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Biofuel Policies and Food Grain Commodity Prices 2006-2012: All Boom and No Bust?

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Biofuels policies have a large impact on food-grain commodity prices, first and foremost by linking biofuel prices to feedstock prices. The multiplier effect of higher biofuel prices on feedstock prices is shown to be very large (about 4) and the biofuel price premiums due to biofuel policies are also very high (above the tax credits) compared to what the biofuel price would have been otherwise. This has important implications for future energy, environmental, and agricultural policies, and for food-grain commodity prices.

Key words: biofuels, mandates, subsidies, environmental regulations, energy.

Introduction

> *"No lessons from the food crisis are of much relevance without understanding how this price spiral happened."* Timmer and Dawe (2010)

Many papers have been written on the role of biofuels policies and the food grain commodity price rise from 2006 to 2008. These papers analyze the food grain commodity price increases through the lens of traditional economic analysis such as the effects of exchange rates, macroeconomic policies and shocks, speculation, commodity supply/demand trends and shocks, the behavior of stockholders, and the like.[1] The methods used vary, ranging from basic supply/demand analysis to running big GTAP (Global Trade Analysis Project) or FAPRI (Food and Agricultural Policy Research Institute) simulation models and econometric models used in the finance literature on volatility (Hochman, Rajagopal, Timilsina, & Zilberman, 2011; Serra, 2012; Zilberman, Hochman, Rajagopal, Sexton, & Timilsina, 2012).[2] The overall conclusion is that biofuels had an impact on food grain commodity prices, but biofuels were only one of many factors in the "perfect storm" (e.g., Baffes & Haniotis, 2010; Headey & Fan, 2010). The literature emphasizes that biofuel policy is only responsible for part of that fraction of price increases in food grain commodities that is due to biofuels (Abbott, Hurt, & Tyner, 2008, 2009).

This article aims to expand the theory of biofuel policy by de Gorter and Just (2009a, 2009b) as developed by Drabik (2011) and derive the implications for the recent food grain commodity price fluctuations. This theory is a careful analysis of which biofuel policy is binding and of the specific relations between the oil, biofuel, and feedstock prices domestically and internationally. The implications of this theory for food grain commodity prices were foreshadowed in de Gorter (2008), de Gorter and Just (2010), Drabik (2011), and de Gorter and Drabik (2012a, 2012b).

The major finding of this article is that biofuel policies under environmental and energy legislation in OECD (Organization for Economic Co-operation and Development) countries, led by the United States, drove the unprecedented price spikes in the food grain/oilseed sectors. The sudden price spike was due to two unanticipated events: the US de facto ban on MTBE (Methyl-tert-butylether, a fuel additive that competes with ethanol) and the sudden realization by the market of US ethanol production capacity doubling in 2006 as unprecedented high oil prices activated the long-dormant US ethanol tax credit, creating a direct link between oil and corn prices for the first time (Tyner, 2008). In 2006, cereal and oilseed prices increased sharply, peaking in 2008 and falling precipitously thereafter with the 2008 financial crisis (Figure 1). But these prices regained their 2008 highs in 2011, while corn and oilseeds have reached new highs in 2012. Non-US corn-ethanol production in OECD countries in terms of volume is 50% of US corn-ethanol production; therefore, it is also a significant contributing factor. Because the yield per acre is much lower for biofuel production other than US corn-ethanol, the impact on food prices is

1. *The most notable, in alphabetical order, include Abbott et al. (2008, 2009); Baffes and Haniotis (2010); Carter, Rausser, and Smith (2011); Food and Agriculture Organization (2008); Headey and Fan (2010); Hochman et al. (2011); McCalla (2009); Roberts and Schlenker (2010); Stoeckel (2008); Timmer (2010); Trostle (2008); and Wright (2011).*
2. *See Table 1 in both Trostle (2008) and in de Gorter and Drabik (2012a) for a summary of all the factors considered by the "perfect storm" literature.*

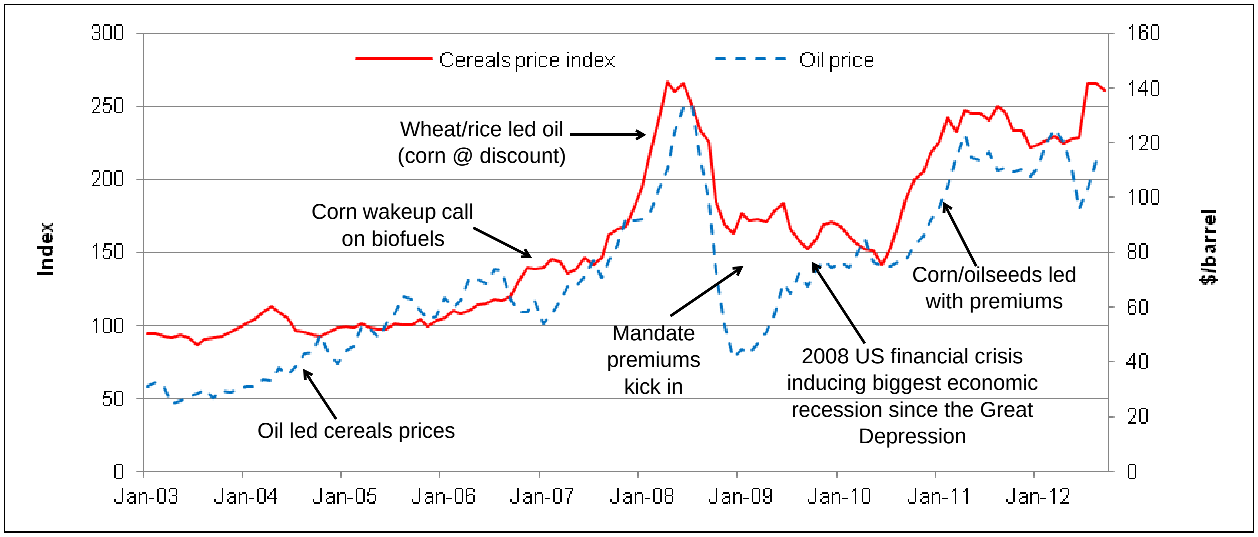

Figure 1. Oil and cereal prices.
Source. World Bank Pink Sheets

therefore expected to be disproportionately higher (e.g., ethanol from wheat in the United Kingdom).

We begin our analysis with US corn-ethanol, as this seems to be the initial biofuel shock to grain-oilseeds markets, although biodiesel production in Europe was taking its toll on wheat stocks (Mitchell, 2008). There was a new and unique role of energy and environmental policies that created a link between biofuel and crop prices. Biofuels policies have had various individual roles in affecting crop prices—varied in magnitude and direction over time—and had particularly nuanced interaction effects with each other and with biofuel policies in the rest of the world (de Gorter & Drabik, 2012a, 2012b; Rausser & de Gorter, 2012). Other countries play an important role as well. We argue that biofuels' impact on food markets is all due to policy. In other words, absent biofuels policy, biofuel production would not have increased dramatically and food prices would have risen only modestly.

How US Biofuel Policy Made its First Impact

We begin with US corn-ethanol to explain when and how biofuel policy linked biofuel prices to commodity prices. The key to understanding how biofuel policies affect food grain commodity prices is to recognize (a) how ethanol and corn prices became directly linked,[3] (b) when and how ethanol prices are linked to gasoline,[4] and (c) how gasoline prices are directly linked to oil prices.[5] The coefficient of the corn-ethanol price transmission relationship is itself extremely important to understand as it is the key driver for corn prices once ethanol and corn prices are linked (de Gorter & Just, 2008a, 2009a; Drabik, 2011). This relationship, as we will show later, transmits oil price fluctuations to all commodity prices.[6]

There are three key time periods: pre-October 2006, when there was no direct or obvious link between corn and ethanol prices; October 2006-August 2007, when there was confusion, adjustment, and learning; and post-August 2007, when corn and ethanol prices followed each other in lockstep. For the 33 months leading up to

3. *There is always the indirect link between oil and corn prices through input costs since corn production uses energy-intensive inputs. This has been emphasized as a major driver for commodity price increases (e.g., Abbott et al., 2008; Baffes & Haniotis, 2010).*
4. *When ethanol price is directly linked to oil prices, gasoline prices move in tandem with ethanol prices but are negatively related when the mandate is binding.*
5. *Du and Hayes (2009) and Irwin and Good (2012) argue that ethanol production has changed this relationship; the former study argues lower margins and hence gasoline prices are lower as a result, and the latter study argues that irreversible refining techniques make ethanol and hence corn prices more insensitive to changes in gasoline prices.*
6. *The link between vegetable oil and biodiesel prices and between biodiesel and diesel prices are equally important, as is the link between sugarcane, sugar, and ethanol prices in Brazil. The sugarcane-sugar-ethanol price link in Brazil had been going on for years. Europe has been producing biodiesel in substantial quantities since 2004, so there has been an EU rapeseed oil-biodiesel price link.*

October 2006, the corn price was around $2.00/bu, while ethanol and oil prices more than doubled. The corn market was not even reacting to the rising input costs resulting from the rise in oil prices (the traditional way oil prices affect commodity prices). Oil prices began their historic rise at the beginning of 2004, breaching the ever-important $40/barrel mark in mid-2004. Ethanol prices also rose sharply, partly because many individual US states were banning MTBE (a lower cost but close substitute for ethanol as an additive for fuel consumption) and partly because high oil prices activated the otherwise dormant US tax credit established in 1978, providing a premium on ethanol over gasoline prices. Ethanol prices soared to a peak of $3.65/gal in July of 2006; they never reached that level again, however. Ethanol prices fell to almost half that in early 2012 but corn prices are, at the time of this writing, about four times the level that prevailed for the 33 months leading up to October 2006.

The complacency of corn markets changed suddenly in October 2006 when the Central Illinois farm price of corn rose 88% (Kansas City white corn price 107%) between August 2006 and February 2007. This precipitated the Mexican Tortilla Crisis in January 2007 where tortilla prices had more than doubled with the ensuing political anxiety leading to the February 2007 ban on wheat exports by India, the first of many developing country policy responses to come. By October 2007, corn and ethanol prices became tightly linked, and corn-ethanol markets reached an equilibrium that the de Gorter and Just (2008a, 2008b, 2009a, 2009b) theory of biofuel policies predicts (Drabik, 2011). Meanwhile, soybean and rapeseed oil prices are tightly linked to biodiesel prices in the United States and the European Union, respectively.

While feed grain and oilseed prices were in lockstep with each other and with oil prices in 2007-2008, both economic and developing-country policy responses to the feed grain/oilseed price shock had a cascading effect on wheat and rice prices, with all prices reaching a peak in and around mid-2008. Biofuel policies ushered in a new era of high grain/oilseed prices that would have been permanent had it not been for the 2008 financial crisis that induced the most severe world economic recession since the Great Depression. But even with sluggish world economic growth post-2008, some grain/oilseed prices surpassed their 2008 peak in 2011 and again in 2012 with the US drought, the effects of which have been exacerbated by biofuel policies (Wright, 2011).

Table 1. Coefficient of variation for price ratios (monthly data, January 1965 to June 2012).

Corn/wheat	14.71
Corn/rice	21.35
Wheat/rice	21.13
Soybean/corn	14.93
Corn/sorghum	7.09

Source: Calculated using data from World Bank Pink Sheets

In theory, corn, oilseed, wheat, and rice prices follow each other, depending on the substitution possibilities in supply (land) and demand (food and feed). By and large, these key food grain commodity prices have followed each other historically. Surprisingly, a measure of variability (the coefficient of variation for corn over wheat prices) is identical to that for soybean over corn prices (Table 1).

Compared to the coefficient of variation of corn over wheat prices or soybeans over corn prices, the coefficient of variation for corn over rice prices is 50% higher; that of sorghum is 50% lower.

Because soybeans and corn prices are expected to be tightly linked with competition for land in the United States, and oilseed prices are tightly linked among themselves because of high substitution in demand, any change in biodiesel production on land use will have one-to-one impacts on oilseed and corn prices and vice-versa for corn-ethanol production on oilseed prices. One would expect wheat to be tightly linked to both corn (and coarse grains in general) and oilseed prices because of both competition for land and substitutability in demand. But rice would be expected to be less linked to coarse grain/oilseed prices in the short run and there is definitely no need for rice prices—unlike corn/oilseed prices—to follow crude oil prices (and hence corn/oilseed prices) in the short run.

As we will show later, corn, soybean, and oil prices tracked each other extremely tightly, peaking at the same time. Wheat futures prices peaked in advance of corn, and rice peaked in between. The crux of our argument will rest on whether developments in coarse grains and oilseeds (directly linked to biofuel production and whose prices are assumed to all go in lockstep)[7] were the major factor that caused the roller-coaster ride in food grain commodity prices since 2006. How wheat

7. *Ethanol is also made from wheat, but its share in production is not as important as that of corn, sugarcane, and vegetable oils. BP is currently constructing the world's largest ethanol plant in the United Kingdom with wheat as its feedstock.*

and rice prices follow coarse grains and oilseed prices will depend on the length of run of the analysis, the ability to switch between different products in consumption, and the competition for land and other inputs. Coarse grains and oilseeds account for 59% of total world crop area; adding wheat brings the total to 83%.

How Biodiesel Policies Affected Markets

The impact of US biodiesel policies early on depended on their interaction with Canadian and EU biodiesel policies (de Gorter, Drabik, & Just, 2011). US biodiesel production was essentially zero until 2004 and then increased sharply from 2005-2008, when US biodiesel exporters became eligible to receive a $1/gallon tax credit for the biodiesel fuel they exported, even when they simply added small amounts of diesel to much larger amounts of biodiesel ("splash and dash"). Some of the biodiesel was imported from other countries, such as palm oil from Malaysia. This tax credit helped raise the US price of biodiesel by making exports to the European Union more profitable, thereby increasing the price of soybeans and also the corn price, as land is taken out of corn and used in soybean production.

But US biodiesel production (and domestic prices) fell sharply in June 2008 with the initiation of the EU anti-dumping/countervailing duty investigation of the 'splash & dash' practice. US biodiesel prices and production plunged because the tax credit had acted as a biodiesel production subsidy (even though it was a biodiesel *consumption* subsidy) when biodiesel prices were determined outside the United States (de Gorter et al., 2011). The US tax credit was still valid but no longer able to keep prices at historical levels. US biodiesel prices stabilized after the duties were implemented in March 2009. The US-EU biodiesel price gap, which had widened sharply in 2008, stayed so until the US biodiesel mandate was finally enforced and so became binding in mid-2010. After mid-2010, US biodiesel prices and production have since increased sharply: current prices are just under $5/gallon (June 2012), well above what prices would be if the only US biodiesel policy were the $1/gallon tax credit. In fact, the expiration of the biodiesel tax credit at the end of 2011 has had little effect on US biodiesel prices as the mandate was binding, thus domestic prices were not directly linked to world prices (Brazilian biodiesel policy isolates their biodiesel sector from world markets).

The Economics of Tax Credits (Exemptions), Mandates, and Food Grain Price Levels

> *"Surprisingly, what is missing in much of the current debate on commodity food price inflation is legitimate empirical analysis."* Enders and Holt (2011)

In this section, we carry out analytical and empirical analyses that are both legitimate and surprising at the same time. We begin with the corn-ethanol price link. Then we analyze the ethanol price premium due to policy, assess what the net effects are on corn prices (while assessing other models along the way), and finally look at how, in theory, other crop prices may be affected.

Several important questions help to determine which factors were actually in play: what was the ethanol price premium, how much was the ethanol price premium due to a biofuel policy versus market forces, and how does the ethanol price premium translate into a change in corn prices? How do corn prices interact with biodiesel policies and oilseed prices? How do wheat and rice prices react to those of corn and oilseeds? We now address each issue in turn.

The Corn-Ethanol Price Link

It is essential to understand that with the advent of biofuels, corn and oilseed prices eventually became directly linked with ethanol and biodiesel prices, respectively.

The theory of biofuels suggests that for every $0.01/gallon change in ethanol prices, the corn price changes by about $0.04/bushel (Drabik, 2011). This high price transmission coefficient reflects two factors. First, one obtains 2.8 gallons of ethanol per bushel of corn. Clearly, the lower bound of this ethanol to corn price transmission is $0.028/bushel for every $0.01/gallon change. But about 26% (recent data) of the value of the corn used for ethanol is returned to the market in corn-equivalent terms as animal feed (Dried Distillers Grains with Solubles, DDGS). Hence, the overall price transmission coefficient depends also on the price of DDGS and the amount of DDGS per bushel, so it varies over time. For 2010, the corn prices change $0.0379/bushel for every $0.01/gallon change in ethanol prices (Drabik, 2011).

If the US tax credit is binding (ignoring international trade price linkages), then ethanol prices follow oil (gasoline) prices, and corn follows the ethanol price. The

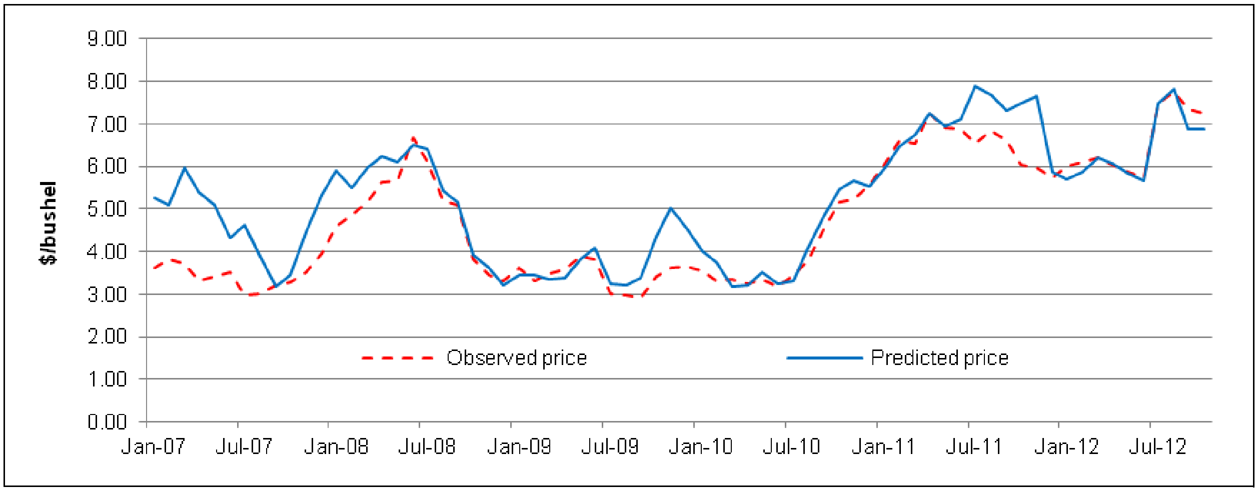

Figure 2. Theory versus practice: Corn-ethanol price transmission.
Note. Derived from Drabik (2011), using data from Iowa State University, CARD (n.d.).

formula, based on de Gorter and Just (2008a), is explained in Drabik (2011).

$$P_C = [\beta/(1 - r\gamma)]\ (P_E - c_0)\ , \qquad (1)$$

where P_C is the price of corn in \$/bushel, $\beta = 2.8$ gallons of ethanol from one bushel of yellow corn, $\gamma = 0.304$ bushels of co-product per bushel of yellow corn returned to the market, r represents the relative price of the co-product and yellow corn, P_E is the ethanol price in \$/gallon, and c_0 is the processing cost of one gallon of ethanol. The right-hand side term before the parenthesis, $\beta/(1 - r\gamma)$, is *about* 4 (e.g., 3.85 in 2010 according to Drabik, 2011). Abbott et al. (2008, 2009) argue the parameter is about 2, not about 4 as we derive it.[8]

Equation 1 governs the corn-ethanol price relationship under any corn or biofuel policy, though modifications may be needed depending on the policy. But there are at least three reasons why the corn-ethanol price link is somewhat moderated from Equation 1. First, we display cash prices. But, as Mallory, Hayes, and Irwin (2010) correctly suggest, it is the futures prices of corn, ethanol, and natural gas (a component of c_0) that one would expect for this relationship to hold. Second, corn prices are to strictly follow ethanol prices (assuming ethanol production does not affect the world oil price), but if the blend mandate is binding—meaning blenders would use less ethanol if not for the mandate—then the prices are determined simultaneously (de Gorter & Just, 2009b). So causality is not clear in this situation. Third, ethanol production subsidies would modify the relationship in Equation 1, adding a parameter to the right-hand side the equation (Drabik, 2011). There are various federal and state subsidies that come and go over the period of time in which ethanol policy has been effective. These policy fluctuations do not allow one to pin down the exact relationship in Equation 1 empirically.

Having said all that, Figure 2 shows that Equation 1 predicts corn prices astoundingly well empirically. But the model tends to over-predict corn price in three periods and this is due to capacity constraints that allowed positive profits in ethanol processing; therefore, corn prices were unable to be up to their equilibrium values as suggested by Equation 1 (de Gorter, Drabik, & Just, 2013a).

The Impact of the Tax Credit on Corn Prices 2008

Continuing with our assumption that the tax credit was binding (typical in literature, e.g., Abbott et al., 2008; Cui, Lapan, Moschini, & Cooper, 2011), and assuming the value for $\beta/(1 - r\gamma) = 3.84$ in 2008, and with federal plus state tax credits of \$0.558/gallon, the increase in the corn price due to the tax credit should be \$2.14/bushel (corn prices averaged \$4.78/bushel in 2008). Did corn prices increase 81% because of the tax credit in 2008? Probably not, due to 'water' in the tax credit where the intercept of the ethanol supply curve is above the free market ethanol price (which is linked to gasoline and oil prices). In other words, 'water' represents an

8. *Abbott et al. (2008. 2009) provide no explanation for why they choose the parameter of 2, nor do they explain why it should differ from about 4 as in de Gorter and Just (2008a).*

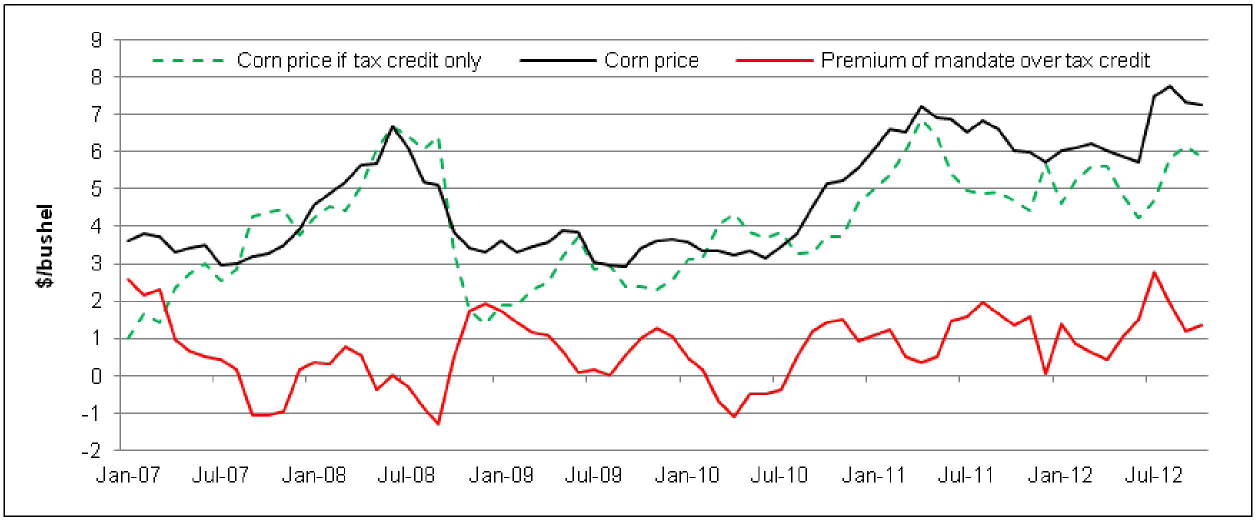

Figure 3. Upper bound of non-US ethanol effects.

Note. Derived from Drabik (2011), using data from Iowa State University, CARD (n.d.).

interval where an ethanol price premium due to biofuel policy has no impact on the corn market price. This generates what we call 'rectangular' deadweight costs before traditional triangular deadweight costs are incurred.

The Ethanol Price Premium Due to Ethanol Policy

Since October 2006, how high has the ethanol price premium been over the ethanol price with no biofuel policy? (We ignore the effects of the import tariff in reducing that free-market ethanol price.) Has it exceeded the federal-state tax credits of $0.558/gallon up to the beginning of 2009, of $0.498/gallon up to the beginning of 2012, and of $0.048/gallon thereafter? How would one calculate or determine this?

If consumers value ethanol and gasoline according to miles traveled, and if the consumers are free to choose between ethanol and gasoline, then the market price of ethanol in $/gallon that consumers are willing to pay (and be indifferent to purchasing a gallon of gasoline) can be expressed as

$$P^*_E = \lambda P^*_G - (1 - \lambda)t \,, \qquad (2)$$

where $\lambda = 0.70$ (the miles per gallon of ethanol relative to a gallon of gasoline), P^*_G is a hypothetical price of gasoline under no US ethanol policy, and t denotes the volumetric fuel tax. We assume this would be the ethanol price when no ethanol policies exist (where 'ethanol policies' are defined here as ethanol mandates, production, and consumption subsidies for ethanol and production subsidies for corn for ethanol—ethanol import tariffs are important but we discussed them separately above). Equation 2 shows that this (clearly hypothetical)[9] ethanol market price is directly linked to the gasoline (oil) market price. However, the ethanol price consumers are willing to pay is substantially less than the price of gasoline for two reasons, represented by each term in Equation 2.

The first term shows that consumers are only willing to pay λ times the price of gasoline, owing to the lower mileage per gallon from ethanol. The second term reflects the effects of the *volumetric* fuel tax, which represents a penalty to blenders; they have to pay the tax but consumers are only willing to pay a fuel tax on ethanol proportional to its mileage per gallon, λt. Blenders have to pay the full tax and therefore are willing to pay less for ethanol as a result. Therefore, the difference $(1 - \lambda)t$ represents the penalty on ethanol (reflected in lower ethanol market prices) due to the volumetric fuel tax.

So the historical ethanol price premiums of the actual ethanol price over the price with the tax credit only are very high, averaging $0.65/gallon (including negative values) since the beginning of 2007 (Figure 3). This was above the average tax credit over the time period—$0.5375/gallon until January 1, 2009, and

9. *This price may not ever be observed in a market under conditions where ethanol would not be supplied (either from domestic production or imports) at such a price.*

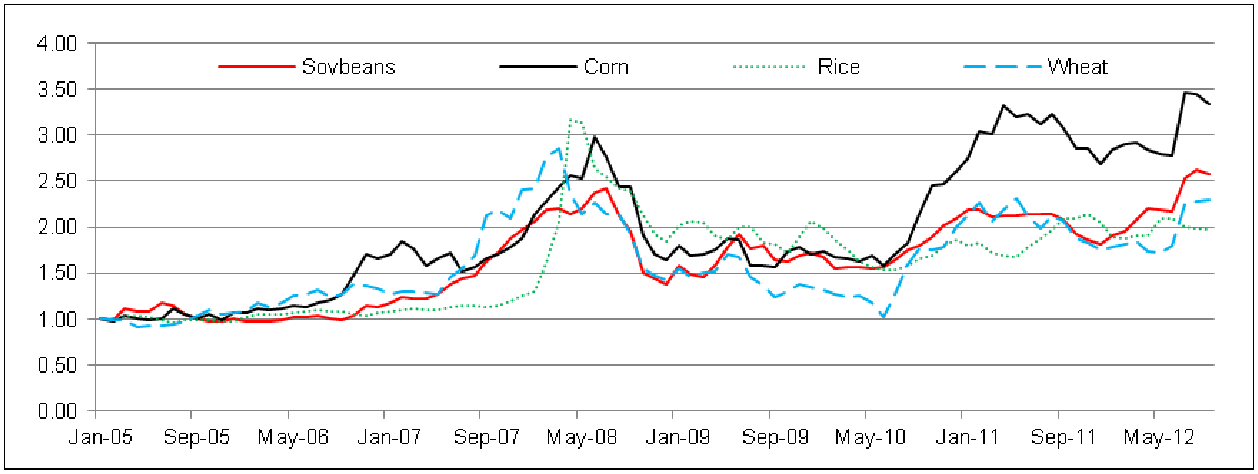

Figure 4. Crop price indices (January 2005=1).
Source. World Bank Pink Sheets

$0.51/gallon thereafter. This indicates that, on average, the mandate (de facto or otherwise) was binding rather than the tax credit.[10] Clearly, all of the biofuel impact on commodity prices is policy induced (there would be no ethanol consumption without US ethanol policy).

On average, the ethanol price has been above the 'no-policy' ethanol price by more than the tax credit throughout the time period. The reasons for this include the de facto MTBE ban until 2008, the binding US mandate in 2008-2009, and US ethanol prices linked to high world prices with US the biggest ethanol exporter in the world for 2010-2012.

So does that mean federal plus state tax credits of $0.52/gallon through the end of 2011 means a $2.08 increase in the price of corn? No, due to 'water' in the ethanol price premium. For 2010, the corn price is estimated to be 45% higher due to ethanol policies (see Drabik, 2011).

Then what is the net effect of the ethanol price premium on corn prices? An ethanol price premium average of $0.65/gallon translates into $2.60/bushel, rather high given corn prices averaged $4.64/bu over the time period of 2005-2012. How can that be? And if the mandate is binding, is the corn price premium higher? How much is due to ethanol policies? Drabik (2011) gives estimates of 'water' and the net effects on corn prices for the 2008-2011 time period.

Drabik's (2011) estimates are underestimated for at least two reasons. First, the calibrated supply and demand curves for corn incorporate effects of biofuel policies everywhere else (corn supply curve and non-ethanol demand curve shift up because of other biofuel policies in the United States and rest of the world, thereby overestimating the intercept of the corn-ethanol supply curve). For example, US biodiesel policy causes land to be pulled out of corn into soybeans; therefore, the 'no-ethanol' corn price is now higher and so the estimate above of a 45% increase in corn prices for 2010 is an underestimate, as other biofuel policies (including those in the rest of the world) have caused the counterfactual corn price with no US ethanol policy to be higher than otherwise would have been the case.

Second, stocks are now lower and a new regime exists between stockholding and market prices. The price response to a supply demand shock depends on the level of inventory (Carter et al., 2012; Hochman et al., 2011; Wright, 2011); therefore, if inventory is drawn down—itself because of biofuels as an unexpected event—then any shock in corn supply and demand results in a higher change in corn prices than if there were no biofuel policy.

How Corn and Oilseeds Led the 2008 and 2010 Price Spikes

Let us now examine in greater detail the price increases in 2008, 2010, and again in 2012. How did it all happen? Was it the perfect storm for corn (and other feed grains and oilseeds with their link to biodiesel)?

The first thing to notice in Figure 4 is that corn and soybean prices (along with oil prices not shown) moved in lockstep since mid-2007.

10. *Some values of the corn price with tax credit only in Figure 3 would not have been observed since they fall below the "no ethanol corn price."*

Wheat and corn prices were following each other until the last quarter of 2006, when corn prices took off, reacting (rather belatedly) to ethanol production capacity and capacity under construction (see Rausser & de Gorter, 2012). Although the Central Illinois corn price increase was 88% from August 2006 to February 2007 (107% for #2 white corn Kansas City), the price increase was lower than otherwise as stocks were being drawn down significantly (Hochman et al., 2011).

Although world wheat production was down 3.7% in 2007, overall grain production was down only 0.6%. But wheat prices were pulled up by this sudden increase in corn prices (Figure 4). The export bans on wheat by India and Ukraine happened right after corn prices finally reacted to high oil prices and skyrocketed to its interim peak in February 2007. Soon after these two wheat export bans, wheat prices increased (up about $3/bushel since January 2005) and actually overtook that of corn. Wheat price increases began their last leg (basically straight up) after the October 2007 rice export ban by India, moving from $7 to $11/bushel in a very short time period. Wheat prices peaked before corn prices and began their descent before corn, although they rose again two months before corn's price peak as corn prices were rising. But wheat prices declined again one month before corn prices did and continued their slide for months.

Corn (and other feed grains and oilseed) prices started to spiral, resulting in price contagion as wheat prices reacted and later affected the political decisions of Asian governments, causing policy responses that affected rice prices.[11] As Figure 2 shows, by September 2007, corn prices were finally linked to ethanol prices as they should be and so corn (and oilseed) prices went their own way—following oil as economic theory would predict when the tax credit is binding. What happened to wheat and rice prices was immaterial to coarse grains/oilseed prices—the latter had to follow oil prices. But were wheat and rice prices independent of coarse grain/oilseed (and hence oil) price movements? It is up to the reader to decide.

Rice prices did not move until the India rice ban in October 2007 (Figure 4). As rice was by far the last price to react, it went ahead of corn at $5.30/bushel in March 2008, while wheat had passed corn earlier in July 2007 after corn had almost doubled to about $4/bushel in February 2007. Both wheat and rice prices descended from their 2008 peaks before corn and even beat it down part way. But after mid-2010, corn (and hence soybean and other oilseed) prices re-emerged as the price leader and went their own way, following crude oil prices again. Not surprisingly, wheat and rice followed along as both compete for land with coarse grains and oilseeds, while wheat can be fed to livestock and is substitutable for rice in human consumption (e.g., in India).

At high oil prices in 2008 (and again in 2011), the ethanol price premium due to the mandate fell to zero—the tax credit was binding and corn and oilseed prices were firmly locked onto oil prices. The official mandate requiring that ethanol constitute a certain percentage of all gasoline began to bind in 2008 and continued to do so off and on (switching with the tax credit) to 2010 (annual average ethanol price premiums were such that mandate was binding most, on average).

The moment corn prices peaked at the end of 2006, India banned wheat exports in February 2007. Wheat prices reacted slightly to the corn price jump but were otherwise going independently but then accelerated with the India wheat export ban and accelerated even more with the Ukraine ban on wheat exports (with wheat prices overtaking corn prices). And finally, on October 7, 2007, India bans exports of rice (sparking rice prices to increase for the first time) and wheat prices continued their increase on the steep trajectory.

The relative wheat-rice prices in Figure 4 shows wheat is far ahead of rice and takes off at an accelerated rate after the India rice export ban. Figure 4 also compares corn and rice prices. But on October 7, 2007, India bans rice exports and rice prices began their rise to their peak in May 2008, two months before corn. Did the corn price spike in 2006 due to US ethanol production and the ever increasing production of biofuels from corn, wheat and oilseeds around the world, taking land that otherwise would be producing food grains and oilseeds make governments, state trading agencies and private traders nervous (even individuals panicked and hoarded rice)? There were no untoward market developments in the rice market (see Footnote 10).

But next time around, after the fallout of the US 2008 financial crisis caused the biggest economic

11. *One might ask what happened in the rice market. Not much: "Rice market fundamentals were not the cause…; the rice crisis was not caused by adverse shocks to rice production or low rice stocks….The world rice-to-stock ratio was roughly constant in the three years preceding the crisis…; world rice trade in the first four months of 2008 ... was 20% higher than in the first four months of 2007....The favorable situation as regards to production, stocks, and trade strongly suggests factors other than basic market fundamentals were at work…" (Dawe & Slayton, 2010).*

Table 2. Price correlation coefficients (January 1965 to June 2012).

Corn/soybean	0.92
Corn/wheat	0.91
Corn/rice	0.88

Source: Calculated using monthly data from World Bank Pink Sheets

Table 3. Average price ratios: Past and expected.

	1965-Sept 2006	1965-June 2012	Oct 2006-June 2012	Dec 2012 futures
Soybean over corn	2.34	2.33	2.28	1.82
Corn over wheat	0.78	0.78	0.79	0.89
Corn over rice	0.59	0.58	0.55	0.61

Source: Calculated using monthly data from World Bank Pink Sheets

depression since the Great Depression (where the Illinois farm price of corn plummeted to a low $3.21, not the $1.77 low in 2005/2006 when the world was enjoying its biggest economic boom ever), corn prices started their march right back up again. It had no choice (see Figure 4); just like in 2008, it had to go to the peaks it did because ethanol prices dictated it (or vice-versa where corn prices have more influence on ethanol prices as the mandate is binding).

Like rice, wheat prices peaked earlier than corn and began its descent before corn prices peaked.

So did corn spark everything? Or did corn follow wheat and then rice? Is it the perfect storm or is it corn? There is only one thing we know for sure: corn had to go up and had to go up to the levels as it did, regardless of rice for the most part and to a lesser extent, regardless of developments in the wheat market. When oil prices peaked, corn prices had to peak. Rice and wheat could peak anytime it wanted to (or not peak at all). When 2010 came around and oil and ethanol prices marched right back up to 2008 levels, corn price had to follow.

The price correlations between corn and soybeans and wheat and rice are summarized in Table 2. Surprisingly, all prices are much correlated.

Average relative prices of corn with soybeans, wheat, and rice over alternative time periods are summarized in Table 3. The price ratios are very stable for the 1965 to September 2006 and 1965 to June 2012 time periods. The October 2006 to June 2012 average price ratios are also very close to historical levels: soybeans were 2.1% lower than corn prices and rice prices are 6% higher. But after the US drought hit markets in mid-June 2012, using December 2012 futures prices at the time of this writing, corn has gone up disproportionately higher than historical data would suggest: soybeans are down 21.6% relative to corn, while corn prices are 13.4% and 5.2% higher than wheat and rice prices, respectively, relative to historical norms.

Table 4. Ethanol price premium above the tax credit.

Month	$/gallon
January 2011	0.29
February 2011	0.34
March 2011	0.15
April 2011	0.11
May 2011	0.13
June 2011	0.36
July 2011	0.41
August 2011	0.50
September 2011	0.44
October 2011	0.40
November 2011	0.49
December 2011	0.06
January 2012	-0.11
February 2012	-0.24
March 2012	-0.29
April 2012	-0.31

Derived from Drabik (2011), using data from Iowa State University, Center for Agricultural and Rural Development (CARD; n.d.)

Other Factors

Biodiesel production affects US corn prices one-to-one because coarse grains and oilseed prices follow each other. It is also important to understand that in the biofuel era, prices of corn and ethanol become linked, as do soybean oil to biodiesel prices; in Brazil, sugarcane and ethanol prices are linked, as each are to sugar prices (de Gorter, Drabik, & Kliauga, 2012). Beginning in 2010, the United States became a significant net exporter of ethanol and the leading exporter of ethanol, even to Brazil. World ethanol prices were determined on the margin in the European Union and Brazil, where ethanol prices were significantly higher (always vis-à-vis the European Union and beginning in mid-2009 vis-à-vis Brazil). The US tax credit acted as a production subsidy for US ethanol but in the form of higher market prices for ethanol (de Gorter et al., 2011; de Gorter & Just, 2009b; Kliauga, de Gorter, & Just, 2011). Note that 80% of ethanol exports received the tax credit through the end of 2011, contrary to what was commonly known. So the

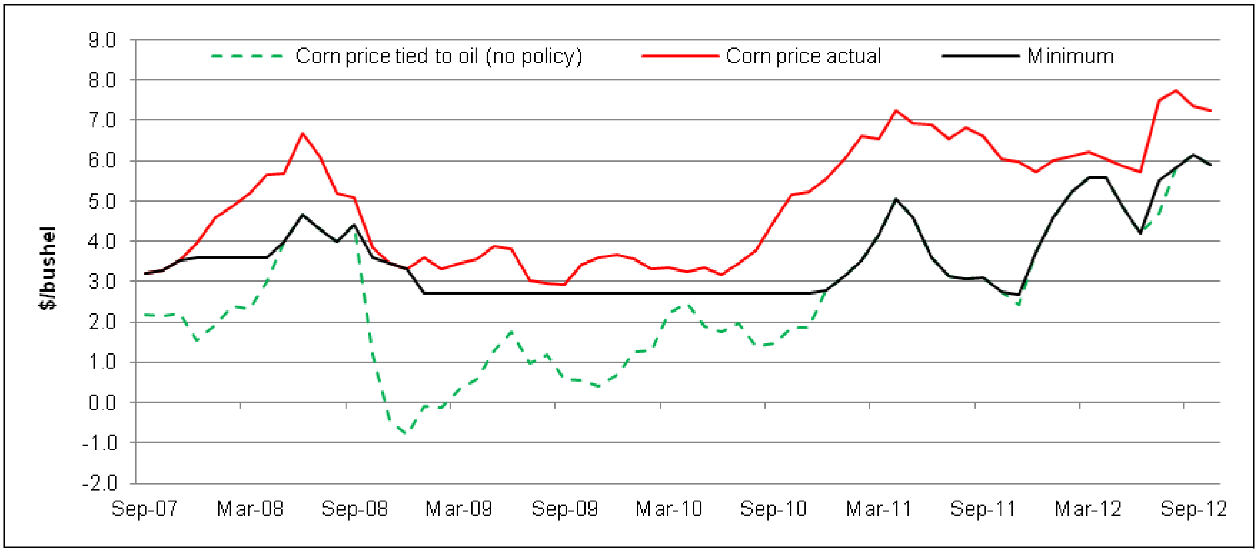

Figure 5. How low can corn price go?

Note. Derived from Drabik (2011), using data from Iowa State University, CARD (n.d.).

tax credit had a very special effect for the 2010-2011 time period, after which it expired.

Furthermore, the United States was successful to classify 2.1% denatured ethanol as a blended fuel and so only paid one-third of the approximately 67% EU import tariff on ethanol. But this loophole was closed in December 2011.[12]

How linked were US ethanol prices to world prices for the tax credit to have an impact on ethanol prices? One way to assess the effect of the tax credits is to look at the ethanol price premium above the tax credit for the past 16 months. The data are presented in Table 4 (note that the tax credit is assumed to be in effect in 2012, too). The average premium prior to December 2011 was $0.32/gallon but -$0.18/gallon thereafter. This differential adds up to exactly the value of the tax credit prior to its expiration. One possible reason it became negative in December 2011 was that the European Union closed the import tariff loophole.

What Would a Bust Look Like?

So far we have highlighted the price increasing effect of biofuels policies. But Figure 5 shows how low corn prices could have gone in the past had ethanol prices been tied directly to oil prices (through gasoline prices) with no ethanol price premiums due to either the tax credit or mandate; the dotted line in Figure 5 represents the corn price in $ per bushel if consumers purchased ethanol solely on the basis of miles traveled. The dotted curve simply links the corn price to ethanol price; the hypothetical corn price would go negative because the ethanol price, directly linked to the oil price (under no tax credit), would be lower than the ethanol processing cost, thus making the corn price negative, as per Equation 1. The black solid line in Figure 5 indicates the predicted corn price from Equation 1 with a tax credit only and consumers continue to purchase ethanol on the basis of miles traveled but puts a ‘minimum’ price of corn equal to the non-ethanol corn price estimated in Drabik (2011) for the years shown in Figure 5. Note that since 2011, corn prices would have varied between $4 and $5 per bushel.[13] These prices are substantially lower than recent prices.

Conclusions

We presented evidence that US and other OECD country environmental and renewable energy policies, activated by high oil prices, have been critically important not only in establishing the link between food-grain

12. *http://www.biofuelsdigest.com/bdigest/2011/10/18/eu-boosts-tariffs-to-block-low-cost-us-ethanol/*

13. *There was an average consumer price discount of 20% for hydrous ethanol in the past 8 years in Brazil to induce E100 and flex car sales (see de Gorter, Drabik, Kliauga, & Timilsina, 2013b). This may also be required in the United States to induce E-85 sales to overcome the “blend wall” and have consumers willing to purchase ethanol on the basis of miles travelled. In such a scenario, corn prices could be below that predicted in Figure 5.*

commodity prices and biofuel prices, but also for the surge in corn, oilseeds, and other coarse grain prices, as well as wheat and rice prices in the 2006-2012 period. As oil prices dropped in 2008-09, biofuels policy also played an important role in moderating the decline in food grain commodity prices as biofuel price premiums over gasoline and diesel prices rose because of the mandates. But both the 2010 and 2012 price run-ups were greatly influenced by biofuels policies as stocks are low and any weather shock has big impacts on prices.

In 2006, cereal and oilseed prices increased sharply, peaking in 2008 and falling precipitously thereafter with the 2008 financial crisis. But these prices regained their 2008 highs in 2011, while corn and oilseeds have reached new highs in 2012. Non-US corn-ethanol production in OECD countries in volume terms is 50% of US corn-ethanol production and so is also a significant contributing factor. Biofuel production other than US corn-ethanol requires more land per unit output and so the impact on food prices will be disproportionately higher.

We show food grain and oilseed prices move very closely together because of substitution possibilities in supply and demand, and because developing country policy responses and speculation (e.g., hoarding of rice) were induced by price spikes due to two unanticipated events: the US de facto ban on MTBE and the sudden realization by the market of US ethanol production capacity doubling in 2006 as unprecedented high oil prices activated the long-dormant US ethanol tax credit.

We show that the link between ethanol and corn prices is very strong; every $0.01 per gallon increase in ethanol prices increases corn prices by $0.04 per bushel. Improving the efficiency of converting ethanol into corn or reducing production costs with lower natural gas prices or higher co-product prices simply increases the price of corn and, hence, other food grain and oilseed prices. For example, taking more oil out of DDGS for biodiesel—prices of which are double that of ethanol because of discriminatory biofuel policies—has increased revenues $0.05 to $0.07 per gallon; this therefore, in theory, adds about $0.20 to $0.28 per bushel to the corn price.

We also show that the price premiums due to ethanol policy are very large. This new and unique role of energy and environmental policies on food grain prices will have long-standing effects, as witnessed by the current drought causing corn prices to be at historic highs while corn production is expected to be at 2007 levels. Biofuels policies have had various individual roles in affecting crop prices—varied in magnitude and direction over time—and had particularly nuanced interaction effects with each other and with biofuel policies in the rest of the world.

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