Energy Economics 34 (2012) 2157–2166

Contents lists available at SciVerse ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

How market efficiency and the theory of storage link corn and ethanol markets

Mindy L. Mallory [a,*], Scott H. Irwin [a], Dermot J. Hayes [b,c]

[a] Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, United States
[b] Department of Economics, Iowa State University, United States
[c] Department of Finance, Iowa State University, United States

ARTICLE INFO

Article history:
Received 28 March 2011
Received in revised form 7 March 2012
Accepted 7 March 2012
Available online 1 April 2012

Keywords:
Ethanol
Corn
Energy
Storage
Arbitrage
Cointegration
Futures
Price-analysis

ABSTRACT

This article uses the theories of market efficiency and supply of storage to develop a conceptual link between the corn and ethanol markets and explores statistical evidence for the link. We propose that a long-run no-profit condition is established in distant futures markets for ethanol, corn and natural gas and then use the theory of storage to define an inter-temporal equilibrium among these prices. The relationship shows that under certain conditions, future price expectations will influence nearby futures prices and that a short-term relationship between input and output prices will exist. We demonstrate validity of the theory using a structural price model and then by means of time-series techniques.

1. Introduction

Thanks to a combination of favorable market conditions and government support, over a third of the U.S. corn crop currently is used to produce ethanol and ethanol production recently overtook exports as the second largest use category of corn behind feed and residual use.[1]

This article uses the theories of market efficiency and supply of storage to develop a conceptual link between the corn and ethanol markets and explores statistical evidence for the link. Unlike previous studies, we propose that the link between the corn and the energy sectors is manifest in *futures* prices at least 1 year to maturity. Previous studies have focused on the link in spot (or nearby futures) markets, with disappointing predictive ability. Our contribution recognizes that the link between corn and ethanol prices should come about from a long-run, no-profit condition; therefore, the link is established in forward prices. Once we have established this long-run relationship, cost-of-carry arbitrage conditions that are specific to the corn, ethanol, and natural gas futures markets are used to calculate a nearby futures corn price forecast.

Our results lend strong support to the forward equilibrium hypothesis even through the recent ups and downs of corn and ethanol prices. This relationship began in mid-2006 and it has continued to at least the winter of 2012. This relationship appears to be sufficiently strong to dominate all other forces at play in setting the relationship between corn and ethanol prices in recent years.

We perform cointegration analyses to econometrically test our hypothesis. These tests lend support for the case that corn, ethanol, and natural gas prices are in fact governed by a breakeven relationship. Further, these tests indicated that the breakeven relationship is established in the futures markets for ethanol, natural gas, and corn 1 year to maturity and then transmitted to the nearby market through the carry costs in each market.

2. Industry background and previous work

The corn-based ethanol industry receives support in two primary ways. Ethanol usage mandates currently are defined by the Renewable Fuels Standard in the Energy Independence and Security Act of 2007. These mandates set annual blending requirements through 2022. Also, the industry has enjoyed a federal income tax credit known as VEETC (volumetric ethanol excise tax credit) which most recently paid blenders $0.45 per gallon of ethanol blended with gasoline; VEETC was accompanied by a per-gallon import tariff that was designed to offset the impact of VEETC on the world market. VEETC and the import tariff were scheduled to expire on December 31, 2010, but were granted a one year extension through 2011. Ultimately, they expired on

* Corresponding author at: 319 Mumford Hall, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, Urbana, IL 61801, United States. Tel.: +1 217 333 6547; fax: +1 217 333 5538.
E-mail address: mallorym@illinois.edu (M.L. Mallory).

[1] Supply and use statistics can be found in the USDA Economic Research Service Feed Grain Database http://www.ers.usda.gov/data/feedgrains/FeedYearbook.aspx.

0140-9883/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.eneco.2012.03.011

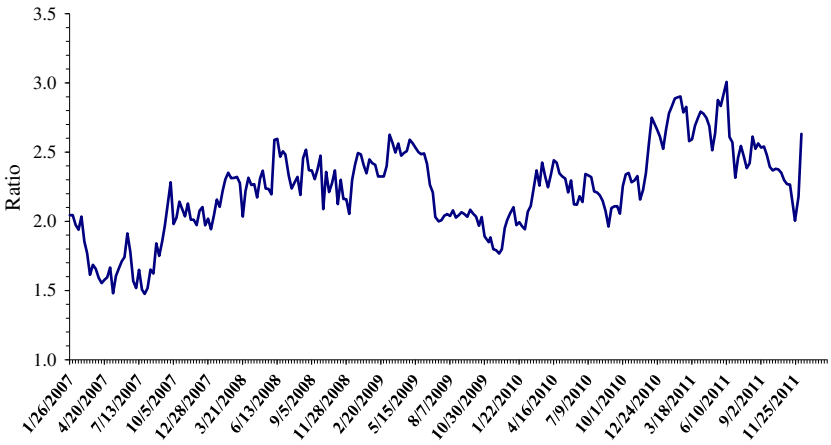

Fig. 1. Ratio of corn to ethanol price at Iowa plants, 01/26/07–2/10/2012.

December 31, 2011. It remains to be seen how much an impact this important change in ethanol policy will have in these markets.

Recent research has attempted to pin down the relationship between energy and agriculture created by corn-based ethanol production. Early work recognized that a long-run no-profit condition is likely to govern the price relationship between ethanol and its components. Then, if one is willing to assume that the price of ethanol and its non-corn components are exogenous to corn prices, one can solve for the long-run equilibrium price of corn.

A model of the corn and fuel markets was developed by de Gorter and Just (2008, 2009) that focused on welfare analysis with a long-run equilibrium relationship tying the two sectors together in their model. This work pointed out that when the intercept of the ethanol supply curve is above what would be the market price of ethanol without any tax credit, much of the tax credit is redundant (de Gorter and Just, 2008, 2009).

Tokgoz et al. (2007) used the model maintained by the Food and Agricultural Policy Research Institute (FAPRI) to make long-run projections of the effect of biofuel production on commodity prices and production. Tokgoz et al. (2008) again used the FAPRI model to simulate the effect of an exogenous event in one market on other markets; in particular, they explore the effect of a spike in crude oil price and the effect of a significant drought coupled with a renewable fuel mandate. These studies both relied on a long-run equilibrium condition in the ethanol market to transmit shocks in the ethanol market to the corn market.

This early research on the price implications of ethanol production clearly implied a belief on the part of the researchers that the price of corn and ethanol should be bound by a no-profit relationship. However, this hypothesis was not well supported by the data. As de Gorter and Just note, the long-run no-profit condition implies a linear relationship between corn and ethanol prices with a slope of approximately four. Fig. 1 displays the ratio of weekly central Illinois corn prices and ethanol prices at Iowa plants[2] from January 26, 2007, to February 10, 2012. It shows that this relationship historically has had an average of slightly larger than two, and has not come close to four.

In an attempt to better explain spot prices in the corn and ethanol markets, Kruse et al. (2007) used a medium-run relationship to analyze the effect of removing biofuel subsidies, and Thompson et al. (2009) in a similar analysis examined the covariance among corn, ethanol, and oil markets. Instead of assuming that a long-run no-profit condition holds, they specify ethanol supply and demand functions that depend on capacity, which requires the assumption that the ethanol market gravitates toward a long run equilibrium in the corn and ethanol markets.

Several studies have taken a more empirical approach to investigating linkages between corn and energy markets. Higgins et al. (2006) conducted a cointegration analysis of spot prices of ethanol, gasoline, natural gas, crude oil, and the fuel oxygenate MTBE. They found two cointegrating relationships containing corn, ethanol, natural gas, and MTBE.

Serra et al. (2008) used a threshold vector error correction model to estimate the cointegration of corn, ethanol, and crude oil nearby futures prices. The error correction model allowed them to estimate a long-run relationship–the error correction vector(s)–as well as short-run impacts of price relationships. They included threshold effects to capture possible nonlinearities in the relationship, which, they argued, may come about because of distribution bottlenecks or other factors. They find a single cointegrating relationship among the variables considered. Tyner (2010) explains how the Renewable Fuel Standard can generate this non-linear relationship. When the mandate is binding, the relationship between ethanol and crude oil or gasoline prices should be different than the relationship when the mandate is not binding. In fact, the presence of the RFS mandate may cause a non-linear relationship between ethanol and corn prices as well. This is because a binding mandate is likely to change the nature of causality in the corn and ethanol price relationship compared to a non-binding mandate.

Harri et al. (2009) used the cointegration framework to analyze whether or not there is a long-run equilibrium relationship between exchange rates, crude oil prices, and corn nearby futures prices. They found two cointegrating relationships but noted that previous research highlighted the effect of exchange rates on crude oil. It is therefore difficult to determine if this relationship was picked up because of the relationship between crude oil prices and exchange rates, or if corn is truly part of the equilibrium relationship.

Wu and Guan (2009) used a GARCH-type model to capture volatility spillover between the crude oil and corn markets, and Trujillo-Barrera et al. (2011) estimate a similar model to estimate the volatility spillover between ethanol and corn markets. Zhang et al. (2010) performed a cointegration analysis of global commodity prices. They analyzed crude oil, gasoline, ethanol, corn, soybeans, wheat, sugar, and rice spot prices, finding no long-run relationship between the energy and agricultural commodities. Only short-run effects were significant between the two groups.

Taking these studies as a whole, there seems to be a disconnection between the economic theory, which predicts that a long-run no-profit condition will dominate the pricing relationship between corn and ethanol, and the empirical literature. The empirical studies are

[2] Corn and ethanol prices are from the USDA Agricultural Marketing Service, which can be accessed in the Market News area of the AMS website: http://www.ams.usda.gov/AMSv1.0/.