Department für Agrarökonomie
und Rurale Entwicklung

2019

Diskussionspapiere
Discussion Papers

The influence of Brazilian exports on price transmission processes in the coffee sector: a Markov-switching approach

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Universität Göttingen
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ISSN 1865-2697

Diskussionsbeitrag 1904

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Abstract

Most analysis of agricultural commodity market integration is solely based on price information. However, adding trade data can improve the understanding of interactions between interrelated markets. We link the analysis of price transmission processes between spot and futures markets with trade information to study the influence of Brazilian coffee exports on global price interdependencies. Using a Markov-switching vector error correction model (MSVECM) we allow for structural changes over time. Our results reveal two regimes. One regime is characterized by periods of sideways or downward trending coffee prices with low price volatility, and the other one by phases of price spikes and high price volatility. Price information is transmitted through both the spot and the futures prices and the speed of the price transmission process is significantly affected by the total daily volume and value of Brazilian coffee exports.

Keywords: Price transmission, Markov-switching models, coffee, customs data, spot and futures markets

1 Introduction

The contemporary analysis of interrelated markets in the field of agricultural commodities is mostly based on price data. Classical time series approaches focus on the empirical behavior of commodity prices to draw conclusions about market equilibria, the allocation of resources, agricultural productivity or economic growth in general. However, the understanding of agricultural intermarket linkages remains limited if trading activities are disregarded (Barrett, 1996). One reason why much previous literature focuses on price data alone is the lack of suitable trade data. Time series data on trade flows are rarely obtainable and even when they are, the data frequency often differs between price and trade data (Baulch, 1997). Futures prices are usually electronically recordable on an intraday basis, and spot prices are usually available at at least monthly and sometimes weekly or even daily frequencies. However, detailed information on market participants and trade flows is often only available aggregated over a range of different commodities on an annual basis. This complicates an adequate analysis of the microstructure of commodity markets, which is a key to understanding price movements, market equilibria and the general functioning of agricultural markets (Ederer, Heumesser and Staritz, 2016).

Our analysis is based on the combination of high-frequency futures and spot prices and customs data on intraday export transactions. Thus, we are able to contribute to the existing literature by analyzing the microstructure of interrelated agricultural markets and the interactions between price movements and foreign trade. Our analysis is based on coffee as it is one of the most important sources of employment, economic growth and foreign trade for many developing countries (Addison, Ghoshray and Stamatogiannis, 2016). About 20 million farmers around the world base their livelihood on the production of coffee and the majority of these producers are small-scale farmers in developing countries or emerging economies (Sette, 2018). Understanding the microstructure of international and domestic coffee markets and the determinants of local market prices is essential for coffee farmers and processors.

Since a significant amount of the trade with coffee occurs on the associated international commodity exchanges, the role of futures markets is of particular importance for producing countries. This importance of futures trading in the coffee sector is associated with opportunities and risks for potential traders and farmers. Futures markets can be used by domestic coffee producers to fix the price for the upcoming harvest to hedge against adverse price fluctuations (Lien and Shrestha, 2008; Pennings and Meulenberg, 1997). Furthermore, futures markets contribute to price discovery (Vollmer and von Cramon-Taubadel, 2018). But a high futures trading volume can also increase the volatility of spot prices (Yang, Balyeat and Leatham, 2005) with negative effects especially for producers in developing countries or emerging economies. Since these farmers often only have restricted access to futures markets and the resulting hedging opportunities, they are especially vulnerable to price risk caused by increased spot price volatility. Hence, information about the relationship between spot and futures prices and the price formation process in the coffee market are crucial for producers and all other market participants.

In general, we can differentiate between two distinct species of coffee, Arabica and Robusta. Robusta is less labor-intensive in its cultivation and coffees made from the Robusta tree have higher caffeine content and a stronger taste. Robusta trees are grown at lower altitudes, typically in West and Central Africa and South East Asia. In contrast, Arabica trees grow at higher altitudes (Latin America, Central and East Africa and India) and produce coffee with a milder and more aromatic and refined taste. At around 60 %, Arabica coffee accounted for the largest share of total coffee production of about 9.6 billion tons in 2017 (International Coffee Organization, 2018a). Brazil is of particular interest as it produces almost half of the total amount of Arabica coffee worldwide (International Coffee Organization, 2018b). This makes Brazil the biggest coffee producer and exporter by far. Hence it is reasonable to expect that changes in the production quantity or export behavior in Brazil will influence international price levels.

Despite the great importance of Brazil for the coffee sector, studies analyzing Brazil's influence on the international price formation are rare. Mattos and Garcia (2004) make an interesting contribution to the literature by analyzing the price discovery process on the Brazilian spot and futures markets. They find that the pricing process on the local spot market is dominated by the futures market when looking at the Brazilian Mercantile & Futures Exchange (BM&F). But since the average daily trading volume of the coffee futures contract of the BM&F is less than 8 % of the trading volume of the associated US futures contract of the Intercontinental Commodity Exchange (ICE), the transferability of the results for the local Brazilian market to the international context is limited. Bohl, Gross and Souza *et al.* (2018) fill this gap by analyzing the role of the Brazilian and the US futures markets as well as the Brazilian spot market in the price formation process of Arabica coffee. Using a multivariate GARCH model the authors find evidence for informational spillovers from both the domestic and the international futures markets to the spot market. Furthermore they find evidence of significant information transmission from the Brazilian BM&F futures market to the ICE futures market. This is especially evident during periods of higher prices and price volatility which underlines the relevance of Brazil for the international price formation process.

Both these studies analyze price transmission solely based on price information. We consider information on trade as well. Our objective is twofold: i) the analysis of price transmission processes between international futures markets and Brazilian spot markets for Arabica coffee and ii) the analysis of whether Brazilian exports of coffee affect international price interdependencies. We hypothesise that the relationship between the international futures market and the Brazilian spot market is affected by changes in Brazil's export transactions with Arabica coffee.

The standard tool for analyzing price transmission processes between interrelated markets is a linear vector error correction model (VECM). A crucial assumption of such a VECM is the structural stability with constant parameters. This expectation of a constant relationship between the spot and futures prices contradicts changing trading conditions such as changes in the export behavior of a large exporting country. To overcome this problem different methods for dealing with nonlinearities are discussed in the literature. One option is the inclusion of dummy variables for known time periods of changing trade conditions (e.g. before and after the imposition of an export ban). However, the timing of such episodes is not always known with certainty. Hence, so-called endogenous regime-dependent modelling approaches are often favored. These regime-dependent modelling approaches include the threshold VECM (TVECM) (Blake and Fomby, 1997; Goodwin and Piggott, 2001; Balcombe, Bailey and Brooks, 2007) which assumes that markets only adjust to price changes larger than trade costs whereas price changes smaller than trade costs are not corrected. Another regime-specific approach is the smooth transition VECM (STVECM) (Terasvirta, 1994; Ghoshray, 2010) as a generalization of the TVECM. Here it is assumed that changes between phases of error correction and no error correction are smooth and not abrupt. However, a critical assumption of these two modelling approaches is that factors such as the magnitude of the error correction term causing switches between different regimes over time are observable and quantifiable and therefore can be defined *a priori*.

In this paper we apply the Markov-switching VECM (MSVECM) which is frequently used in financial or agricultural research (Busse, Brümmer and Ihle, 2012; Ihle, von Cramon-Taubadel and Zorya, 2009; Götz, Glauben and Brümmer, 2013). The advantage of a MSVECM is that regime-switches are governed by unobservable variables in probabilistic ways that do not have to be specified *a priori*. In this sense the MSVECM is more flexible than alternative models. In the context of this study it seems plausible that the price transmission process is regime dependent due to fluctuations in Brazilian export volumes and in the monetary export values, especially in phases of high or low coffee prices and price volatility.

The rest of this study is structured as follows: in sections 2 and 3 we describe the methods and the data that we use, respectively, and in section 4 we present and discuss our empirical results. Section 5 concludes.

2 Methodological approach

To analyze the price transmission process between the spot and futures market for Arabica coffee we first estimate the following vector error correction model (VECM):

$$\begin{bmatrix}\Delta p_t^S \\ \Delta p_t^F\end{bmatrix} = \begin{bmatrix}\alpha^S \\ \alpha^F\end{bmatrix}\left(\begin{bmatrix}1 & -\beta_1\end{bmatrix}\begin{bmatrix}p_{t-1}^S \\ p_{t-1}^F\end{bmatrix} - \beta_0\right) + \sum_{i=1}^{k} C_i \begin{bmatrix}\Delta p_{t-i}^S \\ \Delta p_{t-i}^F\end{bmatrix} + \begin{bmatrix}\nu_t^S \\ \nu_t^F\end{bmatrix}, \qquad (1)$$

where p_t^S and p_t^F denote the spot and futures prices, Δ is the first difference operator, β_0 and β_1 are the constant and slope parameters in the long-run equilibrium relationship between p_t^S and p_t^F, respectively, and the C_i are *2x2* matrices of short-run coefficients. The v_t are white noise error terms with variance-covariance matrix Ω, and k is the lag order of the short-run dynamics, which is determined by using the Akaike Information Criterion (AIC). The α are adjustment parameters that measure the speeds with which p_t^S and p_t^F adjust to correct deviations from the long-run equilibrium relationship.

In a next step, we follow Krolzig, Marcellino and Mizon *et al.* (2002) and estimate a MSVECM. The MSVECM is an extension of Markov-switching vector autoregressive models (MSVAR), initially proposed by Hamilton (1989) to analyze US business cycles. We rewrite the VECM in equation (1) into a MS(R)-VECM(k) that allows for regime-dependency in the adjustment processes and the short-run coefficients. The long-run relationship between the spot and futures prices is assumed to be constant over the sample period:

$$\begin{bmatrix}\Delta p_t^S \\ \Delta p_t^F\end{bmatrix} = \begin{bmatrix}\alpha_t^S \\ \alpha_t^F\end{bmatrix}(r_t)\left(\begin{bmatrix}1 & -\beta_1\end{bmatrix}\begin{bmatrix}p_{t-1}^S \\ p_{t-1}^F\end{bmatrix} - \beta_0\right) + \sum_{i=1}^{k} C_i(r_t) \begin{bmatrix}\Delta p_{t-i}^S \\ \Delta p_{t-i}^F\end{bmatrix} + \begin{bmatrix}u_t^S \\ u_t^F\end{bmatrix}, \qquad (2)$$

where, in addition to the notations defined above, the u_t are residual disturbances, and the state variable $r_t \in \{1, \dots, R\}$ indicates which of the R possible regimes governs the MSVECM at time t. The number of regimes is selected according to the AIC which is the recommended selection criterion for determining the number of regimes in Markov-switching models (Psaradakis and Spagnolo, 2003). To see whether the Brazilian export transactions affect the speed of adjustment, we define the adjustment parameters as follows:

$$\begin{bmatrix}{\alpha_t}^S \\ {\alpha_t}^F\end{bmatrix} = \begin{bmatrix}{\alpha_0}^S \\ {\alpha_0}^F\end{bmatrix} + \begin{bmatrix}{\alpha_1}^S \\ {\alpha_1}^F\end{bmatrix} x_{volume,t} + \begin{bmatrix}{\alpha_2}^S \\ {\alpha_2}^F\end{bmatrix} x_{value,t}, \qquad (3)$$

where $x_{volume,t}$ and $x_{value,t}$ are the 5-day-moving-average of the volume and the monetary value of Green Arabica Dry coffee exports, respectively. Including these two export parameters in the estimation of a MSVECM as described in equation (3) allows the adjustment of spot and futures markets to vary over time.

Since r_t is allowed to be unobservable, the state of the system at any time t does not have to be defined beforehand but is identified by the model itself. In addition, the variances of the u_t are conditional on r_t, so that the model allows for heteroscedasticity. The evolution of the discrete and finite number of regimes r_t at any time t is regulated by a Markov chain. This Markov chain is assumed to be ergodic and irreducible, so that the distribution of the regimes is stationary and any regime can be reached from any other regime. The probability of switching between all possible regimes is characterized by the following transition probability matrix:

$$\Pi = \begin{pmatrix} \pi_{11} & \cdots & \pi_{1R} \\ \vdots & \ddots & \vdots \\ \pi_{R1} & \cdots & \pi_{RR} \end{pmatrix}, \qquad (4)$$

where $\pi_{ij} = Pr(r_t = j | r_{t-1} = i)$ defines the probability of switching from regime i in the previous period $t - 1$ to regime j in the current period t. The rows in matrix Π sum up to 1. Thereby it is assumed, that the probability of r_t only depends on r_{t-1} and the transition matrix Π $\left(Pr(r_t | r_{t-1}, \Pi)\right)$. Consequently, the regime generating process is memoryless and independent from the history of the process.

The model in equation (2) is estimated by maximizing a likelihood function that is based on an implementation of the expectation maximization (EM) algorithm (Hamilton, 1990), which consists of two steps. In the first step, the expectation step, inferences about the unobserved regimes are derived based on arbitrarily chosen starting values for the model parameters and transition probabilities. Based on these expected values of the regime process so-called smoothed probabilities can be estimated. These smoothed probabilities for the occurrence of r_t are conditional on all available information over the entire sample. In the second step, the maximization step, the starting values for the model parameters and transition probabilities are updated based on the smoothed probabilities obtained in the expectation-step. The two steps are repeated until the likelihood function is maximized. In the end, the smoothed probabilities provide the likelihood of being in each of the regimes at any time t and the model parameters at time t can be assigned to the regime of the highest smoothed probability (Hamilton, 1990).

3 Data

To analyze price transmission on the Brazilian coffee market we use 1,558 daily observations from October 2011 to September 2017. For the Brazilian spot market price

(p_t^S) we use the Cepea/Esalq Arabica coffee price index. This price index is based on transactions with Arabica coffee type 6 in the Brazilian wholesale market in five different reference regions all over Brazil (Cerrado, southern Minas Gerais, Mogiana, Paulista, northwestern Paraná). The transactions refer to delivery in São Paulo city and include freight costs as well as taxes. The influence of each of these reference regions is weighted according to the volume of Arabica coffee produced. Information for the Cepea/Esalq Arabica coffee price index is collected by different cooperatives, stockbrokers, roasters and exporters.

For the corresponding futures market price (p_t^F) we use the Coffee C futures contract which is traded at the Intercontinental Exchange (ICE) in New York. The Coffee C contract is considered the world benchmark for Arabica coffee. Brief details of the Coffee C futures contract are as follows. The ICE lists the futures contract with five different delivery months (March, May, July, September and December), a nominal contract size of 37,500 lb (about 17 tons) and a minimum tick size of 0.0005 US$/lb. (equivalent to 18.75 US$ per contract). The settlement is specified for physical delivery in New York, Virginia, New Orleans, Houston, Miami, Bremen/Hamburg, Antwerp and Barcelona. This choice of delivery locations points to the high demand for Arabica coffee in the EU and the USA as the two biggest importers of Arabica coffee worldwide. As it is common in the literature, we construct our futures price series by concatenating the daily settlement prices from the first nearby futures contract to make sure that we work with the most liquid futures contracts. Furthermore, we calculate so-called cash-equivalent futures prices as suggested by Garbade and Silber (1983) and Yang, Bessler and Leatham *et al.* (2001) to correct for a changing correspondence between a spot market price and a futures market price as the futures contract approaches expiry. Thus:

$$p_t^{CEF} = p_{T|t}^F - r_t * [T - t]/360\,, \tag{5}$$

where p_t^{CEF} is the cash equivalent futures price at time *t*, $p_{T|t}^F$ is the price of the futures contract at time *t* that expires at time *T*, and *r* is the daily interest rate of the current 10 year US government bonds. In the following, we refer to this cash-equivalent futures price as 'the futures price'.

The resulting spot and futures prices in levels are presented in figure 1 (left axis). The prices seem to co-move with a downward trend between 2011 and 2013, interrupted by a short period of higher prices and price volatility in mid-2012 and followed by rapidly increasing price levels and price volatility (right axis) in 2014. In the end of 2016 both prices exhibit slightly higher price levels again.

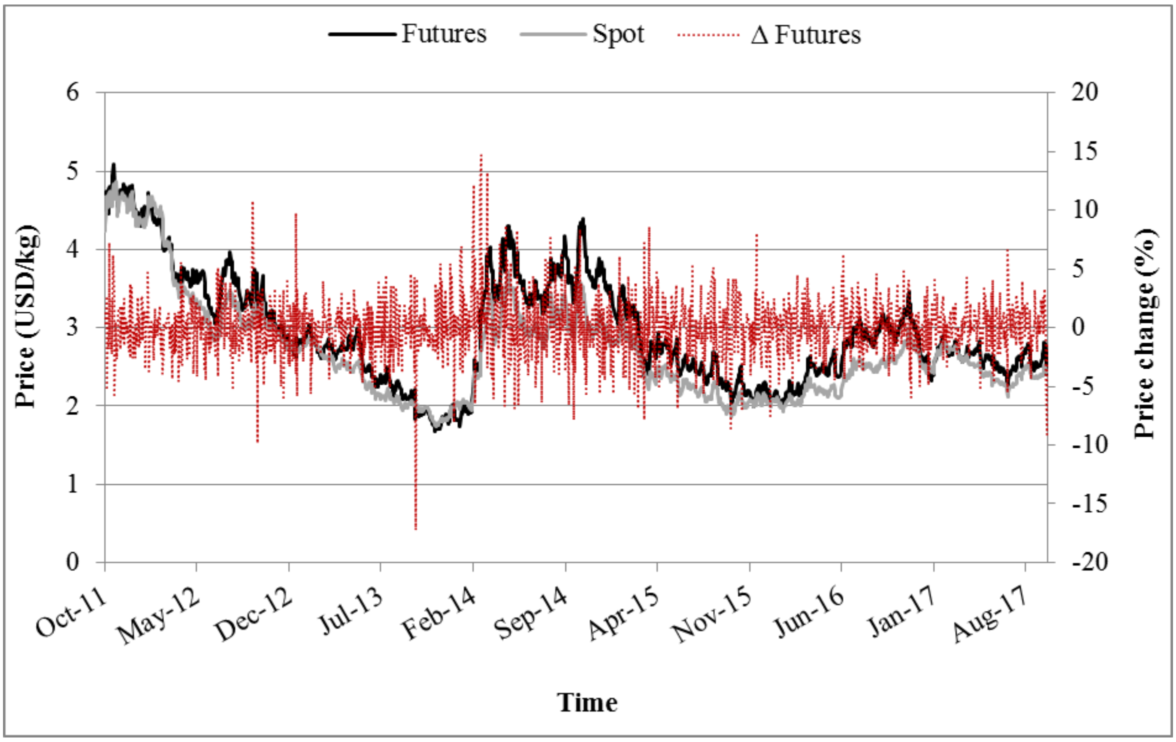
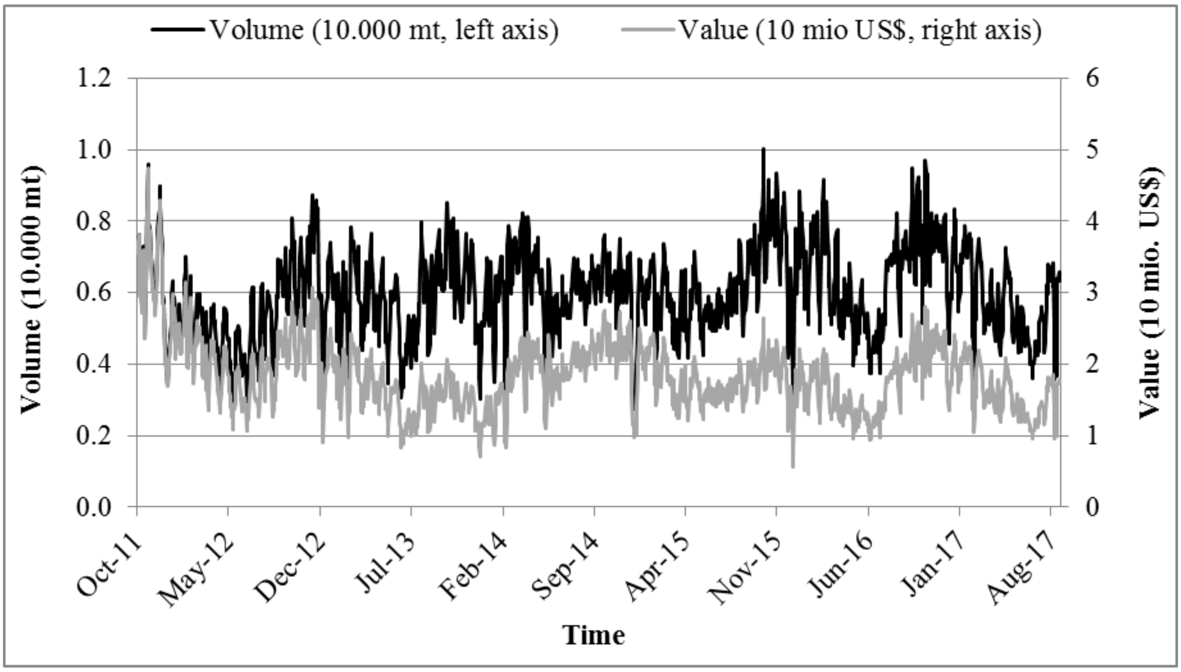


Figure 1: Brazilian spot and US futures prices for Arabica coffee between 2011 and 2017

To analyze the influence of Brazilian coffee exports on the price transmission process between these spot and futures prices we use information on daily trade generated via “Certificates of Origins” and provided by the International Coffee Organization. Figure 2 displays the 5-day moving averages of the total daily volumes (left axis) and values (right axis) of Brazilian Green Arabica dry coffee exports. Although trade data are available for multiple different varieties of Arabica coffees (decaffeinated, organic etc.) we only consider the classical Green Arabica Dry coffee exports, which account for more than 98 % of all Brazilian Arabica coffee exports.

Between October 2011 and September 2017 Brazil exported more than 9 mill. tons of Green Arabica Dry coffees with a total value of nearly 30 bill. US$. The 5-day moving averages of the export values are highly volatile and range between 6 and 47 mill. US$ whereas the total daily volume varies between 2,000 10,000 tons.



Note: Volume and value are displayed as their 5-day moving averages.

Figure 2: Total daily volume and value of Brazil's Green Arabica Dry coffee exports

4 Results and discussion

We first test our spot and futures time series for unit roots (table 1). The results of the ADF tests (Dickey and Fuller, 1979) without a constant or a trend indicate that the null hypothesis of a unit root cannot be rejected for either the spot price or the futures price. Repeating the ADF tests including a constant or a constant and a trend leads to similar results. Hence, we conclude that the spot and futures price time series are integrated of order one (I[1]). The results of the KPSS tests (Kwiatkowski *et al.*, 1992) in table 1 confirm these findings for both price series. The null hypothesis of stationarity can be rejected for both price series in levels but not for the first differences of the price series, regardless of whether the KPSS tests are carried out including a constant or a trend.

Table 1: Results of the ADF tests and KPSS tests

Test	Price	Lags [a]	Test-statistic [b]
ADF test (no constant, no trend)	p_t^S - spot	1	-1.442
	p_t^F - futures	4	-1.233
	Δp_t^S - spot	1	-27.966
	Δp_t^F - futures	3	-19.334
ADF test (constant)	p_t^S - spot	1	-2.531
	p_t^F - futures	4	-2.696
	Δp_t^S - spot	1	-27.982
	Δp_t^F - futures	3	-19.344
ADF test (constant and trend)	p_t^S - spot	1	-2.324
	p_t^F - futures	4	-2.648
	Δp_t^S - spot	1	-28.013
	Δp_t^F - futures	3	19.357
KPSS test (constant)	p_t^S - spot	1	26.293
	p_t^F - futures	4	7.929
	Δp_t^S - spot	1	0.155
	Δp_t^F - futures	3	0.105
KPSS test (trend)	p_t^S - spot	1	6.818
	p_t^F - futures	4	1.749
	Δp_t^S - spot	1	0.050
	Δp_t^F - futures	3	0.050

[a] The number of lags is selected according to the Akaike Information Criterion (AIC).
[b] Critical values: ADF test (no constant, no trend): -2.58 (1 %), -1.95 (5 %), -1.62 (1 0%); ADF test (constant): -3.43 (1 %), -2.86 (5 %), -2.57 (10 %); ADF test (constant and trend): -3.96 (1 %), -3.41 (5 %), -3.12 (10 %); KPSS test (constant): 0.74 (1 %), 0.46 (5 %), 0.35 (10 %); KPSS test (trend): 0.22 (1 %), 0.15 (5 %), 0.12 (10 %)

Next we apply the Johansen trace test for cointegration (Johansen and Juselius, 1990). The results in table 2 show that both price series are cointegrated and share a common long-run equilibrium relationship.

Table 2: Results of the Johansen trace tests for cointegration

Null hypothesis	Lags [a]	Test-statistic [b]	p-value
$H_o^{r=0}$: No cointegrating relationship	5	26,171	<0.001
$H_o^{r=1}$: One cointegrating relationship	5	7.978	0.121

[a] The number of lags is selected according to the Akaike Information Criterion (AIC).
[b] Critical values for Johansen trace test statistics: $H_o^{r=0}$ 24.60 (1 %), 19.96 (5 %), 17.85 (10 %) and $H_o^{r=1}$ 12.97 (1 %), 9.24 (5 %), 7.52 (10 %)

The estimate of this long-run relationship between the spot and futures price is presented in table 3. The spot price equals 0.908 times the futures price minus a constant of 0.314. Both parameters are highly significant (p-values <0.001).

Table 3: The estimated long-run relationship between spot and futures prices

Dependent variable	Independent variable	Estimate	Std. error	t-value	p-value
p_t^S - spot	p_t^F - futures	0.908	0.006	140.874	<0.001
	Constant	-0.314	0.022	-14.34	<0.001

To get a first impression regarding the price transmission process between the Brazilian spot and US futures prices for Arabica coffee we estimate a standard VECM. The parameter results show that the spot price significantly adjusts to deviations from the long-run equilibrium relationship by α^S = -0.016 whereas the adjustment of the futures price is not statistically significant (α^S = 0.008). Hence, price information is transmitted by the futures market to the spot market but not the other way round. However, the speed of error correction is quite low, even though daily data are used. The detailed results of the estimated VECM are presented in the Appendix (table A1). Though this linear VECM allows for some first insights, the generalized M-fluctuation test for parameter instability (Zeileis and Hornik, 2007) points towards structural changes over time.

Therefore we next estimate a MSVECM to account for possible regime-switches over time. To analyze whether Brazilian Arabica exports influence pricing behavior on the spot and futures markets we modify the adjustment parameters in the MSVECM as described in equation (3). Hence, we can see whether the speed of adjustment is influenced by the daily volumes and monetary values of Arabica Dry coffee exports[1]. Instead of using the absolute daily numbers for the export volumes and values, we calculate their lagged 5-day moving averages to capture possible influences of a whole trading week. This is necessary because the customs data record transactions on the day they take place, but traders usually prepare their transactions in advance (e.g. purchase the coffee that is later physically exported), so the effect of an export transaction on prices might be felt before the export physically passes customs. The moving averages are formed over a period of 5 days, as this matches

[1] We only consider Green Arabica Dry coffee exports and neglect all other varieties to avoid biased results due to additional charges for special qualities or processings. Re-estimating the VECM and MS-VECM with the volumes and values of all Arabica coffee exports leads to nearly identical results, since Green Arabica dry coffee exports account for more than 98 % of all Arabica coffee exports from Brazil.

the selection of 5 lags in the MSVECM according to the AIC. The MSVECM with regime-dependency in the adjustment processes and the short-run coefficients is estimated with two regimes as suggested by the AIC. The results of the MS(2)-VECM(5) are presented in table 4.

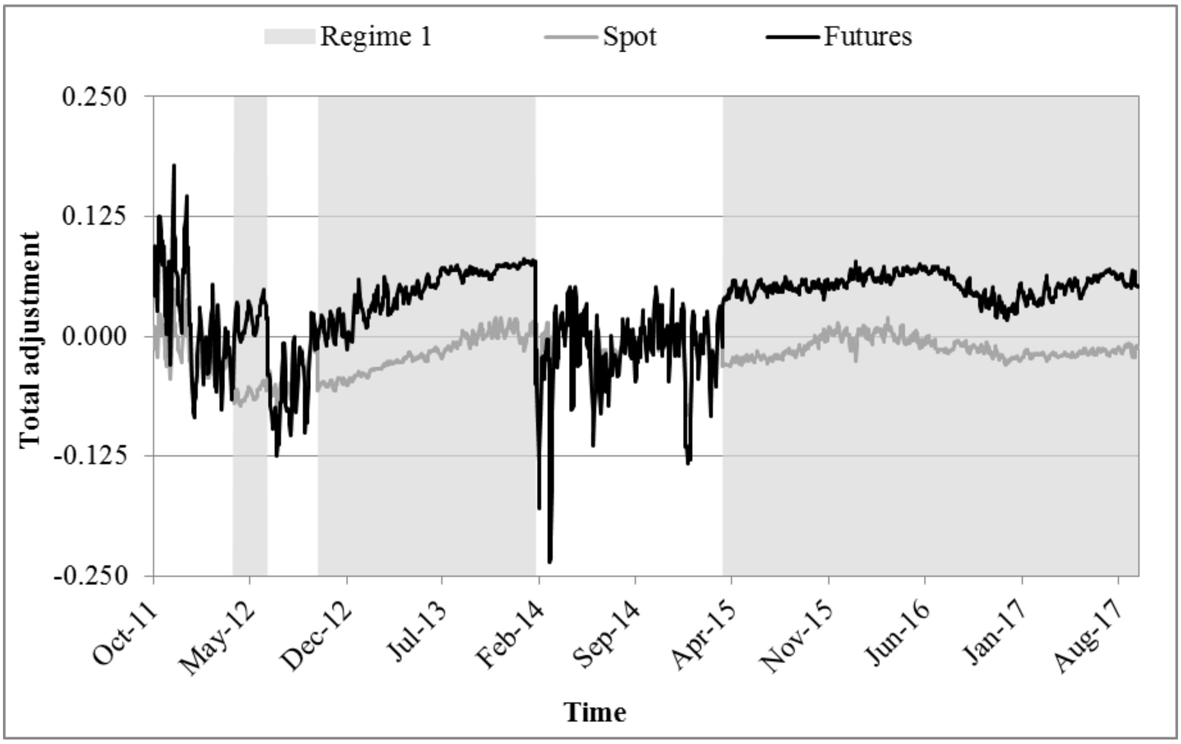
Table 4: Results of the estimated MS(2)-VECM(5) for spot and futures prices for Arabica coffee

Variable	Regime 1				Regime 2			
	Δp_t^S - spot		Δp_t^F - future		Δp_t^S - spot		Δp_t^F - future	
α_0	-0.035	(0.580)	0.089	(0.144)	-0.139	(0.043)	-0.237	(0.040)
α_1	2.301	(0.178)	1.517	(0.280)	2.413	(0.098)	2.347	(0.421)
α_2	-0.710	(0.134)	-0.767	(0.006)	-0.094	(0.723)	0.400	(0.510)
Δp_{t-1}^S	-0.109	(0.019)	0.045	(0.399)	-0.084	(0.201)	0.590	(<0.001)
Δp_{t-1}^F	0.067	(0.041)	-0.050	(0.294)	0.070	(0.178)	-0.403	(<0.001)
Δp_{t-2}^S	-0.096	(0.043)	-0.091	(0.123)	-0.092	(0.172)	0.300	(0.020)
Δp_{t-2}^F	0.065	(0.055)	0.088	(0.051)	0.060	(0.258)	-0.268	(0.002)
Δp_{t-3}^S	-0.063	(0.182)	-0.031	(0.605)	-0.183	(0.006)	0.043	(0.747)
Δp_{t-3}^F	0.053	(0.117)	0.077	(0.099)	0.216	(<0.001)	0.075	(0.452)
Δp_{t-4}^S	-0.107	(0.024)	0.014	(0.817)	-0.125	(0.058)	-0.066	(0.561)
Δp_{t-4}^F	0.026	(0.434)	0.030	(0.474)	0.144	(0.006)	0.071	(0.428)
Δp_{t-5}^S	-0.064	(0.152)	-0.005	(0.905)	-0.177	(0.005)	-0.163	(0.129)
Δp_{t-5}^F	0.017	(0.586)	0.011	(0.747)	0.140	(0.006)	0.059	(0.481)
σ_u^S, σ_u^F	0.036		0.044		0.076		0.105	

Note: The numbers of five lags and two regimes are selected according to the AIC. The p-values related to the estimated parameters are displayed in parentheses. The estimates for ${\alpha_1}^S$, ${\alpha_2}^S$, ${\alpha_1}^F$, and ${\alpha_2}^F$ are not directly interpretable but have to be multiplied with the respective time-varying variables for the export volumes and monetary export values. The total daily adjustment is defined as follows: $\begin{bmatrix}{\alpha_t}^S \\ {\alpha_t}^F\end{bmatrix} = \begin{bmatrix}{\alpha_0}^S \\ {\alpha_0}^F\end{bmatrix} + \begin{bmatrix}{\alpha_1}^S \\ {\alpha_1}^F\end{bmatrix} x_{volume,t} + \begin{bmatrix}{\alpha_2}^S \\ {\alpha_2}^F\end{bmatrix} x_{value,t}$.

The results show that the error correction process and the residual standard errors (σ_u^S and σ_u^F) considerably differ between the two regimes. In regime 1 only the futures market's adjustment to deviations from the long-run equilibrium market is significantly dependent on the total monetary value of Arabica Dry coffee exports (α_2). The export volumes (α_1) do not significantly influence the error correction process. In the second regime the spot price constantly adjusts in a significant way (α_0) and the spot price's total daily adjustment is significantly influenced by the volume of Arabica Dry coffee exports (α_1). Additionally, the futures price constantly adjusts to changes from the equilibrium relationship but the estimated parameter has the wrong sign (α_0). Moreover, the residual standard errors of the futures price (σ_u^F) and the spot price (σ_u^S) more than doubled from regime 1 to regime 2, where σ_u^F is slightly higher than σ_u^S in both regimes.

Multiplying the estimates for the variables ${\alpha_1}^S$, ${\alpha_2}^S$, ${\alpha_1}^F$, and ${\alpha_2}^F$ with the respective daily export volumes and export values, in combination with the estimates for ${\alpha_0}^S$, ${\alpha_0}^F$, lead to time-varying total daily adjustments of the spot and futures prices. Figure 3 displays these parameters for the total daily error correction. Additionally, we multiply the estimates for the variables ${\alpha_1}^S$, ${\alpha_2}^S$, ${\alpha_1}^F$ and ${\alpha_2}^F$ with the respective average values for the export volumes and the export values in both regimes to determine the actual influence of the export parameters on the total adjustment process (table 5).



Note: The total daily adjustment is defined as follows: $\begin{bmatrix}{\alpha_t}^S \\ {\alpha_t}^F\end{bmatrix} = \begin{bmatrix}{\alpha_0}^S \\ {\alpha_0}^F\end{bmatrix} + \begin{bmatrix}{\alpha_1}^S \\ {\alpha_1}^F\end{bmatrix} x_{volume,t} + \begin{bmatrix}{\alpha_2}^S \\ {\alpha_2}^F\end{bmatrix} x_{value,t}$.

Figure 3: Total adjustment of the spot and futures prices over time

Table 5: Results of the average adjustment parameters of the estimated MS(2)-VECM(5) for spot and futures prices for Arabica coffee

Variable [a)]	Regime 1		Regime 2	
	Δp_t^S - spot	Δp_t^F - future	Δp_t^S - spot	Δp_t^F - future
α_0	-0.035	0.089	-0.139	-0.237
$\alpha_1 * x_{volume}$	0.138	0.091	0.141	0.137
$\alpha_2 * x_{value}$	-0.121	-0.130	-0.020	0.086
α [b)]	-0.017	0.050	-0.018	-0.013
	(-0.0259; -0.0097)	(-0.0264; 0.1253)	(-0.0526; 0.0167)	(-0.0524; -0.0021)

[a)] The variables $\boldsymbol{x_{volume}}$ and $\boldsymbol{x_{value}}$ display the mean values of the export volumes and values.
[b)] The confidence intervals (95 %) of the total adjustment parameters are displayed in parentheses. The intervals are calculated using the bootstrap method with 1,000 replicates.

Generally, the total daily adjustment of the spot price is less variable than the total daily adjustment of the futures price (figure 3). In regime 1 the daily error correction of the spot price averages $\alpha^S = -0.017$ with a standard deviation of 0.017 whereas the futures price corrects on average $\alpha^F = 0.050$ with a standard deviation of 0.019. Consequently, both prices adjust to deviations from the long-run equilibrium in the first regime but the futures price adjusts faster than the spot price. The results in table 5 reveal that the monetary export value increases the spot price's adjustment in the first regime (-0.121) but that this increase is completely compensated by the amplification of deviations from the long-run equilibrium of the export volume (0.138). In case of the futures market the export volume enhances the relatively strong constant adjustment in regime 1 but the total adjustment is lowered due to the influence of the export value. Bootstrapping 95 % confidence intervals around the average total adjustment parameters shows that the interval around the average adjustment of the futures price (-0.0264; 0.1253) is wider than the interval around the average adjustment of the spot price (-0.0259; -0.0097). This means that the average error correction parameter of the futures price is more likely to fluctuate.

In regime 2 the situation changes remarkably. The error correction parameters for both the spot and futures prices are highly volatile and very similar to each other so that the futures markets total error correction mostly points to the wrong direction (figure 3). The spot price adjusts by $\alpha^S = -0.018$ on average with a standard deviation of 0.026. The futures price adjusts by $\alpha^F = -0.013$ with an even higher standard deviation of 0.052 which is four times the average value. The export volume again lowers the spot price's total adjustment that goes mainly back to the constant part (${\alpha_0}^S = -0.139$). Although the two export parameters correct the deviations with the correct sign, the futures price amplifies rather than corrects deviations on average in regime 2 because of the wrong sign of the constant parameter (${\alpha_0}^F = -0.237$).

These findings are of special interest for the coffee producers and other market participants since they underline the unpredictability of the market behavior in regime 2. Furthermore these regime-specific estimates might explain the slow error correction in the standard linear VECM, especially for the futures price. As the standard linear VECM provides a mixture of both regimes, the positive and negative adjustment parameters of the futures price nearly cancel out each other leading to a surprisingly low overall error correction.

These major differences in the error correction behavior of both market prices allow for a more detailed look at which points in time are assigned to which regime. Figure 4 presents the smoothed probabilities for regime 1 varying between 0 % and 100 % (right axis) that are conditional on all available information over the entire sample period between October 2011 and September 2017. These smoothed probabilities indicate for each single point in time how likely it is to be assigned to regime 1. Additionally, figure 4 displays the futures and spot prices for Arabica coffee (left axis).

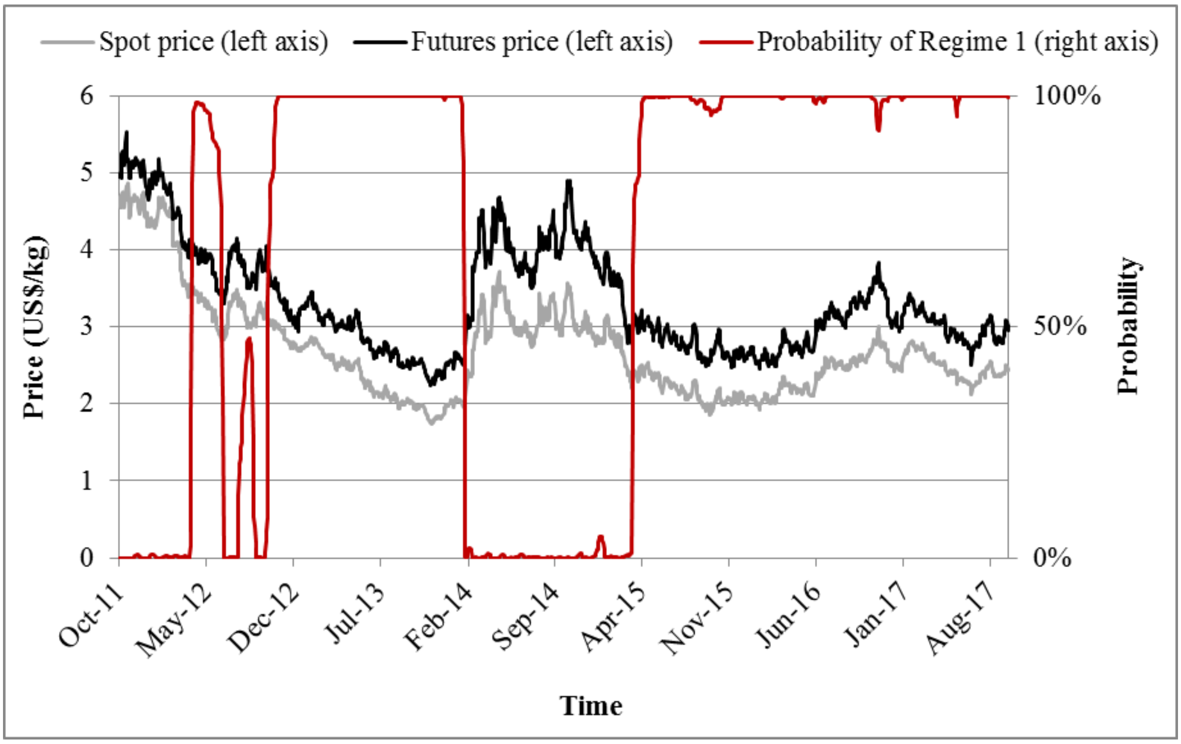


Figure 4: Smoothed probability of regime 1 in comparison to the spot and futures prices for Arabica coffee between 2011 and 2017

Table 6 presents the corresponding transition probabilities for switching between the two regimes. The results for the transition probabilities show that both regimes are highly persistent with probabilities of only 0.4 % (regime 1) and 0.6 % (regime 2) of switching to the respective other regime.

Table 6: Transition probability matrix of the estimated MS(2)-VECM(5)

	To regime 1	To regime 2
From regime 1	0.996	0.004
From regime 2	0.006	0.994

Figure 4 reveals that the time periods of higher prices and higher price volatility are most likely to be assigned to regime 2 whereas time periods with more or less constant or downward trending price levels are assigned to regime 1. When prices tended to decline between October 2011 and the end of 2013 the MSVECM pointed to regime 1 most of the time. The nearly persistent downward trend was only interrupted for short time periods, for example between June and September 2012, when it was more likely to be assigned to regime 2. The price peaks between January 2014 and March 2015 are also assigned to regime 2. The time of lower price volatility and often sideways trending price levels from mid-2015 on is again assigned to the first regime. Hence, the turbulent error correction parameters of both price series in the second regime overlap with phases of price turbulences in the futures and spot markets.

As markets remained well supplied with coffee between 2012 and 2013 (regime 1) prices fell below the production costs with devastating consequences especially for the small-scale coffee farmers (International Coffee Organization, 2013). At the same time the futures prices error correction steadily increased while the adjustment of the Brazilian spot price decreased (figure 3) with export values significantly affecting the adjustment of the futures market (table 4). When prices for Arabica coffee more than doubled between January and February 2014 and the model switched from regime 1 to regime 2, Brazil had faced one of the worst droughts in decades resulting in drastic declines in harvest volumes and crop qualities. At the same time, the export volume collapsed (figure 2) which significantly influenced the price transmission process in the Brazilian spot market (table 4).

Hence, the futures market draws a lot of its information from the Brazilian spot market as long as Brazil lives up to its role as the world's largest producer of Arabica coffee and as a pillar of global coffee market (regime 1). However, as soon as Brazil is no longer able to fulfill this role, futures markets destabilize and the link between Brazilian spot prices and international futures prices becomes more tenuous (regime 2). Consequently, changing price volatility, export volumes and export values affect the price interdependencies between international futures markets and domestic spot markets in emerging economies. This is especially interesting for the debate about the trading activities of financial market investors or speculators. External market investors are often accused of causing increased price volatility and price levels with negative effects in particular for small-scale farmers who are especially vulnerable to price risk caused by increased spot price volatility. Additionally, the wrong sign of the futures prices' turbulent adjustment parameters in the second regime shows that the futures market amplifies rather than corrects deviations from the long-run equilibrium relationship. However, our results point to an average unchanged correction of deviations from the long-run relationship of the spot market in regime 2 during time periods of increased price volatility and price levels. This underlines that the spot market does not become more dependently on the futures market in times when concerns over the futures market's influence on the price formation with negative effects for farmers in emerging economies like Brazil are highest.

Table 7 summarizes further characteristics of both regimes.

Table 7: Characteristics of the estimated regimes

Indicator	**Regime 1**	**Regime 2**	**Δ (%)** [a]
p_t^S – Average spot price (US$/kg)	2.39	3.36	41
p_t^F – Average futures price (US$/kg)	2.95	4.10	39
$x_{weight,t}$– Average export volume (tons)	6,016.76	5,847.95	-3
$x_{value,t}$– Average export value (mill. US$)	17.01	21.55	26
α^S– Average total adjustment of the spot price	-0.0170	-0.0180	5
α^F – Average total adjustment of the futures price	0.0497	-0.0134	-127
Number of observations	1052	501	-52

[a] The percentage difference is calculated as the difference between the parameters in regime 2 compared to the parameters in regime 1.

An interesting feature is the difference in the export coefficients between the two regimes. Due to the generally higher price level in regime 2 the average value of Brazil's Arabica coffee exports of 21.55 mill. US$ per day is 26 % higher in regime 2 than in regime 1, despite the slightly lower export volume (- 3 %).

5 Conclusions

This study assesses the price interdependencies between the international futures prices and the local Brazilian spot prices for Arabica coffee for the time period between 2011 and 2017. Linking classical price transmission analysis with trade information we analyze to which extent Brazilian exports of Arabica coffee influence the global price formation of coffee. In our analysis we focus on Brazil as it is the world's largest producer and exporter of Arabica coffee and it can be expected that changes in the export behavior influence price levels both globally and locally. We factor in the volumes of Brazilian Arabica exports as well as the values of these export transactions to account for the monetary value of the exports as well as changing weights. Combining a MSVECM modelling approach (Hamilton, 1989; Krolzig, Marcellino and Mizon, 2002) with export information and daily data allows us to produce time-varying results to consider structural changes over time.

Our results indicate that in general price information is transmitted by both the spot and futures prices over the whole observation period. The price transmission process between the futures and spot prices is subject to regime switches over time that correspond to periods of changing prices and price volatility. Phases of downward or sideways trending coffee prices with low price volatility are mostly assigned to regime 1 whereas regime 2 captures phases of price peaks and high volatility as in 2014/15. In both regimes Brazilian exports affect the error correction of the domestic spot prices as well as the international futures prices. In regime 1 the spot price adjusts to deviations from the long-run equilibrium slower than the futures market. In comparison, both prices' error correction is much more volatile in regime 2. However, the spot market's average adjustment remains nearly unchanged in regime 2 whereas the futures price amplifies deviations from the long-run equilibrium relationship.

Thus, our results underline the importance of Brazil as the world's largest coffee producer and exporter for global pricing processes in the coffee sector. In times when Brazil lives up to its role as a pillar of the global coffee market the international futures market draws a lot of its information from the Brazilian spot market. But as soon as the Brazilian dominance weakens, the link between Brazilian spot prices and international futures prices becomes more tenuous.

Following this study combining customs data with prices, the influence of additional supply and demand information on the global pricing in the coffee sector should be further investigated. Another potential topic for further research is examining the consequences of the futures markets' dependency on Brazilian coffee markets for coffee producers in developing countries or emerging economies. Since our results are based on 5-day moving averages of export data, further studies may focus on determining the time period traders look back to gather market information to justify the lag length of the model.

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Appendix

Table A1: Results of the estimated VECM

Dependent variable	Independent variable	Estimate	Std. error	t-value	p-value
Δp_t^S - spot	α^S	-0.016	0.008	-1.992	0.047
	Δp_{t-1}^S	-0.084	0.037	-2.266	0.023
	Δp_{t-1}^F	0.069	0.028	2.453	0.014
	Δp_{t-2}^S	-0.076	0.038	-1.995	0.046
	Δp_{t-2}^F	0.055	0.029	1.893	0.058
	Δp_{t-3}^S	-0.126	0.038	-3.334	<0.001
	Δp_{t-3}^F	0.147	0.029	5.084	<0.001
	Δp_{t-4}^S	-0.099	0.037	-2.652	0.008
	Δp_{t-4}^F	0.088	0.029	3.048	0.002
	Δp_{t-5}^S	-0.125	0.036	-3.447	<0.001
	Δp_{t-5}^F	0.085	0.028	3.060	0.002
Δp_t^F - future	α^F	0.008	0.010	0.766	0.444
	Δp_{t-1}^S	0.310	0.049	6.286	<0.001
	Δp_{t-1}^F	-0.208	0.038	-5.526	0.001
	Δp_{t-2}^S	0.084	0.051	1.646	0.010
	Δp_{t-2}^F	-0.073	0.038	-1.904	0.057
	Δp_{t-3}^S	-0.010	0.051	-0.200	0.842
	Δp_{t-3}^F	0.096	0.038	2.496	0.013
	Δp_{t-4}^S	-0.011	0.050	-0.213	0.831
	Δp_{t-4}^F	-0.028	0.038	-0.740	0.459
	Δp_{t-5}^S	-0.068	0.048	-1.400	0.162
	Δp_{t-5}^F	0.027	0.037	0.733	0.464

Note: The number of lags (k=5) is selected according to the Akaike Information Criterion (AIC).

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Die Wurzeln der **Fakultät für Agrarwissenschaften** reichen in das 19. Jahrhundert zurück. Mit Ausgang des Wintersemesters 1951/52 wurde sie als siebente Fakultät an der Georgia-Augusta-Universität durch Ausgliederung bereits existierender landwirtschaftlicher Disziplinen aus der Mathematisch-Naturwis-senschaftlichen Fakultät etabliert.

1969/70 wurde durch Zusammenschluss mehrerer bis dahin selbständiger Institute das **Institut für Agrarökonomie** gegründet. Im Jahr 2006 wurden das Institut für Agrarökonomie und das Institut für Rurale Entwicklung zum heutigen **Department für Agrarökonomie und Rurale Entwicklung** zusammengeführt.

Das Department für Agrarökonomie und Rurale Entwicklung besteht aus insgesamt neun Lehrstühlen zu den folgenden Themenschwerpunkten:

- Agrarpolitik
- Betriebswirtschaftslehre des Agribusiness
- Internationale Agrarökonomie
- Landwirtschaftliche Betriebslehre
- Landwirtschaftliche Marktlehre
- Marketing für Lebensmittel und Agrarprodukte
- Soziologie Ländlicher Räume
- Umwelt- und Ressourcenökonomik
- Welternährung und rurale Entwicklung

In der Lehre ist das Department für Agrarökonomie und Rurale Entwicklung führend für die Studienrichtung Wirtschafts- und Sozialwissenschaften des Landbaus sowie maßgeblich eingebunden in die Studienrichtungen Agribusiness und Ressourcenmanagement. Das Forschungsspektrum des Departments ist breit gefächert. Schwerpunkte liegen sowohl in der Grundlagenforschung als auch in angewandten Forschungsbereichen. Das Department bildet heute eine schlagkräftige Einheit mit international beachteten Forschungsleistungen.

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