Ethanol Price Discovery in U.S. Terminal Markets

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1. Introduction

During the last fifteen years the demand for ethanol has dramatically increased, driven primarily by policy. Starting in 2006, U.S. ethanol demand surged after several states banned the use of methyl tertiary-butyl ether (MTBE) as a gasoline oxygenate additive due to its impacts on groundwater pollution (Anderson and Elzinga, 2014). This led to a replacement of MTBE by ethanol and a rapid growth in ethanol demand. The Renewable Fuel Standard (RFS) first passed in 2005 and its expansion in 2007 (Cedeno, 2016; EPA, 2017) had an even larger impact. The RFS requires that transportation fuels sold in the U.S. contain a mandatory minimum volume of renewable fuels. Domestic ethanol production increased dramatically in parallel with the policy incentives, placing the U.S. at the forefront of worldwide production. The U.S. share in global ethanol production has fluctuated between 50-60% in the last 10 years, doubling Brazil's share (Energy Information Administration - EIA, 2020a). The fuel ethanol industry in the U.S. uses corn as the dominant feedstock (EIA, 2020b) with 35-40% of national corn production being refined into ethanol (Thiesse, 2020). This has created a strong link between the biofuel industry and agriculture.

The growth of the ethanol industry has motivated research that addresses a range of questions, from the impacts of regulations on ethanol and related industries to changing price relationships between ethanol and agricultural commodities (Carter, Rausser, and Smith, 2017; Moschini, Lapan, and Kim, 2017; Mallory, Irwin, and Hayes, 2012; Serra and Zilberman, 2013). Yet to date, we know very little about a fundamental issue—price discovery in the burgeoning U.S. ethanol market. When a commodity is traded in multiple markets and arbitrage ensures these markets transmit information to each other, the process of price discovery involves all these markets in different degrees, which can be captured through price discovery shares (Garbade and Silber 1983; Hasbrouck 1995). Price discovery is based upon the existence of an equilibrium relationship among the prices in the markets involved and the speed with which different markets incorporate new information. Markets with larger price discovery shares incorporate information faster than those with lower shares. In this article we investigate the spatial dimensions of ethanol price discovery in the main U.S. spot markets, which include the regions of the Midwest (Chicago), East Coast (New York, Tampa), West Coast (Los Angeles, San Francisco, Washington), Gulf Coast and Dallas.

An extensive line of research on price discovery has focused on examining whether it occurs primarily in the futures or the spot market in a range of commodities (e.g., Schroeder and Goodwin, 1991; Shrestha, 2014; Shrestha, Subramaniam, and Thiyagarajan, 2020). Consistent with the notion that futures markets are a significant place for gathering and exchanging information (Grossman, 1977), the majority of these studies conclude that futures markets dominate the price discovery process. Quintino, David, and Vian's (2017) article constitutes an exception, as they find that the Brazilian spot ethanol market leads the futures price in long-run price discovery, a result they attribute to the thin futures market in Brazil. Taking advantage of assets cross-listed in different exchanges, other articles have investigated regional price discovery using financial asset prices (e.g., Frijns, Gilbert and Tourani-Rad, 2015; Janzen and Adjemian, 2017; Hu et al., 2020). In the U.S., the Chicago Ethanol (Platts) Futures contract is the most liquid ethanol derivative, yet its trading volume is substantially below traditionally illiquid futures markets such as the Chicago Mercantile Exchange (CME)'s lean hog contract. Moreover, the Platts futures' settlement price is based on the spot price at the Chicago terminal, which leads to virtually a perfect correlation between the two prices. As a result, we focus our price discovery analysis on regional spot prices.

An efficient market is one in which prices always fully reflect all available information (Fama, 1970). Understanding the extent to which different regional ethanol markets reflect relevant information is important to identify the most influential markets in the pricing process and to assess the degree of market integration (Koontz, Garcia, and Hudson, 1990). Market integration results from efficient arbitrage activities that lead to spatial price equilibrium. Under perfect integration, shocks in supply and/or demand conditions are simultaneously reflected in different regional prices. Otherwise, dominant markets reflect the information faster. Overall, the price discovery literature is focused on exploring which markets reflect valuable new information first, which allows identifying dominant and satellite markets (Garbade and Silber, 1983).

The objective of this paper is to identify where ethanol prices are discovered among the largest spot markets in the U.S. and how their price discovery share has changed over time. Ethanol price discovery is not only critical to ethanol-related industries such as ethanol plants, oil refiners or corn producers, but also to policy markets and society at large. Its relevance is not limited to domestic markets, but also extends to international markets such as the Brazilian ethanol market with strong connections with the U.S. domestic market.

We choose Chicago as the central market in our analysis and explore its price discovery share relative to each of the other markets. Pair-wise analyses are a natural choice for studying price linkages since arbitrage conditions should hold for any pair of prices (Serra, Gil and Goodwin, 2006). We focus on Chicago because it is equipped with one of the largest terminals in the U.S. and is widely-regarded as the center of ethanol price discovery in the country. We support our decision through Granger-causality tests in the framework of a multivariate VAR that show that while Chicago Granger-causes each of the other regional markets, none of them Granger-cause Chicago. Our interest in Chicago is also motivated by its role as a reference market in pricing ethanol derivatives. There have been recent allegations that prices at the eWindow trading platform in the Chicago terminal have been subject to manipulation by one of the major ethanol producing companies in the country, Archer Daniels Midland, ADM (Voegele, 2020). Effective manipulation can move the price away from the value implied by market fundamentals at the expense of other market participants, distort price discovery, and reduce market efficiency and welfare (e.g., Pirrong, 2017). Due to data limitations, our analysis does not delve directly into the manipulation question, yet we provide evidence on how price discovery across markets behaved during the alleged manipulation period. Manipulation of a dominant as opposed to a satellite market may have far-reaching consequences, especially if the price discovery share of the dominant market does not decrease during manipulation, which would signal that other markets in the country are adopting an inefficient price. We quantify the Chicago market price discovery share to identify whether Chicago is actually a dominant market. Using a rolling window approach, we investigate how the Chicago price discovery share changed over time and how it evolved during the critical period. We then assess whether the price discovery share changes can be explained by the trading role of ADM in the Chicago terminal, but also by market fundamentals and ethanol policy changes, which helps identifying the reasons underlying the price signal in Chicago and sheds light on any possible price distortion.

We use Hasbrouck (1995) information share (*IS*) and a rolling window approach to study the dynamics of the *IS* for U.S. ethanol markets over time.[1] Based on daily data from 2013 to the beginning of 2021, we find Chicago to be mostly a dominant market, with an *IS* above 50% on average. We then investigate the determinants of the Chicago's *IS* by using a double-hurdle model specification (Cragg, 1971). We consider market fundamentals, policy and the Chicago terminal eWindow trading platform concentration and we derive elasticities to identify the relative importance of each factor in explaining information shares. We find ethanol production has the largest impact, followed at a distance by ethanol exports and policy. With inelastic responses, concentration in the Chicago eWindow terminal plays a lesser role. Nonetheless, results suggest that during the alleged manipulation period, U.S. ethanol markets either placed less confidence on the price signal from Chicago, or completely stopped following Chicago's price. While our results do not prove or disprove manipulation, they do show that increases in the trading platform concentration reduced the role of Chicago as the center of ethanol price setting in the U.S.

We contribute to the literature by providing, for the first time, empirical evidence on regional price discovery in U.S. ethanol spot markets. Also, this is the first study that measures the role of concentration at a spot trading platform on the price discovery shares. In contrast to previous literature, we do not ignore those cases where prices are not cointegrated. Instead, we explain what motivates the price parity to break. Spot prices are observed less frequently than financial prices and thus require the use of creative strategies such as the rolling window approach to investigate price discovery dynamics over time.

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[1] Prices measured at a daily frequency have been widely shown to be free from any microstructure noise (Ait-Sahalia and Yu, 2009). As a result, our empirical analysis does not require the use of methods that correct for noise in market prices (Putnins, 2013).

2. The U.S. Ethanol Market

In this section, we focus on two U.S. ethanol market characteristics that are key to understand regional price discovery: the relevance of the Chicago terminal and the ethanol policies.

2.1. The Chicago Ethanol Market

Large amounts of ethanol are transacted daily in spot markets commonly located in the leading oil refining, barge and pipeline centers in the U.S. As discussed, we consider eight main U.S. spot ethanol markets located in the Midwest (Chicago), East Coast (New York, Tampa), West Coast (Los Angeles, San Francisco, Washington), Gulf Coast and Dallas.

As of 2020, the Midwest generated 92% of the ethanol produced in the country (EIA, 2020c). We thus consider the Chicago market as representative of ethanol supply areas. The remaining markets are considered representative of the largest ethanol demand markets, with San Francisco and Los Angeles representing top ports of entry for ethanol imports, and the Gulf, New York and Washington being top export hubs (RFA 2017, 2020). During the period studied, the U.S. exported on average 7.7% of its ethanol production, fluctuating from 4.6% in 2013 to 10.4% in 2018 (RFA, 2020). Global ethanol demand has been growing as several countries mandate a specific percentage of ethanol to be blended with gasoline. In general, upward trending corn yields and relatively low corn prices have competitively positioned the U.S. in the worldwide ethanol market (USDA-FAS, 2019). On average, the U.S. represents half of global ethanol trade, with Canada and Brazil being top export destinations (RFA, 2020). Canada imports ethanol mainly through the Great Lakes as well as Seattle and Portland. Brazil imports through Gulf, which accounts on average for 74% of the total U.S. ethanol exports. The rest of the world (India, the European Union and South Korea) imports from any of these hubs as well as from the New York port (which accounts for 2-3% of exports) due to its closer proximity to Europe (RFA, 2018; 2019; 2020).

While being a net ethanol exporter, the U.S. imports ethanol almost exclusively from Brazil which represents 90-99% of overall U.S. imports (RFA, 2020). During 2013 to 2015, ethanol entered the country primarily through the West Coast (Los Angeles, San Francisco) but also through the East Coast (New York) in order to be able to satisfy increasing RFS blending targets during these years (RFA, 2015). Since then, California dominates ethanol imports (with San Francisco representing 65% and Los Angeles 23% of total ethanol imports) despite the geographical disadvantage of shipping Brazilian ethanol to the West Coast relative to other U.S. ports of entry (RFA, 2019). The underlying reason is the California Low Carbon Fuel Standard (LCFS) and the lower carbon intensity of Brazilian ethanol relative to the U.S. ethanol (EIA, 2013) which makes imports necessary to comply with environmental regulation. California is not only the first ethanol importer, but also the largest consumer of ethanol as it consumes one-ninth of the nation's fuel ethanol supply due to its large population that uses ethanol through the transportation, commercial and industrial sectors (EIA, 2013).

Particularly relevant among the markets studied is the Chicago terminal, a multimodal facility that handles shipments by barge, rail or truck and is one of the largest storage facilities in the country, serving a wide range of ethanol purchasers such as middlemen, blenders and end users. Especially relevant to the Chicago terminal is its unique role in pricing in the U.S. ethanol derivative markets. The daily settlement price of the Chicago ethanol (Platts) futures contract, the most popular ethanol derivative in the U.S. in terms of trading volume, is based on the Chicago price assessments produced by Platts. The Platts Ethanol Price Assessment (PEPA) heavily relies on transaction prices registered at the Chicago Platts eWindow marketplace during the 30-minute trading window from 1:00 pm to 1:30 pm CT, which precedes the futures market close, known as the Market-on-Close ("MOC") window.

Platts eWindow is an electronic marketplace where bids, offers and transactions are published in real-time throughout the day until the market closes. This formal environment provides an opportunity to participants who seek to have their transparent bids/offers and trades used to form the final price assessment published by Platts. Based on the assumption that price discovery is a function of time, Platts considers that the data published in the MOC eWindow directly preceding the market close is of the highest quality for price assessment purposes. Transactions made outside the MOC eWindow are not considered in the price assessment. Apart from the MOC eWindow prices, the PEPA is also a function of information collected through a survey of market activity throughout the day and other data sources including public news feeds and information provided by entities participating in the relevant markets (S&P Global Platts, 2017, 2021).

The PEPA system has recently been embroiled in controversy. AOT Holding AG and Green Plains Trade Group, both ethanol producers, recently sued one of their largest competitors, Acher Daniels Midland (ADM) for allegedly manipulating the PEPA (Class Action Complaint, 2019, 2020). According to the plaintiffs, since November 2017 ADM forced Chicago terminal ethanol prices artificially lower through a two-step manipulation scheme based on selling at artificially low prices in the terminal, with compensating losses through large short positions in the ethanol (Platts) futures contract (Renshaw and Hirtzer, 2020; Voegele, 2020).

We use nonpublic data from the Platts eWindow which contain, for every day, all ethanol transaction quantities occurring between 1:00 and 1:30 pm, their respective prices and the firms acting as counterparties. We use these data to compute the ADM market share as a seller for the sample period (from January 2, 2013 to February 4, 2021). While from 2013 to late 2017 ADM average seller share was 6%, large sales during the alleged manipulation period increased the average share to 70%, with relatively frequent peaks of 90% and 100% (Figure 1a). Afterwards

ADM essentially stopped sales of ethanol through the eWindow. Interestingly, from 2013 to the end of 2017, ADM was a net buyer of ethanol in Chicago, but thereafter stopped buying through the eWindow (Figure 1b).

As trade is at the core of price discovery, our analysis of regional price discovery in the U.S. ethanol market relies on the MOC eWindow information to assess to what extent ADM has driven the price signal during our sample period and how this changed during the alleged manipulation period. This does not allow us to prove or refute price manipulation, but it provides insights into important changes that occurred during the period.

2.2. Ethanol Policies

During the last fifteen years the demand for ethanol has significantly increased, driven mainly by policy changes. The 2005 RFS and its expansion in 2007 to RFS2 (Cedeno, 2016; EPA, 2017) drove demand by requiring that transportation fuels sold in the U.S. contain a specific minimum amount of renewable fuel. While biofuel blending mandates have become larger over time, the existing fleet of vehicles places a technical constraint on the amount of ethanol that can be safely blended into gasoline without damaging vehicle engines. This constraint is known as the blend wall and represents 10% of the motor fuel for a large proportion of the automobile fleet. The blend wall results in a kinked demand curve with infinite price elasticity before the blend wall is hit and zero price elasticity afterwards (Irwin and Good, 2015). From 2007 to 2010, the implied concentration of ethanol in gasoline (Radich and Hill, 2011) was significantly under 10% but reached values very close to 10% by mid-2011 as domestic ethanol production grew. Starting in 2013, the implied blend rate hit 10% and remained at this level through mid-2015, when the blend wall was breached (see figure 2a). By driving ethanol demand and given the particular characteristics of this demand, U.S. ethanol policy may have a strong impact on price discovery. We capture the influence of policy through the costs of compliance described below.

To ensure compliance of the oil industry (refiners and importers) with the RFS blending mandates, the Renewable Identification Number (RIN) system was created. RINs are generated with each gallon of biofuel produced. When the biofuel is blended with petroleum fuel, the RIN is separated and the refiner can retire it with the Environmental Protection Agency (EPA) as proof of compliance, or trade it in a secondary market. The two most relevant RINs in terms of market value are the D6 and D4 RINs. D6 RINS can be exclusively used to prove compliance with conventional biofuel requirements. The vast majority of the conventional mandate has been met by corn ethanol, so D6 RINs are generally referred to as ethanol RINs. D4 RINs can be used to demonstrate compliance with both the biomass-based diesel and the conventional biofuel requirements. This nested RINs structure results in D4 prices providing a cap on D6 prices (Irwin, McCormack and Stock, 2020). Both prices are highly volatile and reflect the expected cost of compliance with the regulations. These are intrinsically related with the costs of producing the biofuels, but also expectations about the implementation of future RFS mandates.

The relative price of D6 (corn ethanol) over D4 (biodiesel) RINs, the $\frac{D6}{D4}$ RIN price ratio ("RIN price ratio" henceforth), has been identified as a key forward-looking indicator of policy-driven increased demand for ethanol. This ratio should be bounded between 0 and 1. Whether the RIN price ratio is near the lower or upper bound depends on several factors. First, biodiesel is generally much more expensive than the petroleum diesel it replaces as a result of the RFS mandates. This means that biodiesel RIN prices are generally very expensive, typically in the range of $0.50 to $1.50 per gallon (Irwin, McCormack and Stock, 2020). Second, ethanol is a cost competitive component in the E10 gasoline blend (Irwin, 2018). This means that when the RFS conventional mandate is below the E10 blend wall ethanol RIN prices are very cheap, often less than $0.10 per gallon. Third, when the RFS conventional mandate is above the E10 blend wall this necessitates either the expansion of ethanol consumption in form of higher ethanol gasoline blends, such as E15 and E85, or the use of higher nested D4 biodiesel RINs to fill in the gap above the E10 blend wall. To date, obligated parties have used D4 biodiesel RINs most heavily to fill the gap, which has profound implications for D6 ethanol RIN prices. Essentially, when the conventional RFS mandate is below the E10 blend wall the price of ethanol RINs is close to zero. However, when the RFS mandate is above the E10 blend wall, D4 RINs become the marginal gallon for filling the conventional mandate. As a result, the price of ethanol RINs rises dramatically to the level of the much more expensive D4 biodiesel RINs. This can create wild swings in the price of ethanol RINs as market expectations change regarding the likelihood of the conventional mandate being above or below the E10 blend wall (see Irwin and Good, 2015 and Taheripour et al., 2020 for further detail).

With this background, the demand implications of the RIN price ratio can be understood. Specifically, price ratios near zero indicate the market is expecting the conventional RFS mandate to be below the E10 blend wall and the policy pressure on ethanol demand to be lessened. The situation is reversed when the RIN price ratio is nearer to one, with expected policy pressure on ethanol demand to increase. This allows us to interpret the RIN price ratio as a forward-looking indicator of policy-induced pressure on domestic ethanol demand in the U.S. It also allows us to capture expected changes in the ethanol demand elasticity when the blend-wall is reached. When the RIN price ratio is close to zero, expected demand elasticity should be large. When the RIN price ratio is close to one, expected demand elasticity should be small. Daily observed values of the RIN price ratio are presented in Figure 2b for our sample period and reveal that policy support was especially strong up to the end of 2015-16, with the remaining of the sample showing noticeably lower ratio values and larger fluctuations. The lower values and fluctuations reflect the intense political battle that erupted over setting the conventional RFS mandate above or below the E10 blend wall (e.g., Babcock, 2020). Our research considers the RIN price ratio as a possible driver of the Chicago price discovery share through the channel of ethanol demand.

3. Methods

In this section we describe the methods used to derive the pairwise price discovery shares based on ethanol daily prices observed across the U.S. from January 2, 2013 to February 4, 2021 and to identify its determinants.

3.1. Price Discovery Shares

Regional price discovery is a dynamic process whereby information is transmitted across different markets and results in equilibrium prices. As discussed, we adopt a pairwise approach that compares Chicago against every other market. To shed light on how price discovery changes over time, we take a rolling window approach which makes our method more robust to structural breaks. We chose a fixed window size of 480 days to ensure that at least one of the rolling window subsamples in the analysis captures in its entirety the two-year period during which ADM actively sold in the Chicago terminal according to Platts MOC eWindow data (Figure 1a), starting late 2017 up to late 2019. It is also important that the size of the rolling window is wide enough to disentangle the long from the short-run price dynamics. We conduct an impulse-response analysis based on bivariate VECMs fit to the whole sample to examine this issue. The results of the VECM analysis indicate it usually takes less than 40 and up to 70 days for prices to stabilize after a shock, which implies our rolling window of 480 days covers a time span of at least five times required for price dynamics to stabilize.[2] The number of increments between successive rolling windows is one day such that the first rolling window contains observations from day 1 to day 480, the second rolling window encompasses observations from day 2 to 481 and so on. As a result, from our sample of 2,112 observations, we can build 1,632 subsamples of 480 observations for each pair of prices. For each window, we assess the time series properties of the data and, when pertinent, we derive the price discovery shares.

Following Fricke and Menkhoff (2011) and Hu et al. (2020) we use the Johansen rank test[3] to categorize the two price series in each subsample into three groups: 1) Stationarity: prices are both stationary $I(0)$ series if we fail to reject the null hypothesis of a cointegration rank of 2; 2) Cointegration: prices are cointegrated and non-stationary $I(1)$ series if we fail to reject the null hypothesis of a cointegration rank of 1; 3) Non-cointegration: prices are both non-stationary $I(1)$ and not cointegrated, if we fail to reject the null hypothesis of a cointegration rank of 0.

We use the Information Share (*IS*) method proposed by Hasbrouck (1995) to derive the price discovery shares. The *IS* measures are based on a vector error correction model (VECM) (Engle and Granger, 1987) which captures both long-term equilibrium and temporary price linkages between the markets. Since a VECM can be fit to both stationary and nonstationary data (de Boef and Granato, 2000), we derive *IS* measures for all subsamples except when evidence of nonstationary and non-cointegration is found. In the latter case, regional prices are not bound by

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[2] The VECM results are not presented here for the sake of space. In the appendix, a further robustness check is conducted with 560 observations included in the rolling window and results do not change substantially. As expected, however, the longer (shorter) the window size is, the smoother (more volatile) price discovery shares become.

[3] We also conduct Engle and Granger tests for cointegration consistent with Gonzalo and Lee (1997). Results do not change.

an equilibrium relationship and thus no price discovery takes place.[4] We choose optimal VECM lags for each subsample according to the HQ criteria.

Let P_{1t} represent the ethanol price in the Chicago market on day *t*, while P_{2t} corresponds to one of the other ethanol markets' price (New York, Tampa, Dallas, Gulf, Los Angeles, San Francisco or Washington). The VECM for each pair of prices can be expressed as:

$$\Delta P_{1t} = \theta_1 + \alpha_1 * ECT_{t-1} + \sum_{i=1}^{n} \theta_{11(i)} \Delta P_{1,t-i} + \sum_{i=1}^{n} \theta_{12(i)} \Delta P_{2,t-i} + \varepsilon_{1t}$$

$$\Delta P_{2t} = \theta_2 + \alpha_2 * ECT_{t-1} + \sum_{i=1}^{n} \theta_{21(i)} \Delta P_{1,t-i} + \sum_{i=1}^{n} \theta_{22(i)} \Delta P_{2,t-i} + \varepsilon_{2t} \qquad (1)$$

where Δ indicates price differences and $ECT_{t-1} = (P_{2,t-1} - \beta_1 P_{1,t-1} - \beta_0)$ is the error correction term measuring deviations from the equilibrium relationship between the two regional prices. The intercept in the cointegration relationship (β_0) represents constant transaction costs of transferring ethanol between the regional markets during the 480 days subsample. α_1 and α_2 measure how the system responds to the previous day's deviations from the long-run equilibrium. $\theta_{11(i)}$, $\theta_{12(i)}$, $\theta_{21(i)}$,$\theta_{22(i)}$ are the short term parameters and i the number of lags used to represent the short-run dynamics. Finally, $\varepsilon_{1t} \sim iid(0,\sigma_1^2)$ and $\varepsilon_{2t} \sim iid(0,\sigma_2^2)$ are i.i.d. stochastic innovations which may be contemporaneously correlated, with correlation coefficient ρ. The variance-covariance matrix of the residuals is given by:

$$\Omega = \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix} \qquad (2)$$

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[4] Notice that when prices are stationary, we assume that they are bonded by a stable equilibrium relationship. We are comfortable with this assumption given the pattern of the prices throughout the sample period (Figure 3 discussed in section 4).

The *IS* measures are derived based on both α_1 and α_2 and the variance-covariance matrix Ω. Since ρ may be different from zero, Hasbrouck (1995) orthogonalizes innovations based on the Cholesky decomposition of the VECM residual covariance matrix as: $\Omega = MM'$, where M is a lower triangular matrix defined as:

$$M = \begin{pmatrix} \sigma_1 & 0 \\ \rho\sigma_2 & \sigma_2(1-\rho^2)^{1/2} \end{pmatrix} = \begin{pmatrix} m_{11} & 0 \\ m_{12} & m_{22} \end{pmatrix}. \tag{3}$$

The *IS* measures based on Hasbrouck (1995) are then calculated as follows

$$IS_1 = \frac{(\gamma_1 m_{11} + \gamma_2 m_{12})^2}{(\gamma_1 m_{11} + \gamma_2 m_{12})^2 + (\gamma_2 m_{22})^2} \tag{4}$$

$$IS_2 = \frac{(\gamma_2 m_{22})^2}{(\gamma_1 m_{11} + \gamma_2 m_{12})^2 + (\gamma_2 m_{22})^2} \tag{5}$$

where IS_1 (IS_2) is the Chicago (other market) price discovery share, with $IS_1 + IS_2 = 1$, $\gamma_1 = \frac{\alpha_2}{\alpha_2 - \alpha_1}$ and $\gamma_2 = \frac{\alpha_1}{\alpha_1 - \alpha_2}$. Notice that while the Cholesky factorization eliminates the contemporaneous relationship between price innovations (Hasbrouck, 1995), it makes the *IS* results order dependent.[5] To eliminate dependency of the *IS* measures on the ordering in the Cholesky decomposition, we follow Baillie, Booth, Tse, and Zabotina (2002) and calculate *IS* by averaging the measures under each of the two possible orderings.

3.2. Drivers of the Price Discovery Share

Price discovery is based on the hypothesis of the existence of a spatial price equilibrium between the markets studied. If this equilibrium does not exist, no price discovery takes place. To assess the Chicago market price discovery share, we follow a two-step approach. First, we assess what

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[5] More specifically, unless $m_{12} = 0$ (no correlation between market innovations) the first variable in the ordering tends to have higher information share ($IS_1 > IS_2$) than the last variable in the ordering.

causes the long-run equilibrium parity between pairs of prices to break. Second, conditional on the existence of a long-run parity, we assess the drivers of the magnitude of Chicago's price discovery share. This is achieved by using a Double-Hurdle specification (Cragg, 1971), which explains price discovery through a sequential two-step process. First, price dynamics must be characterized by an unobserved equilibrium relationship d_i^* (first hurdle) between P_{1t} and P_{2t} which we model as:

$$d_i^* = \boldsymbol{z}_{\boldsymbol{i}}'\boldsymbol{\gamma} + e_{1i}, \tag{6}$$

where d_i^* denotes the latent equilibrium expressed as a function of a vector of explanatory variables $(\boldsymbol{z}_{\boldsymbol{i}})$ and their corresponding parameters $(\boldsymbol{\gamma})$. The unobserved d_i^* is measured through the binary variable d_i which takes the value of 1 if the two prices are cointegrated or stationary and 0 if the prices are nonstationary and non-cointegrated, which precludes price discovery. Since the outcome of the first hurdle is binary, the error term e_{1i} follows a normal distribution $e_{1i} \sim N(0,1)$, with its variance normalized to 1 in order for the model to be identified.

Second, given the existence of an equilibrium relationship between P_{1t} and P_{2t} $(d_i = 1)$ the speed of adjustment to new information determines the price discovery share of Chicago relative to the other market: y_i^* (second hurdle) which we model as:

$$y_i^* = \boldsymbol{x}_{\boldsymbol{i}}'\boldsymbol{\delta} + e_{2i} \text{ with } e_{2i} \sim N(0,\sigma^2) \tag{7}$$

where $\boldsymbol{x}_{\boldsymbol{i}}'$ and $\boldsymbol{\delta}$ are the vector of the drivers of the magnitude of price discovery share and their corresponding parameters, respectively. Vector $\boldsymbol{x}_{\boldsymbol{i}}'$ includes the inverse of the Mill's ratio which captures the possible correlation between the error terms of equations (6) and (7). The unobserved y_i^* is measured through the price discovery share (IS_1), represented as y_i and related to d_i and y_i^* as: $y_i = d_i y_i^*$.

The double hurdle model is estimated by maximizing the following log likelihood function:

$$lnL = \sum_{y_i = 0} ln\left[1 - \mathrm{\phi}\left(z_i^{'}\boldsymbol{\gamma}\right)\mathrm{\phi}\left(\frac{x_i^{'}\boldsymbol{\delta}}{\sigma}\right)\right] + \sum_{y_i > 0} ln\left[\boldsymbol{\mathrm{\phi}}\left(z_i^{'}\boldsymbol{\gamma}\right)\frac{1}{\sigma}\phi\left(\frac{y_i - x_i^{'}\boldsymbol{\delta}}{\sigma}\right)\right] \quad (8)$$

where $\mathrm{\phi}()$ denotes a standard normal cumulative distribution (CDF) and $\phi()$ denotes a standard normal density function. Parameter estimates of the double hurdle model cannot be interpreted in a sensible way. We thus rely on elasticities for the interpretation of the first and second hurdle results (see Engel and Moffat, 2014).

4. Data and results

This section presents the data and the research results in two subsections, the first being devoted to price discovery shares and the second to the determinants of the shares.

4.1. Price Discovery Analysis

To assess regional price discovery in U.S. ethanol markets and shed light on changes in price discovery over time, we use daily spot prices expressed in \$/gallon for regional U.S. ethanol markets observed from January 2, 2013 to February 4, 2021. All prices are taken from the Oil Price Information Service (OPIS), except for the PEPA price described earlier which is obtained from S&P Global Platts. OPIS reports a daily range of high and low prices for each terminal based on completed transactions. When there is no confirmed trade in a particular day, OPIS uses a "highest bid/lowest offer" methodology based on the open deals posted that day but not traded by the end of the day to assess the daily prices. For the purpose of our price discovery analysis, we use the daily midpoint as the average of the high and low price reported by OPIS.

As explained, we choose Chicago as the central market and estimate pairwise models between Chicago and each of the other spot markets. This allows us to quantify Chicago's contribution to price discovery relative to each of the other main ethanol spot markets. Summary statistics for the eight ethanol price series can be found in Table 1. While in the empirical analysis we use log prices to induce normality and reduce heteroskedasticity (Bierlen, Wailes, and Cramer, 1998), prices in

Table 1 are in $/gallon to facilitate interpretation. Not surprisingly, prices in ethanol producing regions are lower than prices in consumption areas, with prices in Chicago averaging $1.64 per gallon and being the least volatile of the group. Prices in top net ethanol consumption regions such as California (Los Angeles and San Francisco), where the main import ports of entry are located, and Florida (Tampa) are the highest in the country ($1.85 per gallon). Major export markets such as the Gulf and New York have average ($1.73-$1.75 per gallon) prices in the range between the highs for California and Florida and the lows in the Midwest.

Visual inspection of the price series (see Figure 3) suggests a strong co-movement over the whole sample period. In terms of ethanol price levels, the sample encompasses two different subperiods: 2013 and 2014 with relatively high average ethanol price levels on the order of $2.28 per gallon in Chicago, and the remaining sample period with reduced price levels around $1.43 per gallon. The drop in prices was facilitated by historically large corn production in 2014-2018, leading to a sharp decline in corn prices and thus ethanol production costs. This resulted in an increase in ethanol consumption in many regions of the country (USDA-FAS, 2015). Prices in Chicago fluctuated around $1.43 per gallon on average for the remainder of the sample, except during the Covid-19 pandemic, which significantly reduced the demand and price for crude oil and gasoline and spilled over to ethanol (Irwin and Hubbs, 2020). This is reflected in the drastic drop of ethanol prices by March 2020. Prices rebound to previous levels afterwards.

Table 2 presents a summary of Johansen cointegration tests results at the 5% significance level for each pair and across samples. Results show that subsample data are mostly nonstationary and cointegrated. The pairs that display the largest proportion of non-stationary and non-cointegrated subsamples are Chicago-Los Angeles (12.9%) and Chicago-San Francisco (11.4%), whereas Chicago-Washington (1.3%) and Chicago-Tampa (1.8%) have the lowest proportion of non-cointegrated subsamples, followed by Chicago-Gulf (6.3%). Whenever two prices are nonstationary and non-cointegrated, the markets do not hold a common equilibrium relationship which precludes price discovery.[6] This implies that West Coast markets, the major ethanol import hubs are less integrated, on average, with Chicago than the other markets in the sample. Below we identify the periods where cointegration breaks and offer possible explanations.

Between 3.6% and 7% of the subsamples are characterized by stationary data and between 83.2% and 94.6% by nonstationary and cointegrated prices. These cases suggest existence of a long-run parity between the prices investigated and allow price discovery shares to be derived. Results from the price discovery share analysis are summarized in Table 3 for each pair of prices and across subsamples from the rolling window. Since for each pair of price discovery shares add to one, we only present Chicago's IS (IS_1). The second column (Observations) reports the number of subsamples in the rolling window that allow for VECM estimation and thus excludes those subsamples where data are nonstationary and non-cointegrated (these were reported in Table 2, fourth column). The Hasbrouck IS price discovery share for Chicago averages 0.58 across pairs of markets and subsamples. A price discovery share of 0.58 implies that Chicago contributes 58% to the price discovery process while the other market contributes 42%, making the former the dominant market. This suggests that during our sample period, the Chicago price usually reflected new information affecting ethanol markets faster than other markets. However, results also suggest

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[6] We also explored the relationship between Chicago-Brazil and Chicago-Rotterdam market pairs, with Brazil and Chicago representing the two largest international ethanol markets. However, cointegration tests showed that none of the pairs holds an equilibrium relationship. Thus, no price discovery analysis can be conducted for the Chicago-Brazil and Chicago-Rotterdam pairs, which implies that the influence of the Chicago price does not extend beyond the borders of the U.S.

that other markets should not be ignored for price discovery purposes, especially the New York market which on average incorporates information as fast as the Chicago market and Dallas, which dominates the Chicago market by 2% on average. Notice that the price discovery share against major import markets (California) is among the largest (63%), while the price discovery share against the major export markets (Gulf and New York) averages 53%. Table 3 further shows that behind the average price discovery shares there is a wide range of values that fluctuate from minimums that average 16% to maximums that reach an average of 84% across pairs of prices.

Figures 4a to 4g present the dynamics over time of price discovery shares for all pairs of markets. The vertical axis measures the price discovery share of Chicago relative to the other ethanol market and the horizontal axis measures time. Given the rolling window nature of the analysis, the horizontal axis is labeled in intervals of two years since every dot represents a price discovery share produced based on price data collected during 480 days.

Common to all the plots are some patterns that we discuss here. The low price discovery share of Chicago in the beginning of our sample (around 25%) coincides with the decrease in ethanol prices following the historically large corn crops and increased price volatility. Low price discovery shares are indicative of Chicago being slower at incorporating new information during sharp price declines. There is evidence in the literature that market power can lead to asymmetric price transmission patterns (Serra and Goodwin 2013).[7] Once ethanol prices stabilize around a

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[7] We collected price data from 2010 for Chicago, Dallas and New York in order to investigate whether the low Chicago price discovery shares in Figures 4a-4h are indeed related to the large price declines resulting from the historically large corn crop in 2013-2014. We found Chicago's price discovery shares previous to the price decline to be much larger and around 60%, which seems to confirm our hypothesis. Lack of eWindows Platts data does not allow us to conduct our analysis for this extended period.

lower level, Chicago gains dominance, usually in a two-step process, resulting in price discovery levels around 75% in the 2014-2015 period. After peaking, the Chicago price discovery share generally declined around 2016-2017 to a lower level, which coincides with a period when ADM held a large buying market share in the eWindow (31% on average from October 2016 to October 2017) (see Figure 1b). For some market pairs the decline was slow and smooth (Chicago-Dallas, Chicago-Gulf, Chicago-Tampa), for other pairs it was very sharp and substantial Chicago-New York), yet for others the decline was sharp and relatively small (Chicago-Washington). While for the Chicago-San Francisco and Chicago-Los Angeles the decline was very short lived, for the rest of the markets it lasted several years.

The 2018-19 period is usually characterized by several instances where there is no cointegration for all pairs of prices. These are represented by discontinuities in the *IS* line in the figures. The discontinuities are followed by a reestablishment of the long-run parity between Chicago and the other markets, with Chicago price discovery shares either at the same or higher levels than before. It was during this period of time (from the end of 2017 up to the end of 2019) that ADM increased its role as a seller in the Platts eWindow and concerns about manipulation grew. During this period, ADM drastically changed its trading pattern in the eWindow; the company ceased to be a buyer and became a large seller, with an average seller market share of about 70%, with relatively frequent peaks of 90% and 100% (see Figure 1a). The break of the equilibrium relationship during this period reinforces our suggestion that price discovery diffuses across the U.S. geography when concentration in the Chicago eWindow trading platform is relevant. The price discovery share then declined in 2019-2020 and stabilized at levels still well above 50% for most pairs and around 50% for Chicago-New York. Below we investigate the determinants of the Chicago price discovery shares.

4.2. Drivers of Chicago Price Discovery Share

Since price discovery breaks in some sub-periods for all pairs of prices, understanding the drivers of price discovery shares requires the use of a double-hurdle model (equations 6 and 7). We first discuss the explanatory variables that we include in the double-hurdle model (equations 6 and 7). Equation (6) aims at identifying the underlying reasons that motivate the equilibrium parity between the prices to exist or to break. As discussed, all pairs of prices exhibit a break in the equilibrium parity somewhere between 2017 and 2019, which coincides with the alleged manipulation period of the Chicago PEPA price. Under the hypothesis of manipulation, prices in the Chicago market may not reflect market fundamentals, which could break the equilibrium parity between Chicago and other regional markets. It's also possible that rumors spreading on the Chicago price being rigged may have caused the same effect. Hence, we include the role of ADM as a trader in the MOC eWindow when defining $\boldsymbol{z_i}$ in equation (6). Specifically, we calculate the firm's market share as a seller by dividing the daily volume of ethanol sold by ADM over the total daily volume of ethanol sold through the MOC eWindow. We do not consider the share of ADM as a buyer because the company bought virtually no ethanol through the eWindow after the second half of 2017 when the cointegration parity between pairs of prices broke.

We now turn attention to equation (7) measuring the magnitude of the price discovery share held by Chicago conditional upon market prices being bonded by an equilibrium relationship, and discuss the variables included in $\boldsymbol{x_i}$. We consider the ADM market share as a seller here as well, because a large market share by a single company may motivate other market participants to place less confidence on Chicago's price signal. We further consider the role of ADM as a buyer for the same reason, given that the company played a non-trivial role as a buyer during the first part of the sample period. As discussed earlier, we capture the impacts of policy on price discovery through the RIN price ratio, an indicator of policy-driven increased demand for ethanol (Figure 2b). We also examine the influence of a series of market fundamentals that may shift attention towards or away from the Chicago market price. An increase in ethanol production, which is essentially concentrated in the Midwest may increase Chicago's price discovery share as it is the main market in the production region. This is especially true for our sample period, with an implied ethanol blend rate close to the 10% blend wall (Figure 2a). As discussed, this causes domestic demand to be virtually vertical and causes prices to be essentially determined by supply. As shown, Chicago tends to have larger price discovery shares when compared against large import hubs in the West Coast. Ethanol imports in the U.S. essentially come from Brazil (EIA, 2021) which produces sugarcane ethanol. The destination of these imports is the California market that uses advanced biofuels to satisfy the state's stricter environmental regulations. According to the California LCFS scoring system, Brazil's sugarcane ethanol is considered an advanced biofuel relative to corn ethanol since it has a lower carbon intensity score. As a result, sugarcane ethanol displaces corn ethanol by increasing available domestic ethanol supply in the U.S. We thus consider the imports of ethanol as a possible determinant of the degree of dominance of Chicago. We also consider ethanol exports which may shift attention to foreign markets and reduce the role of Chicago in driving the price signal. Finally, we take into account the impact of the Covid-19 pandemic. We anticipate that the noticeable price pattern in 2020 may be connected to the pandemic whose consequences hit the ethanol market and possibly Chicago price discovery share as well. This makes sense if one recalls that in the presence of trading platform concentration, price declines may occur more slowly than price increases, which may result in changes in the Chicago price discovery share.

Ethanol import and export data are available from the EIA on a monthly basis and expressed in thousand barrels per day. We assume imports are evenly distributed across the days in each month in order to pair the trade data with the daily price. Midwest production data are available from EIA on a weekly basis and expressed in thousand barrels per day. We pair these data with daily data by setting production in each day within a week equal to the average EIA daily production data for that week. Ethanol and biodiesel RIN prices (D6 and D4, respectively) are obtained from OPIS on a daily basis and are expressed in $/RIN. Finally, regarding the impact of the pandemic, and based on the visual inspection of the ethanol price series (see Figure 3) we create two dummies to capture the deep decline followed by a recovery to pre-Covid-19 levels. The first dummy represents the period when ethanol prices start decreasing significantly until they reach the minimum level (2020:02:06<t<2020:04:07) and the second dummy captures the period from the trough up to the date when they return to pre-pandemic levels (2020:04:08<t<2020:06:12). Since price discovery during price decreases can be different from price increases, we keep the two dummies separate.

In order to control for possible endogeneity issues, all right-hand side variables are lagged one period except the Covid-19 dummies as they represent an exogenous shock. Given the rolling window nature of the price discovery shares, in the regression analysis we use the average value of the explanatory variables within each rolling window, which results in the explanatory variables being measured as moving averages. Finally, we deal with the possibility of heteroscedasticity and other misspecification issues by bootstrapping the data and re-estimating the double-hurdle model 1,000 times (Engel and Moffatt, 2014). Estimation results are presented in Table 4. For each of the 1,000 samples, we calculate the response elasticities for each right-hand side variable and for the first and second hurdle, and present averages and standard errors in Table 5. This facilitates interpretation of the results.

To better assess the impacts of the variables of interest, we focus the interpretation on the results found in Table 5. Since elasticities cannot be computed for dummy variables, interpretation of the Covid-19 dummy variables is based on parameter estimates in Table 4. Results from the first hurdle show a negative and statistically significant impact of ADM seller share on market integration for each pair of prices.[8] Consistent with visual inspection of figures 4a-4g, this suggests that during the days when ADM plays a large role as a seller in the eWindow, the equilibrium parity between Chicago and the other markets is more likely to fall apart. Hence, the geographical impact of Chicago's price during these days is more limited. More specifically, an increase in the ADM seller share by 1% results in an average decline of the probability of cointegration on the order of 0.19% across the different market price pairs. Generally, largest declines in the probability of cointegration occur in Chicago-Los Angeles, Chicago-San Francisco and Chicago-Dallas. These results suggest that cointegration is more likely to fall apart between Chicago and main import hubs, as well as blending areas during periods of concentration in the Chicago eWindow trading platform. Notice that the impacts of ADM seller share on the probability of cointegration are, however, largely inelastic.

We now turn to the discussion of the equation that measures the degree of Chicago price discovery share. ADM shares either as a buyer or as a seller have both negative and statistically significant elasticities among all pairs of prices, with a few exceptions (out of the 14 coefficients,

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[8] We tested for the robustness of these results to the inclusion of other variables such as imports in the first hurdle. ADM price discovery share continues to be negative and statistically significant, but convergence issues appear and grow as the number of additional explanatory variables increases.

2 are not statistically significant at the 5% significance level and 1 is positive and significant). This suggests once more that whenever ADM holds a larger market share, either as a buyer or as a seller, there is less confidence in the price set by the Chicago market, which motivates its degree of dominance to fall. On average, an increase in the ADM seller and buyer share by 1% causes a decline in Chicago's price discovery share by 0.22%[9] and 0.43%, respectively. Notice that both the sign and size of these parameters are consistent with the results obtained in the first hurdle. Here too, market responses to trading platform concentration are inelastic. Hence, while there is less price discovery from the Chicago terminal, the price discovery does not decline commensurately with the increase in the eWindow trading platform concentration. We find the price discovery share of Chicago against New York to increase by 0.31% with a 1% increase in ADM seller's share. This unexpected result may be due to the role that ADM was also playing in the New York eWindow during the sample period.[10]

Production is found to be positive and statistically significant for all pairs of prices, which indicates that an increase in ethanol production increases the dominance of Chicago in the price discovery process in the country. The production elasticity is very large, with a 1% increase in

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[9] This average excludes the positive and statistically significant elasticity for the Chicago-New York price pair.

[10] During the sample period, we found ADM to be actively selling (and to a lesser extent buying) through the eWindow terminal in New York. ADM's activity in New York was especially relevant up to late 2017 (seller and buyer shares were 13% and 6%, respectively) and declined afterwards up to early 2021 (to 2 and 0.4% shares, respectively). Since on average ADM trade activity in Chicago was larger than in New York, this may have increased the correlation of prices between the two markets and resulted in a larger price discovery share for Chicago. Notice that these values only represent the transactions through the transparent eWindows in Chicago and New York. In this regard, correlation between the two markets may also be established through transactions occurring outside the eWindows.

production resulting in a 25.61% increase in Chicago's price discovery share on average. The elasticity fluctuates between 20.62% and 28.18%. As discussed earlier, during the sample period production was very close to the blend wall, surpassing it by 2016. Once the blend wall is reached, domestic demand becomes essentially vertical (Tyner, 2010) and thus it is the supply that determines the domestic price. When sugarcane ethanol imports displace domestic corn ethanol, this results in an increase in available domestic supply, which causes an increase in Chicago's market dominance through the same mechanism as an increase in supply. This is confirmed by the coefficients representing imports which are all positive and statistically significant. Elasticity values point to an increase in ethanol imports on the order of 1% causing an increase in the Chicago price discovery share of around 0.50%, with a range between 0.41% and 0.62%. Consistent with the argument that exports force the domestic market to focus attention on export market prices to ensure their competitiveness, the dominance of Chicago tends to drop for all pairs of prices as exports increase. Specifically, the Chicago price discovery share declines by an average of 2.23% with an increase in exports on the order of 1%, with values fluctuating from 1.46% to 3.53%. Notice the difference in the elasticity magnitudes between exports and imports, which points to domestic markets being more impacted by exports than by imports. During the period studied, exports were twelve times larger than imports, which helps explaining the difference.

The RIN price ratio is positive and statistically significant for most price pairs. Larger values of the ratio are indicative of expected policy-driven increased demand for ethanol that may shift the largely inelastic domestic demand for ethanol to the right, result in higher prices, signal to the market that the policy is favorable to ethanol demand, and causing an increase in Chicago's price discovery share. An increase in 1% of the RIN price ratio is found to increase the Chicago price discovery share by 1.38% on average, with elasticities ranging from 0.30% to 2.45%. Notice that the Chicago price discovery share does not significantly increase against the Gulf, the major export hub. This is consistent with exporters being less impacted by domestic biofuels policy.

The covid-19 pandemic significantly reduced the demand and price for crude oil and gasoline and spilled over to ethanol (Irwin and Hubbs, 2020). This led to the drastic drop in ethanol prices in February-March 2020 as captured by the Covid-19 dummy decrease. The subsequent recovery to pre-pandemic levels is represented by the Covid-19 dummy increase. The signs of the two dummies (Table 4) show Chicago losing dominance during the price decline and regaining it during the increase. This is another example of asymmetric price transmission where the dominant market, Chicago, is slow at incorporating price declines, but fast at setting higher price levels.

Overall, our results suggest that the ethanol price discovery in the U.S. is essentially driven by market fundamentals and policy changes, with production having by far the largest impact, followed, at a distance, by exports and policy. With inelastic responses, imports and trading platform concentration play a lesser role.

5. Conclusions

This article shows for the first time how U.S. ethanol prices are discovered across the different regional markets. We consider major ethanol markets in the country that cover the Midwest, where ethanol production is concentrated, and East, West and Gulf Coast markets. We adopt a bivariate approach that compares each regional market against Chicago, as it is equipped with one of the largest terminals in the U.S. and is widely-regarded as the center of ethanol price discovery in the country. Ethanol prices in Chicago are also suspected of being manipulated over the 2017-2019 period. We use daily spot prices for the period from January 2, 2013 to February 4, 2021. This sample covers a critical period during which Archer Daniels Midland (ADM) played an important role as a seller in the Chicago market, which led to accusations of price manipulation by other competitors. Our analysis does not allow us to prove or refute existence of manipulation, but it does allow us to assess the implications of ADM activity for the price discovery process. Our sample also covers a period where ethanol demand was essentially vertical, with an implied ethanol blend rate close to the 10% blend wall.

Regional price discovery is a dynamic process whereby information is transmitted across different markets and results in equilibrium prices. We pre-test our price data for any evidence of the equilibrium parity to break and exclude these cases from the price discovery analysis. We use the Hasbrouck (1995) information shares and a rolling window approach that allows us to observe the dynamics of price discovery over time. We explain price discovery shares using a double hurdle model that allows us to assess both the reasons that motivate the equilibrium parity between the pairs of prices to break, as well as the magnitude of the Chicago price discovery share conditional upon existence of an equilibrium parity. We find that during the initial years of the sample, Chicago had a relatively small role in price discovery, with shares on the order of 25% for all pairs considered which then increased to around 75% in the 2014-2015 period.

More interestingly, we find results consistent with the hypothesis that increased concentration in the Chicago eWindow trading platform may be indicative of the price at Chicago not properly reflecting market fundamentals and thus not being followed by other markets. The probability that the pairs of markets considered are bonded by an equilibrium relationship declines with an increase in ADM's market share in Chicago. Further, conditional upon this equilibrium relationship existing, we find that price discovery diffuses across the U.S. geography when Chicago's eWindow concentration grows. Price discovery responses to trading platform concentration are however inelastic and much smaller than responses to fundamentals and policy. Consistent with prices in a market with a vertical demand being essentially driven by supply, we find ethanol production has the largest impact on price discovery among the variables considered. With Chicago representing the supply market, an increase in production shifts attention to Chicago prices, with an average elasticity of +26% across pairs of prices. Through the same mechanism as an increase in supply, imports also increase Chicago's price discovery share. With an average elasticity of only +0.5%, the influence of imports is limited. In contrast, exports drive attention away from Chicago with an average elasticity of -2.2%. Policy has a moderate impact on price discovery, with an elasticity of +1.4%. The RIN price ratio captures expected policy-driven increases in ethanol demand, and the positive elasticity indicates the share of Chicago in the price discovery process increases as this ratio rises.

In summary, Chicago has been at the center of price discovery in U.S. ethanol markets since 2014-15 with market fundamentals, policy and trading platform concentration playing a role in the degree of price discovery. While changes in ethanol production, exports and policy cause elastic responses on price discovery shares, ethanol imports and trading platform concentration cause inelastic responses. While our research does not allow us to prove or refute price manipulation by ADM over the 2017-2019 period, it sheds light on the implications of ADM's activity in the Chicago terminal for price discovery. We find that increases in trading platform concentration cause the dominant market to lose relevance in setting the ethanol prices. In this sense, the center of ethanol price discovery did not hold in the face of increasing trading platform concentration. It also clearly suggests that other market participants understood and reacted to the trading activities of the dominant firm.

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