Corn Price Behavior – Volatility transmission during the boom on futures Markets

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Abstract. Since 2000 a number of factors impacted agricultural markets drastically. Among these are structural changes in global demand and repeated supply constraints that supported the observed positive development of agricultural prices. Given the increasingly interdependent global markets, the question arises of in how far an isolated view of a single market, when analysing price volatility, is sufficient? The paper is a contribution to the debate on the recent commodity price bubble and the relationship among commodity futures markets for agricultural raw materials. More particularly, the transmission of price volatility between commodity future markets is analysed. The background question is whether and to what extent the volatility of agricultural commodity prices at different market places have been transferred during the drastic price changes of 2008. In this analysis the volatility of the maize future price at three different commodity futures exchange is modelled as a multivariate GARCH - process. By doing so, interactions between stock markets in different venues are incorporated. The results of the econometric analysis are discussed against the background of the developments in agricultural and biofuel policy.

Keywords: Commodity Futures, Corn, Time Series, Price volatility transmission, multivariate GARCH..

1. Introduction

In the past few 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 among other international organisations point in their analyses to the driving reasons for changes in the price dynamic on the agricultural markets to an increase of both the price level and the price volatility, (EU-Commission, 2008a; EU-Commission, 2008b, p.6ff; FAO, 2008, p.55-57; Robles et al., 2009; OXFAM, 2008; Rabobank, 2008, p.8ff). 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).
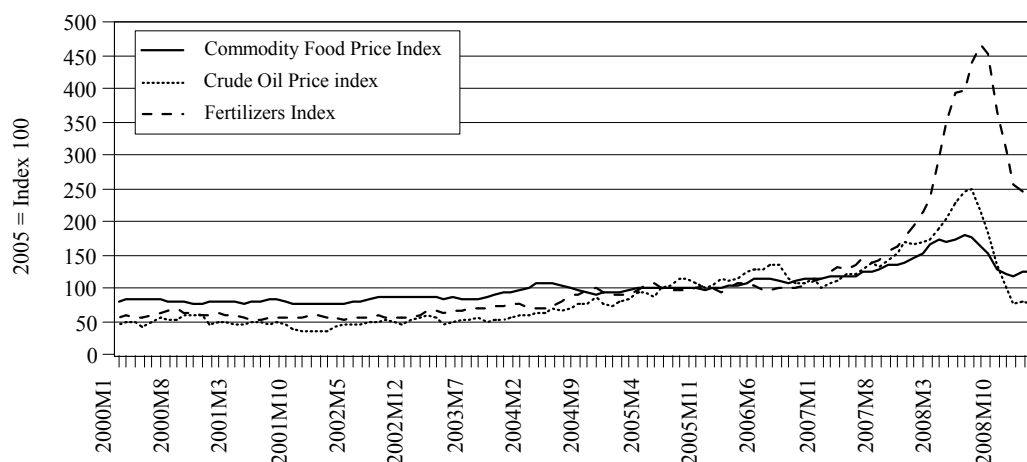
Source: Own calculations based on IMF (2009) and World Bank (2009).

Figure 1: Monthly price index for fertilizer, crude oil and food (Index 2005 = 100, 2000-2008)
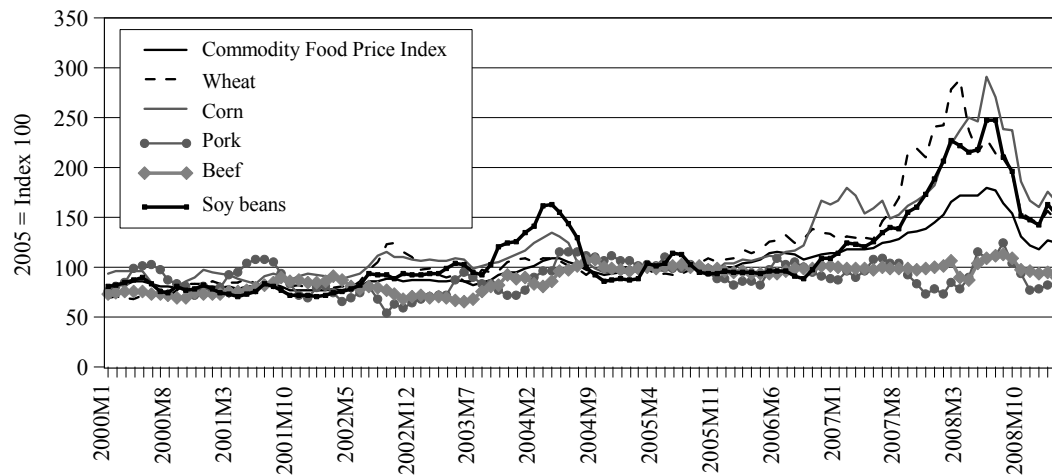
Source: Own calculations based on IMF (2009) and World Bank (2009).

Figure 2: Monthly price index for food agricultural products (Index 2005 = 100, 2000-2008)

A series of factors had an impact on the agricultural markets during the period of price increase. Among these 'fundamentals', like the structural changes in global demand and repeated supply bottlenecks supported the observed positive price development in an understandable manner. Other factors which influenced the agricultural market volatility in the past years were alsomentioned. Among these are changes in the market and trade policy in many countries. The elimination of surpluses in the EU occurred essentially at the same time as the world's most limited market supply situation set in on the cereals market. Several traditional grain exporting countries prevented a relaxing of the world market situation through the implementation of export taxes, at this time increasing the existing scarcity, the supply insecurity and ultimately the market volatility. Also "new" market interventions, such as the additional supply of agricultural raw materials for fuel use as a consequence of the promotion of bio energy, haled to an increase on insecurity. In addition the increase of speculative investors on the futures markets must also be mentioned. Many market observers believe 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 on the price level of agricultural markets, nor a clear causal interaction between the increased activities of speculative investors on the futures markets were found (FAO, 2007, p.48; Rabobank, 2008, p.9; USDA, 2008, p.20).

In this paper the question of the network of futures markets of agricultural raw materials will be considered in the framework of a discussion on the most recent price developments. 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 breeding industry but also in the area of substitution of fossil fuels with biogenous fuels from renewable resources. The emphasis of the approach of substituting fossil fuels with renewable (agrarian) raw materials forced in the United States is based on the use of ethanol stem from corn starch.

The Chicago futures market takes an exposed position in world trade with agricultural raw materials. On the Chicago Board of Trade (CBOT) a large part of worldwide futures trade with corn is realized since the USA is by far the largest corn producer and exporter. The contract prices that are generated on the CBOT in the course of the futures trading thus have a broad reaching signal function for the corn market. 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 Parisian

Exchange MATIF (Marche a Terme d'Instruments Financiers). The Brazilian agriculture markets distinguish themselves with the worldwide largest export surplus. The French exchange takes the role of leading market with regard to cereals markets within the European Union, also a major player on agricultural markets.

The question emerges of whether and to what extent the price volatility between international trading centres during the drastic price changes of 2008 were carried over. This issue has only been dealt with roughly in the scientific literature (Baffes, 2007; EU-Commission, 2008a; EU-Commission, 2008b; Garcia and Leuthold, 2004).

Studies on the volatility of agricultural commodity prices until now have mainly concentrated methodically on an univariate approach. At the heart of the analysis is a modelling of volatility as a GARCH process[1] which was supplemented with exogenous factors. Some examples of this are Crain and Lee (1996), Goodwin and Schnepf (2000) and Boudoukh et al. (2003). The influence of exogenous factors on the volatility of futures prices stood at the centre of these studies. As factors of influence, for example, trade volume, stock inventories, and the government programs in the agricultural sector were here identified.

Against this methodical background, interactions between exchanges at different trading centres were not contemplated. In light of the worldwide increase in independent markets the question emerges of how adequate an isolated consideration of single market is. For this reason we take a different approach in this study. It appears to be urgently necessary to illustrate the relevant markets simultaneously and to document their interdependencies. In order to achieve this for the corn market, we illustrate the markets in a multivariate heteroscedasticity model. The modelling approach of a BEKK model[2] is useful for this purpose. A positive definite covariance matrix $\mathbf{H}_t$ without all too restrictive parameters and a foregoing of an excess of parameters lets this model appear to be suited for this question. This paper is divided into the following areas. The next section introduces the methods of the BEKK model used in detail. Section 3 presents the data used and presents the estimated results. A discussion on the results closes this section. In the final section, some future research paths are outlined.

2. Model

GARCH models serve as the backbone of volatility modelling. Though 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. This type of model can be characterized in two formulas. The first equation is described as a mean equation and illustrates the first moment of the process (Equation 1). In this specification only a long term trend component μ is assumed. The second equation is described as the variance equation. It serves as the second moment of the process (Equation 2). In an ARCH(p) process this is the total p delayed information. The known information set is generated from the returns up to the time point t-1. The returns are calculated as $r_t = \log(F_t/F_{t-1})$. The futures price at time point t is called F_t and r_t describes the illustrated returns at time point t:

$$r_t = \mu + \varepsilon_t$$ Equation 1

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

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

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[1] GARCH stands for Generalized Autoregressive Conditional Heteroscedasticity
[2] BEKK models are named after Baba, Engle, Kraft und Kroner

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

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

Equation 2

The transfer into a multivariate GARCH model (Engle and Kroner, 1995) takes place with a generalization of the resulting variance matrix H_t.

$$H_t = \begin{pmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{pmatrix}$$

Equation 3

Each element of H_t depends on p delayed values of the squared ε_i, the cross product of ε_i and on q delayed values of the elements from H_t. We did not make use of the possibility to draw in 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. For reasons of clarity time indicators are not included in the presentation. A model with the time delay of only a lag (t-1) was modelled.

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

Equation 4

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

$$H_t = C_0' C_0 + A' \varepsilon_{t-1} \varepsilon_{t-1}' A + B' H_{t-1} B$$

Equation 5

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 as 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 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). Furthermore as

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described above only one time lag was included. The resulting variance and covariance equations are as follows:

$$h_{11} = c_{01} + a_{11}^2 \varepsilon_1^2 + b_{11}^2 h_1^2 \qquad \text{Equation 6}$$

$$h_{21} = c_{02} + a_{11} a_{22} \varepsilon_2 \varepsilon_1 + b_{11} b_{22} h_{21} \qquad \text{Equation 7}$$

$$h_{31} = c_{03} + a_{11} a_{33} \varepsilon_3 \varepsilon_1 + b_{11} b_{33} h_{31} \qquad \text{Equation 8}$$

$$h_{22} = c_{04} + a_{22}^2 \varepsilon_2^2 + b_{22}^2 h_2^2 \qquad \text{Equation 9}$$

$$h_{32} = c_{05} + a_{22} a_{33} \varepsilon_3 \varepsilon_2 + b_{22} b_{33} h_{32} \qquad \text{Equation 10}$$

$$h_{33} = c_{06} + a_{33}^2 \varepsilon_3^2 + b_{33}^2 h_3^2 \qquad \text{Equation 11}$$

The indexes used here recede to the notation used in equation 3. The following presentations are equivalent in the framework of the model as proposed here:

$$\text{vech}(H_t) = \text{vec}(H_t) = H_t$$

The Matrix H_t contains redundant expressions. Thus no distinction is made between h_{21}/h_{12}, h_{31}/h_{13} or h_{32}/h_{23}. For this reason the vec expression, corrected for the redundant expressions, is the same as the vech expression. The empirically estimated BEKK – GARCH model is thus based on a multivariate version of equation 1 and equations 6 to 11 (Derived from Equation 4).

3. Data and Results

The interactions of volatilities between the traded price quotations on the exchanges in the USA (CBOT), Brazil (BRAZ) and Europe/France (MATIF) were studied. The topic of the study was the price quotations which ran out in March 2008 and was dealt on all three exchanges with the same running time. Exchange quotations from March 27, 2007 to March 5, 2008 were available. As a courtesy of ZMP, the Central Market and Price Reporting Centre (Zentrale Markt- und Preisberichtsstelle) provided the data. Price quotations are given in US-Dollars. Each Futures contract is based on a different amount of corn quantity. One contract in Europe stands for 50 tons of corn. In Brazil 450 units of 60 kilogram bags/coffers will be traded by one contract, this is equivalent to 27 tones. In the United States the unit per contract is 5000 bushels. This is equivalent to 127 tones (1 bushel = 25,4 kilogram). These different units of measurement explain 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 for this day were deleted. 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 245 daily notations were available. This is due to the different shaping of the contracts in the future exchanges.

The time development of prices per unit of weight for corn between March 27, 2007 and March 5, 2008 is presented in the following Figure 3. The value of one future 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 on the other exchanges. This price development also affects the returns, the logarithmic difference of the price level of the process.
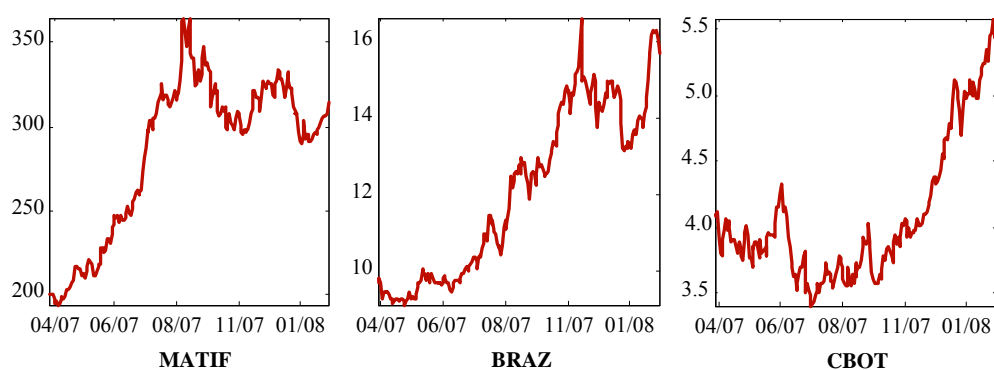
Figure 3: Corn prices per tons in France (MATIF), 60 Kg in Brasil (BRAZ) and per bushel in USA (CBOT)

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 was 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 significant stationary at the 1 percent level and are suited for modelling. 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 them, the assumptions of normal distribution on the basis of 5% level of significance can not be rejected for the CBOT data. This finding is contradictory to the stylized facts of finance market data. Especially regarding the returns, the absence of normal distribution is assumed. This is manifested in a higher Kurtosis (Kurtosis >3) meaning more probability mass in the flanks of the distribution of returns. Higher Kurtosis is given for the remaining returns distributions (see Table 2).

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: Summary of returns for the selected exchanges (27.03.2007-5.3.2008)

	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 changed framework conditions applied for the corn market, particularly in the USA. The massively extended production of ethanol on the basis of corn starch requires correspondent amounts of raw materials. In the USA corn and soy are competing for land in seeding. Already in the 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 have been interpreted as an expression of demand pressure evident through the competition for land during the sowing period (Theis, 2007, p.48-49). 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 4). In light of the expected further demand, increasingly higher prices for corn contracts were offered on the Chicago exchange in order to secure the supply of corn for processing and feeding.
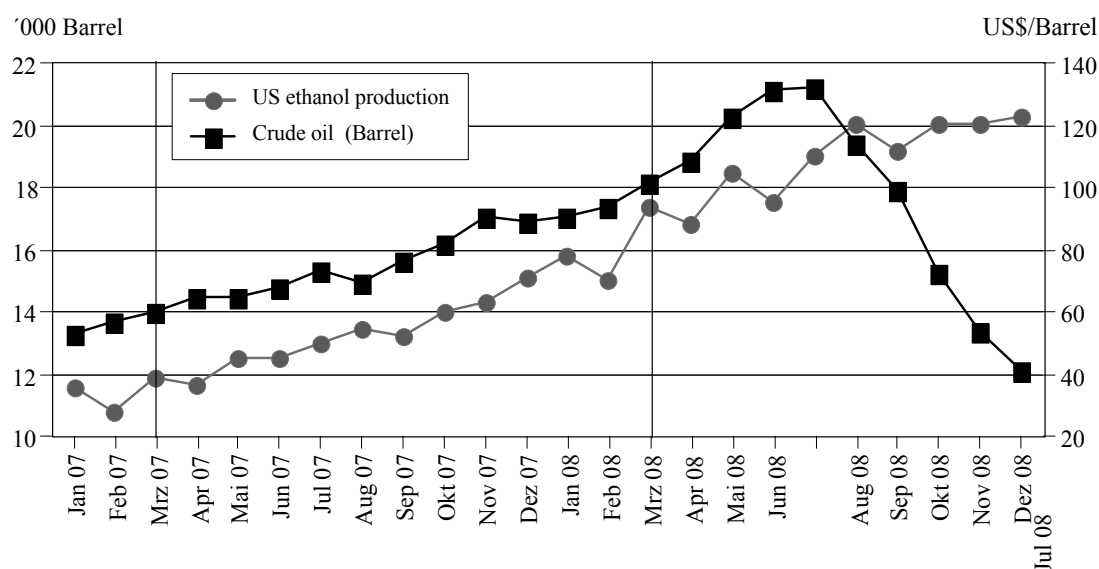

Source: Renewable Fuel Association (2009) and IMF (2009)

Figure 4: US - Ethanol produktion and crude oil price development, 01/2007 – 12/2008.

The increase of corn price in CBOT at the time period October 2007-March 2008 is coeval with a devaluation of the US Dollar, also against the Brazilian Real (Figure 5). 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 gene modified corn cultivation, Argentinean corn did not get 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 EU market without any tariff burden[3]. These factors together led to a significant price impact as can be seen in Figure 3.

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[3] The calculation of tariff rates for corn, by the EU commission, is based on FOB prices of the US goods in 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 liftet under the prevalent market conditions
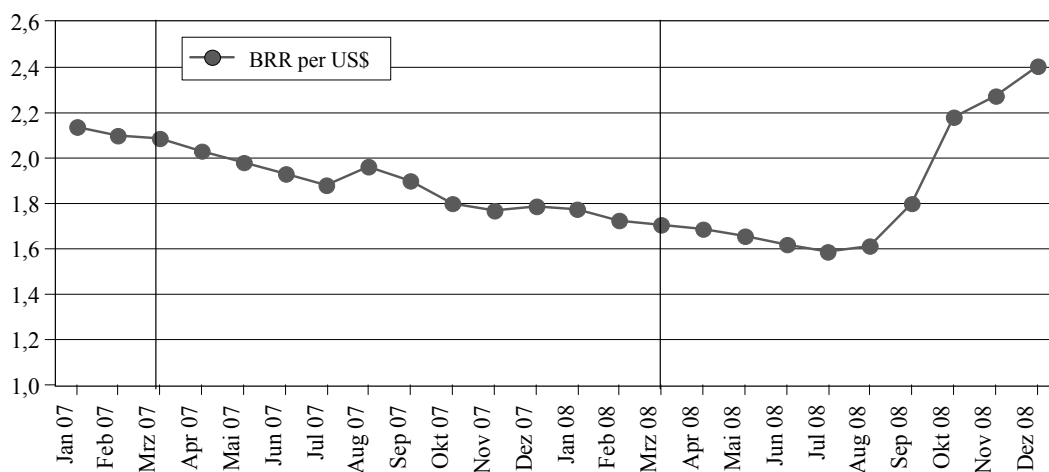
Source: MAPA - Ministério da Agricultura; Pecuaria e Abastecimento, 2009.

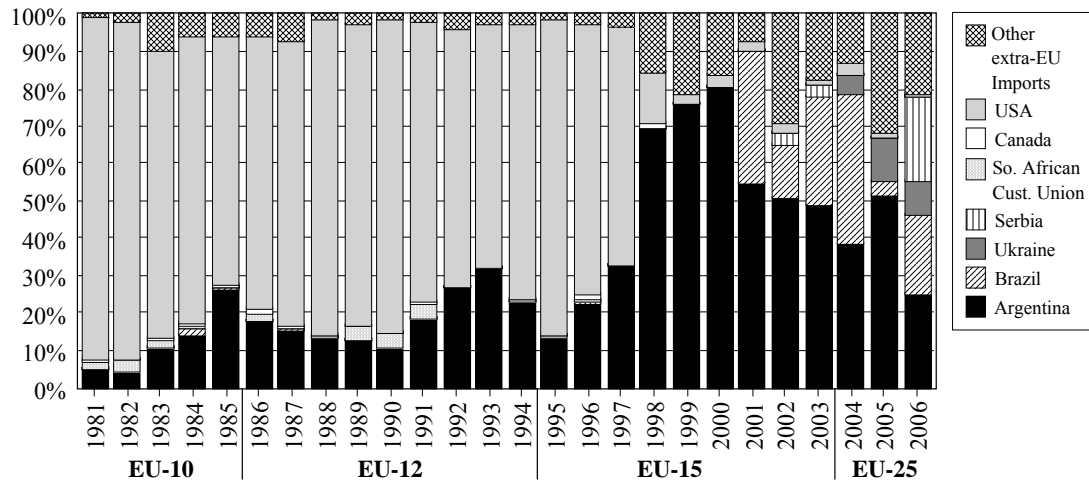Figure 5: Exchange rate development Brazilian Real to US Dollar, 01/2007 bis 12/2008.

A direct European demand pressure on the US corn market is excluded since the import of corn from the USA does not take place due to existing rules in the area of consumer protection since the end of the 1990s. The EU Framework regulations on genetically modified organisms (GMO) is continually being expanded and updated. A series of legal regulations exist with the goal of protecting public health and the environment. An important branch of the EU laws on GMOs deals 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 of GMOs. The prohibition, or rather the nonauthorization 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 6 and Figure 7.

This politically induced market development in the USA led to the solidification of expectations for increasing prices, which ended up among other things in less price deviations. This may have led to the fact that for the futures price on the Chicago Exchange the assumption of normal distribution of returns could not be rejected.
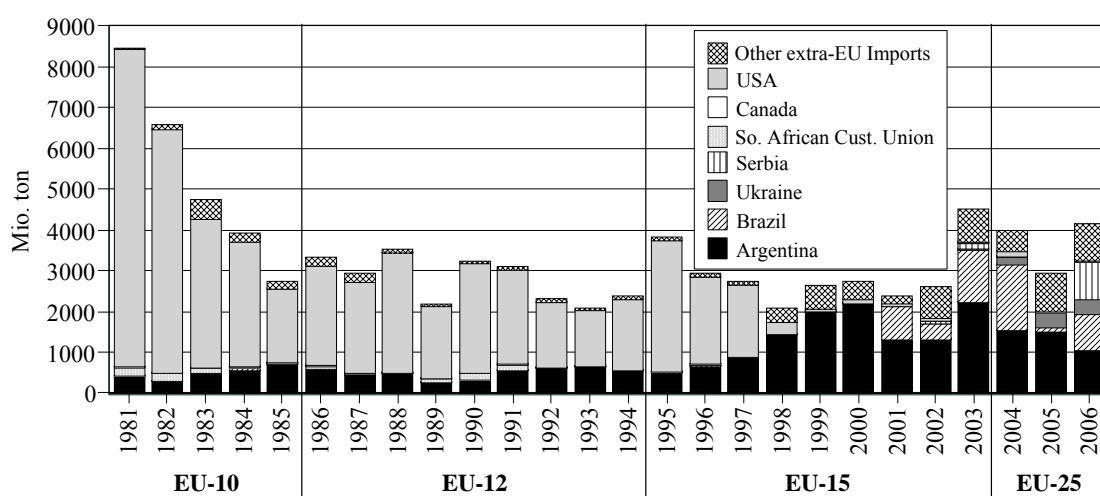
Source: own calculations based on COMTRADE (2009)

Figure 6: Development of Corn Imports from Non EC/EU Member States, 1981-2006

Figure 7: Development of Corn Imports from Non EC/EU Member States, 1981-2006

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 briefly address the equations 6, 9 and 11. Equation 6 is the variance Equation for CBOT, Equation 9 for MATIF and Equation 11 for BRAZ.

Parameters a_{11}, and c_{01} for the CBOT Market are all not statistically significant at the five percent level. This means first, that the according variance equation is partly void (Equation 6). The returns on the Chicago Futures Market were not marked by conditional heteroscedasticity in the time period considered. The conditional variance of prices in CBOT is characterised only by its own lagged variance. As parameter a_{11} is insignificant, information shocks are not accounted for. This finding highlights again the peculiarity of this exchange at this time.

This has a broad reaching meaning since these equations illustrate the spill-over effects of the Chicago Market on MATIF and Brazil. 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 in the market places MATIF and Brazil. Nevertheless CBOT is such important that the other markets considered are influenced via the covariance. The results show that only the lagged conditional variance of CBOT influences the covariance. The politically induced market development in the USA combined with the tight supply situation 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) it came's to a noticeable influence of the other market places 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 trading centre in Chicago, clear interactions between MATIF and Brazil exist. This can be seen due to the significant parameter values a_{22}, a_{33}, b_{22} and b_{33}, which appear in Equation 10. Thus at least an indirect (via a covariance) influence could be seen for both markets. Here both components of the covariance Equation are relevant. Information shocks that occur on one of both market places impact the volatility of the other one. The lagged development of the variance of the other market alone is not determining it's future development.

Each variance equation shows also the special situation during the time period studied. For the trading centres in Europe and Brazil a GARCH (1,1) Process could be identified for each. In both time series a certain amount of heteroscedasticity is apparent. This is normal in financial-econometric studies.

This result must be seen in the context of the above described political framework conditions. From the perspective of the authors, the import ban on genetic corn into Europe as well as the simultaneous ethanol boom led to strongly changed price development of futures on the Chicago Futures Exchange. This resulted in a decoupling of the price development on the exchanges in Europe and Brazil. This decoupling was ultimately measured and confirmed by the model. Even the single consideration of the Chicago prices via a (univariate) GARCH (1,1) model showed no resulting heteroscedasicity (the results of estimates are not provided here).

4 Perspectives

The multivariate analysis framework used here permits the illustration of the price volatility on the futures exchanges as an interplay of many mutually influencing trading centres. The results show that on the futures markets for the considered time period very unusual impact interactions existed and these allow the assumption that the institutional framework conditions influenced the markets, or rather isolate them from each other. It could successfully be shown that the volatility of future prices at different market places do impact each other. Hence, an additional building block of the explanation of the volatility could

be identified. 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 facets of the determinants of price volatility are clear. In the future, it must also be checked whether the interactions identified here are time independent or not 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. Also the expansion of the framework of the analysis in order to identify interactions between futures of different (agricultural) raw products is a topic for further research.

Acknowledgment

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