Summer 8-1-2022

What is the Value of Ethanol to Nebraska Corn Producers?

Austin Harthoorn
University of Nebraska-Lincoln, austinharthoorn@gmail.com

WHAT IS THE VALUE OF ETHANOL TO NEBRASKA CORN PRODUCERS?

by

Austin J. Harthoorn

A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Agricultural Economics

Under the Supervision of Professors Cory Walters and Kathleen Brooks

Lincoln, Nebraska

August, 2022

WHAT IS THE VALUE OF ETHANOL TO NEBRASKA CORN PRODUCERS?

Austin Harthoorn, M.S.

University of Nebraska, 2022

Advisors: Cory Walters, Kathleen Brooks

In this thesis, we examine the role of local ethanol plants on net price received by Nebraskan corn growers, with net price comprised of the grain buyer's bid onsite less the transportation cost incurred through delivery. As each farm operation is uniquely located between different sets of grain buyers, an ethanol plant impacts each grower's net price to a different degree, depending on location. Exploring this, we use grain bid and transportation cost data based on actual ethanol plants, grain elevators, and sample farm locations in Nebraska, estimating the diversely located corn grower's net prices received from surrounding grain buyers. We find higher net prices available at ethanol plants for a large majority of farm locations considered in this study. This not only indicates that ethanol plants generally offer higher prices than grain elevators; it also suggests the offered price sufficiently compensates for transportation costs and incentivizes corn growers to travel more miles to deliver to an ethanol plant. We observe some cases where corn growers bypass their local elevator and still attain a higher net price at the ethanol plant, while farm locations in closer proximity to the plant achieved as much as $0.54 per bushel more delivering to the ethanol plant over nearby grain elevators. In addition to varying across location, ethanol's impact is also found to differ by ethanol plant size and fluctuate by season. Our findings suggest ethanol plants with larger capacities provide greater value over a wider scope. In addition, the net price differential between ethanol plant and grain elevators is found to be the greatest in Spring.

Author Acknowledgments

Over the past few days, I've had the opportunity to reflect on not only my graduate school experience, but also the state of my life over the course of these last two years. There's been heartache, joy, frustration, sense of achievement, confusion, and so much support. This has been the most transformative time of my life, and I owe it to the great people around me for not only the work done here, but also in the person I've become.

I'll never be able to thank my major advisors, Dr. Cory Walters and Dr. Kate Brooks, enough for their contributions to this paper and my life. Without their guidance and encouragement, the research presented here would be either 1) unclear and unmeaningful or 2) unfinished altogether. The two of them have a positive influence on everyone around them, and I'm so grateful to have been within the scope of that influence these last two years.

Cory – you've been a never-ceasing advocate. You've helped to show me my capabilities far surpass what I tend to believe, and those impacts extend far beyond this paper. Your focus on the big picture and ability to pose tough questions provides the backbone for this work, and you've challenged me to become better in many ways – thank you.

Kate – your fresh perspective, attention to detail, and ability to never lose focus of paper's overall mission was invaluable. The high-level depth and clarity of the story we tell here is largely due to your contribution. Throughout, you have been so kind and helpful, and it's truly been a pleasure working with you.

I would also like to thank Dr. Richard Perrin, the final member serving on this committee. Dr Perrin, simply have your eyes on this paper brings value. By questioning our initial assumptions, this work is of much higher quality and more relevant.

Outside of the great people involved in this thesis, I've been blessed with a phenomenal support system of family and friends. While they didn't write or proofread anything here, their contribution can be found in between the lines, in the spirit of the author.

To my family – Dad, Mom, Haley, Mark, Maria, and Jordan. I simply would not be the person I am today, in the place I am today, without you guys. Thank you, I love you.

To those doing the graduate student life with me – Alie, Jared, and Olivier. Your automatic ability to relate to this challenging life stage/transition and your friendship throughout has kept me going and made this experience so much more.

To some other outstanding friends – Peyton, Will, Racheal, Dane, and Jill. You mean so much. There was no shortage of dark days in my time here, and so many times, you were the ones to bring the light, probably without realizing it. Thank you for being here.

Contents

1. Introduction

Driven by aspirations of reducing greenhouse gas emissions and becoming less dependent on foreign oil, Congress authorized the creation of the Renewable Fuels Standard (RFS) through the passing of the Energy Policy Act of 2005. Since then, ethanol has served as the primary biofuel accomplishing their vision, becoming a staple in the nation's gasoline supply. Since the authorization of the RFS, U.S. ethanol production capacity has grown from 4.4 billion gallons in 2005 to 17.5 billion gallons in 2021, with the total number of U.S. ethanol plants increasing from 81 to 201 (U.S. Energy Information Administration, 2021). Corn, the primary feedstock of ethanol, has seen production grow by 4 billion bushels since the authorization of the RFS – from 11.1 billion bushels in 2005, to 15.1 billion bushels in 2021 (USDA NASS - Quick Stats, 2021). Based on present production capacities, ethanol plants have the capability to consume as much as 6.2 billion bushels annually, over 40% of the most recent corn production estimate.[1]

Following the new policy and the outstanding growth of the corn and ethanol industries, corn growers stood to substantially benefit. Prior to the Energy Policy Act of 2005, limited ethanol production capacity and scattered existing plants made it unfeasible for many corn producers to consider selling their grain to ethanol plants. Instead, those producers relied upon nearby grain elevators when looking to sell. Then, amid ethanol's rapid expansion, the corn market landscape was altered by the introduction of new

[1] Data is calculated based on U.S. Energy Information Administration (2021) national ethanol production capacity estimates, a corn-to-ethanol conversion of 2.8 gallons of ethanol per bushel of corn, and USDA NASS – Quick Stats (2021) national corn production estimates.

demand centers and existing facility expansions. With ethanol plants exhibiting greater demand and having capacity advantages over the typical grain elevator, more competitive prices were offered, and corn producers across the Midwest were now operating in a more complex decision environment – sell to the local elevator or sell to the ethanol plant.

Delivery destination can have a substantial impact on the grain producer's net income, as their revenue stream is largely dependent on the price they receive from the grain buyer. With prices varying between buyers, the producer's bottom line depends on where, and when, the sale is made. Thus, the corn grower must consider the benefits and costs of delivering their grain to each nearby buyer. While case-specific benefits and costs such as relations with the buyer, cost of time, and discount schedules should be weighed individually, producers interested in achieving a higher net price for their crop need to consider posted grain bids and transportation costs at the intended time of sale.

The net price the corn producer receives for their grain is a function of these two elements: the grain bid posted by the buyer and the transportation cost associated with making delivery to the grain buyer. In terms of grain bids, the price the farmer sees will vary from one buyer to the next. Ethanol plants may offer different prices (possibly higher) than grain elevators due to market conditions they face, while grain elevators with storage/rail opportunities likely offer higher prices than elevators without the same capabilities. In addition, differing market dynamics, such as an ethanol plant's continuous corn demand throughout the year, cause the price spread between the plant and surrounding grain elevators to fluctuate across time. While obtaining the highest price is the grower's mission, the corn producer is not *always* better off selling to the location with the highest grain bid. Growers must also consider the cost component of their net price, transportation cost. Transportation cost is specific to each producer's operation – the further they are from the grain buyer, the more miles it is to deliver, and the higher the transportation cost. As a result, producers located closer to a grain buyer can achieve a net price closer to the posted bid, while those located a greater distance away achieve a lower net price. As it stands, grain elevators are more densely located throughout the Midwest compared to ethanol plants, and many producers must travel more miles to deliver their grain to an ethanol plant than to a nearby grain elevator.

With a potential different price available at the ethanol plant and the transportation cost advantage of delivering to a closer buyer, the extent to which a local producer benefits from ethanol facilities is unclear. A producer located near the plant and a producer located farther away may both receive the highest price delivering to the ethanol plant, but the two will not achieve the same net price. Thus, the benefit that ethanol production provides is not the same for any two operations. Meanwhile, the grain bids and transportation costs faced by producers vary across time, so the benefit ethanol provides to any one operation will not be the same from one period to the next. Thus, to study ethanol's benefit to the corn producer, grain bids and transportation costs need to be considered at specific points in time for specific producer locations.

In this study, our objective is to observe the value local ethanol production brings to the diversely located corn grower. By considering sample farm locations in varying proximity to grain elevators and ethanol plants at different points throughout the year, we can identify how ethanol's benefit to corn producers changes as a function of time and space. To achieve our objective, we first expand upon the spatial equilibrium model developed in McNew and Griffith (2005), demonstrating how price observed is dependent on location within a spatial system featuring multiple demand centers. Following this logic, we study ethanol's influence for the case of corn growers in Nebraska, considering sample farm locations within a representative spatial system consisting of grain elevators and an ethanol plant in the state. Based on grain bids and transportation costs within the system, net prices are estimated for each farm location, one for each grain buyer. The value of ethanol production, the focal point of this work, is the difference between the farm's net price from the ethanol plant versus the highest net price from a grain elevator. This estimate is analyzed across different times in the year (Pre-harvest, Harvest, and Spring), as well as across multiple locations, thereby improving our understanding of the ethanol market's influence on producer net price.

Our area of study is Nebraska, a nationwide leader in the production of both corn and ethanol. The state ranks third and second in the country in those areas, respectively, and, following the nationwide trend, has seen production for both segments increase since the authorization of the RFS. From 2005 to 2021, Nebraska corn production has increased from 1.27 billion bushels to 1.85 billion (USDA NASS – Quick Stats, 2021). Over that same time frame, ethanol production capacity has grown from 0.52 billion gallons to 2.29 billion gallons, with the total number of ethanol plants within the state increasing from 11 to 25 (U.S. Energy Information Administration, 2021). Based on current production capacities, Nebraska's ethanol plants have the capability to consume 0.82 billion bushels of corn, roughly 44% of the state's corn production.[2]

[2] Data is calculated based on U.S. Energy Information Administration (2021) Nebraska ethanol production capacity estimates, a corn-to-ethanol conversion of 2.8 gallons of ethanol per bushel of corn, and USDA NASS – Quick Stats (2021) Nebraska corn production estimates.

The ensuing sections of this work will serve to frame the scope of ethanol's influence, explore how diversely located corn growers may be affected, and discuss the magnitude and seasonal variation of those impacts. We first review previous literature discussing the role of ethanol's presence on markets and, specifically, corn price. Thereafter, we describe a theoretical model detailing how the value of local ethanol production to the corn grower varies by location. We then discuss our methods and the data used to estimate this value to Nebraska corn growers. In the final sections, we present our results and their implications, while also offering a few concluding remarks.

2. Literature Review

With the rapid expansion of the ethanol industry over the last two decades being a major source of market disruption, many studies have attempted to measure its economic impact (Sneller and Durante, 2006; De La Torre Ugarte, English, and Jensen, 2007; Low and Isserman, 2009). Brooks et al. (2022), sets its focus on Nebraska, conducting economic impact assessments and quantifying ethanol's impact on Nebraska's economy in terms of employment, labor income, and total output. Other studies have considered the influence of a new ethanol plant on local land values. Fortenbery, Turnquist, and Foltz (2008) did not find a significant difference between agricultural land values in locations with an ethanol plant compared to those locations without one. However, later studies, such as Henderson and Gloy (2009) and Gardner and Sampson (2021), observed increased cropland values resulting from local ethanol plant production.

No matter ethanol's impact on land value, the effects of its expansion extend into how land is used as well. As new ethanol plants may incentivize local growers to plant more acres to corn, several studies consider ethanol's impact on changes to land use, whether that be through crop switching or conversion of non-cropland into corn production. Overwhelmingly, studies found significant increases to corn acreage following ethanol expansion, although the extent of the increase was wide-ranging. Miao (2013) and Fatal and Thurman (2014) find significant positive effects to corn acreage from ethanol plants, with the latter observing increases in acreage up to 300 miles away from the plant site. Brown et al. (2014) and Motamed, McPhail, and Williams (2016) post similar results, while also finding strong evidence of corn acreage expanding into previously uncultivated areas. Finally, Li, Miao, and Khanna (2018) find the increase in ethanol capacity occurring from 2003-2014 to have increased total corn acreage by 3%.

While ethanol has had a noteworthy economic impact and has altered land use patterns across the Midwest, more applicable research to this study exists, considering its impact on prices. Collins (2008), Baier et al. (2009), Chakravorty et al. (2010), Babcock (2011), and Roberts and Tran (2012) all explore how the rise of biofuels is correlated with rising food prices, primarily finding biofuel expansion to have a negligible role in rise of food prices in the late 2000s. The studies state factors such as increased demand for U.S. products and higher energy prices contribute a greater share to the increase in food prices. In this project, however, the focus will remain on the link between ethanol production and corn price, specifically.

Ethanol's impact on corn price is highly correlated, and many studies have considered the influence of ethanol on the price of its primary feedstock. One study, Fortenbery and Park (2008), predicts corn price based on national supply and demand factors, estimating the role of increasing ethanol production. From this, short-run corn price elasticity associated with ethanol production is estimated, indicating a 1% increase in ethanol production leads to a 0.16% increase in corn price. Much of the remaining related literature has looked to examine the impact of ethanol policy (RFS) on corn price, finding wide-ranging results. Anderson and Coble (2008) consider the impact on supply shocks with and without ethanol mandates, finding a 10% reduction in corn supply to cause corn price to rise 10.2% without mandates and 18.1% with mandates, a 7.9% difference. Babcock and Fabiosa (2011) also discover modest attributions to policy, stating $0.14 of an overall $0.59 per bushel improvement in corn price from 2005-2009 to be a direct result of ethanol policy effects, with the remaining $0.45 resultant of natural market expansion. Carter, Rausser, Smith (2012) find more substantial impacts, estimating corn prices to be 30% higher from 2006–2011 than they would have been without ethanol mandates. They also conclude 2012 corn prices would have been 40% lower in the absence of ethanol policy. Condon et al. (2014) synthesizes much of the literature looking at ethanol policy's impacts on corn price, determining a 2.4% increase in corn price for each 10% increase in ethanol production.

This previous literature evaluates ethanol's influence on national corn price. Corn price in any location is a function of two aspects: national corn price and local basis. The national corn price reflects U.S. supply and demand conditions, while grain buyers adjust basis postings to reflect local supply and demand conditions. One study, Lewis and Tonsor (2011), states these local corn markets to have a long-term equilibrium price relationship, moving together across time (i.e., cointegration). In studying the substantial increase of ethanol from 1998 – 2008, the authors find neither new ethanol production nor the number of plants to impact the cointegration of local corn market relationships. While local corn markets continue to move together independent of ethanol's influence, location creates differences among the markets. For example, two studies, O'Brien (2009) and Katchova (2009), find corn prices to be higher in locations without ethanol plants, affirming that 1) spatial differences in corn price exist and 2) an ethanol plant's existence in a local area does not guarantee higher prices relative to those areas without an ethanol plant.

While corn prices could be higher elsewhere, the presence of an ethanol plant represents greater demand for corn in the local area, and its existence is related to higher local corn price. Urbanchuk and Kapell (2002) provide evidence for this, predicting an immediate \$0.05 - \$0.10 improvement in local corn basis following the introduction of a 40 MGY (million gallons per year) ethanol plant. Ferris and Joshi (2004) further affirm this, forecasting corn prices on the farm level to increase 18% from 2003 to 2007 from high ethanol demand. In South Dakota, Olson, Klein, and Taylor (2007) estimate a statewide \$0.24 improvement in corn basis from ethanol production, based on OLS regression results from 2005. The authors also predict the introduction of a 40 MGY ethanol plant would result in a \$0.06 - \$0.16 improvement in local basis and a \$0.03 basis improvement throughout the state. Behnke and Fortenbery (2011) study corn basis over a wider scope, focusing on 1999 – 2009 price data from over 150 grain elevators across the Midwest. In their spatial error components model, the authors consider five primary factors affecting corn basis level: national/local corn production ratio, diesel fuel costs, storage costs, seasonality, and local ethanol production. After estimating coefficients for each of the factors considered, local ethanol production was tied to a $0.07 increase in corn basis in the short run, with price impacts dissipating over time.

It should be confidently said that ethanol plants offer at least some sort of positive benefit to corn prices in their local market. The work of Gallagher, Wisner, and Burbacker (2005) and McNew and Griffith (2005) further affirms this, via a different approach. Rather than achieving one average estimate, these studies consider how the impact of ethanol production on corn price may change across space. In theory, corn prices should be highest near the ethanol plant and decrease as distance to the plant increases, due to the role of transportation costs. Gallagher, Wisner, and Burbacker (2005) consider the introduction of ethanol plant into nine market areas in Iowa. While a plant's introduction should increase local corn price overall, the increase will only benefit producers over a certain distance – within a circular boundary around the ethanol plant. As producers located farther away (outside this boundary) have higher transportations costs, they may deliver elsewhere to achieve a higher net price for their grain. The authors estimate market radii for the nine ethanol plants, finding radius to range from 23.5-50 miles, depending on the market area. In those areas, there was evidence that farm price decreases exactly by the transportation cost as one moves away from the ethanol plant. McNew and Griffith (2005) also study corn price impacts associated with the establishment of a new ethanol plant, developing a spatial equilibrium model to estimate corn price across space. The authors of this study consider corn price impacts of 12 newly opened ethanol plants, estimating positive impacts of an ethanol plant to be felt up to 68 miles on average, with one plant's influence extending up to 150 miles away. Overall, corn basis increased by 5.9 cents per bushel within the plant's sourcing region following its introduction, with price increasing by 12.5 cents on average at the plant site.

Even as Gallagher, Wisner, and Burbacker (2005) and McNew and Griffith (2005) have considered the spatial impacts of ethanol production, past literature has ultimately failed to address ethanol's impact on a major stakeholder: the individual corn grower. Clearly, the role of transportation costs means corn producers derive less benefit from an ethanol plant as distance increases. However, this isn't the entire narrative. Spatial competition for corn bushels exists from other grain buyers in the area. And with grain buyers and producers situated in unique locations in a region, each farm location will benefit from ethanol production to different extent. The existing literature seeks to estimate ethanol's value on average, considering only the representative corn grower. It would then be interesting to consider the case of the heterogenous corn grower, seeking to better understand the impact of ethanol on corn growers in different locations, at various points in time. Thus, we consider the case for sample farm locations using real-time corn prices and transportation costs from existing ethanol plants and grain elevators, providing relevant and in-depth results of ethanol's influence on corn price on a location-by-location basis throughout the year.

3. Model

To estimate ethanol's impact on the corn producer differentiated by location, our model first builds upon the spatial equilibrium model developed in McNew and Griffith

(2005).[3] The U.S. grain distribution system relies on growers, elevators, and transportation networks to move grain from production regions to consumption markets (McNew and Griffith, 2005). In their introductory model, the authors assume grain producers to be distributed along a line segment $d \in [0,1]$, with all grain in the region being delivered to a terminal market located $d = 1$. The terminal market offers price P_T, and all locations upstream from this terminal market are associated with a lesser price $P(d)$, one that is inversely proportional to the distance away from the terminal market, due to the role of transportation costs:

(1) $$P(d) = P_T - r(1 - d)$$

where P_T is the offered price at the terminal market and r is the per unit cost of shipping. In full, $r(1 - d)$ represents the cost of shipping grain from any location d to the terminal market, located at $d = 1$.

In this setup, original grain trade patterns and prices may be impacted by shocks to demand and transportation costs. The introduction of a new ethanol plant E represents one possible demand shock to a local market – one impacting the transportation costs observed by producers. Through entry, the ethanol plant can offer a better net price than the terminal market to some surrounding producers due to transportation cost savings. The terminal market, now receiving less grain, responds by raising their prices to incentivize delivery among locations now delivering to the ethanol plant. As a result, a new spatial equilibrium is established, and a spatial boundary between the two demand centers is created. At this spatial boundary, net price is equivalent between the two

---

[3] Their spatial equilibrium model stems from the agents-on-links model. In the agents-on-links model, production is assumed to occur along a line segments or links. The links contain demand centers.

markets. Producers located on the ethanol plant's side of the boundary receive a higher net price from the plant, while those on the opposing side obtain a better net price from the terminal market.

To investigate the degree to which ethanol production provides value to individual corn growers, we expand on this McNew and Griffith (2005) model, increasing relevancy by considering two initial demand sources prior to the ethanol plant's entry. Thus, our model starts with two demand centers: Grain Elevator a and Grain Elevator b. In a closed system, each elevator is situated along a line segment d, with their reach of acquiring grain extending to the end points $d \in [0,1]$.[4] Corn producers supplying the grain to elevators are assumed to be uniformly distributed along this line segment, situated at location d. Figure 1 portrays this two-elevator demand system graphically.

Each grain elevator has their respective location along the line segment, a and b, and price, P_a and P_b, which is equal to their posted bid at the location of the facility.[5] As one moves along the line segment away from the elevators in either direction, this price slopes downward, as increases in transportation distances create lower net prices. Thus, two unique net prices $P(d)_a$ and $P(d)_b$ are available at each unique location d, with the difference between the posted bid for grain buyer i, P_i, and the price specific to that

[4] Note: Line segment d may adjust as elevator prices and transportation costs change. Outside the endpoints are other elevators acquiring grain. The endpoints represent spatial boundaries with these competing elevators – locations where corn producers receive equivalent net prices (grain bid less transportation cost) between grain buyers. Elevator a and Elevator b may extend their reach beyond the line segment endpoints, but corn producers located outside these endpoints will achieve higher net prices elsewhere.

[5] Grain bids between elevators vary, even for those in close proximity. In our model, it is assumed Elevator b is positioned on a main rail line and has unit loading capacity. As such, Elevator b has a transportation cost advantage over Elevator a, and as a result, $P_b > P_a$.

location, $P(d)_i$, being equal to the cost of transportation. All producers along the line segment receive a higher net price by delivering to one of the two elevators, apart from those located at spatial boundary s, who receive equivalent net prices at each elevator and are indifferent in where delivery is made. With producers interested in selling and delivering to the location where they achieve the best net price, those growers located $[0, s]$ deliver their grain to Elevator a and travel $|a - d|$, while those located $[s, 1]$ deliver to Elevator b and travel $|b - d|$. As location 0 and location 1 represent the grain sourcing boundaries for each elevator, it is assumed any producer located to the left of $d = 0$ and to the right of $d = 1$ would achieve a higher net price from a grain buyer outside this two-elevator demand system.

Now, assume an ethanol plant also exists along the line segment at a location between the original two elevators ($a < E < b$). Due to its capacity advantages and greater demand, the ethanol plant offers a higher price than the elevators, P_E, and captures a portion of the bushels previously delivered to Elevator a and b under the two-elevator demand system. As in McNew and Griffith's (2005) model, increased competition for bushels translates into higher prices offered by competing grain buyers. In this case, the grain elevators offer higher prices with the presence of the ethanol plant than in the original two-elevator demand system, to attract a portion of the bushels that would otherwise be delivered to the ethanol plant. Figure 2 illustrates the existence of an ethanol plant within the original two-elevator demand system, where $P_a < P_b < P_E$ and E is located equidistantly between the two grain elevators.[6]

---

[6] The two elevator, one ethanol plant spatial demand system creates a simple, two-dimensional figure. This model behaves in a way so that an x-dimensional figure is created based on x number of grain elevators in

Under this new demand system, a new spatial equilibrium is established. With the ethanol plant included, new unique net prices $P(d)_i$ are available along line segment d. In addition, two spatial boundaries, s_1 and s_2, are created, and producers located between these boundaries now achieve the highest net price by delivering to the ethanol plant. Those producers located outside (s_1, s_2) receive higher net prices from their respective elevators but still benefit indirectly from the overall higher prices within the demand system. As was the case for those located at spatial boundary s in the original demand system, producers located at s_1 and s_2 receive equivalent net prices at their respective elevator and the ethanol plant and are indifferent between which delivery is made. Elevator a will source all grain along $[0, s_1]$, ethanol plant E sources all grain along (s_1, s_2), and Elevator b sources all grain along $[s_2, 1]$.[7] In terms of grain transportation, corn producers will travel $|i - d|$ to their respective grain buyer i.

All producers are better off in this scenario, achieving higher net prices from the increased competition in the region. However, producers attaining the highest net price at the ethanol plant achieve an additional value because of the higher offered prices and/or reduced transportation costs. This value is evident in the difference between net price received at the ethanol plant versus net price received at grain elevator, identified as area A in Figure 2. With ethanol impacting the pricing structure of this system, this area can be defined as the value of ethanol production to the corn producer.

---

the demand system. For simplicity, our model does not extend beyond this simple two elevator system, although our approach utilizes a three-elevator demand system.

[7] As higher prices are offered with the ethanol plant included, Elevator a and b both increase their grain sourcing outside of endpoints 0 and 1, respectively. For simplicity, we do not show this effect.

For those farms located outside the spatial boundaries, the value provided by ethanol is inherently zero in this model. The true value is greater than zero, as the heightened price competition in the region from the sheer existence of the ethanol plant provides an unobserved value to farms located outside of spatial boundaries s_1 and s_2. However, for those farms located between spatial boundaries s_1 and s_2, the value provided by ethanol is positive. As one can see in Figure 2, that value is unique to each operation. It is dependent on the farm's proximity to the elevators and the ethanol plant, as well as the strength of each grain buyer's bid.

In the case of Figure 2 the value derived from ethanol between s_1 and s_2 is different for locations on each side of the plant. The ethanol plant's value is comparably greater for farms located to the left of E than those located the same distance from the plant to the right. In addition, the value from the ethanol plant extends over a greater distance towards Elevator a than to Elevator b. This has to do with the positioning of the ethanol plant in accordance with the original spatial boundary s, which is created according to the price offerings of the two elevators.

Let's consider individual scenarios for each producer location. Producers located $[s, E]$ all derive the exact same value from ethanol production. These locations are better off delivering to Elevator b than Elevator a. In addition, the ethanol plant is located enroute to Elevator b. As a result, all producers in this range enjoy the exact same transportation cost reduction by making delivery to the ethanol plant over the elevator. So, although locations closer to s observe a comparatively lower net price, the value that ethanol production adds to these farms is the same for each.

For the remaining producers receiving a positive value from ethanol production, those located $[s_1, s]$ and $[E, s_2]$, the value derived decreases as one moves away from the ethanol plant E. In both cases, farms haul their grain back to the ethanol plant, against the natural flow of grain that would occur if the ethanol plant ceased to exist. These producers do not receive the full transportation cost savings of those farms located $[s, E]$, and thus, derive less value from ethanol production.

Farms located at and outside of spatial boundaries s_1 and s_2 do not directly receive value from delivering to the ethanol plant. Those located at the spatial boundaries receive equivalent prices between elevator and ethanol plant, and those outside the boundaries receive a better net price by delivering to their nearby elevators. As a result, these locations do not derive a direct benefit from ethanol production. However, the higher prices offered by grain elevators in this demand system creates an indirect benefit that is enjoyed equally by all locations along the line segment. The heightened price competition from the ethanol plant's existence allows all producers along the line segment to achieve a higher net price, including those not delivering to the plant. This benefit can be clearly seen in the comparison of grain bids within the region before and after the introduction of an ethanol plant. In the case where an ethanol plant already exists within a region, as is assumed in the scope of this project, this shared benefit is unobservable, however. Thus, the value of ethanol identified in this study is the value corn producers derive in present time.

4. Approach

Consider a scenario similar to the spatial demand system laid out in Figure 2, in which corn growers have the option of delivering to two grain elevators (a and b) and an ethanol plant (E), but now also have an additional third grain elevator c to consider.[8] Under this scenario, four different net prices are available at any farm location d, one for each combination of price received and cost of shipping associated with each grain buyer.

(2) $$P(d)_a = P_a - r|a - d|$$

(3) $$P(d)_b = P_b - r|b - d|$$

(4) $$P(d)_c = P_c - r|c - d|$$

(5) $$P(d)_E = P_E - r|E - d|$$

We derive an estimate for the value of ethanol production at any farm location d by finding the difference between $P(d)_E$ and max $[P(d)_a, P(d)_b, P(d)_c]$. This is the difference between the net price farm location d receives at the ethanol plant and that of the best-priced elevator. It is this difference that we are interested in calculating – the value of ethanol production at any farm location d.

To understand the value of ethanol across time and space, we consider multiple ethanol plant regions at different times throughout the crop year. We seek to observe this value based on actual grain buyer bids and transportation cost estimates using sample farm locations. Based on the layout of ethanol and grain elevator sites, farm locations derive a unique value from ethanol production specific to the grain bids and transportation cost faced in that location. The following paragraphs detail the process by

---

[8] See footnote 6. This three-elevator, one ethanol plant spatial demand system creates a three-dimensional figure. For simplicity, we only discuss a two-elevator system in our model.

which these values, the premiums farm locations receive from an ethanol plant over a grain elevator, are observed.

In total, this study focuses on six “regions” across the state of Nebraska where ethanol plants exist. The ethanol plants vary in production capacity and location within the state. Table 1 details this variation among the selected ethanol plants. Due to the differences in location and capacity among the plants, they vary in price competitiveness in relation to competing grain buyers. An ethanol plant offering more competitive prices will provide more value to local corn growers over a greater distance. Thus, the level of value farm locations derive from ethanol production will vary from one region to the next.

Within each region, three accompanying grain elevators are chosen to represent competing grain buyers within range of the ethanol plant. The three grain elevators vary in location relative to the plant, as well as in terms of rail access and loading capacity. Table 1 details these differences among the selected elevators. Grain elevators with superior rail access and loading capacities are more efficient and characteristically offer more competitive grain bids. As the price spread between the ethanol plant and the elevators diverges and converges across time, so too will the amount of benefit corn growers attribute to ethanol production. In total, with the six ethanol regions, eighteen grain elevators are considered in this study.

For each of the three grain elevators within a region, four sample GPS coordinates were chosen to serve as farm locations. The farm locations allow us to estimate ethanol’s value to those specific locations. The method for choosing the four sample farm locations is the same for each grain elevator location. In that, each sample farm location chosen is in proportional distance to the ethanol plant and its associated grain elevator. The four farm location conditions are as follows: 1) near the ethanol plant, 2) equidistant between ethanol plant and grain elevator, 3) near the grain elevator, and 4) beyond the grain elevator. Additional details regarding these conditions can be found in the data section. With four farm locations associated with each grain elevator, a total of seventy-two farm locations are under scope in this study.

For each farm location, four unique prices are available, one associated with each grain buyer in the region. Actual grain bids and projected transportation costs for each grain buyer can be used to estimate these farm prices. To understand how ethanol value changes throughout the year, the four prices available to any one farm location were estimated at three distinct times: Pre-harvest, Harvest, and Spring. Each season represents an important component in producers' decision-making. Pre-harvest contracting offers producers fixed prices to help understand harvest revenue prior to having a finished crop, while harvest delivery is when the majority of crop is sold, and spring sale offers producers potential returns to storage. Grain bids among the four buyers were observed and transportation costs estimated for each season to arrive at a farm price associated with each grain buyer. This was repeated for the years of 2009 to 2021 to obtain a larger sample size and further understand how the value of ethanol production changes across time.

Ethanol's value for each farm location was observed by finding the difference between the farm's net price at the ethanol plant and the farm's net price at the highest-priced grain elevator for each season over the years considered. Each farm location receiving the best price at the ethanol plant derives a positive value from ethanol production, with the difference between this price and the price received at the “next-best” grain buyer being the quantifiable value derived. In Figure 3, these farm locations appear along the line segment $d \in [0,1]$ introduced in our model. This allows us to consider several scenarios as to how farm locations will benefit from ethanol differently. As described, there are four farm proximity conditions for each ethanol plant and grain elevator combination, all attributing unique value to the ethanol plant in their region. With the plant offering a higher bid than both grain elevators in this scenario, the farms near the ethanol plant and those located equidistant between the buyers all obtain a higher net price at the ethanol plant. In addition, the ethanol plant’s bid is high enough in relation to that of elevator a so that even the farm near a is better off delivering to the plant, deriving a positive value from local ethanol production. Grain elevator b offers a more competitive grain bid, and as a result, the farm near b obtains a higher net price there. Likewise, both farms located beyond their respective grain elevator do not derive value from delivering to the ethanol plant. In these locations, where farms are better off delivering to a nearby grain elevator, the ethanol premiums observed are negative. However, the present value the farms derive from the plant is not negative. These farms fundamentally derive zero value from the ethanol plant, as they are no worse off for delivering elsewhere. Across thirteen years and three seasons within each year, thirty-nine ethanol value observations were obtained for each of the seventy-two farm locations.

5. Data

This section examines the origins of the various data used throughout this work. The scope of this study takes place in Nebraska, the nation’s second-leading ethanol producer, third-leading corn producer, and a relevant site for this study focusing on the link between ethanol production and corn price on the farm. Net farm price is comprised of the grain bid and transportation cost, with all findings expressed on a dollars per bushel basis. Bid postings from grain elevators and ethanol plants within Nebraska are used, while transportation costs are based on rental truck rates. Key characteristics of these grain buyers are presented in Table 1, while summary statistics for the grain bid and transportation cost data are presented in Table 2. Based on data limitations, the range of this study takes course over thirteen years, from 2009-2021.

The corn price data was obtained from DTN, an agricultural company specializing in data delivery and analysis. The data contains daily price postings for grain merchants located across the state of Nebraska. Specifically, cash price and basis postings were collected for both the spot and new crop markets, with spot bids representing present-day delivery and new crop bids indicative of harvest delivery. Corn bids from each of the six selected ethanol plants, as well as a total of eighteen elevator locations (three locations for each ethanol region), were used for analysis. Ethanol plants were chosen based on variation in capacity and location, as well as price data availability. For the purpose of our study, findings from each ethanol plant region are grouped by plant production capacity size. By doing this, one can observe the link between ethanol plant size and the magnitude of ethanol premiums observed within the region. The six ethanol plants are grouped into Large, Medium, and Small categories. Of these, one plant has the capacity to process more bushels of corn than the other five combined, so all observations from this specific plant are grouped into the Large category. Three plants have production capacities comparable to the average ethanol production capacity in Nebraska and are grouped into the Medium condition. The remaining two ethanol plants have among the smallest production capacities in the state and are grouped into the Small condition. Grain elevators, on the other hand, were chosen based on corn basis bid competitiveness, location relative to the ethanol plant, location relative to other grain elevators, company ownership, rail access (or lack thereof), and train-car capacity. This price data provides four gross price offerings available to each farm: one from the ethanol plant, and the others from each of the three grain elevators in the region.

Rather than using corn price from any one day, corn price averages were calculated based on two-week windows to provide a less biased figure. For our analysis, two-week corn price averages were observed at three distinct seasons during the year. The three seasons are: Pre-harvest, Harvest, and Spring. Observing corn prices at different times of the year allows for the ability to understand how ethanol's value to corn growers shifts across the growing season. Table 3 summarizes the pricing windows, providing the average time frame for each season, as well as the range. Overall, corn prices were observed at each of the three time frames during the year, each year from 2009–2021, for a total of thirty-nine seasonal price observations in this study.

Pre-harvest is relevant to consider, as it is common for corn growers to sell bushels in advance of harvest, avoiding seasonal lows often occurring at harvest-time. Under this condition, corn price is set at the time of sale and bushels are delivered at a later date. Thus, new crop prices and harvest-time transportation rates are used. The two-week pricing window for the Pre-harvest is based on data from USDA's Crop Progress Report. Based on weekly "corn silking" percentages in Nebraska, the point in time in which the state achieved 75% silking is estimated to the closest day possible. From this date, usually occurring in late July, the day exactly 3 weeks afterward is chosen. Grain bids ranging from one week before to one week after this day are then averaged to be used as the pre-harvest price for each grain buyer. This time-period is chosen specifically to account for the point in the growing season where growers can begin accurately predicting yield. The yield component method, a popular yield prediction method used by growers, can be done as early as the R3 stage in corn, which typically occurs 18-22 days after silking (Nielsen, 2021).

The Harvest season is included to consider harvest-time price conditions. Nearly all corn growers deliver and sell at least a portion of their grain directly from the field, so this time frame is one of interest to the farmer. As with Pre-harvest, the two-week time window for the Harvest season is chosen based on estimates in the USDA's Crop Progress Report. Using a similar method, the day Nebraska reaches 50% harvest progress is estimated each year. From this selected day, grain bids ranging from one week before to one week after are averaged, and this price is used as the average harvest price for each location.

Spring is included in this analysis to consider a relevant non-harvest time frame where corn producers may have incentive to sell their grain. As it stands, seasonal highs in corn price often occur during the months of May and June (Center for Agricultural Profitability, 2022), and higher corn prices may induce additional corn movement.[9] The two-week pricing window for Spring is chosen to occur exactly 7 months after each

[9] Waiting to sell is not without cost, as storage costs are incurred post-harvest. While storage costs are relevant for the grower to consider, they are external to this study. Storage costs to the producer will be the same independent of where the grain is sold, and they will not impact a corn producer's attributed value to ethanol.

harvest two-week window. In the average production year, May and June fall approximately 7 months after harvest. Also, with achievement of 50% harvest progress ranging anywhere from September all the way to late-November in recent years, choosing a 2-week window specific to the previous year's harvest provides a bit of consistency from year-to-year in terms of grain flow.

Transportation cost is the centerpiece in this work. Difference in location, as captured by transportation cost, is what causes the value provided by an ethanol plant to vary from one farm to the next. Farms located closer to an ethanol plant will have the lowest transportation cost associated with making delivery, and thus, will derive the most value from the ethanol plant. Farms located farther away will have a steeper transportation cost and may derive no value from an ethanol plant if they are able to achieve a higher net price by delivering their grain elsewhere.

Transportation cost data was sourced through Grain Truck and Ocean Rate Advisory (GTOR) compiled by USDA–AMS. GTOR provides a quarterly overview of the transportation market for grain trucks and ocean freight. Important for our research, GTOR compiles estimated truck availability, current truck use, and future truck use to report rate per mile figures for grain trucks. Rates are estimated for each of the 5 geographic regions, with separate rates for 25-mile, 100-mile, and 200-mile travelling distances. The rates are reported on a per loaded mile basis and serve to capture the rental rate of grain trucks, accounting for all cash and non-cash costs of operation. As we are considering grain buyers in close proximity to farms, we use the 25-mile rate for this study. Although Nebraska lies within the Midwest Region in the GTOR report, we use the reported national rate due to limited regional data availability prior to 2015. As

GTOR is compiled quarterly, the transportation rate used for each season will be the one as reported in the corresponding GTOR report for that quarter. Using a standard truckload capacity of 1000 bushels (Nafziger, 2019), the per loaded mile rate is converted into a per bushel transportation cost, making it possible to arrive at a net farm price expressed in dollars per bushel.

Transportation cost is specific to each farm location, as distance to ethanol plant and elevator changes spatially. To provide some consistency among chosen farm locations for this study, the number of miles to elevator and to ethanol plant for each farm will remain proportional across all six ethanol plant regions. For each of the three elevator locations within a region, four farm locations are developed, amounting to a total of 12 farm locations within each region. Each of the four farm locations are located a different proportional distance away from their associated elevator and the ethanol plant. The four conditions are 1) near the ethanol plant, 2) equidistant between ethanol plant and grain elevator, 3) near the grain elevator, and 4) beyond the grain elevator. Table 4 summarizes the farms' proximity between ethanol plant and grain elevator for each of the four location conditions in mileage terms.

Farm location conditions 1, 2, and 3 are all located in between the elevator and ethanol plant. The "near the ethanol plant" farm is located at a point 10% of the total distance from the ethanol plant to the elevator. Similarly, the "near the grain elevator" farm is located at a point approximately 10% of the total distance from the grain elevator to the ethanol plant. The "equidistant between" farm location is located at the midpoint between the ethanol plant and elevator. Farm condition 4, the "beyond" farms, are located on the other side of the grain elevator, where making delivery to the ethanol plant would theoretically require driving by the grain elevator. These farms are situated so that they are the "equidistant between" number of miles away from the grain elevator. However, as they are located on the opposite side, they are three times that distance away from the ethanol plant.

Using these criteria and Google Maps technology, sample GPS coordinates are chosen to represent the farm locations under scope in this study. With four farms for each elevator, three elevators in each region, and six ethanol plant regions, a total of 72 farm coordinates across Nebraska are chosen for estimating the net price difference between delivering to the regional ethanol plant as compared to delivering to a grain elevator. This price difference will vary for each farm location, and all will derive a unique value from ethanol production specific to the grain bids and transportation cost faced in that location. Refer to Appendix A for an extensive geographic view of each of the ethanol plant regions used in this study.

6. Results

Results suggest ethanol's value to corn growers to be positive for most farm locations across the six ethanol plants considered in this study. Each data point in Figure 4 represents an individual ethanol premium[10] observed by a farm location within a season. The data on the right side on the dividing line indicates instances where growers

---

[10] In these results, "ethanol premium" represents the corn grower's net price advantage of delivering to the ethanol plant over a grain elevator. A grower achieving an ethanol premium of $0.10 per bushel would indicate that the corn grower obtains a net price that is $0.10 per bushel higher at the ethanol plant than the best-priced grain elevator in the region.

achieve a higher net price at the ethanol plant, whereas the data on the left represents instances where the grower achieves a better price at a grain elevator. Although negative ethanol premiums are observed, this is not indicative of farms attributing a negative value towards local ethanol production. These simply tell how much better off the grower is at a grain elevator, and in these instances, the value growers attribute to local ethanol production is inherently zero. In 1513 of 2140[11] (71%) instances, farm locations achieved a greater price by delivering to the ethanol plant. Across all six regions, the average ethanol premium was $0.09 per bushel, with the producers achieving as much as $0.54 per bushel more at the regional ethanol plant.

In terms of ethanol plant size differences, the results shown in Figure 4 suggest larger ethanol plants provide higher premiums. Ethanol plants with greater capacities exhibit greater demand for corn, and to remain in operation, must attract a larger quantity. Offering a higher corn bid than competitors is necessary to obtain more grain, and this translates directly to a greater ethanol premium received by corn growers in the region. The larger ethanol plants may also hold production efficiency advantages over smaller plants, making the larger plants more cost-effective and more able to maintain profitable margins while still offering higher grain bids. In any case, the region featuring the large ethanol plant exhibits the most positive ethanol premiums to corn producers, averaging $0.20 per bushel and ranging from -$0.06 to $0.53 per bushel. The regions including medium-sized ethanol plants also exhibit positive ethanol premiums on average, at $0.06

[11] Across the six ethanol regions, there are a total of 72 farm locations. Ethanol premium is estimated for each farm across the 39 time frames considered in this study, for a total of 2808 ethanol premium observations. Of these, grain bid was missing in 668 instances. These were excluded, resulting in the 2140 ethanol premium observations.

per bushel, although these observations occur over a larger range, from -$0.31 to $0.49 per bushel. Average ethanol premium in regions with small ethanol plants also range widely, from -$0.37 to $0.54 per bushel, with the overall average being positive, at $0.03 per bushel.

As our objective is to consider how the diversely located corn producer benefits from local ethanol production, it is more relevant for us to examine ethanol premiums for each farm location condition rather than an overall average. While it's helpful to note the average farm location in our study attributes $0.09 per bushel to ethanol production, we are chiefly interested in the degree to which *each* farm location benefits. For a complete overview of ethanol premiums among the four farm locations, summary statistics are provided in Table 5.

Figure 5 divides the ethanol premiums from Figure 4 into those premiums observed for each of the four farm location types. As one could infer, ethanol premiums increase as distance to the ethanol plant decreases. For farm operations located on the other side of a grain elevator in relation to the ethanol plant, most were able to obtain a higher net price from the elevator. However, in 227 of 535 (42%) of instances, growers were better off delivering to the ethanol plant, even as this would mean directly bypassing a nearby grain elevator[12]. The other three farm proximities all achieved a higher net price from the ethanol plant on average, even those operations located very near to a grain elevator. Just over half of farm operations in the near elevator condition

---

[12] In the scenario where the "beyond" farm obtains a higher net price at the ethanol plant, our model indicates a situation where *no* farm location along the line segment achieves a higher price at the grain elevator. Due to the model's assumptions, the grain elevator will not source any grain. In a practical sense, however, there are external factors to our model, such as the nonlinearity of grain production, that would allow the grain elevator to remain in operation.

were better off at the ethanol plant. For those farm operations equidistant between the grain buyers and those near the ethanol plant, nearly all attained a higher net price from the plant. In only 48 of 535 (9%) observations were growers located between the buyers better off delivering their grain to a regional grain elevator. Similarly, growers located near the ethanol plant saw a better net price at the plant in 521 of 535 (97%) observations. On the high side, growers were able to achieve as much as $0.48 and $0.54 per bushel more at the ethanol plant for the equidistant and near ethanol plant proximities, respectively.   Across the board, more positive ethanol premiums are tied to those operations within larger ethanol plant regions, independent of farm proximity. Generally, the most positive premiums are found within the Large ethanol region, followed by the Medium and Small regions, respectively. Considering the Large region specifically, nearly all farm operations within the region derived positive ethanol premiums, no matter the farm's location. In 452 of 468 (97%) instances, the farm location was better off at the ethanol plant. Even for the most distant farm operation in this region, located 56 miles away from the ethanol plant, a $0.09 per bushel average ethanol premium was obtained, though in one season the spread was as great as $0.29.

Figure 6 serves to demonstrate the differences between farm proximities more plainly. These yearly observations are averaged across all ethanol plant locations. Overall, "beyond" farm operations achieved an average ethanol premium of -$0.02 per bushel, while "near elevator" farm operations achieved a positive premium on average, at $0.02 per bushel. "Equidistant between" farm operations achieved an average ethanol premium of $0.13 per bushel, and "near ethanol plant" farm operations achieved $0.22 per bushel more at the ethanol plant.

While the magnitude of ethanol’s value to corn producer is revealed to be dependent on location, we also investigate whether the time of year impacts ethanol premiums. Figure 7 and Figure 8 showcase ethanol premiums for three seasons considered in this study: Pre-harvest, Harvest, and Spring. Pre-harvest reflects late-summer prices for harvest delivery, Harvest reflects mid-fall spot price conditions, and Spring represents late-spring spot price conditions. So as to better showcase differences, seasonal results presented here are those for the “equidistant between” farm locations only. As each farm proximity is subject to the exact same grain bids and transportation rates within a season, the seasonal differences will be consistent across the four farm location conditions.

Figure 7 depicts ethanol premiums across the ethanol plant region sizes for each of the three seasons. At first glance, the seasonal differences appear relatively minor, although slightly more positive ethanol premiums may be associated with Spring compared to Harvest and Pre-harvest. In addition, the difference in premiums between seasons seems to vary for the different ethanol plant sizes. The difference between Spring and Harvest premiums for the Small and Medium regions are greater than for the Large region. Ethanol premiums do not change much across seasons for the Large region, but the greater premiums in Spring for the Medium and Small regions is notable. For the Large region, average ethanol premium is $0.23 per bushel at Harvest and $0.24 per bushel in Spring. Average ethanol premium in the Medium region increases from $0.08 per bushel at Harvest to $0.12 per bushel in Spring, while the Small region increases from $0.05 per bushel to $0.12 per bushel.

The greater ethanol premiums available in the Spring can perhaps be explained by demand differences between grain elevator and ethanol plant. Contrary to grain elevators, ethanol plants need consistent corn flow to remain in operation year-round. Grain elevators, on the other hand, may acquire most of their grain at harvest time and not exhibit as strong of demand the rest of the year. Thus, ethanol plants may offer comparably higher prices at non-harvest time frames to incentivize delivery, resulting in higher ethanol premiums to corn growers. While the data from the medium-sized and smaller ethanol plants follows this logic, the results from the large ethanol plant do not strongly suggest greater ethanol premiums in Spring. This may be due to the plant's prominent role in Nebraska corn demand. With an annual operating capacity near 200 million bushels of corn, the one plant itself is responsible for one-quarter of Nebraska's ethanol production capacity, while having the capability to consume 10% of Nebraska's annual corn production.[13] Being so large, the ethanol plant likely holds efficiencies over competitors and offers higher prices to corn growers, resulting in greater ethanol premiums. Already offering the highest price, the ethanol plant may not need to incentivize delivery during non-harvest months in the same way as ethanol plants with smaller operating capacities.

Figure 8 averages the seasonal observations across ethanol plant to more evidently illustrate how ethanol premium varies by season. Just as before, Figure 8 also exhibits the case for the " equidistant between" farm proximity. Although the greatest ethanol premiums seem to be available in Spring, there is also some evidence forward

[13] Data is calculated based on U.S. Energy Information Administration (2021) Nebraska ethanol production capacity estimates, a corn-to-ethanol conversion of 2.8 gallons of ethanol per bushel of corn, and USDA NASS – Quick Stats (2021) Nebraska corn production estimates.

contracting grain prior to harvest translates to higher premiums than spot sale at harvest. The Pre-harvest condition, representative of a forward contract, has an average ethanol premium of $0.13 per bushel among all ethanol regions. At Harvest, the average premium is $0.10 per bushel. This is logical, as abundant corn supply at harvest-time means ethanol plants may not need to offer more competitive prices and incentivize delivery to remain in operation. Prior to harvest, ethanol plants may offer higher prices in relation to competitors to ensure they acquire an adequate number of bushels at harvest to remain in operation in the ensuing months.

7. Conclusion

Ethanol's expansion over the last two decades has enabled many growers in the Midwest to enjoy higher offered prices for their grain. However, due to the role of transportation costs, those operations located closer to the ethanol plant see the greatest net price differential between the plant and the next-best buyer, and operations located farther away may be able to achieve a greater price elsewhere. To determine which operations benefit from ethanol production and to what extent, this study examines the dollar value corn growers located in varying locations attribute to ethanol production in their region.

The study is guided by an expanded upon model of McNew and Griffith (2005). By considering a spatial demand model featuring two grain elevators and an ethanol plant, one may depict the value any location attributes to ethanol production, as it is dependent upon grain bids and transportation cost. We consider ethanol plants, grain elevators, and sample farm locations in Nebraska for this study. We examine how the price difference between delivery to the ethanol plant and delivery to a grain elevator varies by the ethanol plant, the season, and the farm proximity considered. Our findings suggest that ethanol plants with larger capacities provide greater value over a wider scope, and ethanol premiums are greatest in Spring. A large majority of farm locations in this study derived a positive value from ethanol production on average. Some were able to bypass their local elevator and still attain a higher price at the ethanol plant, while others achieved as much as $0.54 per bushel greater at the ethanol plant.

We recognize several limitations to exist in this study, with potential implications to our results. Due to price data availability, we do not consider ethanol's role prior to 2009. In addition to this, grain bids from grain elevators and ethanol plants were occasionally missing. In those cases, ethanol premium observations were excluded from our analysis. Our study was also limited by the number of ethanol plant regions and grain elevators considered. Of Nebraska's twenty-five ethanol plants, six were included here. Including more ethanol regions in analysis would result in a more accurate prediction of ethanol premiums in the state. In addition, only three grain elevators were considered within each region. The number of grain buyers chosen was again constricted by price data availability, and while those chosen well-represent the wide-ranging characteristics of Nebraska's grain buyers, a more complete regional analysis would be desirable. Related to this, we do not consider impacts of other grain buyers within the regions considered, including other ethanol plants, grain elevators, feedlots, etc. Finally, the GPS coordinates representing farm locations, as well as the number of farm locations in each region, are subjective to this study and its analysis. If one were to consider additional farm locations near the ethanol plant, ethanol premiums would appear greater overall. On the other hand, if this study considered more expansive ethanol regions, including farm locations a greater distance from the ethanol plant, ethanol premiums would appear lesser. The positive impact of local ethanol production on surrounding corn producers should remain, as the wide range of farm locations used in this study serves to objectively estimate ethanol's role, but it should be noted the results presented here tell one specific narrative and altering the arrangement would result in different attributed values to local ethanol.

Capitalizing on some of these limitations presents some interesting extensions to the research presented here. With price data limited prior to 2009, we are unable to consider the impact of ethanol's expansion on the diversly-located corn producer. Evaluating the net price received for corn growers in different locations prior, at, and following the introduction of an ethanol plant would provide a more complete analysis of the grower's value to local ethanol. Another extension includes considering the case over a different geographical region than Nebraska only. In addition, choosing many sample farm locations within an ethanol region and focusing on equal representation of location would result in a more extensive evaluation, enhancing our view on how local ethanol is valued differently across farm locations.

References

Anderson, J. and K. Coble. (2010). "Impact of Renewable Fuels Standard Ethanol Mandates on the Corn Market". *Agribusiness*, 26 (1), 49–63.

Babcock, B. (2011). "Impact of Alternative Biofuels Policies on Agriculture, Biofuels Industry, Taxpayers, and Fuel Consumers." *Proceedings at the 2011 Agricultural Symposium*. Federal Reserve Bank of Kansas City.

Babcock, B.A. and J. F. Fabiosa. (2011). "The Impact of Ethanol and Ethanol Subsidies on Corn Prices: Revisiting History." CARD Policy Brief 11-PB5, *Center for Agricultural and Rural Development*, Iowa State University.

Baier, S., M. Clements, C. Griffiths, J. Ihrig. (2009). "Biofuels Impact on Crop and Food Prices: Using an Interactive Spreadsheet". *Board of Governors of the Federal Reserve System*. Washington, D.C.

Behnke, K. and T.R. Fortenbery. (2011). "The Impact of Ethanol Production on Local Corn Basis." *Proceedings from the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management*. St. Louis, MO.

Brooks, K., T. Meyer, E. Thompson, and C. Walters. (2022). "Economic Impacts of the Nebraska Ethanol and Co-Products Industry (2018-2019)." Working Paper, Department of Agricultural Economics, University of Nebraska-Lincoln.

Brown, J. C., E. Hanley, J. Bergtold, M. Caldas, V. Barve, D. Peterson, R. Callihan, J. Gibson, B. Gray, N. Hendricks, N. Brunsell, K. Dobbs, J. Kastens, and D. Earnhart. (2014). "Ethanol Plant Location and Intensification vs. Extensification of Corn Cropping in Kansas". *Applied Geography*, 53, 141–48.

Carter, C. A., G. Rausser, and A. Smith. (2013). “The Effect of the US Ethanol Mandate on Corn Prices.” Working Paper, Department of Agricultural and Resource Economics, University of California at Davis.

Center for Agricultural Profitability (CAP). University of Nebraska–Lincoln. Crop Price Patterns. June 2022. Web. < https://farm.unl.edu/crop-price-patterns >

Chakravorty, U., M.H. Hubert, M. Moreaux, and L. Nostbakken. (2010). “Will Biofuel Mandates Raise Food Prices?” Working Paper No. 2011-01, University of Alberta.

Collins, K. (2008). “The Role of Biofuels and Other Factors in Increasing Farm and Food Prices: A Review of Recent Development with a Focus on Feed Grain Markets and Market Prospects”. Report commissioned by Kraft Food Global, June 19, 2008.

Condon, N., H. Klemick, and A. Wolverton. (2014). “Impacts of Ethanol Policy on Corn Prices: A Review and Meta-Analysis of Recent Evidence.” *Food Policy*, 51, 63-73.

De La Torre Ugarte, D., B. English, and K. Jensen. (2007). “Sixty Billion Gallons by 2030: Economic and Agricultural Impacts of Ethanol and Biodiesel Expansion”. *American Journal of Agricultural Economics*, 89(5), 1290-1295.

Fatal, Y. and W. Thurman. (2014). “The Response of Corn Acreage to Ethanol Plant Siting”. *Journal of Agricultural and Applied Economics,* 46(2), 157–171.

Ferris, J. and S. Joshi. 2004. "Evaluating the Impacts of an Increase in Fuel-ethanol Demand on Agriculture and the Economy". *Proceedings from the American Agricultural Economics Association Annual Meeting*. Denver, CO.

Fortenbery, T.R. and H. Park. (2008). "The Effect of Ethanol Production on the U.S. National Corn Price", *Staff Papers 92200, Department of Agricultural and Applied Economics,* University of Wisconsin-Madison.

Fortenbery, T.R., A. Turnquist, and J. Foltz. (2008). "Progress or Devastation: Effects of Ethanol Plant Location on Local Land Use". *Proceedings from the American Agricultural Economics Association Annual Meeting*. Orlando, FL.

Gallagher, P., R. Wisner, and H. Brubacker. (2005). "Price Relationships in Processors' Input Market Areas: Testing Theories for Corn Prices Near Ethanol Plants". C*anadian Journal of Agricultural Economics*, 53(2-3), 117-139.

Gardner, G. and G. Sampson. (2021). "Land Value Impacts of Ethanol Market Expansion by Irrigation Status". *Proceedings from the 2021 Joint Agricultural & Applied Economics Association and Western Agricultural Economics Association Annual Meeting*. Austin, TX.

Henderson, J. and B. Gloy. (2009). "The Impact of Ethanol Plants of Cropland Values in the Great Plains." *Agricultural Finance Review*, 69(1), 36-48.

Katchova, A. (2009). "The Spatial Effect of Ethanol Biorefinery Locations on Local Corn Prices". *Proceedings from the Agricultural & Applied Economics Association's 2009 AAEA Annual Meeting*. Milwaukee, WI.

Klein, R. and G. McClure. (2022). *Nebraska Crop Budgets*. CropWatch. Retrieved January 20, 2022, from https://cropwatch.unl.edu/budgets.

Lewis, K.E. and G.T. Tonsor. (2011). "The Impact of Ethanol Production on Spatial Grain Market Relationships." *International Food and Agribusiness Management Review,* 14(4), 201–214.

Li, Y., R. Miao, and M. Khanna. (2018). “Effects of Ethanol Plant Proximity and Crop Prices on Land-Use Change in the United States”. *American Journal of Agricultural Economics*, 101(2), 467–491.

Low, S.A., and A. M. Isserman (2009). “Ethanol and the Local Economy: Industry Trends, Local Factors, Economic Impacts, and Risks.” *Economic Development Quarterly*, 23, 71-88.

McNew, K. and D. Griffith. (2005). “Measuring the Impact of Ethanol Plants on Local Grain Prices.” *Review of Agricultural Economics*, 27(2), 164–180.

Miao, R. (2013). “Impact of Ethanol Plants on Local Land Use Change”. *Agricultural and Resource Economics Review*, 42(2), 291–309.

Motamed, M., L. McPhail, and R. Williams. (2016). “Corn Area Response to Local Ethanol Markets in the United States: A Grid Cell Level Analysis”. *American Journal of Agricultural Economics*. 98(3), 726–743.

Nafziger, E. (2019). “Wet Grain, Test Weight, and Late Corn Harvest.” farmdoc daily (9): 224, *Department of Agricultural and Consumer Economics*, University of Illinois at Urbana-Champaign.

Nielsen, R.L. (2021). “Estimating Corn Grain Yield Prior to Harvest.” Corny News Network, Purdue University. Web. < https://www.agry.purdue.edu/ext/corn/news/timeless/ yldestmethod.html >

O’Brien, D. (2009). “The Effects of the Micro-Market Structure for Kansas Elevators on Spatial Grain Price Differentials”. *Proceedings from the NCR-134 Conference of Applied Commodity Price Analysis, Forecasting, and Market Risk Management*. St. Louis, MO.

Olson, A., N. Klein, and G. Taylor. (2007). “The Impact of Increased Ethanol Production on Corn Basis in South Dakota.” *Proceedings from the Western Agricultural Economics Association (WAEA) 2007 Annual Meeting*. Portland, OR.

Roberts, M. and A.N. Tran. (2012). “Commodity Price Adjustment in a Competitive Storage Model with an Application to the US Biofuel Policies”. *Proceedings from the Agricultural & Applied Economics Association’s 2012 AAEA Annual Meeting*. Seattle, WA.

Sneller, T. and D. Durante. (2006). “Economic Impacts of Ethanol Production”. Ethanol Across America.

Urbanchuk, J.M. and J. Kapell. (2002). “Ethanol and The Local Community”. Discussion Paper, AUS Consultants and SJH & Company. June 21, 2002. Boston, MA.

U.S. Department of Agriculture, Agricultural Marketing Service. Grain Truck and Ocean Rate Advisory. November 2021. Web. < http://dx.doi.org/10.9752/TS265.11-2021 >

U.S. Department of Agriculture, National Agricultural Statistics Service. NASS – Quick Stats. June 2022. Web. < https://quickstats.nass.usda.gov >

U.S. Energy Information Administration. U.S. Fuel Ethanol Plant Production Capacity. September 2021. Web. < https://www.eia.gov/petroleum/ethanolcapacity >

Figures

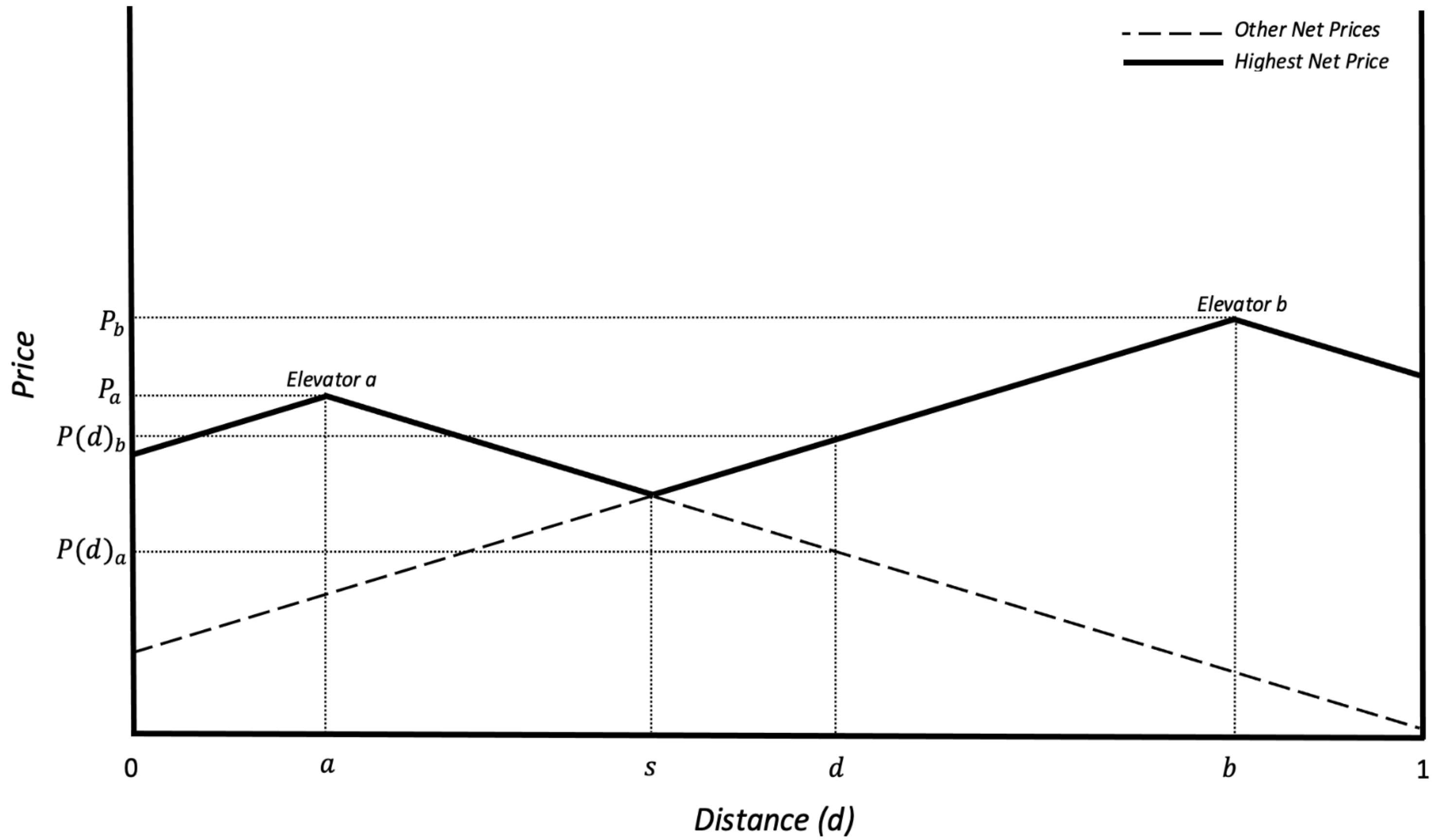


Figure 1: Two-Elevator Spatial Demand System

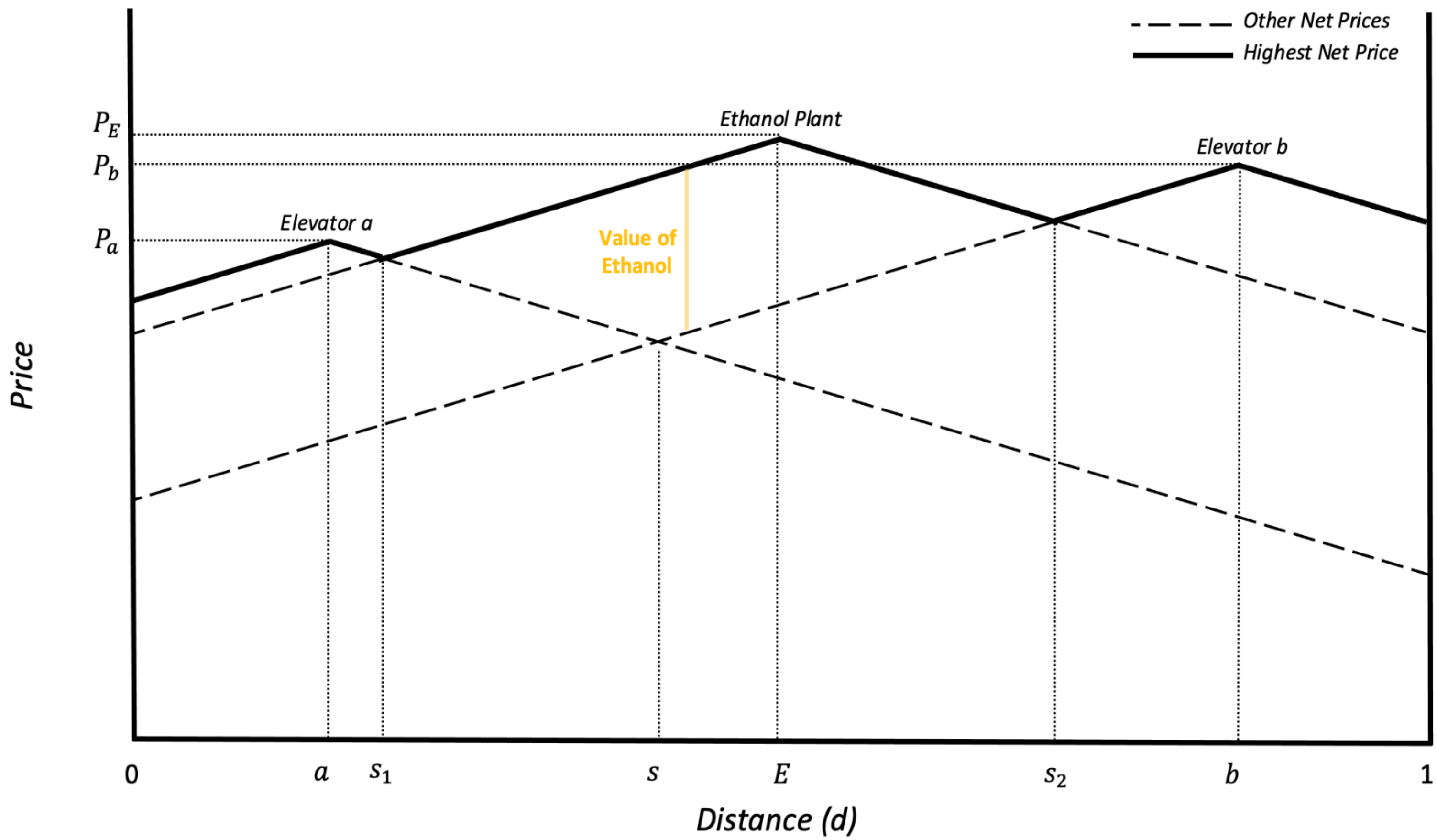


Figure 2: Two-Elevator, One Ethanol Plant Spatial Demand System

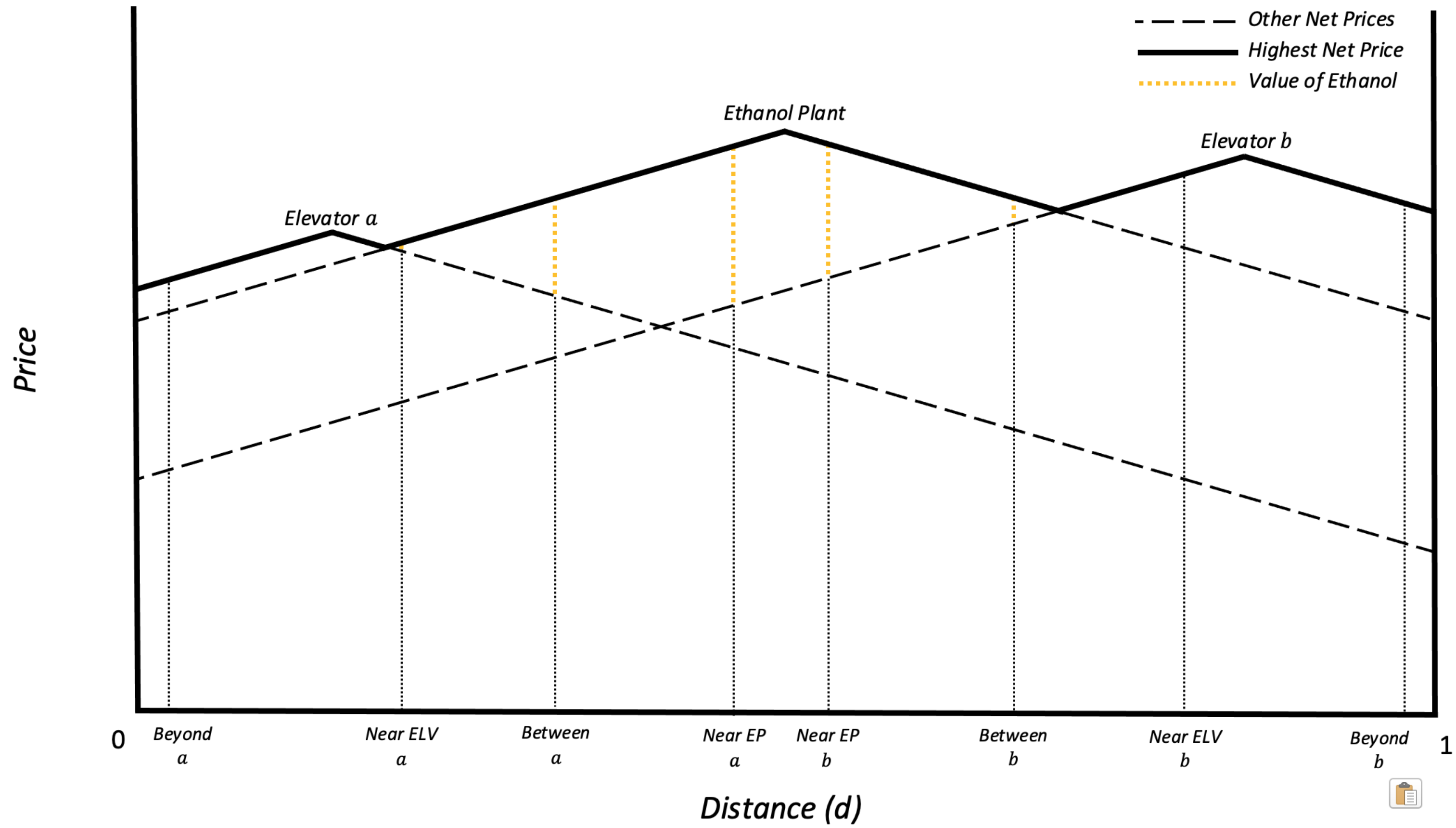


Figure 3: Farm Location Conditions in the Two Elevator, One Ethanol Plant Spatial Demand System

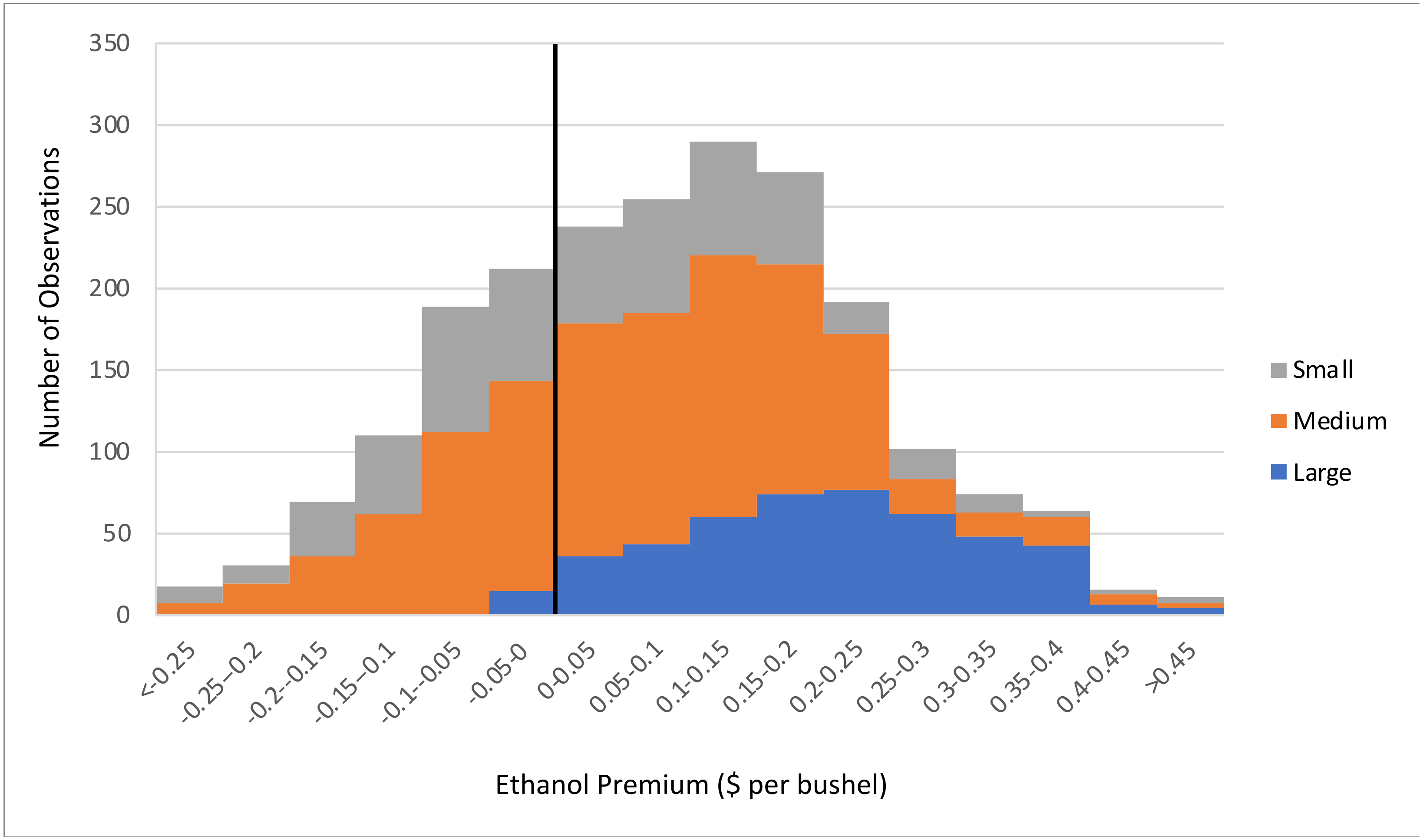


Figure 4: All Farm Ethanol Premiums by Ethanol Plant Size

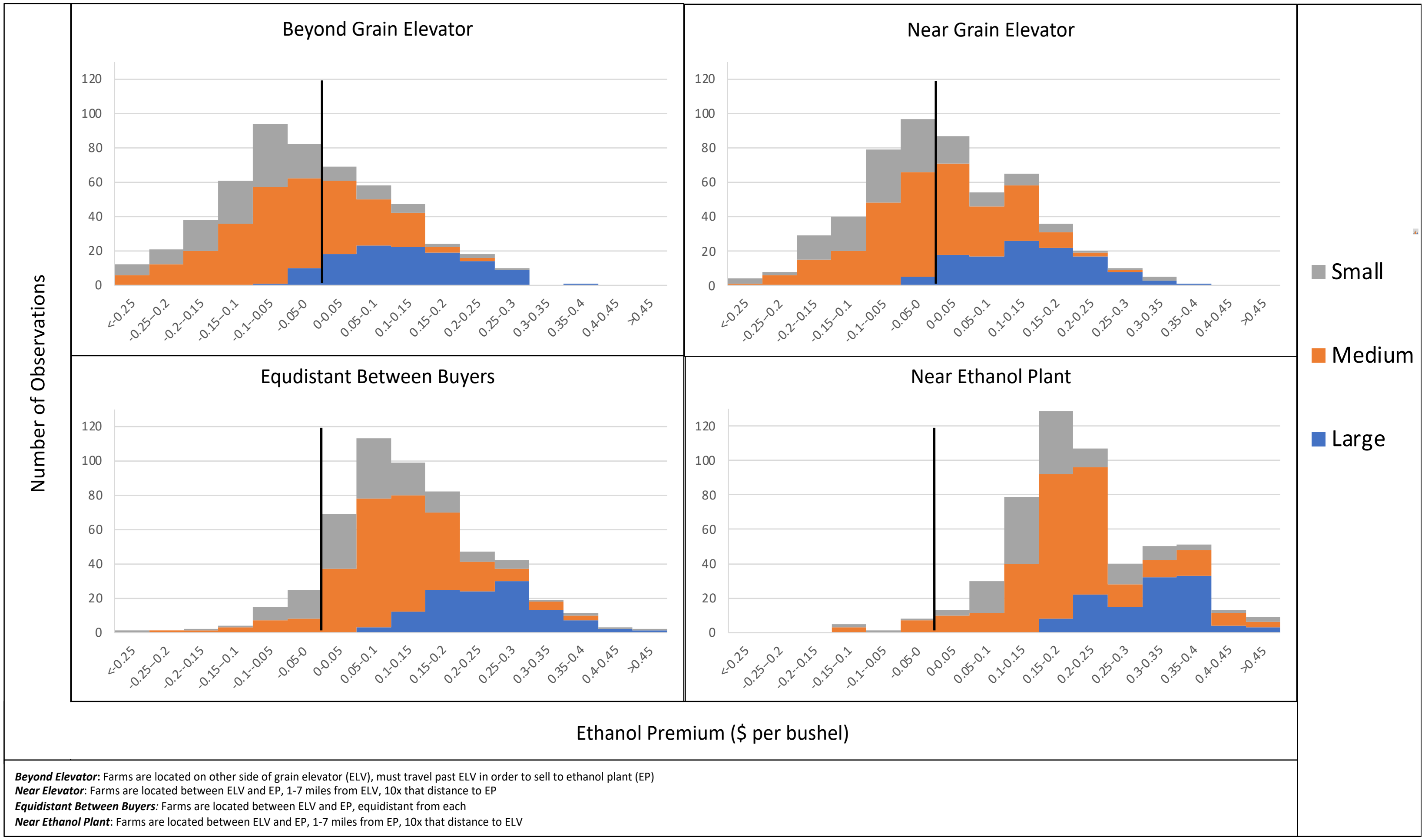
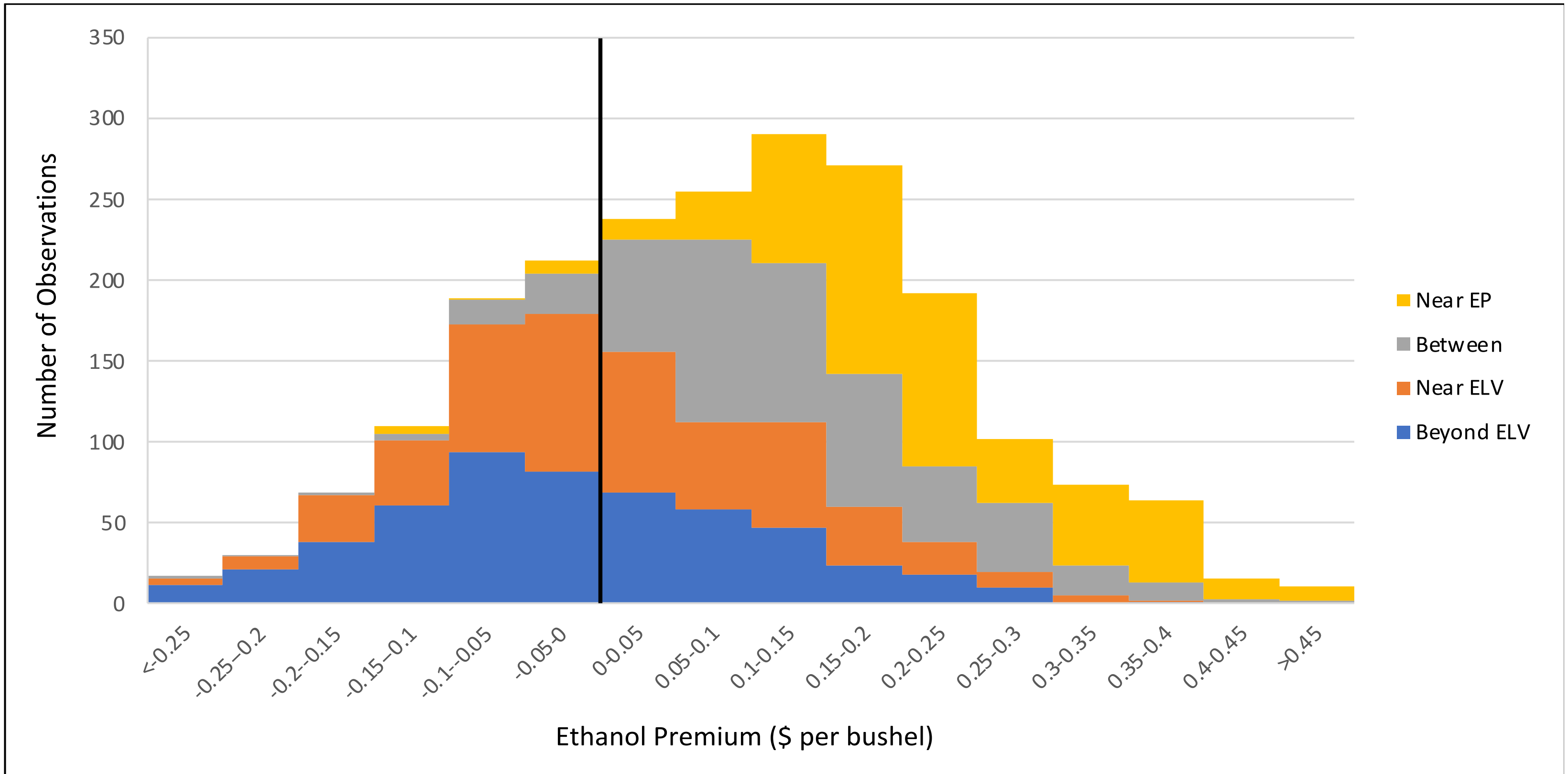
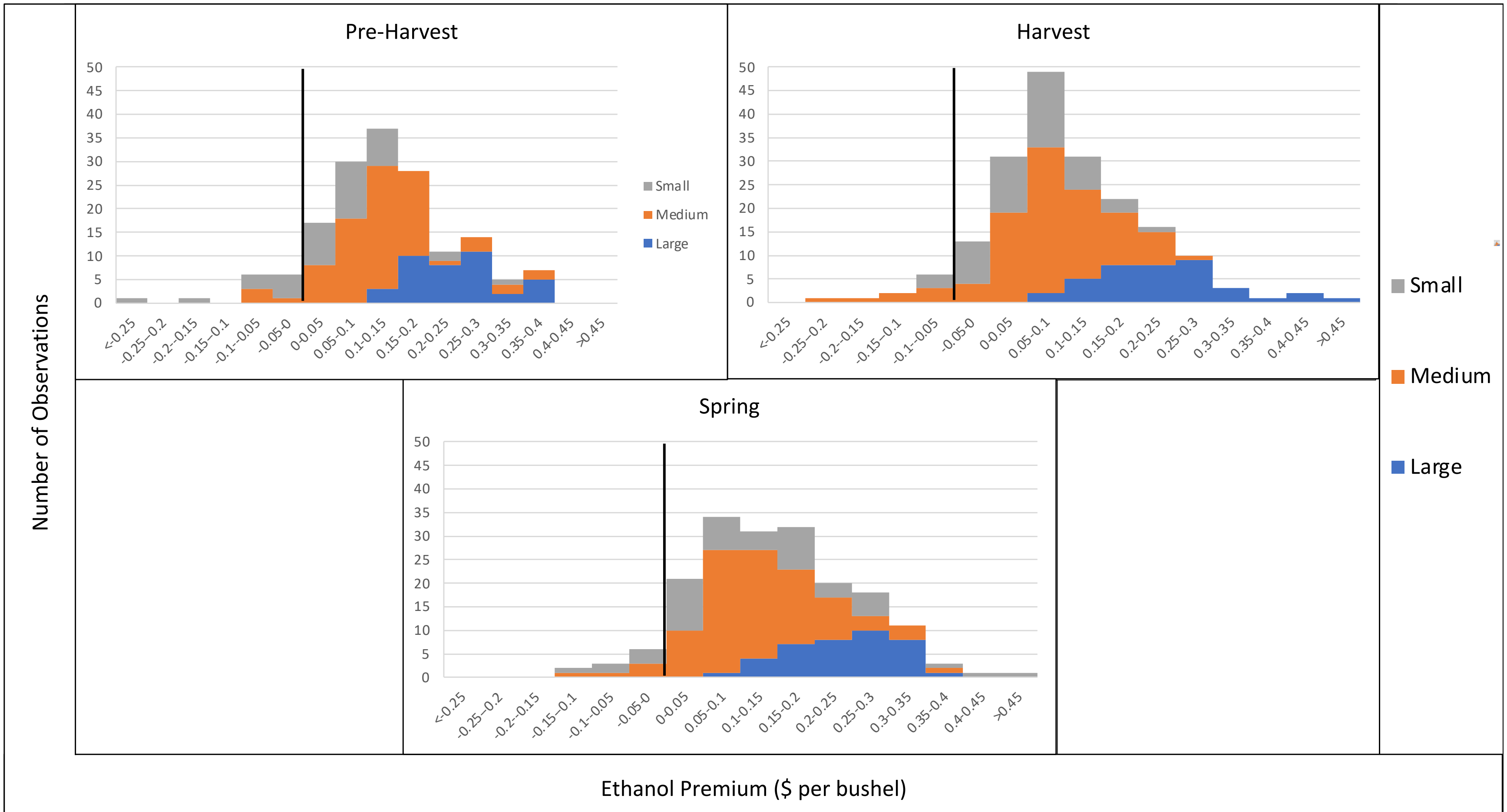


Figure 5: Farm Ethanol Premiums for Each Proximity, by Ethanol Plant Size



Beyond Elevator: Farms are located on other side of grain elevator (ELV), must travel past ELV in order to sell to ethanol plant (EP)
Near Elevator: Farms are located between ELV and EP, 1-7 miles from ELV, 10x that distance to EP
Equidistant Between Buyers: Farms are located between ELV and EP, equidistant from each
Near Ethanol Plant: Farms are located between ELV and EP, 1-7 miles from EP, 10x that distance to ELV

Figure 6: All Farm Ethanol Premiums by Farm Proximity



Pre-Harvest: Corn is sold based on summertime new crop corn prices and delivered during harvest. Prices observed 3 weeks after silking (i.e. August)
Harvest: Corn is sold and delivered during harvest (i.e. late-October)
Spring: Corn is sold and delivered in late-spring, 7 months after harvest (i.e. May/June)

Figure 7: Farm Ethanol Premiums for Each Season, by Ethanol Plant Size – "Equidistant Between" Proximity

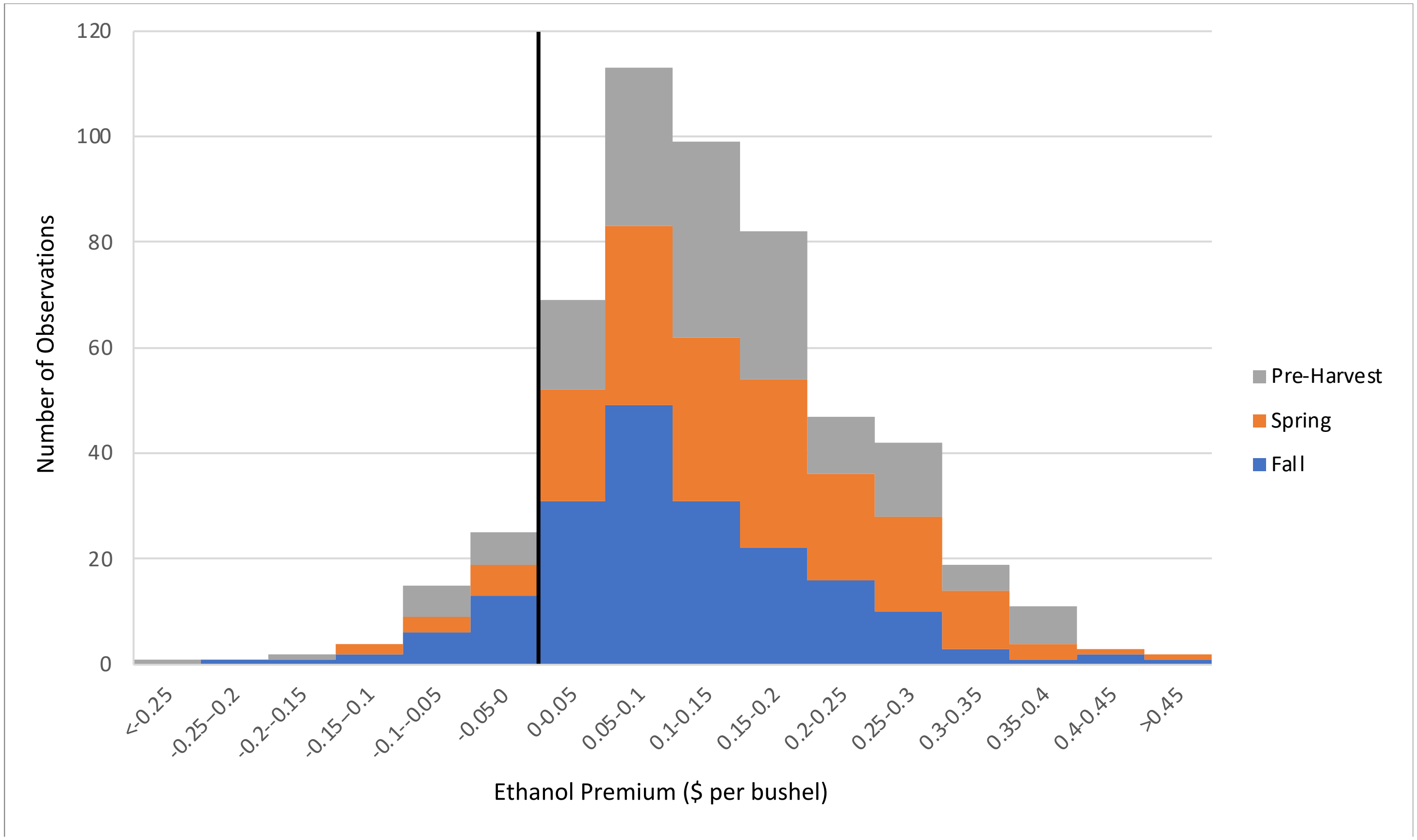


Figure 8: Farm Ethanol Premiums by Season – " Equidistant Between" Proximity

Tables

Table 1: Ethanol Plant and Grain Elevator Characteristics

Ethanol Plant	Nebraska Location	Capacity (MBY)	Avg. Grain Bid
EP1	South Central	17	$4.50
EP2	East Central	195	$4.52
EP3	Southeast	42	$4.31
EP4	Southwest	18	$4.13
EP5	Northeast	29	$4.36
EP6	Central	31	$4.58

	Name	Rail Capacity (Line)*	Mi. from E-Plant	Avg. Grain Bid
EP1	ELV1	Shuttle (BNSF)	23	$4.28
	ELV2	Non-Shuttle (NKCR)	36	$4.41
	ELV3	Shuttle (NKCR)	49	$4.24
EP2	ELV4	–	39	$4.27
	ELV5	Shuttle (UP)	29	$4.30
	ELV6	Non-Shuttle (BNSF)	17	$4.27
EP3	ELV7	–	10	$4.22
	ELV8	Shuttle (UP)	28	$4.43
	ELV9	Non-Shuttle (BNSF)	43	$4.05
EP4	ELV10	Shuttle (UP)	66	$4.31
	ELV11	Shuttle (NKCR)	28	$4.10
	ELV12	Non-Shuttle (BNSF)	49	$4.25
EP5	ELV13	Shuttle (NENE)	50	$4.33
	ELV14	Non-Shuttle (NENE)	33	$4.08
	ELV15	–	32	$4.25
EP6	ELV16	Shuttle (UP)	48	$4.39
	ELV17	Non-Shuttle (BNSF)	61	$4.36
	ELV18	–	52	$4.32

For this study, ethanol plants were selected by variation in location within Nebraska and production capacity size. They also vary by grain bid competitiveness. Grain elevators were selected by variation in rail access, train car loading capacity, location relative to the ethanol plant and other grain elevators, and grain bid competitiveness.

* Rail loading capacities can help to serve as a proxy for grain elevator size. Grain elevators are differentiated by rail car loading capacity: Shuttle (110+ cars) and Non-Shuttle (< 110 cars), while some selected grain elevators are not located on a rail line at all. Grain elevators are further differentiated by rail line. The rail lines identified here are: Burlington Northern and Santa Fe (BNSF), Nebraska Kansas Colorado Railway (NKCR), Nebraska Northeastern Railway (NENE), and Union Pacific (UP).

Table 2: Corn Bid and Transportation Cost Summary Statistics

Grain Bid ($ / bu.)

	Variable	**N**	**Mean**	**SD**	**Min**	**Max**
	Ethanol Plant	195	4.401	1.430	2.975	8.051
SIZE	*Large*	39	4.518	1.477	3.036	7.877
SIZE	*Medium*	103	4.404	1.457	2.975	8.051
SIZE	*Small*	53	4.310	1.360	2.988	7.741
SEASON	*Pre-Harvest*	65	4.267	1.489	2.988	8.051
SEASON	*Harvest*	67	4.310	1.269	3.101	7.687
SEASON	*Spring*	63	4.637	1.520	2.975	7.340
	Elevator	642	4.273	1.431	2.694	7.772
SEASON	*Pre-Harvest*	196	4.093	1.471	2.694	7.772
SEASON	*Harvest*	218	4.184	1.296	2.912	7.584
SEASON	*Spring*	228	4.514	1.491	2.808	6.980

Transportation Cost ($ / bu.)

	Variable	**N**	**Mean**	**SD**	**Min**	**Max**
	To Ethanol Plant	2808	0.127	0.109	0.004	0.599
FARM	*Near Ethanol Plant*	702	0.017	0.008	0.004	0.042
FARM	*Equidistant Between*	702	0.086	0.035	0.021	0.189
FARM	*Near Elevator*	702	0.152	0.064	0.030	0.360
FARM	*Beyond Elevator*	702	0.254	0.106	0.050	0.599
	To Grain Elevator	2808	0.086	0.064	0.003	0.368
FARM	*Near Ethanol Plant*	702	0.156	0.065	0.032	0.368
FARM	*Equidistant Between*	702	0.086	0.035	0.020	0.188
FARM	*Near Elevator*	702	0.017	0.008	0.003	0.042
FARM	*Beyond Elevator***	702	0.085	0.035	0.017	0.188
FARM	*Harvest Delivery*	468	0.086	0.036	0.017	0.188
FARM	*Spring Delivery*	234	0.084	0.034	0.017	0.164

Grain bids and transportation costs are sourced from DTN and the USDA–AMS GTOR report, respectively. Grain bids vary by the season considered and by production capacity among ethanol plants. Ethanol plants are grouped by capacity size: Large (1), Medium (3), and Small (2). Missing grain bid data is excluded from these summary statistics.

Transportation costs vary by the proximity of the farm to the grain buyers and by the season considered. A transportation cost is estimated from each farm to each grain buyer, across each season. Seasonal differences are equivalent across farm locations and are only reported once here. In addition, as transportation costs are the same for the Pre-Harvest and Harvest seasons, these are reported together under “Harvest Delivery”.

Table 3: Seasonal Pricing Window Summary Statistics

Variable		N	Mean	SD	Min	Max
			Pricing Windows (Dates)			
SEASON	*Pre-Harvest*	13	8/6 – 8/20	3.3	7/31 – 8/14	8/13 – 8/27
	Harvest	13	10/17 – 10/31	10.9	9/22 – 10/6	11/9 – 11/23
	Spring	13	5/18 – 6/1	11.5	4/22 – 5/6	6/9 – 6/23

Two-week time windows were selected as the time frame to observe grain bids and transportation costs for each season considered from 2009 – 2021. The Pre-Harvest and Harvest pricing windows are based on data from the USDA Crop Progress Report, while the Spring pricing window occurs 7 months after the corresponding Harvest pricing window.

Table 4: Farm Proximity Summary Statistics

	Variable	N	Mean	SD	Min	Max
			Farm Proximities (Miles)			
	To Ethanol Plant					
FARM	*Near Ethanol Plant*	18	3.9	1.7	1.1	7.4
FARM	*Equidistant Between*	18	19.7	7.9	6.2	33.1
FARM	*Near Elevator*	18	34.9	14.4	8.9	63.1
FARM	*Beyond Elevator*	18	58.2	23.9	15.0	105.0
	To Grain Elevator					
FARM	*Near Ethanol Plant*	18	35.8	14.6	9.5	64.5
FARM	*Equidistant Between*	18	19.7	7.8	6.1	33.0
FARM	*Near Elevator*	18	3.9	1.7	0.9	7.3
FARM	*Beyond Elevator*	18	19.6	7.9	5.0	33.0

Four farm conditions were used in this study's analysis, with each varying in proximity between the regional ethanol plant and a nearby elevator.

Table 5: Ethanol Premium Summary Statistics

	Variable	N	Mean	SD	Min	Max
		Ethanol Premium ($ / bu.)				
	"Near Ethanol Plant" Farms	535	0.216	0.109	-0.130	0.542
PLANT SIZE	*Large*	117	0.312	0.073	0.171	0.527
	Medium	277	0.196	0.100	-0.124	0.493
	Small	141	0.174	0.105	-0.130	0.542
SEASON	*Pre-Harvest*	163	0.217	0.107	-0.130	0.462
	Harvest	189	0.191	0.106	-0.124	0.527
	Spring	183	0.239	0.109	-0.038	0.542
	"Equidistant Between" Farms	535	0.127	0.108	-0.262	0.482
PLANT SIZE	*Large*	117	0.236	0.078	0.078	0.460
	Medium	277	0.108	0.086	-0.209	0.394
	Small	141	0.075	0.107	-0.262	0.482
SEASON	*Pre-Harvest*	163	0.132	0.109	-0.262	0.394
	Harvest	189	0.103	0.105	-0.209	0.460
	Spring	183	0.147	0.107	-0.136	0.482
	"Near Elevator" Farms	535	0.016	0.118	-0.325	0.379
PLANT SIZE	*Large*	117	0.139	0.087	-0.031	0.379
	Medium	277	-0.008	0.096	-0.291	0.296
	Small	141	-0.038	0.111	-0.325	0.329
SEASON	*Pre-Harvest*	163	0.022	0.118	-0.325	0.300
	Harvest	189	-0.011	0.119	-0.291	0.379
	Spring	183	0.039	0.113	-0.248	0.329
	"Beyond Elevator" Farms	535	-0.016	0.125	-0.368	0.367
PLANT SIZE	*Large*	117	0.120	0.090	-0.056	0.367
	Medium	277	-0.041	0.100	-0.307	0.234
	Small	141	-0.078	0.112	-0.368	0.292
SEASON	*Pre-Harvest*	163	-0.009	0.125	-0.368	0.290
	Harvest	189	-0.043	0.127	-0.310	0.367
	Spring	183	0.007	0.119	-0.278	0.292

The term “ethanol premium” represents the corn grower’s net price advantage of delivering to the ethanol plant over a grain elevator. This calculation is based on grain bids and transportation costs faced by each farm location considered. The magnitude of the ethanol premium varies by ethanol plant capacity size and season considered. Ethanol plants are grouped by capacity size: Large (1), Medium (3), and Small (2). When grain bid data was unavailable, ethanol premium observations were excluded from analysis.

Appendix A

Six ethanol plant regions were chosen for analysis in this study, with each plant located in unique corn-producing regions across the state and serving a different set of corn growers. In addition, each of the six ethanol plants retain different ownership, and the variation in production capacity ranges from 17 million bushels per year (MBY) to 195 MBY. Figure A1 maps the relative ethanol plant locations within Nebraska.

Figures A2 – A7 illustrate the relative locations of the ethanol plant, grain elevator, and farm location sites used in this study for each ethanol region. Grain buyers are indicated in red, with grain elevator locations being represented by triangles and ethanol plants by stars. For each grain elevator, there are four associated farm locations (indicated in blue), one for each farm proximity condition. Farm location groups 1-4, 5-8, and 9-12 are each associated with a different grain elevator. The first farm location of each elevator (farm numbers 1, 5, and 9) serve to represent the “near the grain elevator” proximity. The second (2, 6, and 10) represents the “equidistant between” proximity, while the third (3, 7, 11) and fourth (4, 8, 12) associated farm locations represent the “beyond the grain elevator” and “near the ethanol plant” proximities, respectively. To determine ethanol’s value to a farm location, a net price is estimated from the farm to each of the grain buyers. The difference between the ethanol plant’s net price and the highest net price among the grain elevators is the farm’s attributed value to local ethanol production. With each farm located in unique proximity to the ethanol plant and grain elevators, the farm’s value to ethanol production is resultingly also unique. In addition, as prices and transportation costs change across seasons and years, so too will ethanol’s value change across time.

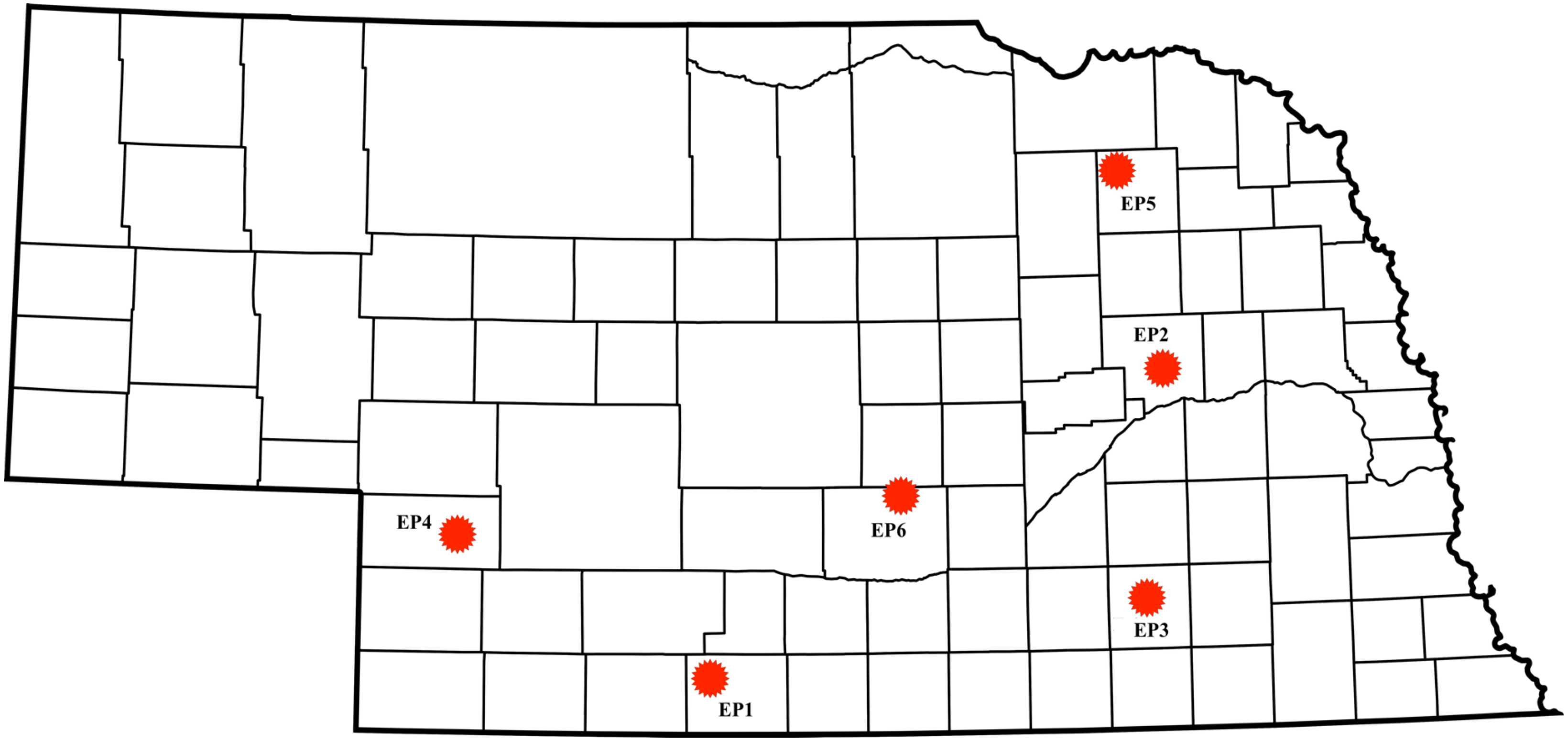


Figure A1: Selected Nebraska Ethanol Plants

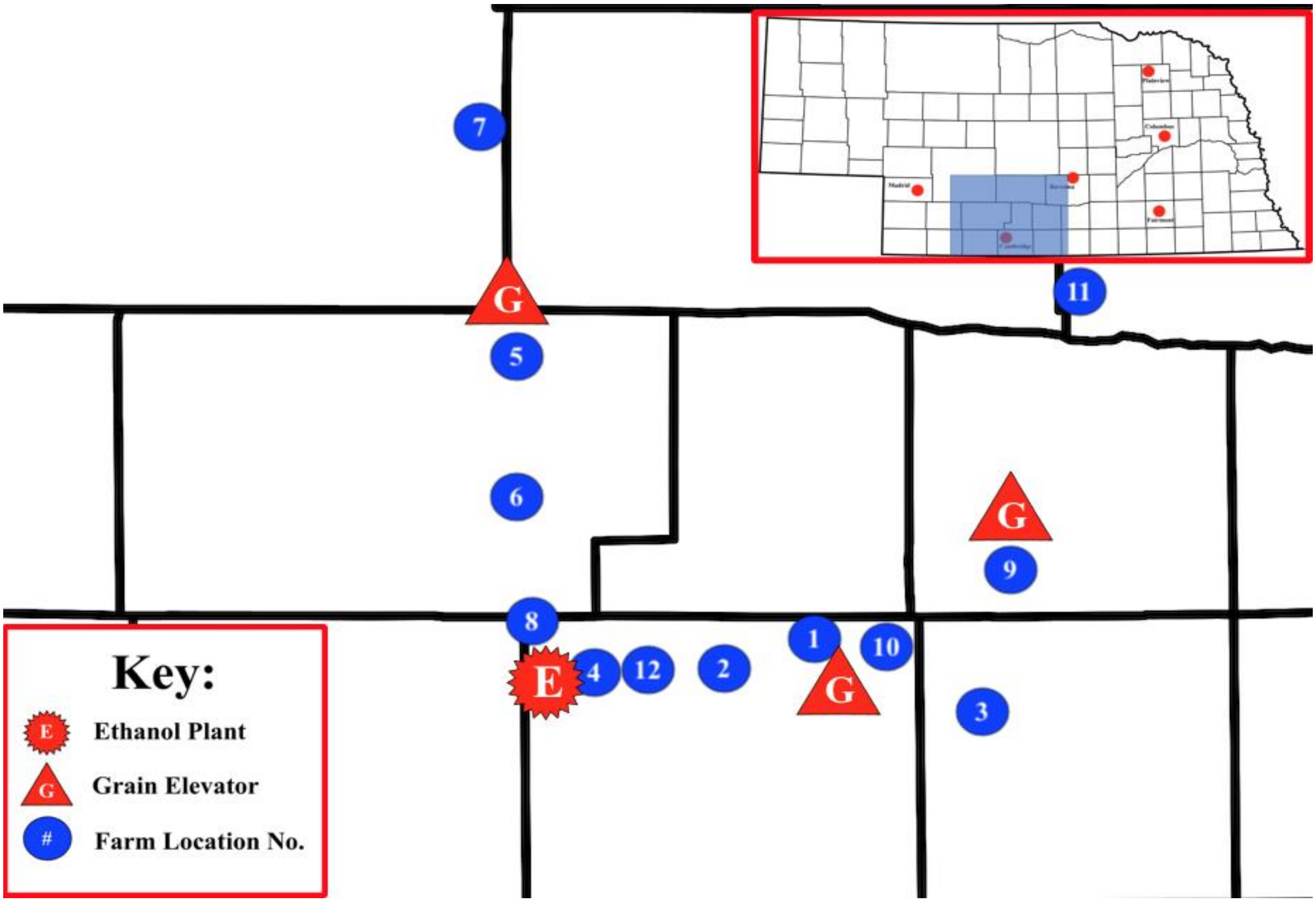


Figure A2: EP1 Region – Ethanol Plant, Grain Elevators, Farm Locations

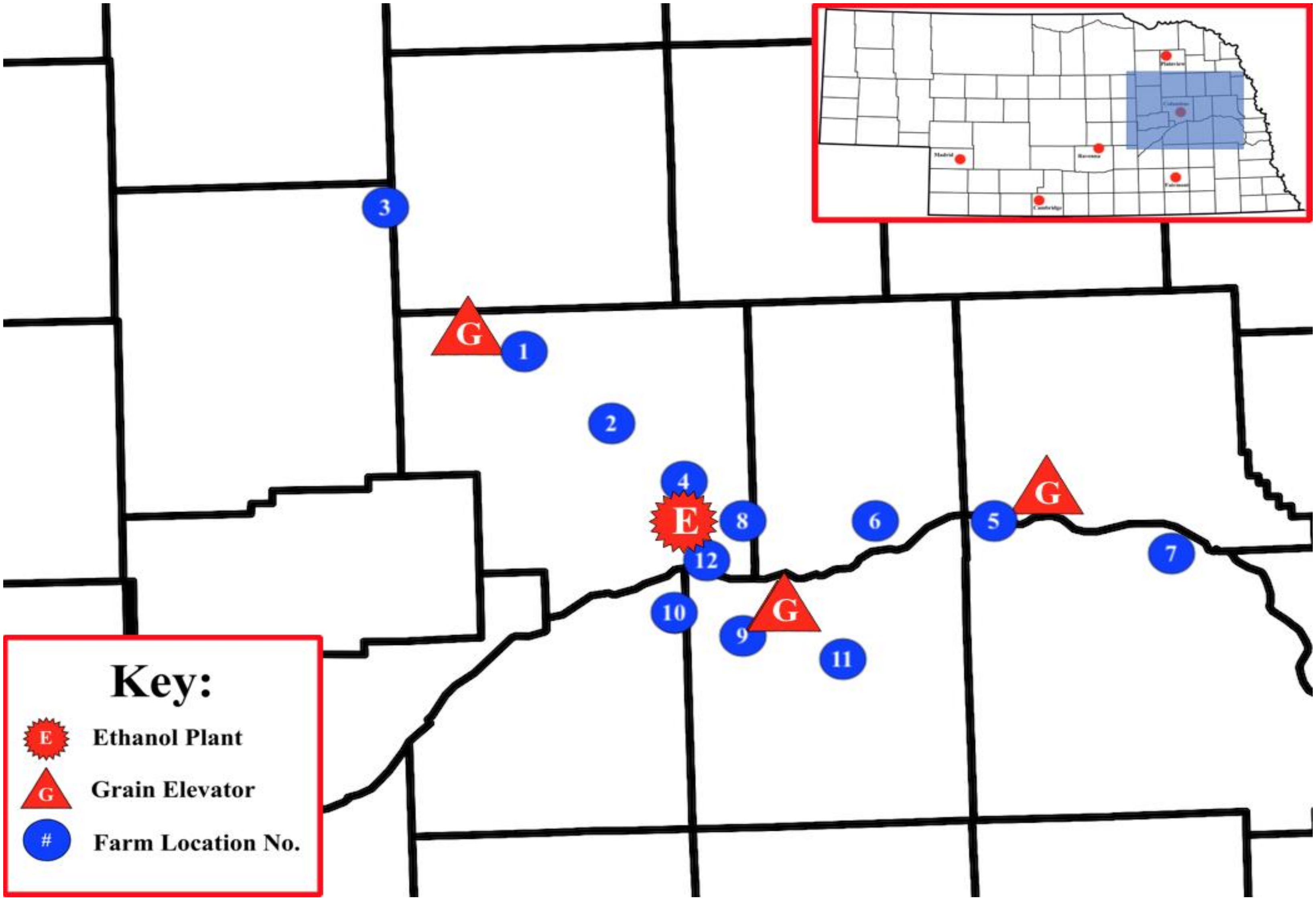


Figure A3: EP2 Region – Ethanol Plant, Grain Elevators, Farm Locations

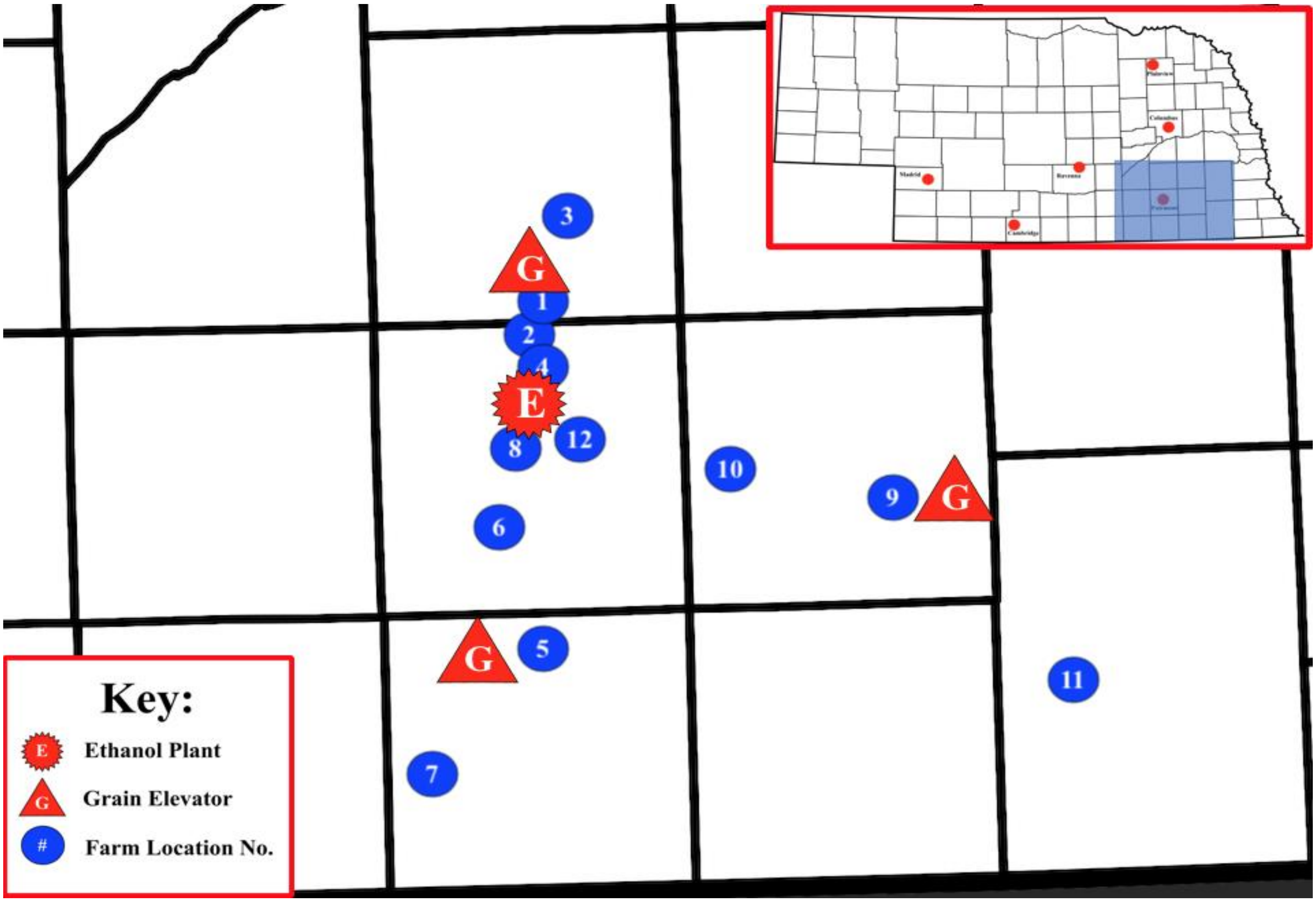


Figure A4: EP3 Region – Ethanol Plant, Grain Elevators, Farm Locations

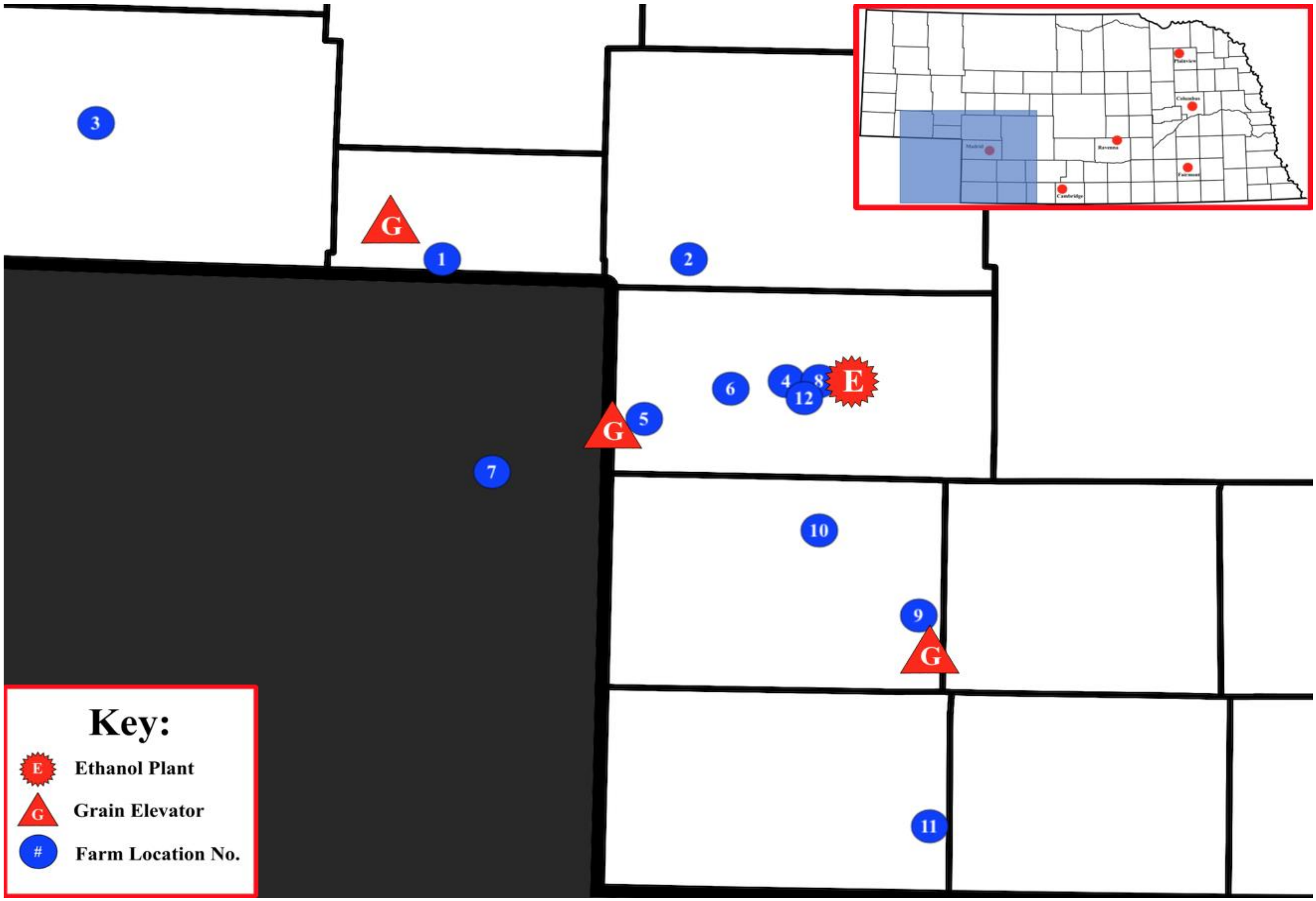


Figure A5: EP4 Region – Ethanol Plant, Grain Elevators, Farm Locations

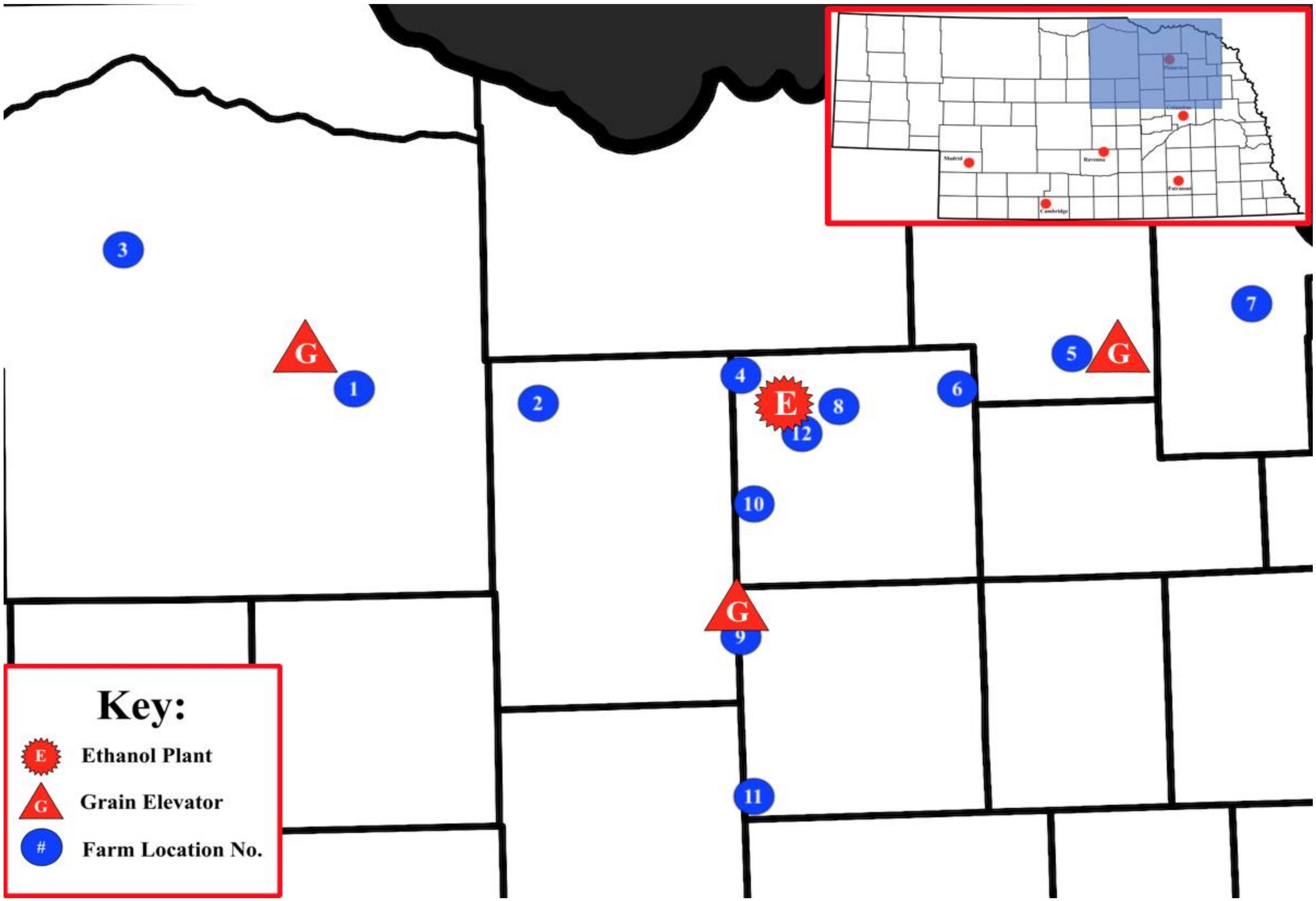


Figure A6: EP5 Region – Ethanol Plant, Grain Elevators, Farm Locations

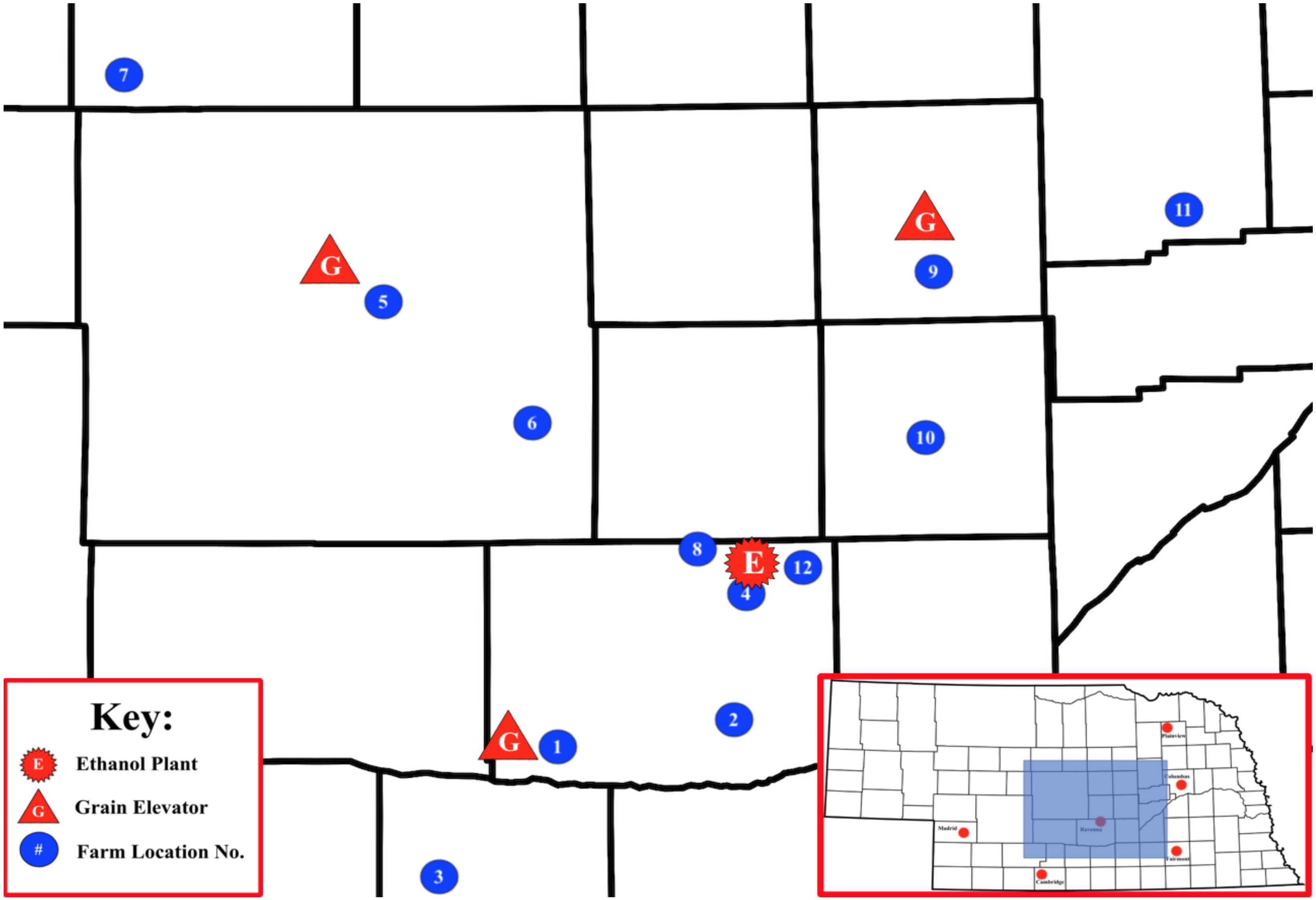


Figure A7: EP6 Region – Ethanol Plant, Grain Elevators, Farm Locations