Volatility transmission on international futures markets during the 2007/08 price surge

Jochen Schmitz* and Oliver von Ledebur*

Abstract

The study is a contribution to the debate on the commodity price spike in 2007 to 2008 and the relationship among commodity futures markets. The transmission of price volatility between futures markets is analysed. The background question is whether, and to what extent, the volatility of agricultural futures at different market places was transferred during the price changes of 2008. The volatility of maize futures at different exchanges is modelled as a multivariate GARCH-process. By doing so, interactions between markets in different venues are incorporated. Estimation results are discussed against the background of the developments in agricultural and biofuel policy.

Keywords: commodity futures, corn, time series, price volatility transmission, multivariate GARCH.

Zusammenfassung

Volatilitätsübertragung auf internationalen Terminmärkten während des 2007/08 Preisschubs

Diese Studie liefert ein Beitrag zur Debatte über den Preisanstieg auf den Rohstoffmärkten in 2007 bis 2008 sowie dem Verständnis der Beziehungen zwischen Warenterminmärkten. Die Übertragung von Preisschwankungen zwischen Warenterminmärkten wird analysiert. Die Kernfrage ist, ob und in welchem Umfang, die Volatilität der Agrar-Futures auf verschiedenen Marktplätzen während der Preisänderungen des Jahres 2008 übertragen wurde. Die Volatilität des Mais-Futures an verschiedenen Börsen wird als ein multivariater GARCH-Prozess modelliert. Dadurch sind die Wechselwirkungen zwischen den Märkten an verschiedenen Börsenplätzen aufgenommen. Die Ergebnisse der Schätzung werden vor dem Hintergrund der Entwicklungen der Agrarpolitik und der Biokraftstoff-Politik diskutiert.

Keywords: Warenterminkontrakte, Mais, Zeitreihenanalyse, Volatilitätsübertragung, multivariates GARCH

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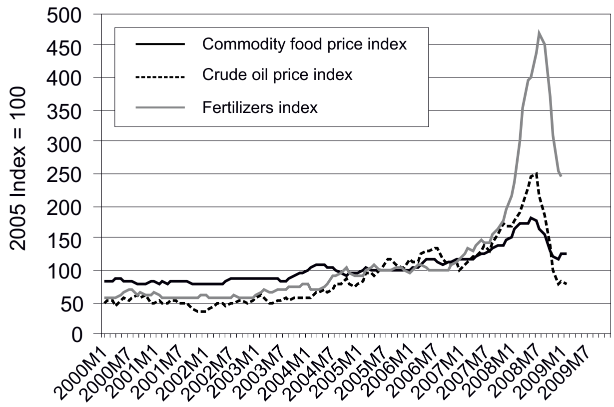
1 Introduction

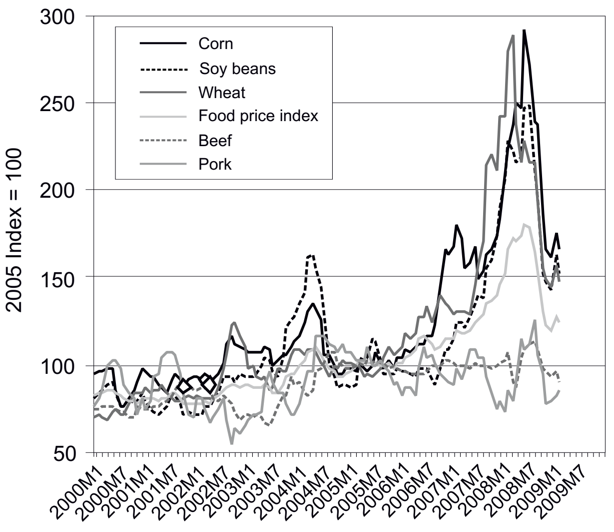
In the past couple of years major changes could be observed on the agricultural markets. Within a short period of time, the price level of agricultural raw materials rose with serious consequences for the entire agricultural sector. The FAO, the EU Commission, IFPRI, the World Bank and other organisations point price dynamics on the agricultural markets as the driving cause of increases of both the price level and price volatility, (EC, 2008a; EC, 2008b: 6ff; Food and Organisation, 2008: 55 to 57; Robles et al., 2009; Cavero and Galian, 2008; Rabobank, 2008: 8ff).



Source: Own calculations based on IMF (2009) and World Bank (2009).

Figure 1:

Monthly price index for fertilizer, crude oil and food (Index 2005 = 100, 2000 to 2008)



Source: Own calculations based on IMF (2009) and World Bank (2009).

Figure 2:

Monthly price index for food agricultural products (Index 2005 = 100, 2000 to 2008)

The price changes on the agricultural markets took place in the course of a general increase in raw materials prices (see Figure 1 and Figure 2).

A series of factors had an impact on the agricultural markets during the period of price increase. Among these, structural changes in global demand and repeated supply shortages in important producing regions during the first decade of the century. This led to continuous global stock reductions which supported the observed positive price development. Other factors were mentioned which influenced the agricultural market volatility in the past years. Among these were changes in the market and trade policy in many countries. The reduction of exportable surpluses in the EU occurred at essentially the same point in time as the world's market supply situation on the cereals market was most constrained. Through the implementation of measures that burden exports at this time, several traditional grain exporting countries prevented a relaxing of the world market situation. With these measures they even increased the existing scarcity, and consequently the supply insecurity, and ultimately the market volatility. Also "new" market interventions, such as the additional demand of agricultural raw materials for fuel use as a consequence of the promotion of bio energy lead to an increase of insecurity related to market supply. Finally, the increase of uninformed and speculative investors on the futures markets must also be mentioned. Many market observers argued they influenced the price level and volatility on the futures markets as well as the physical markets. In the lively debate on this topic, neither a consensus on the level of the influence of policy instruments in the areas of renewable energy providers on the price level of agricultural markets, nor an clear causal interaction between the increased activities of speculative investors on the futures markets, have yet been found (FAO, 2007: 48; Gilbert, 2009; Rabobank, 2008: 9; Tangermann, 2011; USDA, 2008: 20).

This paper analyzes the interrelationship of futures markets of agricultural raw materials. In particular the transmission of price volatility between markets will be considered. The corn market was chosen as the key market for this analysis. This product plays a central role worldwide for the livestock production but also in the area of substitution of fossil fuels with bio-fuels from renewable resources. The emphasis of the approach of substituting fossil fuels with renewable agricultural raw materials as implemented in the United States is based on the use of ethanol from corn starch.

The Chicago futures market takes an exposed position in world trade with agricultural raw materials. A large part of worldwide futures trade with corn is realized at the Chicago Board of Trade (CBOT) since the USA is by far the largest corn producer and exporter at global level.

Contract prices achieved at the CBOT in the course of the futures trading have a wide reaching signal function for global corn markets. In addition to this exchange, there are two other exchanges of interest. These are the Futures Exchange in São Paulo (Bolsa Mercantil e de Futuros, BMF, here denominated BRAZ) in Brazil and the Paris-based Exchange, the Marche a Terme d'Instruments Financiers (MATIF). The Brazilian agricultural markets are characterized by notable large export surplus growth rates. Since the Brazilian macroeconomic stabilization succeeded the 1990's, trade at the BMF has increased, and currently the exchange assumes the role of regional reference market for some commodities. The French exchange takes the role of leading market with regard to cereals markets within the European Union.

In the context of globally increasingly interrelated agricultural and financial markets, the question emerges whether and to what extent futures price volatility was carried over between international trading centres during the drastic price changes of 2008. This question has only been dealt with approximately in the agricultural economic scientific literature (Baffes, 2007; EC, 2008a; EC, 2008b; Garcia and Leuthold, 2004).

Until now, studies on the volatility of agricultural market prices have mainly concentrated methodically on a univariate approach. At the heart of the past analysis is a modelling of volatility as a GARCH (Generalized Autoregressive Conditional Heteroscedasticity) Process, which was supplemented with exogenous factors. Factors that have been identified are government programs for the US futures and cash wheat markets (Crain and Lee, 1996) or inventories and trading volume for the US corn and wheat futures markets (Goodwin and Schnepf, 2000). Regarding the variability in futures markets, a better understanding of the factors that affect price changes and volatility is needed (Goodwin and Schnepf, 2000; Boudoukh et al., 2003).

Against this methodological background, interactions between futures markets at different trading centres were excluded. In light of the joint price increase across commodity markets, the question emerges of how adequate an isolated consideration of a single market is. For this reason we take a different approach in this study. It appears to be necessary to illustrate the relevant markets simultaneously and to document their interdependencies. In order to achieve this for the global corn market, we illustrate the markets in a multivariate heteroscedasticity model. The modelling approach of a BEKK Model[1] is useful for this purpose. A positive definite covariance matrix H_t (Engle and Kroner, 1995) due to the model set-up let this model appear to be suited for this analysis. This article is divided into the following areas. The next section introduces in detail the methods of the BEKK model. Section 3 presents the data used and the estimated results. A discussion on the results closes this section. The final section concludes with a discussion of possible future research.

2 Model

GARCH models serve as the backbone of volatility modelling. Through the approach by (Engle, 1982), it is possible to model the (unobserved) second moment. The resulting variance is dependent on the amount of currently available information. The whole GARCH model can be characterized by 4 equations. The first part describes the mean equation and illustrates the first moment of the process (Equation (1)). In this specification only a long term trend component μ is assumed. Daily percentage price changes (Price returns) are used for estimation. Those returns are best characterized by a long term trend component.

The second part describes the variance equation. It serves as the second moment of the process (Equation (4)). The known information set is generated from the returns up to the time point *t*-1. Further model characterizations are needed to fully describe the GARCH model. Equation (2) serves as a link between Equation (1) and Equation (4). It states that the second moment is driven by conditional heteroscedasticity. Equation (3) declares the distribution of the innovation of the process as a normal distribution.

The returns are calculated as $r_t = \log(F_t/F_{t-1})$. The futures price at that point in time is called F_t, and r_t describes the illustrated returns at time point t:

$$r_t = \mu + \varepsilon_t \tag{1}$$

$$\varepsilon_t = \sqrt{h_t} z_t \tag{2}$$

$$\varepsilon_t \mid I_{t-1} \sim N(0, h) \tag{3}$$

The resulting variance of r_t yields the generalization of the model by (Bollerslev, 1986). It permits the inclusion of past variances in addition to the consideration of past innovations. This leads to the general univariate GARCH (*p,q*) model:

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \ldots + \alpha_p \varepsilon_{t-p}^2 + \beta_1 h_{t-1} + \ldots + \beta_q h_t \tag{4}$$

The past innovations $\left(\alpha_1 \varepsilon_{t-1}^2 + \ldots + \alpha_p \varepsilon_{t-p}^2\right)$ are called the ARCH-terms while the past variances $\left(\beta_1 h_{t-1} + \ldots + \beta_p h_{t-p}\right)$ are called the GARCH-terms.

The transfer into a multivariate GARCH model takes place with a generalization of the resulting variance matrix H_t.

[1] BEKK models are named after Baba, Engle, Kraft und Kroner.

$$\mathrm{H}_t = \begin{pmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{pmatrix} \quad (5)$$

Each element of H_t depends on p delayed values of the squared ε_t, the cross product of ε_t and on *q* delayed values of the elements from H_t. We did not make use of the possibility to draw exogenous factors into the resulting variance equation. In general, a multivariate GARCH (1,1) model without exogenous factors can be presented as follows as a BEKK model (Engle and Kroner, 1995). For reasons of clarity time indicators are not included in the presentation. A model with the time delay of only one lag (*t*-1) was modelled.

$$\mathrm{H}_t = C_0^{'}C_0 + \begin{pmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{pmatrix}^{'} \begin{pmatrix} \varepsilon_1^2 & \varepsilon_1\varepsilon_2 & \varepsilon_1\varepsilon_3 \\ \varepsilon_2\varepsilon_1 & \varepsilon_2^2 & \varepsilon_2\varepsilon_3 \\ \varepsilon_3\varepsilon_1 & \varepsilon_3\varepsilon_2 & \varepsilon_3^2 \end{pmatrix} \begin{pmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{pmatrix} + \begin{pmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{pmatrix}^{'} \begin{pmatrix} h_1^2 & h_1h_2 & h_1h_3 \\ h_2h_1 & h_2^2 & h_2h_3 \\ h_3h_1 & h_3h_2 & h_3^2 \end{pmatrix} \begin{pmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{pmatrix} \quad (6)$$

Through the model construction via the quadratic form it is possible to positively define the resulting variance-covariance matrix H_t. This ensures that all variances and covariances are always positive. In compact form, the above equation can also be written in this manner:

$$\mathrm{H}_t = C_0^{'}C_0 + A^{'}\varepsilon_{t-1}\varepsilon_{t-1}^{'}A + B^{'}H_{t-1}B \quad (7)$$

The matrices A, C_0 and B possess the dimension (n × n). C_0 is a (lower) triangular matrix. In the model assumed here, we are dealing with the matrices A and B on diagonal matrices. A generalization of the model is possible. Further interactions could be implemented, but then the matrices A and B are not diagonal anymore and results in a much more complex matrix H_t.

Apart from the achievement of a positive definite matrix H_t, there is another advantage of the BEKK specification. Due to the diagonal BEKK model assumed here, a checking of the stationary nature of the process is determined solely through the diagonal elements of matrices A and B. The diagonal BEKK model is stationary if $\sum_{k=1}^{n}(a_{ii,k}^2 + b_{ii,k}^2) < 1 \forall i$ (Engle and Kroner, 1995, p.133). In accordance with the questions stated in the introduction, three trading centres (exchanges) were studied (n = 3). The according variance and covariance equations are as follows:

$$h_{11} = c_{01} + a_{11}^2\varepsilon_1^2 + b_{11}^2h_1^2 \quad (8)$$

$$h_{21} = c_{02} + a_{11}a_{22}\varepsilon_2\varepsilon_1 + b_{11}b_{22}h_{21} \quad (9)$$

$$h_{31} = c_{03} + a_{11}a_{33}\varepsilon_3\varepsilon_1 + b_{11}b_{33}h_{31} \quad (10)$$

$$h_{22} = c_{04} + a_{22}^2\varepsilon_2^2 + b_{22}^2h_2^2 \quad (11)$$

$$h_{32} = c_{05} + a_{22}a_{33}\varepsilon_3\varepsilon_2 + b_{22}b_{33}h_{32} \quad (12)$$

$$h_{33} = c_{06} + a_{33}^2\varepsilon_3^2 + b_{33}^2h_3^2 \quad (13)$$

The indexes used recede to the notation used in Equations (5) and (6). The matrix H_t contains redundant expressions. For the sake of a clear and comprehensible analysis, no distinction is made between h_{21}/h_{12}, h_{31}/h_{13} or h_{32}/h_{23}. So the influence from Commodity Market 1 (in our later model implementation CBOT) on Commodity Market 2 (in our later analysis MATIF) is the same and vice versa. The same holds for all other possible market interactions. This analysis should reveal whether there is any relationship between markets at that period of time. It should not answer which market influences the other markets most. The empirically estimated BEKK-GARCH model is thus based on a multivariate version of Equation (1) and Equations (8) to (13) (derived from Equation (6)).

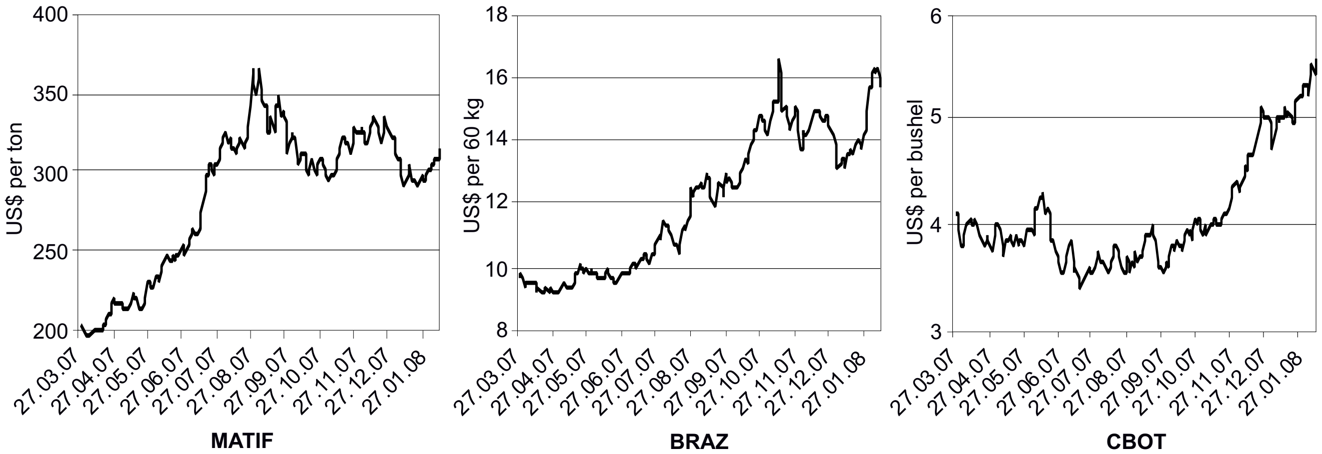
3 Data and results

The interactions of volatilities between the traded price quotations on the commodity exchanges in the USA (CBOT), Brazil (BRAZ) and Europe/France (MATIF) were studied. The topic of this analysis is related to price quotations which ran out in March 2008, and was dealt with on all three exchanges with the same running time. Exchange quotations from 27. March 2007 to 5. March 2008 were available. The Central Market and Price Reporting Agency (Zentrale Markt- und Preisberichtsstelle – ZMP) provided the data as a courtesy. Price quotations are given in US-Dollars. Each futures contract is based on a different corn quantity. In Europe one contract stands for 50 tons of corn. In Brazil, 450 units of 60 kilogram bags are traded by one contract. This is equivalent to 27 tonnes. In the United States, the unit per contract is 5000 bushels. This is equivalent to 127 tonnes (1 bushel of corn is equal to 25.4 kilogram). This different unit of measurement explains the observed price levels per unit of weight on these markets. Due to holidays, etc., on some days, price notations were not available for all three markets. Thus all exchange quotations were deleted for these days. Overall at the start, 245 exchange quotations were available. After the validation, 226 observations remained for the estimates. In the framework of a GARCH estimate, this is just a small sample. At the MATIF and BRAZ trading centres, the appropriate futures were not placed and traded earlier. Thus, only the mentioned 245 daily notations were available. This is due to the different definition of the contracts at the future exchanges.

The time development of prices per unit of weight for corn between 27. March 2007 and 5. March 2008 is presented in the following Figure 3. The value of one futures contract consists of the price per unit of weight multiplied with the corresponding unit of trading. One can recognize a continual price increase on the Chicago exchange. This increase began in October 2007. A comparably strong and permanent price increase cannot be observed for the other exchanges. Consequently, this price development also affects the returns, the logarithmic difference of the price level, of the process.

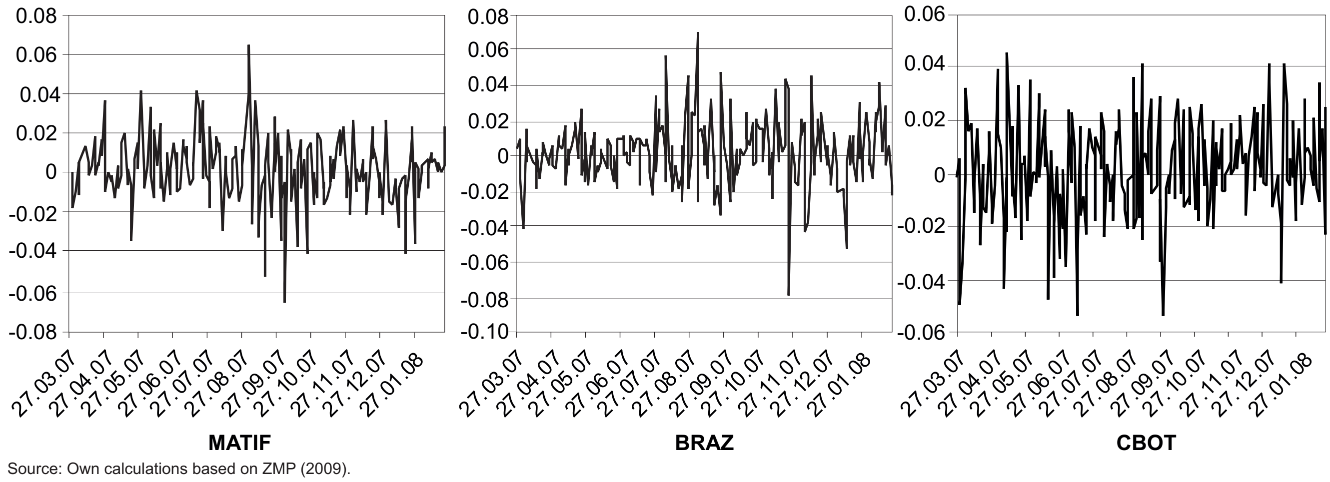
According to Figure 3, the processes show a very clear non-stationary behaviour. Stationarity of time series data can be tested by Unit-Root tests. The validation of stationarity will be conducted by the Augmented-Dickey-Fuller-Test (ADF-test). For this test the null hypothesis is non-stationarity. Results are given in Table 1. The results clearly endorse the non-stationary behaviour of the series. Since the estimation of the model using price levels is not indicated, stationary variables are to be used.

The correspondent returns are significantly stationary at the 1 percent level and are suited for modelling (see Figure 4).



Source: ZMP (2009).

Figure 3:
Corn prices per ton in France (MATIF), per 60 kg in Brazil (Bolsa Mercantil e de Futuros, BRAZ) and per bushel in the USA (CBOT)



Source: Own calculations based on ZMP (2009).

Figure 4:
Corn prices returns in France (MATIF), in Brazil (Bolsa Mercantil e de Futuros, BRAZ) and in the USA (CBOT)

Table 1:

Unit-root tests for price level and returns

	MATIF		BRAZ		CBOT	
	Future	Return	Future	Return	Future	Return
Observations	224	223	224	223	224	223
ADF - Test	1.200	-12.9035	1.2520	-13.0326	1.400	-14.3167
	(0.9411)	(0.0000)	(0.9464)	(0.0000)	(0.9594)	(0.0000)

Prob. Value in parenthesis (Prob.value)
Source: Own calculations.

Table 2 contains a summary of the data for the returns of the corn prices. Most clearly evident are the results of the Jarque-Bera statistics in Table 2. According to these values the assumption of normal distribution on the basis of 5 % level cannot be rejected for the CBOT data. This finding is in contrast to the stylized facts of finance market data. This market data reaction can be interpreted as an influence of the political institutional framework at that period of time. In a normal market situation one should expect one price for one product on different markets (in absence of transport cost, etc.). The classic economic "Law of one price" principle was not valid in this time period.

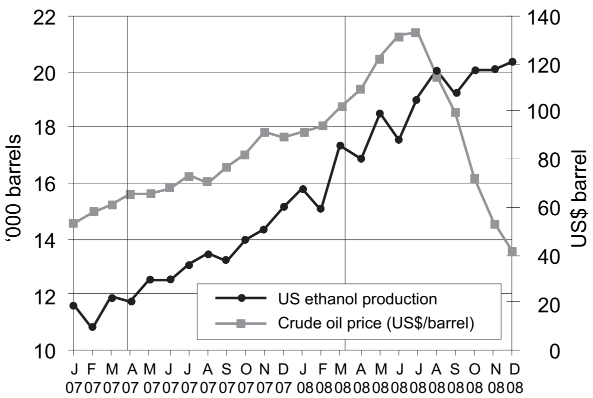
Table 2:

Summary of returns for the selected exchanges (27. March 2007 to 5. March 2008)

	MATIF	BRAZ	CBOT
Mean	0.0020	0.0020	0.0014
Median	0.0026	0.0022	0.0012
Max	0.0645	0.0701	0.0457
Min	-0.0657	-0.0788	-0.0537
Std. deviation	0.0167	0.0182	0.0185
Skewness	-0.2844	-0.0094	-0.2595
Kurtosis	5.0355	5.4022	3.2843
Jarque-Bera	41.6920	53.8667	3.2682
Prob. value	0.0000	0.0000	0.1952

Source: Own calculations.

The reasons for such surprising results could have their origin in the political institutional framework conditions. Here changes in framework conditions apply for the corn market, particularly in the USA, where the corn ethanol industry expansion is highly subsidized. The massively extended production of ethanol on the basis of corn starch, induced by the US ethanol policy, requires according amounts of raw materials. In the USA, corn and soy production compete for land. Already in the previous period (October 2006 to May 2007), one could observe a simultaneous price increase for both products on the futures exchanges and also on the physical markets, which was interpreted as an expression of demand pressure evident through the competition for land during the sowing period (Theis, 2007: 48 to 49). The time period considered here comes with a further increase in the price of crude oil, which drove the ethanol boom further. Against the background of this price development, the price competitiveness of the biogenic fuel as a substitute for fossil fuel increased (see Figure 5). In light of the expected further demand, increasingly higher prices were offered for corn contracts on the Chicago exchange in order to secure the supply of corn for processing and feeding.

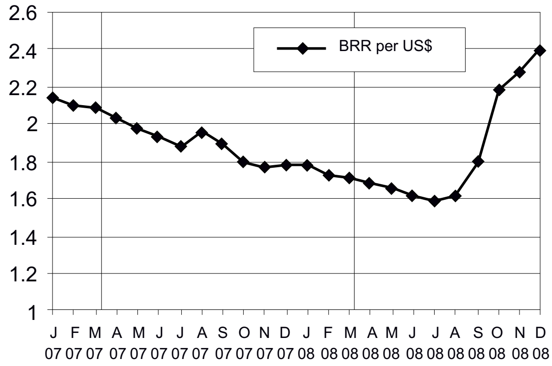


Source: Renewable Fuel Association (2009) and IMF (2009).

Figure 5:

US ethanol production and crude oil price development, January 2007 to December 2008.

The increase of corn price at the CBOT during the time period October 2007 to March 2008 coincides also with a devaluation of the US Dollar against the Brazilian Real (Figure 6). This exchange rate development leads to a relative price advantage of the US priced product, which finally may have led to an increase in foreign demand for US corn. This applies particularly against the background of the tense supply situation of feeding stuff in 2007/08. In the European Union wheat has been substituted by corn and corn has been increasingly imported. Due to genetically modified corn, Argentinean corn did not obtain access to the European markets at this time. This led to an increased demand for Brazilian corn. According to extremely high world market prices, Brazilian corn could be transported to the EU market without any tariff burden[2]. These factors together lead to a significant price increase, see Figure 3.



Source: (MAPA – Ministério da Agricultura; Pecuaria e Abastecimento, 2009).

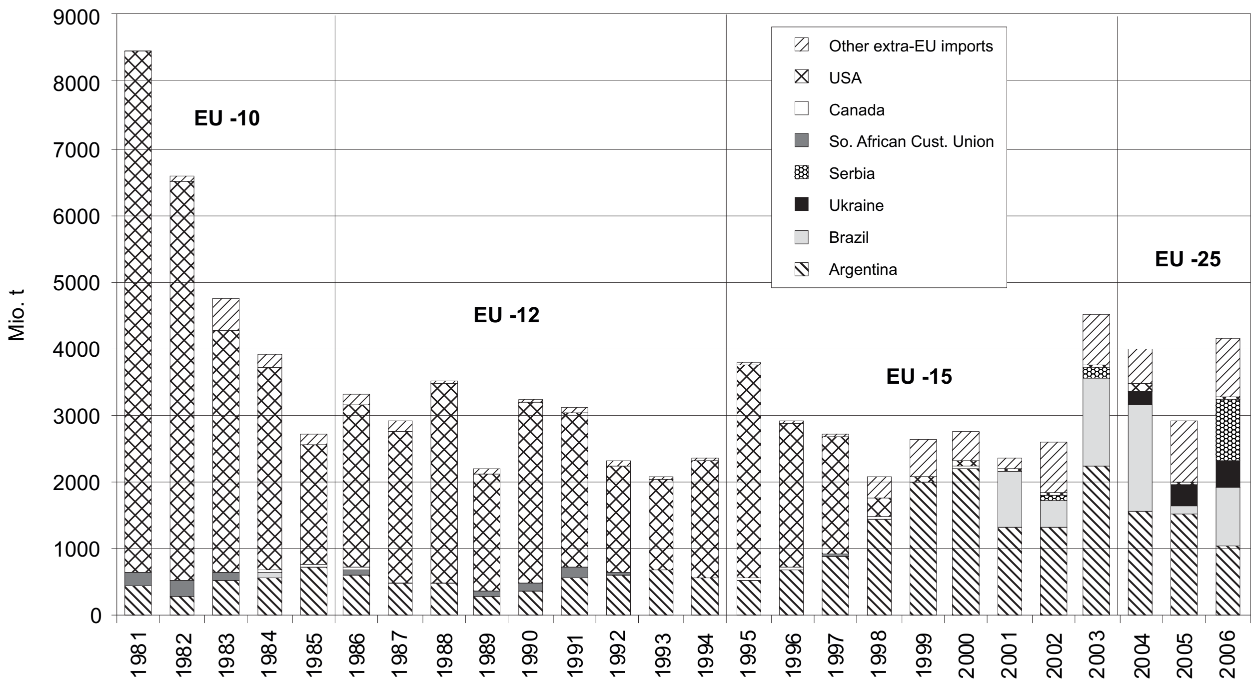
Figure 6:

Exchange rate development Brazilian Real to US Dollar, January 2007 to December 2008.

An impact of an increasing European demand on US corn prices can be excluded because corn imports from the USA have not taken place since the end of the 1990s due to consumer preferences and existing regulations in the area of consumer protection. The EU Framework regulations on genetically modified organisms (GMOs) are continually being expanded and updated. A series of legal regulation exist with the clear goal of protecting public health and the environment. An important branch of the EU laws on GMOs deal with the release of genetically modified organisms into the environment. In 2002, an authorization procedure was introduced dealing with the release of GMOs or any type of product made from GMOs. The prohibition, or rather, the non-authorization of some so-called Bt Corn varieties led to an actual end of the US exports into the EU (Wirtschaftswoche, 2005), as can be seen in Figure 7.

The politically induced market development in the USA led to a solidifying of expectations for increasing corn prices, which ended, among other things, in fewer price deviations. This may have led to the fact that for the futures price at the Chicago Exchange, the assumption of normal distribution of returns could not be rejected.

Additionally, the prevailing corn price level in the observed period was so high that the variable tariff system



Source: Own calculations based on COMTRADE (2009).

Figure 7:

Development of Corn Imports from Non EC/EU Member States in tonnes, 1981 to 2006

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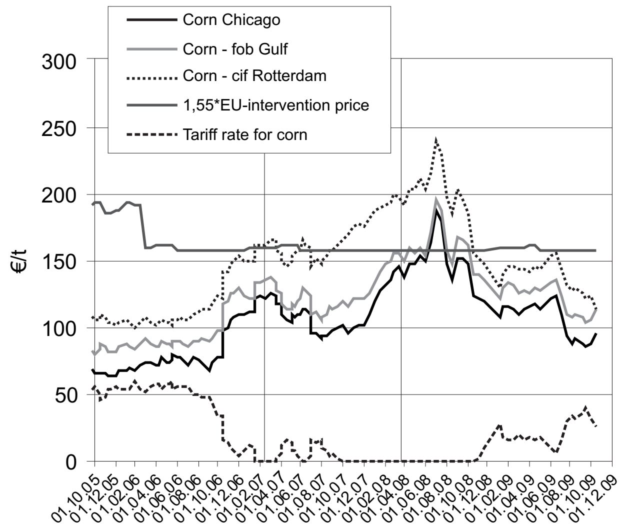
[2] The calculation of tariff rates for corn by the EU Commission is based on FOB prices of the US goods at the Gulf of Mexico, transport costs to Rotterdam and the administrated intervention price (CAP Monitor, 2009). This link to the US corn market has been lifted under the prevalent market conditions

of the EU for corn was de facto inactive. This system bases upon a series of prices that end with the entry price for imported corn at the port of Rotterdam and allows the European Commission to set and publish the import tariff in the Official Journal of the European Union in a two-week rhythm. Figure 8 illustrates how, due to a high market price level, the resulting import tariff results in zero.



Source: Own calculations based on EU Commission Regulations (several issues).

Figure 8:

Development of EU Corn Imports Tariff, October 2005 to October 2009

Regarding the variance and covariance equations described in Section 2, the interdependence of the markets can now be checked. Particularly the covariance equations provide insight into the interactions of the markets. From the estimated parameters given in Table 3 the following can be seen:

In order to better comprehend the results we address the Equations (8), (11) and (13). Equation (8) is the variance Equation for CBOT, Equation (11) for MATIF and Equation (13) for BRAZ.

Parameters a_{11}, and c_{01} for the CBOT Market are all not statistically significant at the five percent level. This means that the according variance equation is partially valid (Equation (8)). The returns at the Chicago Futures Market were not marked by conditional heteroscedasticity in the time period considered. The conditional variance of CBOT prices is characterised only by its own lagged variance. As parameter a_{11} is insignificant, information shocks are not accounted for. This finding again highlights the peculiarity of this exchange at this time.

This is an important result since Equations (9) and (10) illustrate the spill-over effects of the Chicago Market on MATIF and Brazil and the ARCH-terms of this equations described by parameters ($a_{11}a_{22}$) and ($a_{11}a_{33}$) are null. Thus in the time period considered, no spill-over of price or information shocks from Chicago (e.g., updated harvest forecast in the USA) took place on the development of prices at marketplaces MATIF and Brazil. Nevertheless CBOT is of such importance that the other markets considered are influenced via the covariance as the GARCH-term is described by the parameters ($b_{11}b_{22}$) and ($b_{11}b_{33}$) which are different from zero. These results mean that only the lagged conditional variance of CBOT influences the covariance. The politically induced market development in the USA caused a partial decoupling of the US market from the other markets analysed here. Due to the significance of the Futures exchange in Chicago (it is the global key market), a noticeable influence of the other market places came only via the covariance.

Table 3:

Estimated parameters of the BEKK model

	Coefficient	Prob. value
μ_1	0.0012	0.2850
μ_2	0.0024	0.0475
μ_3	0.0026	0.0210
c_{01}	0.0026	0.6539
c_{02}	0.0018	0.5760
c_{03}	0.0037	0.5903
c_{04}	0.0047	0.0093
c_{05}	-0.0005	0.9102
c_{06}	0.0000	1.0000
a_{11}	-0.0700	0.4179
a_{22}	0.2332	0.0002
a_{33}	0.4709	0.0000
b_{11}	0.9855	0.0000
b_{22}	0.9216	0.0000
b_{33}	0.8745	0.0000

Source: own calculations.

In contrast to the commodity exchange in Chicago, estimation results show that clear interactions exist between MATIF and Brazil. This can be seen due to the significant parameter values a_{22}, a_{33}, b_{22} and b_{33}, which appear in Equation (12). Thus at least an indirect (via the covariance) influence could be identified for both markets. Here both components of the covariance equation are relevant. Information shocks that occur on one of the two market places impact the volatility of the other. The lagged development of the variance of the other market alone does not determine its future development.

Each variance equation shows also the special situation during the time period studied. A GARCH (1,1) process could be identified for each of the trading centres in Europe and Brazil,. This is not the case for the US market. Major corn markets prices are not always tied together, nor therefore volatility. Transmissions of volatility impulses are disrupted with relation to CBOT. This revision of the volatility market characteristics was one intention of this study. It was shown that the US corn market was decoupled from other corn markets. International corn traders therefore cannot rely on a permanently stable relationship between these markets. So there might be trading opportunities. Also (international) hedging of corn positions gets complicated in such time periods.

This result must be seen in the context of the above-described political framework conditions. The de facto import ban on genetic corn into Europe, as well as the simultaneous ethanol boom, led to strongly changed price development of futures at the Chicago Futures Exchange. This resulted in a decoupling of the price development and volatility transmission at the commodity exchanges in Europe and Brazil. This decoupling was ultimately measured and confirmed by the model. The driving factors behind this cannot be analysed with this methodology approach. No clear identification between the GMO ban and the US biofuel politics can be set as the main factor. The major obstacle in resolving this lies in the different time frequency of available data. This study was carried out with daily data. Decisions regarding GMO ban or biofuel politics are made on a yearly or less frequent basis. Adding (daily) explanatory data, based on low frequent decisions, in models for daily volatility is an unresolved task.

4 Perspectives

The multivariate analysis framework used here contributes to a better understanding of price volatility on the futures exchanges as an interaction of many mutually affected trading centres. It could successfully be shown that the volatility of futures prices at different market places do impact each other. In particular the analysis results show that interactions existed among futures markets for the considered time period. Price formation (price level and volatility) are interrelated at different commodity exchanges. This specific analysis showed that the linkage among exchanges at different market places might be affected by policies as in the case of the support for corn ethanol in the USA during the observed period. Hence an additional building block in the explanation of the volatility could be identified.

The inter-market relationships should not be disregarded. Those volatility spill-over effects play a significant role in explaining volatility patterns on different markets.

This work extended the existing research of Crain and Lee, 1996; Goodwin and Schnepf, 2000; Boudoukh et al., 2003, through a multivariate analysis.

Nevertheless, not all aspects of the determinants of price volatility are clear and fully identified. Future research should also analyse whether or not the interactions identified here are time independent, and if not, which factors of influence play a role. This holds in particular true for the analysis of the markets during and after the turns in the crude products markets as a consequence of global finance market crises. Another topic is the expansion of the current analytical framework to identify interactions between price formation of agricultural and non-agricultural raw products.

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