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The Impact of Biofuels Policy on Agribusiness Stock Prices

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Abstract: Corn markets are important for many industries. These include the seed, fertilizer, meat production/processing and agricultural machinery sectors, all of which are highly concentrated. Oligopoly theory suggests that corn input and field equipment suppliers likely benefit from policies that support corn markets, such as U.S. biofuels policy, while meat companies likely lose. This study investigates the impact of biofuels policy on U.S. agribusiness stock prices. Corn futures prices are found to have a structural change in November 2006, consistent with the expansion of U.S. biofuels policy support. A linear two-factor (S&P500 and corn prices) equilibrium asset pricing model is estimated on two subsamples, one before and one after the estimated change point. Conditional heteroskedasticity in stock returns is accounted for using a GARCH(1,1) model. In the more recent period, corn price increases are found to have positive effects on excess stock returns for seed, fertilizer and machinery companies, while the impact on meat companies is negative. The results may be interpreted as evidence that crop input suppliers gain from U.S. biofuels policies while meat processors lose.

Keywords: Biofuels policy, excess stock returns, GARCH effect, linear factor model.

JEL Classification: D43; L13; Q14.

1. Introduction

Corn ethanol production in the United States increased from 3.9 million gallons in 2006 to 9.0 million gallons in 2008 (RFA, 2009). United States corn use in ethanol production increased from about 5% of production in the mid 1990s to about 30% in the 2008/09 crop year (FAPRI, 2009). Not surprisingly, corn prices have risen. Average U.S. corn prices traded in the \$1.80-\$3.00 per bushel range over the 30 years to 2006, deviating mainly due to large supply side shocks. Since the late 2006 however, corn prices have risen to trade consistently above \$3.00 per bushel in spite of an increase in acres planted (see Figure 1). This shift in use has been due in no small measure to the substantial support provided by the U.S. government.

The U.S. federal government has supported ethanol development since passage of the 1978 Energy Tax Act, which provided federal tax incentives to encourage ethanol production and use. The act has been revised on several occasions, but the fundamental structure of the tax breaks have remained in place. As of 2010, the main federal-level ethanol market supports are a 45 cents per gallons tax credit provided to refiners for blending ethanol with gasoline, together with a 2.5% ad valorem tariff and a per unit tariff of 54 cents per gallon on ethanol imports. States, and major corn producing states in particular, have also been active in encouraging ethanol production (California Energy Commission 2004). The market for ethanol as a fuel additive has also grown due to air quality regulations. This market received a major boost in 2001-'02 when California banned the use of methyl tertiary butyl ether as an additive.

Ethanol production expanded again upon implementation of the Renewable Fuel Standard (RFS). This provision of the Energy Policy Act of 2005 mandated that 7.5 billion gallons of biofuels be used annually by 2012. The Energy Independence and Security Act (EISA) of 2007 further expanded the RFS, requiring the use of 9.0 billion gallons of renewable fuel in 2008 and 36 billion gallons in 2022, which includes up to 15 billion gallons of corn ethanol. In order

to meet their blending obligations under the RFS, refiners and fuel marketers can trade renewable fuel credits (RINS) under the U.S. renewable fuel trading system.

The corn market is critical for many input suppliers. Seed costs account for about 16% of total corn production costs in Iowa (Duffy and Smith, 2009), while fertilizer and machinery costs amount to about 16% and 14% of total costs, respectively. Corn is the dominant crop in the U.S. Midwest and its price correlates strongly with other field crop prices. Prices correlate because the commodities can substitute in use, and also because an increase in corn acres means a decrease in acres planted to other crops and/or an increase in overall acres under crops. Thus, a demand-driven increase in corn prices should be reflected in an increase in demand for agricultural inputs. Corn is also an important input in many markets, most notably in meat markets. Corn accounted for about 24% of total costs in the feeder to finish pig business in Iowa, 2009 (Ellis *et al.*, 2009).

Many field crop input markets are concentrated in structure. This may be because, as is the case with phosphate and potash, control of deposits is concentrated. Or, as is the case with the crop seed industry, some firms have invested heavily over many years in developing high quality foundation seed. In addition, formal intellectual property rights over yield-enhancing and cost-reducing traits give certain firms strong competitive advantage and constitute a barrier to entry.

The agricultural machinery manufacturing industry requires intensive technology and capital investments, as well as complementary knowledge over a wide range of equipment lines. High product development fixed costs need to be recouped in a limited market so that there can only be room for a handful of competitors. Concentration also exists in corn use markets, including North American poultry and hog production/processing. The reasons for this are less clear, but large integrated processors may have access to better quality animal genetics. They may also be better positioned to coordinate with retailers in delivering the meat

qualities that consumers demand, and to work profitably with the heavily concentrated North American grocery sector.

Our concern is with how biofuels policy, and by extension corn prices, affect agribusiness stock prices. We wish to establish whether investors in share-traded corn input suppliers gain from biofuels policies and whether investors in meat processors lose. These outcomes will arise if the business is possessed of some form of bargaining power over corn growers. Related work concerns the capacity of land owners to extract higher rents for crop land when crop profitability rises. For example, Alston (2007) provides an overview on analysis of the incidence of agricultural policy. Kirwan (2009) has sought to establish how agricultural subsidies are distributed between the landlord and the tenant. He found that 25% is captured by the landlord through increasing the rent. Presumably land scarcity in the vicinity of the tenant's farming operation endows the landlord with some bargaining power. In this paper we ask whether share markets indicate that input suppliers have the power to participate in the pecuniary good fortune that biofuels have brought to corn farmers, and whether meat processors lose?

Study of agribusiness stock price determination has been limited. Turvey *et al.* (2000) employ various measures, including share prices and CAPM returns, to analyze the relationship between economic value added (EVA) and stock market performance among seventeen Canadian food processing companies. High EVA is not found to be correlated with higher shareholder value. Using different data sets, Sparling and Turvey (2003) revisit the issue and support the same results. A related line of research has used event study methods to measure effects of economic events on firm values (MacKinlay, 1997; Henson and Mazzocchi, 2002; Jin and Kim, 2008).

In empirical finance, the multifactor model proposed by Fama and French (1993, 1996) has been found to successfully explain average portfolio returns. Related studies investigating and

documenting the relationship between multiple factors and asset returns for the U.S. financial market include, for example, Chen, Roll and Ross (1986), McElroy and Burmeister (1988) and Jagannathan and Wang (1996). In this study, we will employ a two-factor model when analyzing excess returns of stock prices for leading companies in the crop seed, fertilizer, machinery and poultry/pork industries. The sample industries have the common characteristic that corn is either a major user or input, and thus corn price changes induced by U.S. biofuel policies are expected to affect the firms' profitability significantly.

The paper proceeds as follows. In Section 2 the standard oligopoly theory model is reviewed to establish what microeconomic theory has to relate about how price movements affect profits in imperfectly competitive markets, and so how share prices should be affected. The market environments for the companies to be studied are then provided. Section 4 presents the empirical model and describes the data. Estimation results are summarized and analyzed in Section 5, and we follow with some concluding comments.

2. Microeconomic Model

Our empirical analysis will consider oligopolist input suppliers to corn producers, and also oligopolist meat producers where corn is a major input. In order to establish how biofuels policy should affect agribusinesses, we will develop a microeconomic model of sectors supplying inputs for corn production. Farm-level production is given as $y = f(s, x_1, x_2, \dots, x_K)$, where s represents the input at issue and x_1 through x_K represent other inputs. Input prices are given as w_s and w_1 through w_K with the obvious assignments. For convenience, other inputs are summarized as $X = \{x_1, x_2, \dots, x_K\}$ while other input prices are summarized as W .

Producers are price takers where the corn price is given as $P(\theta)$, with θ as an exogenous biofuels policy variable where $P_\theta(\cdot) \geq 0$, i.e., an increase in the policy variable increases demand for corn. The producer's problem is to arrive at

$$(1) \quad \Lambda(P(\theta), w_s, W) \equiv \max_{s, X} P(\theta) f(s, X) - w_s s - \sum_{i=1}^K w_i x_i,$$

with dual supply and factor demand functions as

$$(2) \quad \begin{aligned} \text{Supply :} & \quad y^*(P(\theta), w_s, W); \\ s : & \quad s^*(P(\theta), w_s, W); \\ \text{Other inputs :} & \quad x_i^*(P(\theta), w_s, W), i \in \{1, \dots, K\}; \end{aligned}$$

Our particular concern is with how demand for input s responds to the policy variable. Namely, does $\partial s^*(P(\theta), w_s, W) / \partial \theta \equiv s_p^*(\cdot) P_\theta(\cdot) \geq 0$ apply? Given $P_\theta(\cdot) \geq 0$, the condition is that $s_p^*(\cdot) \geq 0$, i.e., that the input is normal rather than inferior (Chambers, 1988).

Limited econometric information is available on whether this assumption applies for fertilizer, seed and machinery, in part because of data aggregation across crops and inputs. The data that are available, mainly for fertilizer and machinery, provide mixed but generally supportive results (McKay, Lawrence and Vlastuin, 1983; Huffman and Evenson, 1989). In addition, the law of supply requires that output increases in response to an increase in own price so that some input must increase. If an input decreases in response to an increase in the output price then some other input must substitute in for it. Given the importance and distinctive roles that macronutrients, seed and machinery play in the crop production process, it is hard to imagine a plausible technology with substitution so strong as to render any of these inputs as inferior.

If we agree that biofuels policy should increase demand for these inputs, then the next question is how the increase in demand should affect profitability for input suppliers. The markets are oligopolistic and the effect of demand shifts on oligopoly profits has been addressed in the literature, most notably by Quirnbach (1988). In the exposition to follow, we briefly present Quirnbach's reasoning so as to better understand how stock prices should respond to biofuels policy innovations. Upon aggregating over farm-level demands for an input, we arrive at the market-level inverse factor demand function for, say, seed as $S(Q; \theta, t)$

where $S_\theta(\cdot) \geq 0$. And we have allowed demand to shift with time t .

Let there be a fixed number N of the input producing companies labeled as $n \in \{1, 2, \dots, N\}$, or $n \in \Psi$ to abbreviate, where each produces q_n so that $Q \equiv \sum_{n \in \Psi} q_n$. Each firm is held to be identical with time conditional cost function $C(q_n, t)$ so that n th firm profit in period t is

$$(3) \quad \Pi_n(\theta, t) \equiv S(Q; \theta, t)q_n - C(q_n, t).$$

With $\beta_n \equiv (q_n / Q)dQ / dq_n$ as the n th firm conjecture about the elasticity of industry supply, perfect competition is given by $\beta_n \equiv 0 \forall n \in \Psi$, cartel behavior to support the monopoly solution is given by $\beta_n \equiv 1 \forall n \in \Psi$, and the Cournot quantity-setting solution is given by $\beta_n \equiv 1 / N \forall n \in \Psi$. The restriction $\beta_n \in [0, 1]$ is imposed for otherwise the conjectured response would be outside the bounds of reasonable beliefs about influence on market price.

Writing $R(Q; \theta, t) \equiv S(Q; \theta, t)Q$ as industry revenue, and $C_q(q_n, t)$ as firm marginal cost, consider the symmetric solution with $q_n = Q / N \forall n \in \Psi$ and $\beta_n = \beta \forall n \in \Psi$ so that the firm subscript may be omitted. Then simple algebra shows that the standard optimization condition for an oligopolist is

$$(4) \quad \frac{d\Pi_n(\theta, t)}{dq_n} \equiv (1 - \beta)S(Q; \theta, t) + \beta R_Q(Q; \theta, t) - C_q(Q / N, t) = 0,$$

with equilibrium value for aggregate output as Q^* . If the conjectural variation is independent of the demand shifter, then¹

$$(5) \quad \frac{dQ^*}{d\theta} \equiv - \frac{[(1 - \beta)S_\theta(Q; \theta, t) + \beta R_{Q\theta}(Q; \theta, t)]}{\Omega};$$

where $\Omega = (1 - \beta)S_Q(\cdot) + \beta R_{QQ}(\cdot) - C_{qq}(\cdot) / N$ while $\Omega < 0$ is the standard, and quite intuitive, convention.

¹ This is eqn. (3) in Quirmbach (1988).

As pointed out by Quirnbach, $(1 - \beta)S_\theta(\cdot) + \beta R_{Q\theta}(\cdot) < 0$ is conceivable since $R_{Q\theta}(\cdot)$ can be negative and of sufficient absolute magnitude. In that case the policy shift makes industry marginal revenue decline so that there is private incentive to reduce output, even among oligopolists who do not share all of the gains from their own efforts to reduce supply. Since $R_{Q\theta}(\cdot) \equiv QS_{Q\theta}(\cdot) + S_\theta(\cdot)$ and $S_\theta(\cdot) \geq 0$, attribute $R_{Q\theta}(\cdot) < 0$ requires that $S_{Q\theta}(\cdot) < 0$. This means that an increase in the value of θ makes the inverse demand function more negatively sloped, i.e., less elastic. Thus, and though unlikely, it is conceivable that equilibrium input production decreases with the advent of policies intended to promote corn-based ethanol. Were $R_{Q\theta}(\cdot) \geq 0$, so that industry marginal revenue shifts up with an increase in θ , then $dQ^* / d\theta \geq 0$ for sure. But that may not be to the benefit of oligopolists as the shift may reduce their pricing power.

Of direct relevance to our empirical analysis is the effect on aggregate period t profits in equilibrium, $\Pi^*(\theta, t)$. The derivative is²

$$(6) \quad \frac{d\Pi^*(\theta, t)}{d\theta} \equiv \overbrace{S_\theta(\cdot) \frac{Q^*}{N}}^{\text{Term I: } \geq 0} + \overbrace{\frac{\{R_Q(\cdot) - C_q(\cdot)\}}{N} \frac{dQ^*}{d\theta}}^{\text{Term II: ?}},$$

where (4) ensures that $R_Q(\cdot) - C_q(\cdot) = (1 - \beta)[R_Q(\cdot) - S(\cdot)] = (1 - \beta)Q^*S_\theta(\cdot) \leq 0$. Thus, if $dQ^* / d\theta \leq 0$ then both terms I and II are positive and input industry profits will certainly increase upon the advent and strengthening of biofuels policies intended to promote demand for corn. But when $dQ^* / d\theta > 0$, as is more likely the case, then term II is negative and we cannot preclude the possibility that the policies decrease industry profits.

To summarize our analysis to this point, two possibilities need to be acknowledged. They are generally unlikely to occur, but may be relevant in some settings. One is that an input is inferior in corn production so that input demand declines with the strengthening of policies that

² See eqn. (7) in Quirnbach.

promote corn biofuels. The other is that the biofuels policy shifts demand up, but does not rotate demand to be too inelastic, such that output expands greatly and oligopolist profits decline.

For the sake of completeness, we present how standard theory would suggest the biofuels policy will affect share prices. If the firm's discount factor is r , then the (continuous time) discounted present value model identifies the company value as

$$(7) \quad V(\theta) = \sum_{t=0}^{\infty} \frac{\Pi^*(\theta, t)}{(1+r)^t},$$

so that the sign of $d\Pi^*(\theta, t)/d\theta$ in (6) determines the effect on the share price. Based on the above reasoning, the main hypothesis that we wish to test is that an increase in the level of corn prices should increase the rate of returns for companies supplying inputs to crop agriculture.³

3. The Companies

For the purpose of this study, we choose a sample of fifteen companies from concentrated industries likely to be materially affected by corn prices. All firms are import players in their respective sectors. In the crop seed industry we choose DuPont, Monsanto and Syngenta. Seed costs account for about \$103 per corn acre in Iowa (Duffy and Smith, 2009), while about 89 million corn acres were sown each year over 2007-2009 in the United States. Pioneer, long the dominant supplier of corn seed was purchased by DuPont in 1999. Its market share in corn seed was above 40% of production through much of the 1990s (Fernandez-Cornejo, 2004), but was believed to have declined to about 30% by 2008 (Gerson Lehrman Group, 2008). The Agricultural Seed and Nutrition sector accounted for about 25% of DuPont sales over the 2007 and 2008 accounting years, and a slightly smaller percentage of gross profits.⁴

³ A similar model can be constructed for oligopsony to motivate the claim that an increase in corn price is likely to decrease the rate of returns for companies using corn as an input. But to conserve on space, we do not present the model.

⁴ Unless otherwise stated, company financial data are from audited reports retrieved from

Monsanto's interest in seed markets arose from the realization that glyphosate tolerant seed would promote sales of its Roundup herbicide, which was patent protected at the time. The idea was to exploit complementarity in demand between tolerant seed and the herbicide. The company first licensed seed trait technologies in the middle 1990s, but it also decided to enter the seed business directly. Through grower demand for seed traits and seed company purchases, the company's share of the corn seed market grew to about 25% in 2008 (Gerson Lehrman Group, 2008). To the extent that higher corn prices would increase the sale of all seed, it would also increase profits from the herbicide. Corn seed and traits accounted for about 36% of total gross profits over the 2006, 2007 and 2008 accounting years. Albeit with a smaller corn seed market presence, Syngenta also seeks to exploit complementarity between seed and agrichemicals. Over the accounting years 2007 and 2008, seed sector activities were attributed an average of 21% of company sales and 19% of company gross profits.

The major crop macro nutrients are Nitrogen, Potash, and Phosphate. Corn is the most fertilizer intensive among major field crops grown in the United States. Nitrogen, Phosphate and Potash account for about \$59, \$23, and \$22 expenditures, respectively, per grown acre in Iowa (Duffy and Smith, 2009). Macro nutrient markets are international, but location does matter as the commodities are bulky and some chemical forms can be volatile. The five companies we consider are Agrium, CF Industries, Potash Corp., Mosaic and Terra Nitrogen, specialists in agricultural crop macro nutrient fertilizer and allied markets.

Both Potash and Phosphate deposits are mined so that ownership of deposits determines capacity to benefit from demand growth.⁵ While available data are not definitive, Potash Corp. and Mosaic each control 13% or more of global Potash deposits. Morocco is the largest Phosphate exporter, competing on the North American market with Potash Corp. and Mosaic where Agrium and CF Industries are smaller players in that market. Potash Corp. controls

company websites, retrieved 8/4/'09 and 8/5/'09.

⁵ Information are from company websites, retrieved 8/3/'09.

about half of North American Phosphate deposits while Mosaic controls a further third.

Commercial Nitrogen production for crop fertilization is overwhelmingly produced through the Haber-Bosch process, which uses natural gas to remove Nitrogen from the atmosphere. As such, Nitrogen fertilizer can be produced at low cost in parts of the world where natural gas is cheap. Yara International, an Oslo listed commodity merchandiser, had a 25% share of the global trade in ammonia fertilizers in 2009. Utilizing plentiful natural gas in Trinidad (off the Venezuelan coast) for much of its production, Potash Corp is the second largest global Nitrogen producer with about 16% of world trade in 2009. Agrium and CF Industries both have a somewhat smaller presence in these markets. Terra Nitrogen is much smaller and focuses on North American Nitrogen markets.

The four meat sector companies we consider are Pilgrim's Pride, Tyson, Sanderson Farms and Smithfield Foods. According to Hendrickson and Heffernan (2007), the four firm concentration ratio in Broiler processing was 58.5% circa 2006-'07. The largest chicken producer, Pilgrim's Pride at about 25% market share in the United States, declared bankruptcy in late 2009 due in some measure to rising corn prices. Tyson was second largest at about 20% market share circa 2006 and Sanderson Farms was fourth largest at about 5%.⁶ The third largest firm, Perdue Farms, is privately held.

With about 31% of the market, Smithfield Foods is the largest pork processor in an industry where the four firm concentration ratio is about 66% (Hendrickson and Heffernan, 2007). As with broiler processors, Smithfield is heavily vertically integrated back through the production chain and owned about 1 million sows during much of the decade 2000-'09. Through its *Butterball* brand, Smithfield is also the largest turkey processor in the United States. Tyson is the second largest pork processor in the United States and also has a strong presence in the highly concentrated beef packing market.

⁶ From [http://www.wikinvest.com/stock/Tyson_Foods_\(TSN\)](http://www.wikinvest.com/stock/Tyson_Foods_(TSN)), retrieved 8/4/'09.

We also consider the three dominant players in the U.S. farm machinery sector. These are Deere & Co., CNH, and AGCO in descending order of company sales. All three provide a full-line of agricultural field machinery, including tractors, combines, planters and cultivation equipment. Deere & Co. and CNH are also diversified into construction equipment markets whereas AGCO is focused on the agricultural sector. Machinery expenditures can amount to \$80 or more per corn acre planted (Duffy and Smith, 2009). An increase in corn prices is likely to increase acres planted, and also to increase intensity of cultivation on those planted acres. Furthermore, new farm machines are very expensive where the typical tractor for row cropping costs about \$150,000 while a combine costs about \$200,000. Farmers tend to purchase when cash flow is strong, i.e., when corn prices are high. In addition, Deere and CNH stock prices might be affected whenever conditions deteriorate in construction equipment markets.

Though the nature and levels of exposure differ across these fifteen companies, all are heavily exposed to corn price movements. If a crop input supplier owns resources that afford it bargaining power then it should be able to participate in gains from a non-transient increase in corn prices. In the next section we will develop a two-factor equilibrium share price model to discern the extent of a firm's capacity to profit from favorable corn price movements.

4. Empirical Model and Data

To empirically evaluate the impact of U.S. biofuel policy on the stock prices of agricultural companies in seed, fertilizer, farm equipment and meat processing sectors, we assume that firm-specific stock returns are largely determined by the general market risk premium and a common risk factor represented by corn price. Our linear two-factor capital asset pricing model (CAPM) is specified as

$$(8) \quad R_{t,i} - R_{t,f} = \beta_{0,i} + \beta_{1,i}(R_{t,m} - R_{t,f}) + \beta_{2,i}R_{t,C} + \varepsilon_{t,i}, \quad \varepsilon_{t,i} \sim N(0, \sigma_{t,i}^2);$$

where time t returns on individual stock i and the market are denoted by $R_{t,i}$ and $R_{t,m}$,

respectively. Excess stock (market) returns, $R_{t,i} - R_{t,f}$ ($R_{t,m} - R_{t,f}$), are obtained after subtracting risk free rate $R_{t,f}$. Return on corn is given by movement in corn futures contract prices and is represented by $R_{t,C}$.

Specifically, returns $R_{t,k}$ ($k = i, m, C$) are considered as continuously compounded and calculated as the natural log of changes over consecutive daily prices, i.e., $R_{t,k} = \ln(P_{t,k} / P_{t-1,k})$. To calculate returns, daily closing stock prices $P_{t,i}$ are adjusted to account for historical corporate actions such as stock splits, dividends, distributions and rights offerings. For each company, we choose the longest time span possible given the data availability from the source. The closing value of the Standard & Poor's 500 composite price index is employed to represent the general market price $P_{t,m}$. Settlement prices for December maturity corn futures contracts traded on the Chicago Board of Trade (CBOT), are used to represent corn price $P_{t,C}$. Expiring contracts are rolled over into the next December contract on the last trading day of November, a few weeks prior to contract expiration.⁷ The risk free rate $R_{t,f}$ is the 3-month Treasury bill secondary market rate.⁸

Selected firms in seed, fertilizer, machinery and poultry/pork processing industries, their stock tickers, sample periods and revenues in 2008 are listed in Table 1. As of December 2009 all of these stocks continue to trade daily on the NYSE and NASDAQ markets.⁹ We pick up coverage of DuPont commencing October 1999 upon its acquisition of Pioneer Hi-bred. Historical stock price and S&P 500 index data are collected from the website of *Yahoo!*

⁷ The return on the rollover date is calculated using the prior date within the appropriate price series.

⁸ Data were retrieved from the Federal Reserve System website <https://www.federalreserve.gov/datadownload/Download.aspx?rel=H15&series=bd891f9aa455467f8e6d0abbd14eda18&from=01/02/1990&to=06/02/2009&lastObs=&filetype=sheet&label=include&layout=seriescolumn>.

⁹ Pilgrim's Pride Corp. was effectively taken over by Brazilian meat company JBS SA on Dec. 28, 2009.

Finance.

In the empirical finance literature, it has long been recognized and widely documented that daily financial returns series display strong conditional heteroskedasticity. In order to produce appropriate and efficient estimation, corrections for heteroskedasticity must be made. ARCH and GARCH models have been very successful in doing so and are widely used. Bollerslev, Engle and Nelson (1994) provide a comprehensive overview of this matter. In ARCH/GARCH type models GARCH(1,1), as introduced in Bollerslev (1986), is the mostly widely used specification. It has proved to be a superior model and is parsimoniously parameterized (Hansen and Lunde, 2005). So the conditional heteroskedasticity of individual excess stock return is modeled as

$$(9) \quad \sigma_{t,i}^2 = \omega + \alpha_1 \varepsilon_{t-1,i}^2 + \gamma_1 \sigma_{t-1,i}^2,$$

where α_1 and γ_1 are the so-called ARCH and GARCH effects. Equations (8) and (9) are jointly estimated using the maximum likelihood method and standard errors are computed using the robust method of Bollerslev and Wooldridge (1992).

Our primary goal is to pin down the effect of U.S. biofuels policies on agribusiness stock prices. To do so, first we examine a possible structural change in corn prices induced by biofuels policies. Applying the structural change test proposed in Bai and Perron (2003)¹⁰ on corn price series, we identify one structural change on November 3, 2006, which is represented by the vertical line in Figure 1. The whole sample is then split into two subsamples by using the estimated timing of the structural change where period I covers prices before 11/03/2006 and period II covers prices after that date. ARCH effects are tested on the subsamples using the

¹⁰ Estimating breaks in time series regression models was firstly proposed in Bai (1994) and was extended to multiple breaks by Bai (1997) and Bai and Perron (1998). The break test algorithm applied in this study is described in Bai and Perron (2003) and is implemented by Zeileis et al. (2003). The algorithm is based on a dynamic programming approach and the related Bellman principle.

Lagrange multiplier (LM) test proposed by Engle (1982). The test results presented in Table 2 and 3 indicate the presence of significant ARCH effects in all stock return series except Pilgrim's Pride in period I, which may be in part because of its relatively short sample period, and Mosaic and CF Industries in period II. Equation (8) is then estimated on each of the two subsamples with results presented in Tables 2 and 3.

5. Discussion

It can be seen from the results in Table 2 that in period I, without the impact of U.S. biofuels mandate policies, all of the β_2 coefficients are insignificant except that for DE. But in period II, after the expansion of biofuels production, an increase in corn prices tends to significantly increase excess stock returns for companies in the seed, fertilizer and machinery sectors. The impacts on meat processing companies are negative. In terms of magnitude, compared with those for period I, the absolute values of the coefficients for corn price changes, β_2 , are larger in period II. In other words, corn prices have bigger impact on companies' profitability after the biofuels policy shock.

In the following, we focus on the Table 3, post-break, β_2 corn price coefficients. Of the fifteen companies considered, all are of the hypothesized sign. Ten have corn price coefficients that are significant at the 1% level while four are not significant at the 10% level. All five fertilizer companies have corn coefficients that are significant at the 1% level. Two of three farm machinery companies have strongly significant corn coefficients while Deere & Co. is not significant at the 10% level. For seed companies, DuPont and Monsanto have corn coefficients that are significant at the 1% level while Syngenta has corn coefficient significant at the 5% level. Meat protein companies are generally less significant. Interestingly, three of the four corn coefficients that are not significant at 10% are among the four meat protein companies.

Although the included companies are quite comparable in terms of diversification and

market dominance in their sectors, responses to corn price changes are heterogeneous. The absolute values of the corn coefficients range from 0.06 to 0.34 with average value 0.18, where 0.18 would imply that a 1% increase on the corn price level increases stock price by 0.18%. In that case a \$1.4/bushel increase from \$2.00 to \$3.40, which is broadly what has happened over the 2006-'09 period, should increase company value by about 12.6%. The effect is not large but bear in mind that the presence of competitors will limit a firm's capacity to take advantage of higher corn prices by re-pricing corn inputs while growers can also adjust their input intensity and/or mix if re-pricing does occur.¹¹

The estimation results for companies in the meat processing sector are relatively insignificant. This could be in part due to the offsetting impact of the ethanol byproduct, dried distillers grains (DDG), which can also be used as a feedstock. An alternative explanation concerns the fact that meat processing companies don't purchase corn directly. They purchase livestock and feed cost pass-through may be incomplete. Input suppliers don't sell corn directly either. Pass-through may also be incomplete at that firm boundary. But, in the short run for meat companies at least, much of the incidence is likely to be on the hog and cattle breeding herds as the supply of animals is fixed in the short run.

Results in Table 2 and 3 provide strong support for our hypotheses. The results indicate that agribusiness responses to corn prices had been very different before ethanol became a significant use of corn. In earlier times, supply shocks were likely the dominant factor moving corn futures markets. Supply shocks are less likely to persist as corn stocks are likely to be replenished after a bad harvest due to near horizon price rationing, additional plantings and a return to normal weather patterns. While supply-side shocks may move company profitability

¹¹ Huffman (2009) has noted the role of plant population per planted corn acre in North American yield improvements during the latter part of the 20th century. To some extent, more plants mean less sunlight per plant. Farmers can respond to more expensive seed prices by reducing corn acres or reducing the seeding rate.

for a year or two, the effect on stock price would likely be small. In more recent years, corn futures markets have responded strongly to evidence on the strength of support for corn biofuels legislation and demand for biofuels. Such evidence is likely to have persistent effects on company profitability, and so on company valuation.

The future of ethanol as a fuel may be decided by the development of cellulosic ethanol, which is still far from large scale production. Were developments in cellulosic ethanol too slow to meet mandate volumes, developed in time for commercial production, then EISA provides for the mandate to be set aside, leaving corn ethanol as the main source. It is also possible that further legislation will seek to maintain the corn for ethanol market by imposing a minimum use mandate. If investors are rational then these considerations will be evaluated for entry into stock price determination.

6. Concluding Comments

Concentration among corn input suppliers suggests the possibility that these firms will gain from biofuels policies that support corn prices. Similarly, concentration in the processing of corn-fed meat animals suggests the possibility that these firms will lose from biofuels policies. We have sought to establish how agribusiness stock prices have responded to changes in biofuels policies. A study of nearby corn futures prices over the period January 1982 through December 2009 identifies one structural break, in November 2006. This is consistent with the additional support provided by the renewable fuel standards imposed through the Energy Policy Act of 2005 and Energy Independence and Security Act of 2007.

We quantify the impact of biofuels policy on stock prices of fifteen companies in various agricultural inputs and meat processing sectors over two time intervals, one preceding the estimated structural break point and one following it. On each interval we estimated a linear two-factor (and corn prices) equilibrium asset pricing model where daily market returns were

represented by the S&P500 index and the second factor was the nearby corn futures price. In the earlier period, the response to a change in corn futures price was of the predicted sign for fourteen of the fifteen stocks but the coefficients were generally not strongly significant. In the later period, with expanded biofuels use mandates in place, the response to a change in the nearby corn futures price was of the predicted sign for all fifteen stocks and was generally strongly significant. In all fifteen cases the response was stronger over the later period. That is, seed, fertilizer, and agricultural machinery company expected stock returns response to a one percent increase in the corn price became more positive while meat protein company expected stock returns became more negative in response to a one percent increase in the corn price.

The average absolute value of the corn price response coefficient over November 2006 through December 2009 was 0.18. Although the effects are not large, they provide some evidence that stock investors believe off-farm input suppliers will gain from policies intended to promote corn-based ethanol. The effects are generally weakest for meat protein companies, an observation that deserves further attention. After all, one of the considered companies went into bankruptcy protection over the study period, citing corn prices as a reason (Smith, 2009).

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Table 1. Selected Firms in the US Stock Market

| Sector/Company | Ticker | Sample Period I | Sample Period II | 12 Months Revenue (ending 12/31/'08; in \$ mill.) |
|---------------------------------------|------------|----------------------|----------------------|---|
| <i>Seed</i> | | | | |
| E.I. du Pont de Nemours & Co. | NYSE: DD | 10/01/1999-11/02/'06 | 11/03/2006-12/31/'09 | 31,836 |
| Monsanto Co. | NYSE: MON | 10/24/2000-11/02/'06 | --- | 11,365 |
| Syngenta AG (ADR) | NYSE: SYT | 11/15/2000-11/02/'06 | --- | 11,624 |
| <i>Fertilizer</i> | | | | |
| Mosaic Co. | NYSE: MOS | 10/26/2004-11/02/'06 | --- | 10,298 |
| Agrium Inc. | NYSE: AGU | 05/05/1995-11/02/'06 | --- | 10,031 |
| Potash Corp. of Saskatchewan, Inc. | NYSE: POT | 04/05/1990-11/02/'06 | --- | 9,446 |
| CF Industries, Inc. | NYSE: CF | 08/11/2005-11/02/'06 | --- | 3,921 |
| Terra Nitrogen Co. | NYSE: TNH | 03/10/1992-11/02/'06 | --- | 903 |
| <i>Meat Protein</i> | | | | |
| Tyson Foods, Inc. | NYSE: TSN | 01/02/1990-11/02/'06 | --- | 26,862 |
| Smithfield Foods, Inc. | NYSE: SFD | 03/26/1990-11/02/'06 | --- | 12,478 |
| Pilgrim's Pride Corp. | OTC: PGPDQ | 12/04/2003-11/02/'06 | --- | 8,525 |
| Sanderson Farms, Inc. | NASD: SAFM | 01/02/1990-11/02/'06 | --- | 1,724 |
| <i>Ag. Machinery</i> | | | | |
| Deere & Co. | NYSE: DE | 01/04/1982-11/02/'06 | --- | 28,292 |
| CNH Global | NYSE: CNH | 11/01/1996-11/02/'06 | --- | 18,476 |
| AGCO Corp. | NYSE: AGCO | 04/20/1992-11/02/'06 | --- | 8,425 |

Table 2. Estimation Results for Period I

| Sector Variables | Seed | | | | Fertilizer | | | |
|---------------------|-----------|----------|-----------|----------|------------|-----------|-----------|-----------|
| | DD | MON | SYT | MOS | AGU | POT | CF | TNH |
| β_0 | -0.0001 | -0.0001 | -0.002*** | 0.001 | -0.005*** | -0.004*** | 0.002 | -0.009*** |
| β_1 | 0.986*** | 0.944*** | 0.864*** | 1.010*** | 0.861*** | 0.886*** | 1.037*** | 0.760*** |
| β_2 | 0.003 | -0.011 | 0.030 | 0.071 | 0.019 | 0.042** | 0.066 | 0.003 |
| α_1 | 0.027*** | 0.034 | 0.035 | 0.067 | 0.022 | 0.025*** | 0.341* | 0.104 |
| γ_1 | 0.968*** | 0.960*** | 0.958*** | 0.530 | 0.962*** | 0.969*** | -0.203 | 0.899*** |
| ω | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.0004*** | <0.001 |
| Wald $\chi^2(2)$ | 4221.5*** | 873.4*** | 1041.3*** | 236.3*** | 1919.4*** | 4353.2*** | 215.2*** | 453.6*** |
| ARCH test | 44.18*** | 37.92*** | 48.09*** | 6.52** | 9.12*** | 45.45*** | 10.25*** | 126.45*** |

| Sector Variables | Meat Protein | | | | Ag. Machinery | | |
|---------------------|--------------|-----------|----------|-----------|---------------|-----------|------------|
| | TSN | SFD | PGPDQ | SAFM | DE | CNH | AGCO |
| β_0 | -0.004*** | -0.004*** | 0.001 | -0.004*** | -0.005*** | -0.004*** | -0.0006*** |
| β_1 | 0.898*** | 0.891*** | 1.040*** | 0.890*** | 0.901*** | 0.897*** | 0.973*** |
| β_2 | -0.006 | -0.033 | -0.030 | -0.016 | 0.073*** | 0.054 | 0.029 |
| α_1 | 0.015* | 0.008*** | 0.036 | 0.127*** | 0.137*** | 0.034*** | 0.133* |
| γ_1 | 0.982*** | 0.991*** | 0.510*** | 0.694*** | 0.875*** | 0.964*** | 0.825*** |
| ω | <0.001 | <0.001 | <0.001* | <0.001* | <0.001 | <0.001 | <0.001 |
| Wald $\chi^2(2)$ | 3133.8*** | 2285.3*** | 346.9*** | 1571.7*** | 7439.7*** | 937.7*** | 1303.0*** |
| ARCH test | 52.53** | 15.37*** | 0.05 | 13.42*** | 395.96** | 22.26** | 21.93*** |

Notes: 1. Single (*), double (**), and triple (***) asterisks denote significance at 0.10, 0.05, and 0.01 levels, respectively. 2. For the LM ARCH test, *, **, and *** denote that the null hypothesis of no ARCH effects is rejected at the 10%, 5%, and 1% significance levels, respectively. One lag of squared residuals is included for the test. 3. z values calculated from Bollerslev-Wooldridge robust standard errors are in the parentheses. 4. The null hypothesis of the Wald chi-square test is that the two coefficients of interest are simultaneously equal to zero. *, **, and *** denote that the null hypothesis is rejected at the 10%, 5%, and 1% significance levels, respectively.

Table 3. Estimation Results for Period II (11/03/2006-12/31/2009)

| Sector | Seed | | | | | Fertilizer | | |
|------------------|-----------|-----------|-----------|----------|-----------|------------|----------|----------|
| Variables | DD | MON | SYT | MOS | AGU | POT | CF | TNH |
| β_0 | 0.002** | -0.001 | <0.001 | 0.003* | 0.004*** | 0.003* | 0.002 | -0.002 |
| β_1 | 1.061*** | 0.937*** | 0.975*** | 1.014*** | 1.076*** | 1.009*** | 0.935*** | 0.787*** |
| β_2 | 0.062*** | 0.142*** | 0.074** | 0.309*** | 0.344*** | 0.296*** | 0.235*** | 0.157*** |
| α_1 | 0.333*** | 0.040*** | 0.045** | 0.107** | 0.100*** | 0.060** | 0.093** | 0.071 |
| γ_1 | 0.131 | 0.959*** | 0.949*** | 0.899*** | 0.877*** | 0.930 | 0.895*** | 0.923*** |
| ω | <0.001*** | <0.001 | <0.001 | <0.001 | <0.001 | 0.0004*** | <0.001 | <0.001 |
| Wald $\chi^2(2)$ | 2475.9*** | 1273.0*** | 1814.9*** | 504.9*** | 1115.3*** | 763.9*** | 587.9*** | 264.1*** |
| ARCH test | 10.71*** | 6.99*** | 44.08*** | 0.03 | 9.02*** | 3.47* | 0.59 | 22.35*** |

| Sector | Meat Protein | | | | Ag. Machinery | | |
|------------------|--------------|----------|----------|-----------|---------------|----------|-----------|
| Variables | TSN | SFD | PGPDQ | SAFM | DE | CNH | AGCO |
| β_0 | <0.001 | -0.002 | -0.004 | -0.001 | -0.006*** | 0.005** | 0.004*** |
| β_1 | 1.004*** | 0.946*** | 0.894*** | 0.910*** | 0.750*** | 1.114*** | 1.076*** |
| β_2 | -0.078 | -0.067 | -0.106 | -0.144*** | 0.097 | 0.331*** | 0.247*** |
| α_1 | 0.380** | 0.137* | 0.435** | 0.029*** | 0.241*** | 0.029*** | 0.071 |
| γ_1 | 0.397 | 0.872*** | 0.651*** | 0.963*** | 0.892*** | 0.972*** | 0.916*** |
| ω | <0.001 | <0.001 | <0.001 | <0.001 | <0.001* | <0.001 | <0.001 |
| Wald $\chi^2(2)$ | 1047.6*** | 444.1*** | 161.7*** | 630.6*** | 210.2*** | 228.9*** | 1065.0*** |
| ARCH test | 68.21*** | 14.91*** | 28.74*** | 6.37*** | 35.71*** | 0.41 | 25.73*** |

Notes: Same as in Table 2.

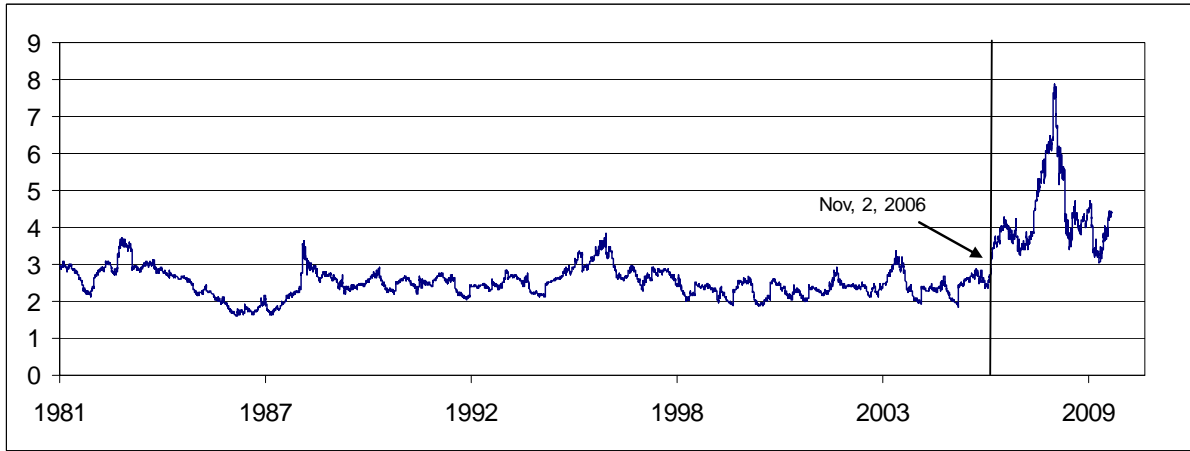


Figure 1. Corn December Maturity Futures Prices (01/04/1982-12/31/2009)