Commodity Markets Volatility Transmission: Roles of Risk Perceptions and Uncertainty in Financial Markets

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Abstract

This paper uses a GJR–GARCH estimations to analyze the price volatility transmissions among the crude oil, corn, soybeans, sugar, and wheat markets. Special role is also given to two driving mechanisms of the relationship: *i*) the volatility index (VIX) as a measure of risk perceptions, and *ii*) the equity market uncertainty (EMU) index as a measure of uncertainty in financial markets. The analysis covers the daily futures markets data from January 1, 1990 to July 31, 2015, and several sub-periods in the empirical strategy are also considered. The empirical results show that i) crude oil return is positively related to four agricultural commodity returns; ii) a higher risk perception in financial markets suppresses the both corn and soybeans returns over the period August 1, 2008–July 31, 2015; iii) a higher uncertainty in financial markets is negatively related to the corn and soybeans returns for the period from June 1, 2010 to July 31, 2015; iv) the results for the effects of risk perceptions and uncertainty on wheat market returns are not statistically robust; i.e., these results are time-specific in the different sub-period analyses.

Keywords: Uncertainty; Risk Perceptions; the VIX; Volatility Spillover; in Financial Markets; Futures Markets; Commodity Markets; Crude Oil Markets

JEL Classification Codes: F30; G15; Q02; Q41

1. Introduction

In the last couple of years, the global economy faced the challenge of increased contagion across financial markets with increasing political and financial market uncertainties (e.g., Broadstock and Filis, 2014; Chen et al., 2013; Kenourgios et al., 2011; Mensi et al., 2013; Smales, 2014; Yarovaya et al., 2016). In addition, the analysis of global commodity market linkages is one of the key areas of financial and economic research, but effects of political and financial market uncertainties are neglected in the literature (Gupta et al., 2014; Kang and Ratti, 2013; Lau and Bilgin., 2013). These issues promoted the discussion among financial regulators and academics about the role of financial market stability and economic stability in maintaining commodity market's stability (Creti et al., 2013). At this point, the transmission of the first moment (price) and second moment (volatility) shocks between crude oil and agricultural commodity markets is well discussed,[1] but lack of research on the role of the risk perceptions and uncertainty in financial markets in particular. The goal of this paper is to reassess price volatility spillovers among the crude oil and agricultural commodity markets. To this end, a special role is given to two driving mechanisms of the relationship: *i*) the volatility index (VIX) as a measure of risk perceptions, and *ii*) the equity market uncertainty (EMU) index as a measure of uncertainty in financial markets.

Indeed, not only the level commodity prices, but also their volatility are important for several aspects, and the inferences are threefold. First, commodity price volatility can negatively affect consumers and producers as well traders and investors via uncertainty channel (Baker et al., 2015; Bloom, 2009). If empirical evidences are in favor of the "financialization of commodity markets" hypothesis (e.g., in Cheng and Xiong, 2013; Henderson et al., 2015), the magnitude of the uncertainty effect will be higher: Because now not only the uncertainty shocks in commodity markets, but also risk perceptions and

[1]See the recent literature reviews of Serra (2013) and Serra and Zilberman (2013).

uncertainty in financial markets will be able to affect the sentiments of consumers and producers as well as decisions of traders and investors. At this point, a distinction between uncertainty and risk is firstly done by Shewhart (1931), and he indicates that the risk has a "predictable variation" but uncertainty has an "unpredictable variation"; i.e., it has surprise, new or unexpected nature. As a matter of fact, we do refer to the risk perception, and it is a more complicated concept since perceptions depend on the subjective ideas of financial market participants. In short, this paper considers the VIX to capture the effects of risk perceptions and the EMU index to capture the effects of uncertainty that is shaped in financial markets. Therefore, it is aimed to analyze whether the risk perceptions and financial market uncertainty can be explanations for volatility spillover among commodity markets. In other words, it is tested whether the "financialization hypothesis" can be an alternative explanation for the commodity market volatility spillover from the crude oil market to agricultural commodity markets.

Second, the price volatility in commodity markets has importance in all open-economies, mainly due to the commodity price volatility can be related to the volumes of imports and exports, and these issues relate to welfare gains from international trade.

Third, price volatility in commodity markets would have also directly influence the real income, especially in developing economies, but affecting the real income mainly depends on a specific country context. Therefore, it is important to empirically examine the price volatility interactions among commodity markets for policy makers, consumers, and producers, traders and investors.

This paper conducts a multivariate Glosten–Jagannathan–Runkle (GJR) Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model of Glosten et al. (1993) to examine volatility spillovers from the crude oil to four agricultural commodity markets: corn, soybeans, sugar, and wheat. The empirical analysis covers the daily futures markets data from

January 1, 1990 to July 31, 2015, and several sub-periods are also considered in the empirical strategy. The main contributions of this paper to the existing literature are as follows. First, to the best of our knowledge, this paper represents the first empirical results on the effects of risk perceptions and uncertainty in financial markets in the energy-agriculture commodity prices volatility spillover literature. Second, whole observations are divided into four sub-periods to examine the volatility spillovers among the crude oil, corn, soybeans, sugar, and wheat futures markets. In other words, the robustness of the benchmark findings are checked, i.e., whether the empirical results on the commodity markets volatility spillover are time-specific or not.

The remainder of the paper is organized as follows. Section 2 reviews the related literature on the price volatility transmission among crude oil and agricultural commodity markets. Section 3 explains the data and empirical model as well as discusses the methodology of the volatility model. Section 4 reports the empirical results and discusses implications. Section 5 concludes.

2. Literature Review

2.1. Motivation from Previous Findings

First, the price and the price volatility transmissions among energy and agricultural commodity markets are mainly biofuel-related in the recent literature. For instance, the Renewable Fuel Standard of the Energy Policy Act in 2005 has a crucial role in the rising ethanol production in the United States (U.S.) that leads to higher demand for biofuels, and this can be the main explanation of a stronger relationship between oil and agricultural commodity prices after 2006 (Serra, 2013). Indeed, the relationship between the energy and agricultural markets are heavily affected by policies to promote ethanol production (Hertel and Beckman, 2012; Trujillo-Barrera et al., 2012). According to Hertel and Beckman (2012), the dynamics behind the ethanol market, crude oil, and corn markets leads to the linkage

among the three markets that did not exist before 2006, and the correlation of crude oil and corn markets from September 2007 to October 2008 is 0.92. In parallel, there are also several empirical findings suggesting significant price volatility spillovers from crude oil to the corn markets, and their explanations are based on biofuel production (Serra, 2013; Wu et al., 2011)[2]. On contrary, for example, Natalenov et al. (2011) indicate that biofuel production is not the main reason for the co-movement between the oil and agricultural commodity markets. Along with biofuels production, there are additionally other notable linkages between oil and agricultural commodity markets.

The second linkage is that the price of oil as cost of production, and a higher oil price is one of the fundamental sources of the agricultural commodity price volatility (Alghalith, 2010).

A third linkage arises from the boom trend in agricultural commodity prices, due to funds' trading activity, in other words, "financialization of commodities" (Du et al., 2011)[3]. For instance, the feedback effects of futures markets (Sockin and Xiong, 2013) and the speculation in both spot and futures markets (Du et al., 2011; Frankel, 2014) are also influential factors on the interrelationship between oil and agricultural commodity markets. For instance, Gozgor and Kablamaci (2014) analyze how strong the linkage between crude oil and 29 agricultural commodity prices in the light of the perceived global market, and their empirical results from the panel data test techniques indicate that the crude oil price has direct and positive effects on almost all agricultural commodity prices over the period 1990–2013. Their results also highlight the role of speculation and financialization in the price transmission mechanism from the crude oil to agricultural commodity markets. In addition, Kristoufek (2014) finds that the long-memory effect is important for the crude oil price volatility. He also observes that significant leverage effect on the crude oil market that is

[2] See also Serra (2013) for the recent survey of the related literature on biofuels-related volatility.
[3] See Cheng and Xiong (2013) for the recent review of the related literature and the mechanisms behind financialization of commodity markets.

highly relevant to the daily data in our study. Gozgor and Memis (2015) also concludes that modeling leverage effect on the futures of oil, soybeans, corn, and wheat markets are crucial to understand the price volatility transmission mechanism among the crude oil and agricultural commodity markets. In light of these recent findings, the GJR–GARCH model specification in this paper is able to capture the long-memory and the leverage effects in the crude oil and agricultural commodity markets (Yarovaya et al., 2016). In contrast, according to Knittel and Pindyck (2013), speculation has a small effect on driving crude oil and agricultural commodity prices. In short, there is still no consensus in the literature on the effects of investment fund activity, financial factors, and policy changes on biofuels but simply such issues create even more complex market structure.

Fourth, there are also several other views in the literature to explain the interactions among agricultural commodity and oil markets. For example, some external factors, such as the global demand that is related to the rapid economic growth of emerging market economies (Sockin and Xiong, 2013), the real value of the USD exchange rate (Gozgor and Kablamaci, 2014), and the monetary policy stance in the rich-world; in other words, the world interest rate (Frankel, 2014) all can affect the price transmissions among oil and agricultural commodity markets. For example, according to Gilbert (2010), the rising economic growth, and thus the high domestic demand in emerging markets, developments in financial products related to commodity futures, and the easing monetary policy stance are among the main reasons for the stronger co-movement of oil and agricultural commodity markets. Therefore, empirical results in the paper can also be noteworthy for traders, risk management issues, and hedging strategies or portfolio diversifications related to the crude oil and agricultural commodity futures.

2.2. Previous Literature on Price Volatility Spillover: Direct Mechanism

The interaction between energy and agriculture commodity markets has attracted growing interest in the literature, and several papers focus on "direct" price volatility spillover mechanism among oil and agricultural commodity markets (e.g., Alghalith, 2010; Chang and Su, 2010; Haixia and Shiping, 2013; Harri and Hudson, 2009; Nazlioglu et al., 2013; Serra, 2011; Trujillo-Barrera et al., 2012; Wu et al., 2011). For example, Harri and Hudson (2009) analyze volatility transmission among the crude oil, soybeans, and corn markets for the period from April 2003 to March 2009 using daily data. The results from the variance causality analysis show that there is a price volatility transmission from the oil to corn markets only after April 2006. Alghalith (2010) examines a volatility transmission from the crude oil price to the food price index over the period 1974–2007 with annual data in Trinidad and Tobago. The findings of the nonlinear ordinary least square regression indicate that a rise in the volatility of crude oil pioneers to a higher food price. Chang and Su (2010) use daily data of crude oil, corn, and soybean markets for the period from January 4, 2000 to July 14, 2008, and the results from the Exponential GARCH (EGARCH) model suggest that there are price volatility spillovers from the crude oil to the corn and to the soybean markets. Using weekly data over the period November 1998–January 2009, Du et al. (2011) apply the Bayesian Markov Chain Monte Carlo models to examine volatility spillovers among crude oil, corn, and wheat markets, and their results indicate that there are significant price volatility spillovers among all mentioned markets only after the fall of 2006. Serra (2011) uses the semi-parametric GARCH model for the period from July 2000 to November 2009 within monthly data sets of the Brazilian crude oil, ethanol, and sugar markets. She finds that crude oil and sugar markets yield to a rise in the price volatility of ethanol markets. Trujillo-Barrera et al. (2012) examine volatility spillovers among the U.S. crude oil, ethanol, and corn futures markets. They find that the volatility of the crude oil markets affects the volatility of both the corn and ethanol markets and that there is one direction relationship that runs from the corn to

the ethanol markets. Nazlioglu et al. (2013) examine spillover from oil to wheat, corn, soybeans, and sugar markets within daily price volatility data from January 1, 1986 to March 21, 2011. They use causality test related to the variance, and find that volatility in the oil markets has transmitted to the related agricultural markets only for the period from January 1, 2006 to March 21, 2011 as well as they highlight the roles of biofuels and speculation. Haixia and Shiping (2013) examine volatility spillovers of the crude oil, corn, and fuel ethanol markets in China with weekly data for the period from September 5, 2003 to August 31, 2012. They find that there is a unidirectional spillover effect from the crude oil to the corn and fuel ethanol markets, and bi-directional spillovers between the corn and the fuel ethanol markets.

3. Econometric Methodology, Empirical Model, and Data

3.1. *Econometric Methodology and Empirical Model*

In this paper, a GJR–GARCH model is estimated for the logarithmic return (R_t) of four agricultural commodities: Corn (co), Soybean (sb), Sugar (su), and Wheat (wh). The mean equation is specified as:

$$R_{co,sb,su,wh} = \beta_0 + \beta_1 CR_t + \beta_2 VIX_t \tag{1}$$

$$R_{co,sb,su,wh} = \delta_0 + \delta_1 CR_t + \delta_2 EMU_t \tag{2}$$

Where; CR_t , VIX_t and EMU_t denote the crude oil (West Texas Intermediate) logarithmic return, volatility index (VIX) in logarithmic form, and the equity market uncertainty (EMU) index in logarithmic form, respectively. The variance equation is also included to capture the conditional heteroscedasticity in all commodity returns. Thus, a GJR–GARCH (1,1) specification can be written for the conditional variance of each return as such:

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \delta_{t-1} \varepsilon_{t-1}^2 + b h_{t-1} \tag{3}$$

Where h_t is the conditional volatility, α_0 is the constant term, ε_{t-1} is the innovation in period *t*, α_1 is the news coefficient capturing the impact of the most recent innovation, and α_2

captures the asymmetric impact of positive and negative news. δ_{t-1} is also an indicator, which takes the value of unity, if ε_{t-1} >0 ; and zero otherwise. b is a measure of volatility persistence. If α_2 is positive and statistically significant, it will indicate that negative innovations increase volatility more than positive innovations.

In each model, all parameters in the conditional mean and variance equations are estimated simultaneously by the maximum likelihood estimation (MLE). The WinRATS 8.0 software is used, and the numerical optimization is based on the Newton–Raphson and Berndt–Hall–Hall–Hausman (BHHH) algorithm.

3.2. Data

This paper focuses over the period January 1, 1990–July 31, 2015 (9334 observations in total). Furthermore, different periods are also considered: *i*) the period from January 1, 1990 to December 31, 2005 is captured the period for the pre–biofuel and the pre–crisis, *ii*) the period from January 1, 2006 to July 31, 2008 is the pre–global crisis in the post–biofuel era, *iii*) the period from August 1, 2008 to May 31, 2010 is the global crisis in the post–biofuel era, *iv*) the period from June 1, 2010 to July 31, 2015 is the post–global crisis in the post–biofuel era. These break dates are related to the boom–and–bust cycle in the commodity markets, and they are used in many empirical papers (e.g., Gozgor and Memis, 2015; Nazlioglu et al., 2013) The agricultural commodity markets (corn, sugar, soybeans and wheat) price and crude oil price data are based on the futures markets, and they are obtained from the data source by Bloomberg. The VIX data are also obtained from the Chicago Board Options Exchange (CBOE) and the equity market uncertainty (EMU) index data are obtained from Baker et al. (2015) within the website (http://www.policyuncertainty.com/) of Scott R. Baker, Nick Bloom, and Steven J. Davis. A summary of the descriptive is reported in Table 1.

[Insert Table 1]

Table 1 illustrates that all commodity returns are positive on average. The greatest volatility value (standard deviation) is observed in the crude oil market. The correlation matrix among variables is also reported in Table 2.

[Insert Table 2]

The first result in Table 2 is that there is a positive correlation between crude oil- and all agricultural commodity returns (from 0.10 to 0.15). Second, returns in each commodity have also positive correlations with other commodity returns. Third, crude oil and agricultural commodity returns are also negatively related with the VIX and the EMU index. Four, the correlation between the VIX and the EMU index is 0.37; therefore, it can be said that there is positive relationship between the VIX and the EMU index but the magnitude of the relationship is moderate. So, there is a significant distinction between the uncertainty and risk perceptions in financial markets.

4. Empirical Results

4.1. Benchmark Results

Tables 3–8 present the maximum likelihood estimates of the model described by Equations (1), (2), and (3). It can be seen that the coefficients describing the conditional variance process are all statistically significant at 1% for the full sample estimations (i.e., Tables 3 and 4). This implies that current volatility is a function of the last period's squared innovation and the last period's volatility. It is found that the parameters of crude oil price returns in Tables 3 have positive impacts on all agricultural commodity returns as expected. Sugar is the commodity that is the most sensitive to change of crude oil price, followed by wheat, corn, and soybeans. The return of sugar will be increased by 0.062% as a 1% increase in crude oil return (Panel A, Table 3). Interestingly, it is also found that the parameters of the VIX index have negative impacts on three commodity returns with an exception of the sugar market. Wheat is the commodity that is the most sensitive to change of the VIX index,

followed by corn and soybean markets. The return of wheat will be decreased by 0.0017% as a 1% increase in the VIX (Panel A, Table 3).

[Insert Table 3]

As a further analysis, EMU index is used as an alternative to the VIX, and it can be seen that the coefficients describing the conditional variance process are all significant for the full sample estimations in Table 4. This again implies that the current volatility is a function of the last period's squared innovation and the last period's volatility. It is observed that the parameters of crude oil price return have again positive impacts on agricultural commodity price as expected. Again, sugar is the commodity that is the most sensitive to change of crude oil returns, followed by wheat, corn, and soybean. The return of sugar will be increased by 0.062% as a 1% increase in crude oil return (Panel A, Table 4). Interestingly, it is also found that the parameters of EMU index have negative impacts corn, wheat, and soybean markets. Corn is the commodity that is the most sensitive to change of the EMU index, followed by wheat and soybean markets. The return of corn, wheat, and soybeans will be decreased by 0.0004%, 0.0002%, and 0.0001% as a 1% increase in the EMU index, respectively (Panel A, Table 4).

[Insert Table 4]

4.2. Results for Before and After Financial Crisis of 2008–09

As we are also interested in the effects of the Financial Crisis of 2008–09 in the transmission mechanism among crude oil market, the VIX, and the EMU index on commodity returns, we therefore divide the data into the pre–2008 and the post–2008 periods. It is found that the parameters of crude oil price returns have positive impacts on the commodity returns in the pre–2008 period, with an exception of wheat. Sugar is the commodity that is still most sensitive to change of crude oil returns, followed by corn and soybean. The return of sugar will be increased by 0.03% as a 1% increase in the crude oil return (Panel A in Pre–2008,

Table 5). Interestingly, the VIX has no significant effect on commodity returns in the pre–crisis period.

[Insert Table 5]

On the other hand, the parameters of crude oil returns have also positive impacts on all commodity returns in the post–2008 period. In addition, corn is the commodity that is the most sensitive to crude oil return (recall that crude oil has no impact on the corn market before July 2008), followed by soybean, sugar, and wheat. The return of corn will be increased by 0.21% as a 1% increase in crude oil return (Panel A in Post–2008, Table 5). The VIX is also negatively related to the returns in corn and soybean markets in the post–2008 period. Interestingly, the parameters of the VIX have only negative impacts on the corn and soybean returns after the July 2008. The return of corn will be decreased by 0.0004% as a 1% increase in the VIX. In addition, the return of soybean will be reduced by 0.0002% as a 1% increase in the VIX (Panel A in Post–2008, Table 5).

Furthermore, the results in Table 6 show that the parameters of crude oil return have positive impacts on commodity returns as expected in the pre–2008 period, with an exception of wheat. Sugar is still the commodity that is most sensitive to changes of crude oil return, followed by corn and soybean. The return of sugar will be increased by 0.03% as a 1% increase in crude oil return (Panel A in Pre–2008, Table 6). Interestingly, the parameters of EMU index have no statistically significant impact on commodity returns in the pre–crisis period.

[Insert Table 6]

Furthermore, it is observed that the parameters of crude oil return have positive impacts on all commodity returns in the post–2008 period. Now, wheat is the commodity that is most sensitive to changes of crude oil return, followed by corn, soybean, and sugar. The return of wheat will be increased by 0.3% as a 1% increase in crude oil price (Panel A in Post–2008,

Table 6). In addition, the parameters of the EMU index have negative and statistically significant effects on corn and soybean returns in the post–crisis period. The return of soybean and the corn will be decreased by 0.0015% and 0.0004% as a 1% increase in the EMU index, respectively (Panel A in Post–2008, Table 6).

4.3. Sensitivity Analysis: Results for Different Periods

The results in Table 7 show that the corn return will be decreased by 0.0008% as a 1% increase in the VIX in the crisis period, and the corn return will be decreased by 0.002% as a 1% increase in the VIX in the post–crisis period, respectively (see, Table 7). Furthermore, that the soybean return will be decreased by 0.0013% as a 1% increase in the VIX in the crisis period, and the soybean return will be decreased by 0.0003% as a 1% increase in the VIX in the post–crisis period, respectively. It is also observed that the wheat return will be reduced by 0.003% as a 1% increase in the VIX in the post–crisis period. Interestingly, the parameters of the VIX index have no impact on commodity returns before July 2008. In addition, the parameters of crude oil price return have positive impacts on all commodity prices in the crisis and the post–2008 periods.

[Insert Table 7]

The results in Table 8 indicate that the corn return will be decreased by 0.00026% as a 1% increase in the EMU index, and also the soybeans return will be declined by 0.00014% as a 1% increase in the EMU index in the post-crisis period (Table 8). Interestingly, the parameters of the EMU index have no impact on agricultural commodity returns before July 2008. In addition, the parameters of crude oil price return have positive impacts on all commodity prices in the post–2008 period.

[Insert Table 8]

4.4. Discussion and Implications

A summary of the empirical results is reported in Table 9. It is found that crude oil returns are positively all agricultural commodity returns. This can be related to the price of crude oil as cost of production for agricultural commodity returns. In a detail, the wheat returns are not driven by crude oil until June 2010 but the financial crisis of 2008–09 provides a stronger positive relationship between crude oil and wheat markets. The significant volatility spillover from the crude oil to corn markets is in line with the previous studies of Harri and Hudson (2009), Trujillo-Barrera et al. (2012), and Wu et al. (2011). In addition, the volatility transmission mechanism seems not to be broken out due to the global financial crisis in 2008.

[Insert Table 9]

Another empirical results are related to the risk perceptions (the VIX) and the uncertainty (the EMU index) measures in the financial markets. It is found that both the VIX and the EMU index are negatively related to the returns in corn, soybean, and wheat markets. Sugar market is not, neither driven by the EMU index nor by the VIX in the whole period and all sub-periods. These results imply that sugar market is not affected by risk perceptions and uncertainty; therefore, there is no evidence in favor of "financialization hypothesis" in sugar markets over the period under concern. These findings in sugar market can also be interpreted as it is still driven by local markets– not financial market measures considered in the paper. These results are in line with the findings of many empirical papers (e.g., Natanelov et al., 2011).

Furthermore, the benchmark results illustrate that both the VIX and the EMU index are negatively related to the returns in corn, soybean, and wheat markets. However, the results for wheat markets are not statistically robust since when the periods before- and after the financial crisis is considered, the effects of the VIX and the EMU index are not statistically significant. It is also observed that the VIX and the wheat market returns are negatively

related, but this result is time-specific, i.e., it is merely statistically significant for over the period June 1, 2010–July 31, 2015.

It is also found that the benchmark results are driven by the period of post–crisis for corn and soybean markets for the effects of both the VIX and the EMU index. More specifically, the period from August 1, 2008 to July 31, 2015 is mainly driven by the negative relationship between the VIX and both the corn and soybean returns. In addition, the EMU index is negatively related to both the corn and soybean returns for the period from June 1, 2010 to July 31, 2015. Interestingly, both commodity returns (corn and soybean) are starting to affect by risk perceptions (measured by the VIX) in financial markets with the global financial crisis of 2008–09. Uncertainty in the financial markets also matters for the corn and soybean returns after the period of post–global financial crisis of 2008–09. These results are in favor with the "financialization hypothesis" for corn and soybean markets. These results are in line with the previous papers in the literature, such as Du et al. (2011) and Cheng and Xiong (2013).

Furthermore, the interrelationship from crude oil to both the soybeans and corn markets can possibly be explained by biofuel production from corn as bioethanol and from soybeans as biodiesel. Actually, the usage of biofuels as corn ethanol and soybean diesel have substantially created additional volatility in the prices of corn and soybeans, even with there is no related change in the crude oil prices. The actual volumes of crops being used for energy production are mainly based on availability of technologies and switching opportunities of these techniques over alternative fuels. However, in today's world, fluctuations in crude oil price can still affect the prices of corn and soybeans, because large scale production of each is still impossible without diesel fuel and gasoline. In short, it is found that the significant amount of biofuel production after 2006 creates additional volatility in the corn and soybean markets, but its effects are not much greater as the effects of the risk perceptions and uncertainty in financial markets on the corn and soybean returns.

5. Conclusion

This paper uses a GJR–GARCH estimations to analyze the price volatility transmissions among the crude oil, corn, soybeans, sugar, and wheat markets. Special role is also given to two driving mechanisms of the relationship: *i*) the VIX as a measure of risk perceptions, and *ii*) the EMU index as a measure of uncertainty in financial markets. The analysis covers the daily futures markets data from January 1, 1990 to July 31, 2015, and several sub-periods in the empirical strategy are also considered.

The empirical results show that i) crude oil return is positively related to four agricultural commodity returns; ii) a higher risk perception in financial markets suppresses the both corn and soybeans returns over the period August 1, 2008–July 31, 2015; iii) a higher uncertainty in financial markets is negatively related to the corn and soybeans returns for the period from June 1, 2010 to July 31, 2015; iv) the results for the effects of the risk perceptions and uncertainty on wheat market returns are not statistically robust; i.e., these results are time-specific in the different sub-period analyses.

The results in this paper highlight the role of risk perceptions and uncertainty in financial markets to explain volatility spillovers from the crude oil to the corn and soybean markets. We suggest that in a future study, one can consider another volatility models that accounting for jumps and feedback effects in the crude oil and agricultural commodity futures markets for a further investigation of the effects of risk perceptions and uncertainty.

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Table 1
Descriptive Statistics: January 1, 1990–July 31, 2015

Variables:	RCO	RSB	RWH	RSU	RCR	VIX	EMU
Mean	5.61E–05	6.36E–05	2.58E–05	–1.48E–05	8.72E–05	2.919709	3.781559
Median	0	0	0	0	0	2.885359	3.734668
Maximum	0.127571	0.076292	0.232957	0.132081	0.164097	4.392719	7.501815
Minimum	–0.276206	–0.17429	–0.286121	–0.234895	–0.400478	2.231089	1.568837
Standard Deviation	0.014413	0.012894	0.016146	0.01799	0.020022	0.346169	1.03021
Observations	9334	9334	9334	9334	9334	9334	9334

Notes: RCO: return for corn; RSB: return for soybean; RWH: return for wheat; RSU: return for sugar; RCR: return for crude oil; VIX: log volatility index; EMU: log equity market uncertainty index.

Table 2
Correlation Matrix

Variables:	RCO	RSB	RWH	RSU	RCR	VIX	EMU
RCO	1						
RSB	0.541682	1					
RWH	0.545725	0.365772	1				
RSU	0.130105	0.141838	0.133226	1			
RCR	0.144878	0.154408	0.126261	0.102936	1		
VIX	–0.01865	–0.01774	–0.01455	–0.00094	–0.02245	1	
EMU	–0.01603	–0.01771	–0.00876	–0.00817	–0.02307	0.37346	1

Notes: RCO: return for corn; RSB: return for soybean; RWH: return for wheat; RSU: return for sugar; RCR: return for crude oil; VIX: log volatility index; EMU: log equity market uncertainty index.

Table 3
Estimation of Commodity Markets with the VIX (Full Sample)

	Corn	Sig	Soybean	Sig	Wheat	Sig	Sugar	Sig
panel A: mean equation								
α	0.003336	***	0.003331	***	0.004913	***	0.00132606	
β1(Crude Oil)	0.039371	***	0.0332	**	0.0466	***	0.06228285	***
β2 (VIX)	–0.00106	**	–0.001056	**	–0.001676	***	–0.0004316	
panel B: variance equation								
α_0	0.000003	***	0.000002	***	0.000012	***	4.989E–06	***
α_1	0.054961	***	0.0991	***	0.0833	***	0.05079133	**
b_1	0.91806	***	0.9219	***	0.927	***	0.94945831	*
α_2	0.038562	***	–0.0554	***	–0.0867	***	–0.01843071	***
ν	1.186249	***	–0.3472	***	–0.3172	***	1.41960573	***

Note: ***, ** and * indicate the 1%, 5%, and 10% significance levels, respectively.

Table 4
Estimation of Commodity Markets with the Equity Market Uncertainty (Full Sample)

	Corn	Sig	Soybean	Sig	Wheat	Sig	Sugar	Sig
panel A: mean equation								
α	0.00171	***	0.00081	***	0.00095	***	0.00096	*
β1 (Crude Oil)	0.03927	***	0.0335	**	0.0472	***	0.06222	***
β2 (EMU)	–0.00037	**	–0.00014	**	–0.00023	***	–0.00023	
panel B: variance equation								
α_0	0.000003	***	0.000002	***	0.00001	***	0.000005	***
α_1	0.0535	***	0.0992	***	0.0787	***	0.05074	***
b_1	0.9183	***	0.9217	***	0.9321	***	0.94956	**
α_2	0.0401	***	–0.0544	***	–0.0806	***	–0.01845	***
ν	1.2095	***	0.6205	***	0.4491	***	1.90274	***

Note: ***, ** and * indicate the 1%, 5%, and 10% significance levels, respectively.

Table 5
Estimation of Commodity Markets with the VIX (Sub–samples)

Pre–Crisis	Corn	Sig	Soybean	Sig	Wheat	Sig	Sugar	Sig
panel A: mean equation								
α	0.00341	**	0.00324	**	0.00181		0.00338	
β1 (Crude Oil)	0.0257	***	0.0172	***	0.01061		0.03022	***
β2 (VIX)	–0.00108		–0.00102		–0.0006		–0.00119	
panel B: variance equation								
α_0	0	***	0	***	0.00002	***	0.00001	***
α_1	0.0641	***	0.1028		0.09548	***	0.04803	***
b_1	0.907		0.9199	***	0.90259	***	0.95011	***
α_2	0.0383	***	–0.0606	***	–0.10121	***	–0.0171	***
ν	0.7829	***	0.8841	***	2.47726		1.13946	***
Post–Crisis	**Corn**	**Sig**	**Soybean**	**Sig**	**Wheat**	**Sig**	**Sugar**	**Sig**
panel A: mean equation								
α	–0.00143	**	–0.0002	**	–0.0018		–0.0061	*
β1 (Crude Oil)	0.21004	***	0.2029	***	0.1973	***	0.2005	***
β2 (VIX)	–0.00038	**	–0.0002	**	0.0005		0.002	
panel B: variance equation								
α0	0.000103	***	0.000006	***	0	***	0	***
α1	0.13603	***	0.0831	***	0.0381	***	0.0407	***
b1	0.51483	***	0.90134	***	0.9584	***	0.96078	***
α2	0.32631	***	–0.01232	***	–0.00227		–0.0104	
ν	1.01046	***	1.68907	***	1.16993	***	1.21351	***

Note: ***, ** and * indicate the 1%, 5%, and 10% significance levels, respectively.

Table 6

Estimation of Commodity Markets with the Equity Market Uncertainty (Sub–samples)

Pre–Crisis	Corn	Sig	Soybean	Sig	Wheat	Sig	Sugar	Sig
panel A: mean equation								
α	0.00164	***	0.00063		0.00048		0.00074	
β1 (Crude Oil)	0.02553	***	0.01737	**	0.01071		0.0304	***
β2 (EMU)	–0.00034		–0.00008		–0.00011		–0.0002	
panel B: variance equation								
α_0	0	***	0	***	0.00002	***	0.00001	
α_1	0.06284	***	0.10281		0.09466	***	0.04805	***
b_1	0.90742		0.91979	***	0.90368		0.95028	
α_2	0.03953	***	–0.05999	***	–0.1005	***	–0.01723	***
ν	1.144	***	2.71679	***	1.45344	***	2.4458	***
Post–Crisis	**Corn**	**Sig**	**Soybean**	**Sig**	**Wheat**	**Sig**	**Sugar**	**Sig**
panel A: mean equation								
α	0.0003	*	0.005	*	0.0001		0.0025	
β1 (Crude Oil)	0.2747	***	0.2679	**	0.3035	***	0.2648	***
β2 (EMU)	–0.0004	**	–0.0015	**	–0.0004		–0.0004	
panel B: variance equation								
α0	0.000004	**	0.000005	***	0.00086	***	0.00004	***
α1	0.00577	**	0.1022	***	0.01168		0.05123	***
b1	0.9588	***	0.8917	***	–0.65775	***	0.87911	***
α2	0.0558	***	–0.0104	***	0.09404		0.02289	
ν	0.7714	***	0.3407	***	3.72276	***	–3.55919	***

Note: ***, ** and * indicate the 1%, 5%, and 10% significance levels, respectively.

Table 7
Estimation of Commodity Markets with the VIX (Sub–samples)

Pre–Biofuel	Corn	Sig	Soybean	Sig	Wheat	Sig	Sugar	Sig
panel A: mean equation								
α	0.002958	**	0.002806	*	0.000750		0.004675	*
β1 (Crude Oil)	0.016293	**	–0.000181	**	0.002285		0.021363	**
β2 (VIX)	–0.000960		–0.000895		–0.000308		–0.001614	
panel B: variance equation								
α_0	0.000005	***	0.000003	***	0.000023	***	0.000003	***
α_1	0.065855	***	0.119645	***	0.100645	***	0.038453	***
b_1	0.893328	***	0.910766	***	0.872877	***	0.962700	***
α_2	0.051387	***	–0.079581	***	–0.106164	***	–0.015861	***
ν	2.538263	***	3.212488	***	5.608227	***	6.935154	***
Biofuel (Pre–crisis)	**Corn**	**Sig**	**Soybean**	**Sig**	**Wheat**	**Sig**	**Sugar**	**Sig**
panel A: mean equation								
α	0.006088	**	–0.003258	*	0.007800		–0.004893	*
β1 (Crude Oil)	0.248747	**	0.255145	**	0.177610		0.181717	*
β2 (VIX)	–0.001700		–0.001644		–0.002330		–0.001605	
panel B: variance equation								
α0	0.000105	***	0.000026	***	0.000020	***	0.000008	***
α1	0.077124	***	0.092931	***	0.119941	***	0.077028	***
b1	0.573183	***	0.742352	***	0.892666	***	0.911223	***
α2	0.118541	***	0.072366	***	–0.109796	***	–0.004186	***
ν	0.967015	***	1.121121	***	2.332119	***	4.556240	***
Biofuel (Crisis)	**Corn**	**Sig**	**Soybean**	**Sig**	**Wheat**	**Sig**	**Sugar**	**Sig**
panel A: mean equation								
α	–0.000655		–0.004743		0.004804		–0.005737	
β1 (Crude Oil)	0.289065	**	0.273768	***	0.334271	***	0.251023	***
β2 (VIX)	–0.00081	**	–0.001374	**	–0.001536		–0.001976	
panel B: variance equation								
α0	0.000001	*	0.000003	*	0.000098	***	0.000039	
α1	–0.004573	**	0.083876	***	0.186400	***	0.051703	**
b1	0.978154	***	0.913690	***	0.766578	***	0.868056	***
α2	0.044747	***	–0.012483	**	–0.275302	***	0.037425	
ν	2.013450	***	3.603050	***	1.595109	***	3.166622	***
Biofuel (Post–crisis)	**Corn**	**Sig**	**Soybean**	**Sig**	**Wheat**	**Sig**	**Sugar**	**Sig**
panel A: mean equation								
α	–0.006290	**	–0.000491	**	–0.008646	*	–0.002877	
β1 (Crude Oil)	0.160362	***	0.166200	***	0.089100	***	0.163900	***
β2 (VIX)	–0.002168	**	–0.000378	**	–0.002932	**	–0.000863	
panel B: variance equation								
α0	0.000134	***	0.000026	***	0.000002	***	0.000001	***
α1	0.128496	***	0.199700	***	0.047800	***	0.040000	***
b1	0.371380	***	0.721200	***	0.943800	***	0.964700	***
α2	0.510688	***	–0.044500	*	0.009812		–0.017200	*
ν	0.561558	***	0.208900	***	0.322500	***	0.598100	***

Note: ***, ** and * indicate the 1%, 5%, and 10% significance levels, respectively.

Table 8

Estimation of Commodity Markets with the Equity Market Uncertainty (Sub–samples)

Pre–Biofuel	Corn	Sig	Soybean	Sig	Wheat	Sig	Sugar	Sig
panel A: mean equation								
α	0.00116	*	0.00009		–0.00011		0.00127	
β1 (Crude Oil)	0.01602	***	0.00031	*	0.00271		0.02150	*
β2 (EMU)	–0.00024		–0.00003		–0.00001		–0.00032	
panel B: variance equation								
α_0	0.00000	***	0.00000	***	0.00002	***	0.00000	***
α_1	0.06181	***	0.11430	***	0.09530	***	0.03860	***
b_1	0.89951	***	0.91570	***	0.88220	***	0.96270	***
α_2	0.04924	***	–0.07640	***	–0.10100	***	–0.01600	***
N	1.13065	***	0.84310	***	0.68100	***	0.73280	***
Biofuel (Pre–crisis)	**Corn**	**Sig**	**Soybean**	**Sig**	**Wheat**	**Sig**	**Sugar**	**Sig**
panel A: mean equation								
A	0.00398	*	0.0023		0.0032		0.0001	*
β1 (Crude Oil)	0.24875	***	0.2516	***	0.1793	***	0.2340	***
β2 (EMU)	–0.00082		–0.0003		–0.0006		–0.0002	
panel B: variance equation								
α0	0.000105	***	0.000015	***	0.00002	***	0.00016	***
α1	0.07483	***	0.08104	***	0.12142	***	0.37333	***
b1	0.57959	***	0.83116	***	0.89138	***	0.39343	***
α2	0.11154		0.02553		–0.10669	***	–0.15042	***
N	1.65530	***	2.32605	***	1.17013	***	2.22900	***
Biofuel (Crisis)	**Corn**	**Sig**	**Soybean**	**Sig**	**Wheat**	**Sig**	**Sugar**	**Sig**
panel A: mean equation								
A	0.00227		0.00446	*	0.0018		0.0001	
β1 (Crude Oil)	0.28689	***	0.27018	***	0.3373	***	0.2493	***
β2 (EMU)	–0.00086		–0.00132		–0.0006		–0.0003	
panel B: variance equation								
α0	–0.000002	***	0.000003		0.00009	***	0.00004	
α1	–0.02139	***	0.08222	***	0.18190	***	0.04768	**
b1	1.00541	***	0.91380	***	0.77584	***	0.87297	***
α2	0.03893	***	–0.01001		–0.26855	***	0.04159	
N	1.54808	***	1.83406	***	0.12803	***	0.31170	***
Biofuel (Post–crisis)	**Corn**	**Sig**	**Soybean**	**Sig**	**Wheat**	**Sig**	**Sugar**	**Sig**
panel A: mean equation								
A	0.00065	***	0.00014	***	–0.0024		–0.00146	
β1 (Crude Oil)	0.15950	***	0.16625	***	0.0906	***	0.16360	***
β2 (EMU)	–0.00026	**	–0.00014	**	–0.0006		–0.0003	
panel B: variance equation								
α0	0.000150	***	0.000024	***	0.00000	***	0.00000	***
α1	0.12789	***	0.19288	***	0.04650	***	0.04000	***
b1	0.32354	***	0.73582	***	0.94580	***	0.96480	***
α2	0.53066	***	–0.04474	***	0.00827		–0.01770	
ν	0.73141	***	1.05108	***	0.99810	***	0.00876	***

Note: ***, ** and * indicate the 1%, 5%, and 10% significance levels, respectively.

Table 9
A Summary of the Empirical Results

Corn Returns:	Whole Period	Pre–Crisis	Post–Crisis	Pre–Biofuel	Biofuel & Pre–crisis	Biofuel & Crisis	Biofuel & Post–crisis
Crude Oil Returns	+	+	+	+	+	+	+
Log VIX	–	N/S	–	N/S	N/S	–	–
Log EMU	–	N/S	–	N/S	N/S	N/S	–
Soybean Returns:	**Whole Period**	**Pre–Crisis**	**Post–Crisis**	**Pre–Biofuel**	**Biofuel & Pre–crisis**	**Biofuel & Crisis**	**Biofuel & Post–crisis**
Crude Oil Returns	+	+	+	+	+	+	+
Log VIX	–	N/S	–	N/S	N/S	–	–
Log EMU	–	N/S	–	N/S	N/S	N/S	–
Wheat Returns:	**Whole Period**	**Pre–Crisis**	**Post–Crisis**	**Pre–Biofuel**	**Biofuel & Pre–crisis**	**Biofuel & Crisis**	**Biofuel & Post–crisis**
Crude Oil Returns	+	N/S	+	N/S	N/S	+	+
Log VIX	–	N/S	N/S	N/S	N/S	N/S	–
Log EMU	–	N/S	N/S	N/S	N/S	N/S	N/S
Sugar Returns:	**Whole Period**	**Pre–Crisis**	**Post–Crisis**	**Pre–Biofuel**	**Biofuel & Pre–crisis**	**Biofuel & Crisis**	**Biofuel & Post–crisis**
Crude Oil Returns	+	+	+	+	+	+	+
Log VIX	N/S	N/S	N/S	N/S	N/S	N/S	N/S
Log EMU	N/S	N/S	N/S	N/S	N/S	N/S	N/S

Notes. i) Whole Period: January 1, 1990–July 31, 2015; ii) Pre–Crisis Period: January 1, 1990–July 31, 2008; iii) Post–Crisis Period: August 1, 2008–July 31, 2015; iv) Pre–Biofuel Period: January 1, 1990–December 31, 2005; v) Biofuel & Pre–Crisis Period: January 1, 2006–July 31, 2008; vi) Biofuel & Crisis Period: August 1, 2008–May 31, 2010; vii) Biofuel & Post–Crisis Period: June 1, 2010–July 31, 2015. N/S: Not statistically significant.