Can the U.S. Ethanol Industry Compete in the Alternative Fuels' Market?

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Abstract

The U.S. ethanol fuel industry has experienced preferential treatment from federal and state governments ever since the Energy Tax Act of 1978 exempted 10% ethanol/gasoline blend (gasohol) from the federal excise tax. Combined with a 54 ¢/gal ethanol import tariff, this exemption was designed to provide incentives for the establishment and development of a U.S. ethanol industry. Despite these tax exemptions, until recently, the U.S. ethanol fuel industry was unable to expand from a limited regional market. Ethanol was dominated in the market by MTBE (methyl-tertiary-butyl ether). Only after MTBE was found to contaminate groundwater and consequently banned in many states did the demand for ethanol expand nationally. Limit pricing on the part of MTBE refiners is one hypothesis that may explain this lack of ethanol entry into the fuel-additives market. As a test of this hypothesis, a structural vector autoregression (SVAR) model of the ethanol fuel market is developed. The results support the hypothesis of limit-pricing behavior on the part of MTBE refiners, and suggest the U.S. corn-based ethanol industry is vulnerable to limit-price competition, which could recur. The dependence of corn-based ethanol price on supply determinants limits U.S. ethanol refiners' ability to price compete with sugar cane-based ethanol refiners. Without federal support, U.S. ethanol refiners may find it difficult to complete with cheaper sugar cane-refined ethanol, chiefly from Brazil.

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The U.S. ethanol fuel industry has experienced preferential treatment from federal and state governments ever since the Energy Tax Act of 1978 exempted 10% ethanol/gasoline blend (gasohol) from the federal excise tax. Combined with a 54 ¢/gal ethanol import tariff, this exemption was designed to provide incentives for the establishment and development of a U.S. ethanol industry. Various states, mainly in the corn producing Midwest, have subsequently enacted additional ethanol fuel tax credits to further promote the industry (North Carolina Solar Center). Currently, the primary use of ethanol in fuels is as an oxygenate additive, designed to improve combustion and decrease emissions.

Despite these tax exemptions, until recently, the U.S. ethanol fuel industry was unable to expand from a limited regional market into a major national supplier of fuel additives. Ethanol as an oxygenate additive was dominated in the market by its close substitute the oxygenate MTBE (methyl-tertiary-butyl ether). Only after MTBE was found to contaminate both ground and surface waters, leading to state bans on its use as a fuel additive, did the demand for ethanol expand nationally (Blue Ribbon Panel).

Limit pricing on the part of MTBE refiners is one hypothesis that may explain this lack of ethanol entry into the fuel-additives market. Using limit pricing MTBE refiners could restrict price markups above marginal cost in response to the threat of potential entry by ethanol refiners. According to this hypothesis, the major impediment to the development of an ethanol industry is the U.S. ethanol refining technology combined with Bertrand competition in the fuel-oxygenate market. Ethanol in the U.S. is produced predominantly from corn. If this technology results in relatively high refining costs, then refiners of ethanol substitutes, MTBE, could either explicitly or implicitly suppress ethanol entry by maintaining the price of MTBE at levels preventing a profitable entry of ethanol into the market.

Under this limit-price hypothesis, ethanol price would be primarily driven by shocks in supply of the raw input (corn). In contrast, the price of MTBE would closely follow changes in ethanol prices as MTBE refiners attempt to prevent ethanol market entry. As outlined by Chowdhury, such competition results in the incumbent firms supplying the whole of demand with the entrant firms obtaining no demand. As a test of this hypothesis, a structural vector autoregression (SVAR) model of the ethanol fuel market is developed and applied to an empirical analysis of the historical U.S. ethanol market. Specifically, we examine whether the response of prices and quantities of ethanol and its substitute MTBE to market shocks are consistent with limit-price competition. Results suggest the markets for ethanol and MTBE are indeed affected by different shocks despite the fact both additives are close substitutes.

While ethanol refiners currently benefit from reduced use of MTBE, the limited competitiveness of ethanol still exists. The future health of the U.S. ethanol industry is predicated on this relative competitiveness. The industry is currently facing another threat from cheaper sugar cane-based ethanol from Brazil (RFA, 2005) and ethanol imports from Central American countries. Ethanol refiners in Central American are exempt from the 54 ¢/gal ethanol import tariff under the Caribbean Basin Initiative (Lilliston). Thus, an analysis of the relative competitiveness of the U.S. ethanol industry will aid in understanding refiners' long-run sustainability.

The rest of the paper is organized as follows. The next section provides a brief overview of the U.S. ethanol market followed by a literature review. The subsequent sections present an economic theory of limit-price analysis, an outline of the SVAR model used in the analysis of the U.S. ethanol market, and a description of the data used. The results of estimation are then presented next followed by concluding remarks.

U.S. Ethanol Market

The market for ethanol fuel had a very limited and regional appeal until the passage of the 1990 Clean Air Act Amendments. The amendments established the Oxygenated Fuels Program which requires a minimum oxygen content of 2.7% by weight in winter fuels for non-attainment regions which do not meet carbon monoxide air quality standards. The act also mandated reformulated gasoline with 2% oxygenates by weight to be used in cities with the worst smog pollution to reduce harmful emissions of ozone. A number of regions increased this minimum federal requirement of oxygenate content to 3 – 3.5% by weight. As a result, two fuel additives, ethanol and MTBE, came into widespread use in all non-attainment regions throughout the U.S. MTBE is refined by reacting methanol, generally obtained from natural gas, with isobutylene.

Fuel-marketing firms purchased conventional (unblended) gasoline, blend stock for reformulated gasoline, and blending agents on the wholesale market. Firms then sold blended fuels to retailers. The determination of which oxygenate to use depended on the relative prices of ethanol and MTBE. Gallagher, Otto, and Dikeman illustrate this substitutability between ethanol and MTBE by considering a 2.7% oxygenate fuel requirement that can be met by either a 7.7% ethanol blend or a 15% MTBE blend. They demonstrate how the price wedge between ethanol and MTBE determines which oxygenate will be used.

Unfortunately for the ethanol fuel industry, MTBE instead of ethanol emerged as the oxygenate of choice. Even with the subsidies, ethanol refiners could not efficiently price-compete with MTBE. Ethanol's lack of competitiveness with MTBE relegated it to remain a regional market with limited growth potential. As a result, in the late 1990s, market share of ethanol fuel remained fairly constant (figure 1). This situation began to change in early 2000s as MTBE was found to contaminate ground and surface waters. Since 2002, a number of states initiated proposals and enacted policies restricting and banning the future use of MTBE. In January 2004, California, Connecticut, and New York discontinued the use of MTBE in reformulated gasoline with ethanol as the substitute. In 2005 a total of 16 states discontinued MTBE with other states either phasing out MTBE within two years or considering similar bans (Dinneen). Currently, MTBE is losing its competitive edge on ethanol, resulting in a boom in ethanol refining and use (figure 1).

This rapidly expanding market received a further boost from the 2005 Energy Bill which, while eliminating the oxygenate requirement, sets a new goal for expanding domestic fuel supplies with renewable fuels mainly ethanol and biodiesel. In particular, the renewable fuels standard sets a national minimum usage requirement of 4 billion gallons in 2006 with a mandated increase to 7.5 billion gallons in 2012.

The growing demand for ethanol is stimulating an increase in the construction of new ethanol refineries and expansion of existing refineries. Twelve new ethanol refineries were built in 2004 alone (Dinneen). However, all of these refineries continue to rely on corn as the raw input as opposed to the technologically more efficient use of sugar cane. Corn yields less sugar per acre than sugar cane, and in refining uses substantial amounts of energy. By comparison, most of ethanol production in Brazil, the largest world ethanol producer and exporter, is based on sugar cane. In contrast, the U.S. sugar cane industry has little incentive to diversify into ethanol refining. Sugar import quotas support the U.S. domestic sugar prices well above world levels, and U.S. expansion of sugar cane acreage is limited. With this lack of private market interest, the 2005 Energy Bill authorized a federally funded three-year demonstration refinery for refining ethanol from sugar cane.

However, as indicated by McNew and Griffith, above normal returns stimulating this refinery construction are unlikely to be sustainable. This may be a classic Cournot competitive market structure leading to a substantial drop in price especially if lower cost ethanol imports are able to penetrate the U.S. domestic market. Ethanol refiners have announced plans or have completed construction on refineries in El Salvador, Jamaica, Trinidad and Tobago, and Panama. These refineries are designed to take advantage of the U.S. duty-free importation of 240 mil gal of ethanol under the Caribbean Basin Initiative (Lilliston). Even with the existing import tariffs, 2004 saw a marked increase in ethanol imports from Brazil, 112 mil gal (Dinneen). Thus, with the growing U.S. demand for ethanol creating an attractive target for importers, the U.S. ethanol industry may again find itself price-competing with less costly alternatives.

Literature

The literature is somewhat limited on the modeling of the ethanol fuel market. Generally, research is directed toward investigating a particular policy or program effect on the ethanol market. For example, Rask (2004) investigates the effect that ethanol subsidies have on the highway trust fund. He determines there are significant and differential transfers of wealth across states with the use of the ethanol tax exemption. The seminal article modeling the ethanol market is also by Rask (1993). In this article, he provides insights into the ethanol market for the period 1984 to 1993. His results indicate the ethanol industry is in no position to fill a major role as a vehicle fuel supplier without continued government subsidies.

Overall analysis of fuel markets is considerably richer especially in the investigation of the broader gasoline market. Recent examples include analysis of competitiveness and vertical relationships of a retail gasoline market (Eckert and West; Hastings). Weinhagen employs the SVAR approach to investigate the nature of price shocks on the consumer gasoline market.

Limit Price Analysis

The theory of an incumbent practicing limit-price competition is illustrated in figure 2. An incumbent in this case is an MTBE refiner with an established market demand, while ethanol refiners represent entrants to the fuel additives market. The oligopoly structure of the U.S. MTBE industry, with only seven refiners in 2004, implies potential monopoly power. An MTBE incumbent firm is then facing a downward sloping average revenue (AR) curve and associated marginal revenue (MR) curve below it. Exercising full monopoly power the MTBE incumbent will set a price at P_m^*. However, the MTBE incumbent has considerable latitude in responding to any ethanol entrant price below this monopoly price of P_m^* down to the contestable market price of P_m'. As figure 2 illustrates, the entry of ethanol fuels at any MTBE-equivalent price of ethanol P_e' in the range between P_m^* and P_m' can be made unprofitable by MTBE incumbents practicing limit pricing.

This limit-price behavior suggests the price of MTBE would exhibit matching responses to any shocks in the price of ethanol. Specifically, a downward movement in the ethanol price will then elicit an MTBE price reduction to thwart any possible ethanol entry into the oxygenated fuel market. In a real options environment, a MTBE incumbent may even lower its price below short-run average variable cost to prevent ethanol entry with the expectation that future prices will recover.

Limit-price analysis demonstrates that ethanol entrance into the fuel-oxygenated market could be blocked by the MTBE incumbent even in the presence of refining subsidies and tax exemptions. This hypothesis is consistent with the limited regional market for ethanol fuels observed in the U.S. until the use of MTBE was legally restricted, allowing ethanol entry. The hypothesis also implies that the U.S. ethanol refiners relying on relatively inefficient corn-based refining technology are residual claimants of market share and may be unable to compete effectively in an open market if facing competition from cheaper ethanol imports.

SVAR Model of the Ethanol Market

To analyze the validity of the limit-price hypothesis as an explanation of pricing patterns in the ethanol-fuel market, a six-variable SVAR model of supply and demand is developed. A vector autoregression (VAR) approach consists of regressing each current variable in the model on all the model variables lagged a specified number of times. VAR is a reduced form approach, so economic interpretation of the results is often difficult or not possible unless this reduced form is linked to an economic model. Using economic theory to provide this link results in an SVAR model. The SVAR approach stems from the seminal contributions of Sims, Bernanke, and Blanchard and Watson who employed economic theory to impose restrictions in order to recover the structure of the disturbances. SVAR models are now a major tool in macroeconomic analysis of monetary, fiscal, and technology shocks (Brüggemann; Enders). Employing SVAR for analysis of the ethanol fuel market provides inferences on the impact corn, gasoline, and MTBE shocks have on this market.

Based on the contemporaneous interactions among the time series associated with ethanol, corn, gasoline, and MTBE, the following structural specifications are selected. The major determinant in ethanol fuel supply is the price of corn, p_c, measured as a percentage change. Thus, in terms of supply, the percentage change in the price of ethanol fuel, p_e, is defined as a function of the price of corn percentage change. Given the possible complementary relation between gasoline and ethanol used as an oxygenate, percentage change in gasoline price, p_g, is also expected to influence the price of ethanol fuel along with the percentage change in ethanol quantity, q_e. This yields

(1) $p_e = \beta_1 p_c + \beta_2 p_g + \beta_3 q_e + \mu_1,$

where the uncorrelated error term μ_1 reflects supply shocks. The parameter β_1 is assumed to be positive, since it is hypothesized that the price of ethanol fuel varies directly with the price of its major input corn. In contrast, the parameter β_2 is hypothesized to be negative, given a decrease in the price of gasoline boosts gasoline demand which simulates an ethanol supply response and corresponding enhanced ethanol price. The quantity of ethanol parameter, β_3, would in general be positive in the short-run based on the Law of Diminishing Marginal Productivity. However, in the long-run it is possible $\beta_3 < 0$. Given the recent rapid expansion of ethanol refining, economies of size may result in a decreasing-cost industry with a negative sloping market supply curve.

Ethanol demand is hypothesized to be a function of its own price, p_e, the price of its close substitute MTBE, p_m, and price of its complement gasoline, p_g

(2) $q_e = \beta_4 p_e + \beta_5 p_m + \beta_6 p_g + \mu_2$,

where all prices are again measured in terms of percentage change, the parameters β_4 and β_6 are hypothesized to be negative and parameter β_5 is positive. Ethanol fuel is assumed to be an ordinary good, so the own price of ethanol fuel is inversely related to its quantity. Gasoline is a complementary good for ethanol fuel and MTBE is a substitute resulting in the negative and positive parameters, respectively.

Finally, the inverse demand for MTBE is represented by

(3) $p_m = \beta_7 p_e + \beta_8 p_g + \beta_9 q_m + \mu_3$,

where q_m is the percentage change in quantity of MTBE. The ethanol and MTBE limit price hypothesis and the complementary nature of MTBE with gasoline suggests positive signs for parameters β_7 and β_8. A negative sign is expected for parameter β_9 given MTBE is an ordinary good. Similar to μ_1, the uncorrelated error terms μ_2 and μ_3, reflect corresponding demand shocks. To complete the system

(4) $p_g = \mu_4$, $p_c = \mu_5$, $q_m = \mu_6$.

Prices of gasoline and corn and supply of MTBE are treated as exogenous shocks, μ_4, μ_5, and μ_6, to the demand and supply system.

Data

Nominal monthly price series, from April 1998 to July 2005, for ethanol, MTBE, and conventional gasoline were collected from *Renewable Fuel News* and matched up with corn prices from the USDA Economic Research Service. The resulting price series are plotted in figure 3.

The trend in corn prices over this period is relatively flat with the exception of the spike in 2004 from unusually large international demand, especially from China, and a general economic expansion following the 2001 recession. The trends in prices of ethanol, MTBE, and gasoline are more clearly defined with a general upward tendency except for the mild downturn during the 2001 recession. Particularly since the recession, ethanol prices have tended to track with corn prices (24% correlation) and MTBE prices track closely with the prices of gasoline (87% correlation). At the 1% significance level, prices of MTBE and gasoline exhibited higher volatility since the period immediately preceding the Iraq war. This volatility represents a tighter balance of supply and demand for oil observed in recent years. However, for the ethanol price there is no significant difference in pre- and post-war standard deviations even at the 10% significance level.

For estimation, the nominal prices were deflated using the monthly Producer Price Index (PPI) data for refined petroleum products (series WPU057) available from the Bureau of Labor Statistics website (BLS 2004). The data, including quantities of ethanol and MTBE also collected from *Renewable Fuel News,* were transformed into percentage changes by taking the first differences of the natural logarithms. Following Pindyck, the augmented Dickey-Fuller test with the time trend, t, was performed by estimating the model

$$\Delta y_t = \gamma_o + \gamma_1 t + \upsilon y_{t-1} + \epsilon_t$$

where y is the time-series variable and γ_o, γ_1, and υ are parameters. The results of the tests are presented in table 1, where the p-values used for significance testing are interpolated MacKinnon approximate critical values for the t-statistics on υ. As indicated in table 1, the hypothesis of a unit-root is rejected at the 99% confidence level for all of the six time series, indicating stationary series.

SVAR Results

Prior to estimating (1) – (4) by SVAR, the log likelihood, Akaike's, and Hannan and Quinn information criterion statistics were computed for determining the lag length in the specifications. The log likelihood statistic indicated a lag length of four compared to higher lags for both the Akaike's and Hannan and Quinn criteria. The resulting discrepancy is the result of very small changes in the summary statistics for these tests when going from one to five or more lags. Estimation of the model in a SVAR framework for alternative lag lengths yielded robust results with nearly identical estimated coefficients. For reporting the results, a four-lag specification was selected.

The four-lagged specification used in a SVAR model based on (1) – (4) resulted in the following estimated coefficients

(5) $p_e = \mathbf{0.927} p_c - \mathbf{0.244} p_g - \mathbf{1.871} q_e + \mu_1,$

$q_e = \mathbf{0.926} p_e + \mathbf{0.651} p_m - \mathbf{0.237} p_g + \mu_2,$

(6) $p_m = \mathbf{0.584} p_e + \mathbf{0.251} p_g + 0.183 q_m + \mu_3.$

The coefficients in bold are all significantly different from zero at the 95% confidence level and have the anticipated signs, except for own price in the ethanol demand equation. This positive effect of own price of ethanol on demand for ethanol may be explained by the institutional structural shift in substituting ethanol for MTBE. With the banning of MTBE, ethanol emerged as the only fuel oxygenate. At least for the time period covered by the data set, as ethanol replaced MTBE, demand for ethanol continued to grow even in the face of raising ethanol prices. Signs of the other parameters were as expected, with price of ethanol positively affected by shocks to corn prices, and price of MTBE positively influenced by shocks to the price of ethanol.

The Wald test was employed to investigate Granger causality. As listed in table 2, the test statistics for prices of ethanol and MTBE support the implication of the limit-price hypothesis that MTBE prices adjust in response to ethanol price shocks. The null hypothesis of ethanol prices not Granger causing MTBE prices is rejected at the 90% confidence level. In contrast, the null hypothesis of MTBE prices not Granger causing ethanol prices cannot be rejected at the 90% level of confidence. This result suggests that prior to government restrictions on the use of MTBE, MTBE refiners may have either implicitly or explicitly manipulated their prices in response to any changes in ethanol prices that would have made ethanol competitive in the market for fuel additives. Finally, the Wald test also indicates a one-way causation between prices for corn and ethanol. Corn prices appear to influence the price of ethanol, but the reverse is not true.[1]

In addition to the direction of causation, the influence of one variable on another provides information on the relative magnitude of its causation. Performing variance-decomposition analysis yields this information by measuring the effect of shocks in each variable on the current and future values of the other variables in (1) – (3). Specifically, decomposition reflects the percentage of forecast variance of each variable in the SVAR model caused by shocks to the other variables. Table 3 lists the decomposition matrix after five periods (months).

From table 3, the variability of ethanol price contributes only 2% of the forecast variance for the corn price. In contrast, for the ethanol price and quantity, the share of forecast variance from the corn price is 17% and 27%, respectively. Similarly, the variability of prices of ethanol and gasoline account for 26% of the variance in th MTBE price. For the price of gasoline and quantity of MTBE variables, none of the variable shares are particularly large with the exception of the corn price share in forecast variance of MTBE. This variance-decomposition analysis further supports the limit-pricing hypothesis, by indicating the variability of the ethanol price has a relatively large impact on the price of MTBE.

Finally, if the limit-price hypothesis is to have any credence, the speed at which the MTBE price adjusts to a shock in ethanol prices should be relatively high. Such a rapid adjustment would indicate a targeted response rather than a random fluctuation of prices. As a measure of this response speed, impulse response functions were constructed for the variables in the SVAR model. The response functions measure the effect of a one standard-deviation shock of a given variable on current and future values of the variables in (1) – (3). For all the variables, the responses to a shock in one variable were found to die out after five periods (months) with a very narrow 95% confidence band encompassing zero impulse response. After ten periods all confidence bands collapsed to zero. This result indicates the price of MTBE adjusted to changes in ethanol prices and quantities within six months, providing further support to the hypothesis that MTBE refiners may have matched changes in the price of ethanol in order to prevent its entry into the alternative fuel market.

Implications and Conclusions

The estimated structural vector autoregression model indicates that although ethanol and MTBE were substitutes in the fuel additives market during the period analyzed, their prices were subject to different shocks. In particular, ethanol prices have been significantly driven by changes in supply. In contrast, the price of MTBE was significantly positively impacted by ethanol demand shocks. This differential supports a hypothesis of limit-pricing behavior on the part of MTBE refiners during the period analyzed. The coefficient associated with the price of ethanol in the MTBE price equation (6) is significant, implying that the price of MTBE responded positively to shocks in ethanol prices. Granger causality further supports this result by indicating price changes in MTBE were caused by a shift in the price of ethanol. The magnitude of this causation is measured by the variance-decomposition statistic. This statistic indicates the price of ethanol has a major influence on MTBE current and future prices. The speed at which MTBE prices responded to ethanol price shocks also supports the limit-pricing hypothesis. Within six months MTBE prices were found to adjust to any ethanol price shocks.

These results suggest the U.S. corn-based ethanol industry is vulnerable to limit-price competition, which could reoccur. The dependence of corn-based ethanol price solely on supply determinants limits U.S. ethanol refiners' ability to price compete with sugar cane-based ethanol refiners. With the market restrictions in the form of a ban on MTBE and tariffs on imports, a window of opportunity is currently open for the U.S. ethanol industry. However, without these restrictions and given the homogeneous product nature of ethanol fuel, U.S. ethanol refiners will find it difficult to complete with lower priced sugar cane-refined ethanol, chiefly from Brazil. In a Bertrand type competition, Brazil's more technologically efficient sugar cane refining process would dump low-priced ethanol fuel onto the U.S. market and squeeze out any U.S. ethanol refiners' market share. If WTO agreements result in the elimination of the existing U.S. tariffs or ethanol refiners begin to take advantage of the Caribbean Basin Initiative duty-free provisions on ethanol imports, low-priced Brazilian ethanol may flood the U.S. market. Brazil could become the OPEC of ethanol.

One avenue which could potentially avoid this Brazilian technological gap with associated Bertrand competition is for U.S. technology to provide a bridge for the corn-based ethanol industry to shift toward a cellulose-based technology. Currently, demonstration facilities are operating or under development to bridge this technological gap. The potential exists in 50 years for commercially feasible cellulose-based ethanol refining facilities to be operational (Perlack *et. al*).

Footnotes

[1] In 2006, this condition may have shifted. The continued strong demand for ethanol is drawing down corn inventories and putting upward pressure on corn prices. Future analysis of these markets may reveal this shift.

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Table 1. Augmented Dickey-Fuller Unit Root Test

Time Series[a]	Augmented Dickey-Fuller Statistic
Quantity	
Ethanol	−14.35
MTBE	−8.60
Price	
Corn	−7.56
Ethanol	−7.84
MTBE	−8.60
Gasoline	−11.69

[a] The statistics indicate a significance level of 0.01 for all six of the series.

Table 2. Granger Causality Wald Tests for the Null Hypotheses of No Granger Causation

Direction of Causality[a]	χ^2	Decision[b]
Ethanol and MTBE Prices		
$p_e \rightarrow p_m$	12.86	Reject
$p_m \rightarrow p_e$	8.32	Do not Reject
Ethanol and Corn Prices		
$p_e \rightarrow p_c$	2.43	Do not Reject
$p_c \rightarrow p_e$	12.15	Reject

[a] The arrow, →, indicates the direction of Granger causality. Prices of corn, ethanol, MTBE, and gasoline, in terms of percentage change, are p_c, p_e, p_m, and p_g, respectively.

[b] At the 90% confidence level.

Table 3. Variance Decompositions after Five Periods (Months)

Variable	Percentage of Forecast Error					
	p_c	p_e	p_g	p_m	q_e	q_m
Price						
Corn, p_c	0.57	0.02	0.29	0.08	0.01	0.02
Ethanol, p_e	0.17	0.08	0.26	0.14	0.30	0.05
Gasoline, p_g	0.06	0.01	0.83	0.01	0.00	0.09
MTBE, p_m	0.07	0.15	0.11	0.58	0.09	0.05
Quantity						
Ethanol, q_e	0.27	0.29	0.06	0.12	0.23	0.03
MTBE, q_m	0.21	0.03	0.03	0.03	0.01	0.68

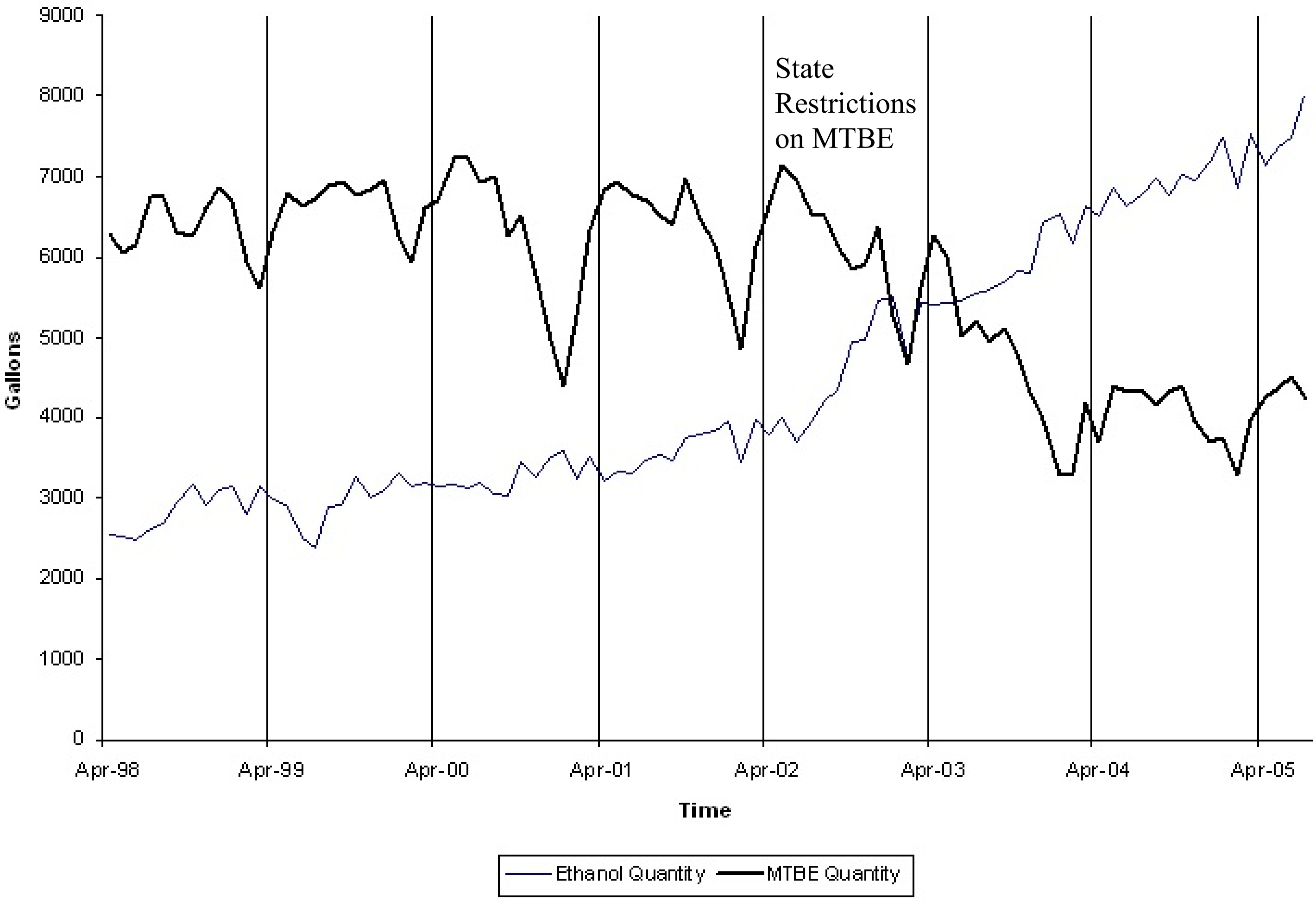

Figure 1. U.S. Refining of Ethanol and MTBE from 1998 through 2005 (Source *Renewable Fuel News*)

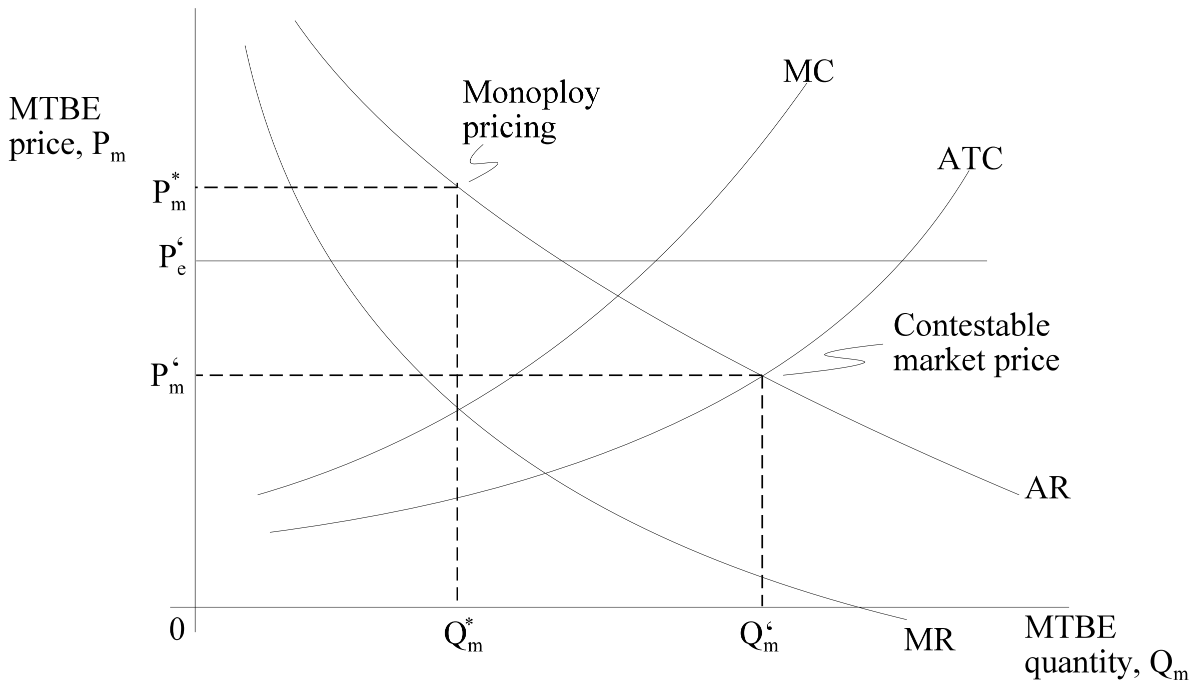

Figure 2. Pricing Range for a MTBE Incumbent

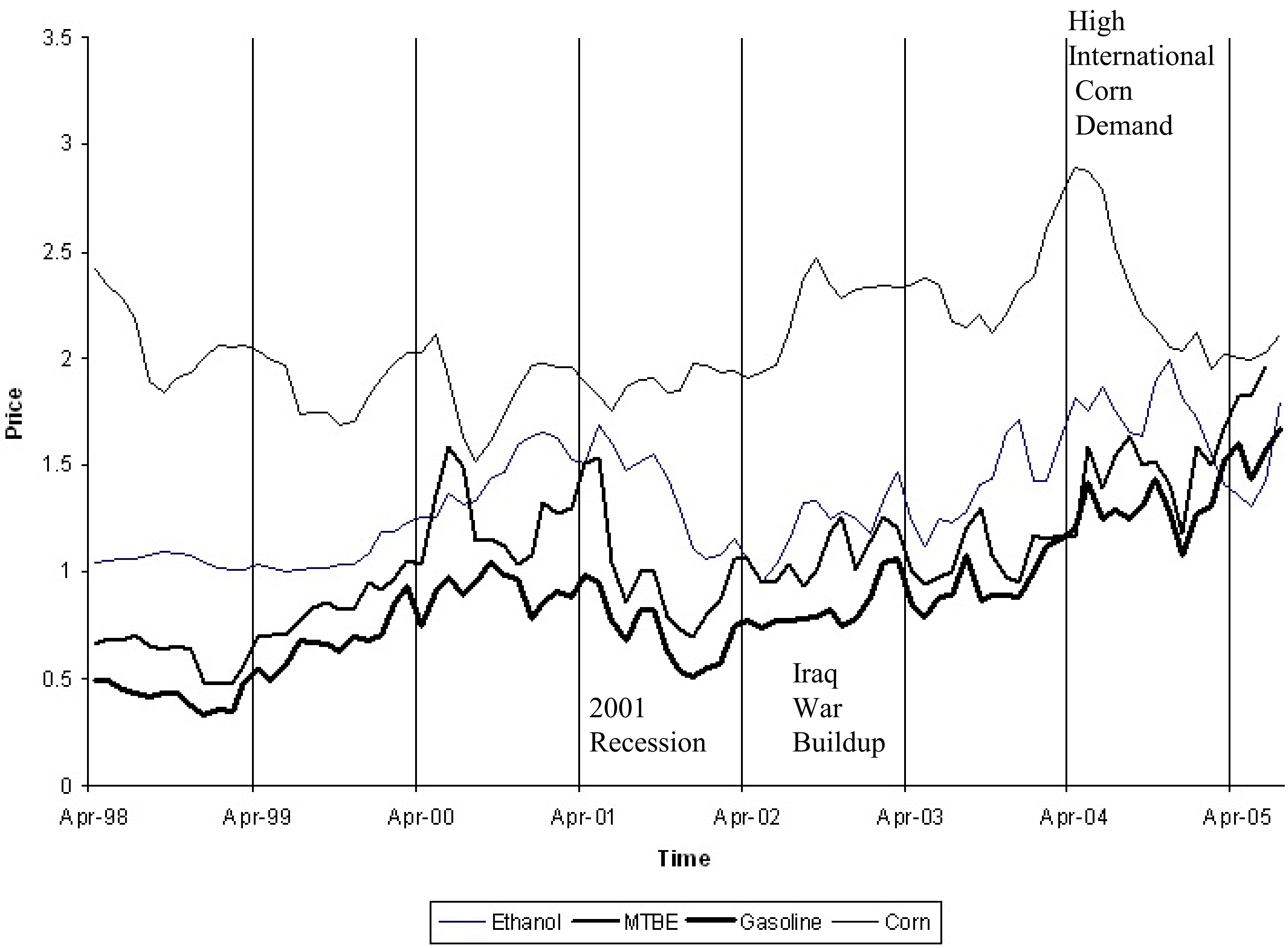

Figure 3. Monthly Price Series for Ethanol, MTBE, Gasoline, and Corn from April 1998 to July 2005