delta'_U = 0$ and $\delta'_D < 0$. That is, upstream markets should experience the same impact from a new plant as the plant site itself, while downstream markets should experience a decaying effect based on the distance from the plant. Of the twelve plants considered, eight conformed to the downstream/upstream hypothesis with statistical significance indicating that the price impact decayed

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for markets that were downstream from the plant. The price impacts were constant for markets upstream from the plant.

Of the four markets that did not conform to the hypothesis, three (Craig, MO; Rosholt, SD; and Lakota, IA) were not statistically different from zero for either the downstream or upstream slopes. Thus, price impacts appeared uniform across all local markets. The final market, Galva, IA, showed a negative and significant upstream coefficient but an insignificant downstream coefficient suggesting the grain for this plant comes from upstream locations. Since our computation of upstream/downstream markets does not account for transportation networks, such as roads and rail lines, our proxy for transportation costs may be problematic for Galva, IA. Even so, it is encouraging that the majority of the plants showed the expected price impacts with constant upstream impacts and a decaying downstream impact.

With a decaying downstream impact, it is informative to estimate how far away from the plant the price impact will reach. This is provided by the term δ'_e/δ'_D, which measures how far downstream the price impact spreads (last column of table 3). For the Galva, IA plant, we present the price impact using the upstream slope coefficient, which is negative and significant. For the three plants that did not have a significant negative slope coefficient, no estimate of the price impact distance is given.

The estimated distance from the plant ranged from 31.6 miles for the Monroe, WI plant to 101.4 in Sioux Center, IA. On average across the nine plants for which a distance calculation could be made, the price impact reached 68 miles from the plant.

Price Impact Variation among Plants

Given that ethanol plants appear to increase corn prices, an interesting issue is how the impact varies among plants. Based on our parameter estimates, the price impact at the plant sites varied from 4.6 cents to 19.3 cents per bushel, suggesting considerable variation across plants. One would expect that available corn in the area relative to a plant's needs would influence the price impact. Plants that have relatively greater corn needs or areas where corn supplies are relatively low would likely have a greater price impact than smaller plants or regions with more corn production.

To investigate this empirically, we constructed a distance measure of available corn supplies relative to a plant's needs. Because ethanol is produced in fixed proportions (one bushel of corn yields 2.7 gallons of ethanol), we computed the annual corn needs of each plant based on plant capacities (see table 1). We used county production data from USDA's National Agricultural Statistics Service to measure an area's available corn supply. Because each county has a different land base, we standardized production by the county land area (in square miles) resulting in a measure of corn density per square mile. Assuming that corn production is uniformly distributed across the county, we computed the distance needed to acquire the necessary needs for each plant.

Formally, this distance measure is

$$\text{Distance for corn needs} = \text{plant's corn needs/corn density} \tag{5}$$

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Table 4. Price impact based on distance of corn needs

Variable	Parameter Estimate
Intercept	−0.333 (0.964)
Log (distance for corn needs)	1.64 (0.183)

Note: $R^2 = 0.209$.

where distance for corn needs is the square miles needed to achieve a plant's corn needs; plant's corn needs is the total annual bushels of corn needed to run the plant at full capacity; and corn density (measured in bushels per square mile) is the ratio of a county's corn production to the land area of the county. This distance measure is expected to be positively related to the plant site price impact. That is, with farther distances to acquire corn a higher plant price is needed to cover added transportation costs. To investigate this, we estimated the following model using ordinary least squares regression:

$$\text{(6)} \qquad \text{Price impact at plant site} = \alpha_0 + \alpha_1 \log \text{(distance for corn needs)}.$$

We use the log ( ) of the distance measure because a concave effect is expected given transportation rates for truck and rail. That is, shorter shipping distances are done by truck that tends to have higher rates per mile compared to rail, which is used for longer hauls.

The regression results show statistically insignificant impacts based on distance (table 4). In addition, the poor R^2 suggests that the variation in the price impact is not explained well by the distance for corn needs variable.

Available corn supplies relative to a plant's needs is only one factor influencing the price impact from an ethanol plant. Unfortunately, a limited number of plant observations prevent us from testing these factors formally, so we simply mention them as possibilities.

First, although the majority of the plants considered in this analysis are farmer owned, plants have different grain procurement policies that may influence the price impact. Of the twelve plants in the analysis, two (Galva, IA, and Lakota, IA) have policies requiring grain to be delivered by its farm owners and disallows purchases from non-owners. These two plants showed the lowest price impact in the study. With farmers required to deliver grain to the plant, this may limit the price impact since the plant does not have to attract grain by offering higher prices. Consequently, farmers might consider forming cooperatives in conjunction with LLCs (limited liability corporations) if their goal is to increase prices.

Second, distance to terminal markets could also explain some of the variation in the price impacts across plants. From our theoretical model, a new ethanol plant reduces transportation costs for those producers that ship to the plant versus terminal markets. Thus, those ethanol plants farther away from terminal markets may be expected to have a larger price impact. For example, a comparison of the price impact of South Dakota versus Iowa plants shows a larger impact in South Dakota. On average, the four South Dakota plants had a 12.5-cent impact at the plant site versus 8 cents for the four Iowa plants. Grain moving from these regions

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largely flows to the Mississippi River for export through the Gulf. Thus, South Dakota markets incur higher transportation cost to the traditional export markets, but benefit more from transportation savings offered by a local plant.

Finally, this research did not address whether the price impacts persist over time. The presence of sizable price impacts in the plant regions would suggest local producers may respond by increasing production. However, we are unable to identify a potential supply response since most of the plants opened within the 2002 crop year and, thus, producers would not be expected to increase supplies until fall 2003. Intuitively, it seems likely that the price impact of a plant would diminish as local producers increase corn supplies over time. As such, estimates here are likely short-run impacts and not indicative of the long-term price impact from an ethanol plant.

Lessons for Future Development

Although ethanol plants appear to impact local grain prices, there are some important caveats to consider for those wishing to develop local plants. First, as was theoretically and empirically demonstrated, price impacts will differ around the plant with upstream markets experiencing the same impact as markets near the plant. As such, when setting a new plant, it is important to consider the availability of corn in the upstream markets (as opposed to downstream markets) since this is where the majority of the grain should be sourced. Likewise, producers considering investing in a new plant should know whether they are in an upstream market with potentially big impacts, or in a downstream market with smaller impacts. Distance to the plant will also limit the benefit.

Second, the plant size relative to the available local corn supplies weakly influenced prices. Other factors, such as grain procurement policies and distance to terminal markets may also influence this impact, although we are unable to quantify these impacts.

Finally, positive price impacts on corn prices may actually be a detriment to the profitability of an ethanol plant. Corn costs account for around 50% of the operating costs of an ethanol plant. Thus, higher corn prices will reduce the profitability of an ethanol plant. In addition, plants that require farm owners to deliver corn may experience a smaller price impact from the plant. As such, there seems to be a trade-off between farm ownership of a plant and the impact on grain prices. Whether farmers would be better off owning an ethanol plant and receiving lower corn prices or not owning the plant and having higher corn prices is an empirical question that should be carefully explored in a development strategy for new ethanol plants.

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Endnotes

[1]The case study by Sparks Companies and Kansas State University shows expected return on investment to an ethanol plant of 3–18% depending on the plant size. Such returns are not abnormal in comparison to food processing, wholesaling, and retailing firms which averaged 11% from 1980 to 1997, according to the research of Borland, Freeberg, and Barton.

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[2]Several alternative models exist for studying spatial markets. In agricultural applications, a commonly used model is the point-location model popularized by Takayama and Judge, which assumes all production and consumption occurs on the points and links that serve only for transportation. Also, a circular model of a centrally located demand center and producers located throughout a circular region would be another alternative. Each of these models lead to similar results. For example, as the number of points becomes more dense in the point-location problem, the model approaches the agents-on-links model (Fackler and Goodwin).

[3]Analysis based on smaller (100-mile square region) or larger (200-mile square region) market impact areas led to findings similar to those presented here.

[4]It may seem puzzling to include national production as a factor influencing local basis. However, because changes in national supplies can have important changes in the price of storage, this impacts basis at a delivery point. In particular, a larger crop that leads to a higher price of storage will reduce the basis at a delivery point. Furthermore, because of spatial arbitrage, other basis levels would be similarly impacted.

[5]For a good treatment of spatial weight matrix issues, see Appendix 1 of Kelejian and Robinson.

[6]We also used 100-mile and 150-mile boundaries and found similar qualitative results in our models.

[7]An alternative model commonly used in agricultural commodity market analysis is the point-location model popularized by Takayama and Judge. This model assumes all production and consumption occurs at the nodes (points) while the links provide the basis for transportation between nodes. The agents on links model can be viewed as a continuous extension of the point-location model, where the number of points grows large (Fackler and Goodwin). As such, both models yield similar implications and the choice of the model is more a matter of preference and which model is representative of the market being studied.

[8]The assumption of no transportation costs for producers located at the plant site E may seem unrealistic since these producers would likely face some costs for loading and unloading grain. However, since all producers would likely face the same load–unload costs, they would have no bearing on the spatial price impact of an ethanol plant.

Appendix A: Spatial Grain Pricing and the Opening of an Ethanol Plant

In this section, we develop a theoretical model of a grain production, transportation, and consumption system. Although several alternative model structures exist for spatial market analysis, we utilize the agents-on-links model that Faminow and Benson and Dahlgren and Blank employed in their studies of agricultural commodity markets.[7]

Grain production is assumed to occur uniformly along a line segment measured in distance $d \in [0, 1]$, with aggregate production of $\bar{Q}$. Grain is shipped to the terminal market located at $d = 1$ with the demand for grain at the terminal given by:

$$P^{\mathrm{T}} = \alpha^{\mathrm{T}} - \beta^{\mathrm{T}} Q^{\mathrm{T}} \tag{A1}$$

where P^{T} is the price paid at the terminal and Q^{T} is the quantity delivered to the terminal. The cost of shipping grain from any point d to the terminal market is $r(1 - d)$, where r is the per unit cost of shipping and $(1 - d)$ measures the distance from point d to the terminal market.

Assuming all grain is shipped to the terminal market ($Q^{\mathrm{T}} = \bar{Q}$), the price at any location d is:

$$P(d) = P^{\mathrm{T}} - r(1 - d) = \alpha^{\mathrm{T}} - \beta^{\mathrm{T}} \bar{Q} - r(1 - d). \tag{A2}$$

Equation (A2) demonstrates how exogenous shocks from the terminal market demand (through parameters α^{T} and/or β^{T}) or production ($\bar{Q}$) will lead to identical

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price impacts at all points along the line segment. In addition, prices continuously increase as one moves closer to the terminal market (d approaches 1) with the transportation rate r dictating the slope of the price surface.

Suppose now that an ethanol plant opens at some exogenously determined point $E \in [0, 1)$. Demand for grain at the plant is assumed to be:

$$P^{\mathrm{E}} = \alpha^{\mathrm{E}} - \beta^{\mathrm{E}} Q^{\mathrm{E}} \tag{A3}$$

where P^{E} is the price paid for grain delivered to the plant and Q^{E} is the quantity of grain delivered to the plant.

In this case, grain now moves either to the terminal market or the ethanol plant. Point s^* will delineate the point of indifference between shipping to the plant or the terminal market. As such, producers located along the line segment $d^{\mathrm{E}} \in [0, s^*]$ will ship grain to the ethanol plant while producers along $d^{\mathrm{T}} \in (s^*, 1]$ will ship to the terminal market. The quantity of grain shipped to the plant and the terminal market is, respectively

$$Q^{\mathrm{E}} = s^* \bar{Q} \tag{A4}$$

$$Q^{\mathrm{T}} = (1 - s^*)\bar{Q}\,. \tag{A5}$$

In equilibrium, the price at the optimal market boundary s^* assures that prices at the terminal market and the ethanol plant adjusted for transportation costs satisfy a no-arbitrage condition:

$$P(s^*) = P^{\mathrm{T}} - r(1 - s^*) = P^{\mathrm{E}} - r(s^* - \mathrm{E}) \tag{A6}$$

where

$$s^* \geq \mathrm{E}.$$

To solve for the optimal market boundary, substitute the demand equations (A1) and (A3) into the no-arbitrage equation (A6), and the quantity shipment equations (A4) and (A5) into the respective demand equations. The solution for the market boundary in terms of the demand parameters, aggregate supply, transportation rate, and ethanol plant location is:

$$s^* = \frac{\alpha^E + rE - (\alpha^{\mathrm{T}} - \beta^{\mathrm{T}}\bar{Q} \ - r)}{(\beta^E + \beta^{\mathrm{T}})\bar{Q} + 2r}. \tag{A7}$$

The optimal boundary solution given by equation (A7) can now be used to solve for equilibrium prices at the ethanol plant site, P^{E}, and the terminal market, P^{T}. These prices reflect the allocation of the total market supply, $\bar{Q}$, between the ethanol plant (which receives the proportion s^*) and the terminal market (which receives the proportion $1 - s^*$).

Although the opening of the ethanol plant impacts all prices along the line segment, this impact varies depending on the location. For example, the ethanol plant causes prices to increase at the terminal because of reduced supplies going

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there. This change in the terminal market price caused by the opening of the ethanol plant is:

$$\text{(A8)} \qquad \Delta P^{\mathrm{T}} = [\alpha^{\mathrm{T}} - \beta^{\mathrm{T}}(1 - s^*)\bar{Q}] - [\alpha^{\mathrm{T}} - \beta^{\mathrm{T}}\bar{Q}]$$

where the first bracketed term on the right-hand side is the terminal market price after the ethanol plant opens and the second bracketed term is the terminal market price prior to opening. Simplifying equation (A8) gives:

$$\text{(A8}'\text{)} \qquad \Delta P^{\mathrm{T}} = \beta^{\mathrm{T}} s^* \bar{Q}.$$

The term $s^*\bar{Q}$ is the lost quantity at the terminal market as a result of the ethanol plant, and the price impact of this lost quantity is determined by the slope of the terminal market demand curve. All producers receive this price enhancement (ΔP^{T}) resulting from the ethanol plant opening even though not all producers ship to the plant.

For those producers who do, the price impact is greater. Specifically, consider the price impact at the point E where the ethanol plant is located. The resulting price change is:

$$\text{(A9)} \qquad \Delta P^{\mathrm{E}} = [\alpha^{\mathrm{E}} - \beta^{\mathrm{E}} s^* \bar{Q}] - [\alpha^{\mathrm{T}} - \beta^{\mathrm{T}}\bar{Q} - r(1 - \mathrm{E})].$$

The first bracketed term on the right-hand side is the equilibrium price at the plant while the second bracketed term is the price at the site of the plant prior to the plant opening. This latter term reflects the terminal market price adjusted for transportation costs. After some algebraic manipulation, the price impact at the plant site is given by:

$$\text{(A9}'\text{)} \qquad \Delta P^{\mathrm{E}} = [(\alpha^{\mathrm{E}} - \beta^{\mathrm{E}} s^* \bar{Q}) - (\alpha^{\mathrm{T}} - \beta^{\mathrm{T}}(1 - s)^* \bar{Q})] + \beta^{\mathrm{T}} s^* \bar{Q} + r(1 - E).$$

The price impact at the site of the ethanol plant (equation (A9′)) consists of three components. First, the term in brackets is the price spread between the ethanol plant and the terminal market, which could be negative if the terminal market price is above the ethanol market price. Second, the term $\beta^{\mathrm{T}} s^* \bar{Q}$ is the effect on the terminal market price from the opening of the plant, which impacts all producers regardless of whether they ship to the ethanol plant or the terminal market. Finally, the term $r(1 - E)$ is the transportation savings to those producers located at the plant site E who formerly shipped to the terminal market, a distance of $(1 - E)$. With the new ethanol plant these producers now ship directly to the plant site E at no cost.[8] Indeed, all producers located to the left of the plant site E (referred to as "upstream" producers) enjoy the same price impacts as those located at the plant. This is because all producers in this region enjoy the same transportation cost savings by shipping to the ethanol plant compared to the terminal market. On the other hand, downstream producers do not enjoy the full transportation cost savings of $r(1 - E)$ because they must haul their grain back to the ethanol plant, at a cost of $r(d^0 - E)$ for some location d^0 where $E \leq d^0 \leq s^*$.

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