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The interdependence of Coffee spot and futures markets

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Abstract

Coffee is both an important source of export revenue for developing countries and the underlying asset for the largest futures markets in soft commodities. This paper examines the interdependence of these spot and futures markets, with particular emphasis on the effect futures trading activity, especially speculative behaviour, has on the price risk in spot markets. We identify change points associated with particularly poor harvests and modifications made to the underlying futures contract on one exchange. Findings indicate that spot and futures markets for coffee are indeed interdependent. However, futures markets for coffee appear to be increasingly driven by risks associated with the underlying spot markets.

Keywords: econometrics, international financial markets, micro finance institutions, agriculture, financial economics

JEL classification: C01, G15, G21, O13, P34

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1. Introduction

Coffee is an important source of export revenue for many Less Developed Countries (LDCs). World Bank and IMF policy has often directed developing countries to invest in the production of cash crops and the exports of many developing nations are often concentrated upon a limited number of primary commodities (Milas et al. (2004)). Consequently, the determination of coffee prices and the role played by futures markets has been the subject of significant academic attention (see e.g. Kaminsky and Kumar (1990), Morgan et al. (1999), Mohan (2007)). Significant amounts of trade occurs on the associated futures markets, making them important subjects of research in their own right. However, as discussed in Morgan et al. (1999), coffee sector participants in LDCs may have restricted access to such markets. The question of how futures' market trading activity affects the volatility of coffee spot prices is therefore important in both economic and welfare terms. Of particular interest is how speculative behaviour in futures markets affects the associated spot markets. Also of interest is the wider question of the interdependence of spot and futures markets, with a range of theoretical and empirical work suggesting that causality may also run from spot markets to futures markets.

Futures markets present an opportunity for participants to hedge their exposure to variations in the value of the underlying asset. In this regard they provide a valuable economic function. Transparent price discovery and price dissemination are key features of successful futures markets (Hall et al. (2006)). Even speculation in futures markets may thus provide value in driving market efficiency and depth. However, there remains the possibility that futures' market trading activity contributes to volatility in the price of the underlying asset (Yang et al. (2005)). These effects may be further compounded if some of the participants in the spot market, particularly those in LDCs, do not have easy access to futures markets and the hedging opportunities that they present. We therefore examine the effect of speculative activity (unexpected trading volume) and hedging demand (unexpected open interest) upon spot volatility.

However, the interplay between spot and futures markets may exhibit richer behaviour and may not be restricted to a unidirectional flow of information from futures markets to spot markets. In other settings, causality running from spot price volatility to futures market trading activity has been found empirically: a number of papers report bi-directional causality or simultaneity between spot market volatility and futures market trading activity (Bessembinder and Seguin (1992), Figlewski (1981), Kocagil and Shachmurove (1998), Kyriacou and Sarno (1999)). We seek to address the further question of whether or not similar relationships exist in the case of coffee markets. Lying alongside these aims is a constantly changing physical and economic environment faced by all coffee sector participants. The International Coffee Organisation (ICO) lists periods of drought or frost which have, on occasion, significantly affected harvests in some regions. An International Coffee Agreement (ICA) has, in various incarnations and extensions, also attempted to manage the production and hence price of coffee (Gilbert (1987)). External shocks faced by market participants in our sample period also include changes on the underlying futures contract specifications (discussed in more details in Section 3). We therefore seek to examine whether interdependencies exist between spot and futures markets for coffee and further whether any such interplay is affected by any of these external shocks.

Motivated by the study of agricultural futures markets in LDCs, Morgan et al. (1999), and following the approach of Yang et al. (2005) for other commodities, we examine the interdependence between spot and futures markets for coffee using daily data for 1994-2010 downloaded from Thomson Datastream. The layout of this paper is as follows. In Section 2 we review the literature. In Section 3 we describe the structure of spot and futures markets for coffee before describing the data set in more detail. In Section 4, we proceed to an econometric analysis using a vector autoregressive (VAR) approach. Section 5 discusses the results obtained and Section 6 is a brief conclusion.

2. Literature review

2.1 The interdependence between spot and futures markets

A small number of works have discussed the interdependence between spot and futures markets for coffee although in a manner different to that considered here. Palm and Vogelvang (1986) develop an econometric model to describe price formation on spot and futures markets as a result of the interplay between the consumption and production of coffee and the variation of inventory levels and observe a reasonable degree of agreement between their theoretical model and empirical results. The interdependence of spot and futures *prices* is also discussed in Kebede (1993). A bi-directional causal relationship is found between spot and futures prices – the relationship becoming stronger as the time to maturity decreases. Here, in contrast, we explicitly focus upon the interdependence between futures trading activity and spot market volatility. The methodology used in this paper is itself closely linked to that Yang et al. (2005), who whilst they do examine agricultural commodities (corn, soybeans, sugar, wheat, cotton), do not study coffee.

The interplay between futures market trading activity and spot market volatility has long been a subject of academic debate within a wider financial literature. A broad range of findings have been reported and appears to depend on the setting and the range of individual circumstances that apply in each case. Weaver and Banerjee (1990) find no evidence of cash price destabilisation due to futures trading in the US. On a related note, Darrat and Rahman (1995) find no evidence for causality running from S&P 500 futures trading activity (volume and open interest) to cash price volatility.

However, some evidence of causal relationships has been found. Chen et al. (1995) produce a theoretical model in which an increase in spot volatility leads to an increase in open interest (hedging demand). Fung and Patterson (1999) show that spot volatility helps to predict futures trading volume. Chang et al. (2000) find open interest for large hedgers increases as volatility increases. Hagelin (2000) reveals a unidirectional causality from cash market volatility to option market activity (though the evidence for this is stronger for call option activity than it is for put option activity). Yang et al. (2005) investigate several major agricultural commodities and find that futures trading volume causes an increase in cash price volatility for most commodities.

Several authors also find evidence of a bi-directional causal relationship. Kocagil and Shachmurove (1998) detect bilateral causality in the intertemporal relationship between cash volatility and futures trading for the S&P 500. Kyriacou and Sarno (1999) find significant evidence for simultaneity between spot volatility and derivative trading. Figlewski (1981) found evidence of a contemporaneous association between cash price volatility and futures trading activity for Government National Mortgage Association (GNMA) pass-through certificates. Bessembinder and Seguin (1992) find a positive contemporaneous association between spot volatility and futures trading volume on the S&P 500, with the effect particularly pronounced for the unexpected component of trading volume. Shalen (1993) provides a theoretical model in which a "dispersion of expectations" leads to a contemporaneous relationship between trading volume and absolute (spot) price changes.

To summarise, although coffee spot and futures markets have received academic attention the question of whether or not they are interdependent has not been sufficiently addressed. This question is of economic significance both in absolute terms, given the size of the markets, and because of the importance of this commodity to many developing economies.

2.2 Spot and futures markets for coffee

The exports of many developing countries are often concentrated upon a limited number of primary commodities (Milas et al. (2004)). As such, commodity prices constitute a considerable challenge from a policy perspective as booms and slumps in prices can represent a major source of macroeconomic instability. Among agricultural commodities, coffee is a major source of export revenue for a range of countries across Latin America, Africa, and South East Asia.

There is thus an extensive literature on commodity price instability and its effect on developing countries. Primary commodity prices are notoriously volatile and this is particularly true for crops such as coffee, cocoa and tea (Gemech and Struthers (2007)). A number of studies have therefore suggested that commodity futures markets may thus play a role in mitigating price instability. A key issue which therefore arises is the extent to which futures markets, especially futures markets for coffee, are efficient in econometric terms. In an efficient market, futures prices should be an unbiased predictor of subsequent spot prices (Fortenbery and Zapata (2004), Morgan et al. (1994)). For example if futures prices systematically under-predict spot prices traders could purchase futures contracts and then subsequently sell on the spot markets, thus generating a systematic profit.

Rajaraman (1986) conducts tests of efficiency for futures markets for coffee, concluding that the coffee futures market in New York is efficient but rejects this hypothesis for the London-based market. Kaminsky and Kumar (1990) conduct a series of related tests for market efficiency over a range of commodity futures markets including coffee. For coffee, only weak evidence against market efficiency is found, although a range of macroeconomic variables are found to have some predictive ability for futures prices. Kebede (1993) studies causality and efficiency in coffee futures markets. On longer maturity contracts, futures prices are seen to Granger cause spot prices. On shorter contracts, 7 weeks or less, bi-directional causality between spot and futures prices is found. Similarly, the hypothesis of market efficiency is rejected for shorter term contracts, but retained for contracts with longer maturities (55-77 weeks). Morgan et al. (1994) analyse the efficiency of commodity markets (including coffee) in terms of price discovery and risk reduction. It is found that the coffee futures market provides both an adequate means of forward price discovery and an effective means of facilitating risk management via hedging. Karbuz and Jameh (1995) conduct tests for cointegration and for the Law of One Price for coffee futures traded in New York and London. Evidence for cointegration is found between New York and London and is interpreted by the authors as indicative of a state of prefect competition between the two exchanges. However, the hypothesis of the Law of One Price is rejected, and is linked to product differentiation between the two major varieties of coffee, Arabica (traded in New York) and Robusta (traded in London). Fortenbery and Zapata (2004) examine the relationship between the New York coffee futures market and cash markets in two Latin American LDCs. The authors find that the futures market in New York acts as a centre for price discovery and futures contracts in New York may offer hedging opportunities for coffee sector participants in South America. However, it is also found that to do so may only be risk-efficient over relatively long time horizons. Mohan and Love (2004) test London and New York coffee futures markets for efficiency. Coffee futures markets are found to be inefficient in terms of predicting subsequent spot prices. Rather than predicting spot prices futures prices appear to adapt to prevailing spot prices.

Transparent price discovery and price dissemination are key functions of successful futures markets (Hall et al. (2006)). As such, the price discovery process on coffee futures markets is also of interest. In Kofi (1973) futures markets for coffee are seen to perform their forward pricing function well, with the coffee spot price well predicted by futures prices in preceding months. Bryant and Haig (2004) examine bid-ask spreads in commodity futures markets and find that the bid-ask spread increases following the introduction of automated electronic trading. Thomson (1986) analyses returns to storage in coffee futures markets based on theoretical work in Working (1949). The theory of storage is found to inadequately explain futures prices. Futures prices are seen to reflect only a small subset of world stocks and in fact are seen more closely linked to coffee supplies in the US. Hall et al. (2006) examine intra derivatives trade migration which occurs as part of the price discovery process on limit hit days on Coffee C. Some evidence is found of a flow in volume from regulated (long) maturity contracts to the unregulated (short) maturity contracts on locked-limit days. Gemech and Struthers (2007) examine the effect of market reforms and the International Coffee Agreement (ICA) upon the volatility of real Ethiopian coffee prices and conclude that volatility increases following the abolition of the ICA. Newman (2009) explores the extent to which financial investment on futures markets affects prices over and above effects due to supply and demand conditions in the underlying physical market. Newman (2009) conducts tests for structural breaks in trading volume and the ratio of non-commercial to total open interest for Coffee C, deducing that the behaviour of coffee prices has been affected both by the sheer volume, and changing nature of trade on the New York coffee exchange.

As discussed in Vogelvang (1992) there is a rich history of economic research into commodity prices. One interesting aspect of this is that prices of commodities such as raw materials and agricultural products often display similar characteristics (Vogelvang (1992)). Such similarities can usually be explained by general factors affecting the worldwide economy (interest rates, inflation, general economic circumstances etc), and quasi-seasonality in prices (Anderluh and Borovkova (2008)). However, when the commodities under study are closely related to each other a finer market structure may become visible. Specific factors such as substitution, changes in aggregate demand, international commodity agreements etc may be brought to bear. A number of different types of coffee can easily be distinguished. This product differentiation for coffee has thus led to a number of econometric studies of the spot prices of the four major types of coffee. This was the approach taken by Vogelvang (1992) and subsequently extended to incorporate nonlinear models (Otero and Milas (2001), Milas and Otero (2002), Milas et al. (2004), Ghoshray (2010)) and asymmetric models (Ghoshray (2009)).

3. Background and data description

There are two principal types of coffee - Robusta and Arabica. Robusta is grown at lower altitudes, typically in West and Central Africa and South East Asia, has a higher caffeine content and is generally considered to have a harsher taste. In contrast, Arabica is lower in caffeine content and is commonly thought to have a more refined taste. Arabica coffee is grown in Latin America, Central and East Africa and in India, and at generally higher altitudes than Robusta. There are two major futures contracts for coffee, each of which effectively acts as a numeraire with which to compare coffees of different source and quality. Coffee C, traded on the Intercontinental Exchange (ICE) in New York, is the benchmark for Arabica coffee. The Robusta futures contract traded on the London International Financial Futures and Options Exchange (LIFFE) serves as the standard for Robusta coffee. Here, we restrict to considering these two Futures markets for Coffee as these are by far the two largest (Scholer (2004)). Note that in addition to London and New York there are a number of smaller coffee futures markets around the world including Brazil, France, India and Japan.

Brief details of the two coffee futures contracts are as follows. The Coffee C contract has five delivery months (March, May, July, September, December) compared to six for the Robusta contract (January, March, May, July, September, November). The nominal contract sizes also differ and are 37,500lb (approximately 17 tonnes) for Coffee C and 5 tonnes (later amended to 10 tonnes) for the Robusta Futures contract. Minimum tick sizes are 0.0005$/lb on Coffee C (approximately $1.10 per tonne), corresponding to a minimum tick value of $18.75, and $1 per tonne on the Robusta Futures contract. From 2007 ICE also began to list a contract for Robusta coffee which was subsequently delisted at the end of 2008. Robusta contract specifications on LIFFE were modified from 2008 onwards with a "rollover" period of one year. The modifications made were intended to provide a closer match between futures contract specifications and physical delivery[2]. These included a doubling of the nominal delivery size from 5 tonnes to 10 tonnes, minor alterations to grading procedures and increasing the number of different varieties of coffee which could be traded on the exchange. We thus address this issue of change of contract. Volume and open interest are recorded as the number of contracts issued and so doubling nominal values of volume and open interest places all volume and open interest data onto a common scale. Finally, the quoted values for volume and open interest are calculated by aggregating across all contracts. We take the futures price to be the official settlement price of the contract nearest to maturity. From the end of September 2008[3] we take the futures price to be the price of the new contract and use these values in our computation of futures market volatility below.

As was the case with the above futures markets, we need to consider spot markets for coffee in a way which adequately reflects differences in source and quality. The International Coffee Organisation (ICO) produces a set of composite price indices for this purpose. By construction, these ICO indices are intended to form representative benchmarks for the major varieties of green coffee. Further, these data are often used as the means by which coffee authorities calculate payments to farmers in producing countries and are often used by

[2] For more on this point see the notification issued by LIFFE, London Notice No. 2986, particularly subsection 2.2.1.

[3] This timing corresponds to the first date that the "new" contract is (joint) closest to maturity. We note that coffee prices are quoted in $/tonne throughout so no further price adjustments are required.

analysts in academic and related work[4] - these are the data used for instance in a study of spot markets for coffee in Milas et al. (2004). The four spot indices for coffee considered here are Colombian Mild Arabicas ("Colombian"), Brazilian and Other Natural Arabicas ("Brazilian"), Other Mild Arabicas ("Mild") and Robusta.

Plots of historical spot market volatilities are shown in Figure 1. For comparison, a plot of historical futures market volatility is shown in Figure 2. Volatility is seen to fluctuate randomly and there are some periods of high volatility - especially over the first half of the sample period. Some spikes in volatility in the spot prices of the Arabica varieties appear roughly coincident. Summary statistics are shown in Table 1 and reinforce the initial impression that the spot markets for coffee are quite volatile in nature, with the average volatility levels far exceeding the mean return on all markets. These figures also offer the suggestion that Robusta is the least volatile market but also offers the smallest rate of return.

Plots of open interest (number of futures contracts which remain in force or "open" at the end of each trading day) and trading volume series for the two futures markets under investigation are shown in Figure 3. These show broadly similar characteristics for both markets. Open interest seems to be generally increasing over time - suggesting a growing use of the futures markets to hedge risk. Volumes for both futures markets appear to be under-going a marked increase from around 2004 onwards. Note, for comparison, that we appear to have reduced volatility on spot and futures markets towards the end of the sample period (Figures 1-2). If volume and open interest serve as proxies for the level of futures market liquidity, this may then admit the interpretation that futures market volatility starts to decrease as liquidity increases.

As discussed in Yang et al. (2005), the appropriate way to look at open interest and trading volume in this context is to decompose these series into expected and unexpected components. An (approximately) efficient market will automatically price information included in anticipated trends in volume and open interest. The standard in the literature is that estimates of expected open interest and expected trading volume are based on moving averages. The unexpected open interest and unexpected trading volume components are then constructed by subtracting expected values from observed sample values. Plots of unexpected open interest and unexpected trading volume are shown in Figure 4. These figures suggest that trading volume on futures markets becomes increasingly volatile as the unexpected components seem to fluctuate more wildly in the latter parts of the sample – reinforcing our earlier impression of possible change points.

4. Methodology

4.1 Estimated model

The aim of this paper is to examine the interdependence of spot and futures markets for coffee. Here, this is addressed by estimating vector auto-regression (VAR) models. A VAR process of order *p*, VAR*(p)*, is a system of *K* variables $X_t = (X_{1,t},..., X_{K,t})'$ described by the equation

$$X_t = \mu + \Phi_1 X_{t-1} + ... + \Phi_p X_{t-p} + \varepsilon_t , \qquad (4.1)$$

[4] For details see for example the relevant sections of the website of the ICO: http://www.ico.org/about_statistics.asp.

where the Φ_i are $K \times K$ coefficient matrices and the ε_t are uncorrelated and satisfy

$$E(\varepsilon_t) = 0, \quad E[\varepsilon_t \varepsilon_t'] = \Sigma, \tag{4.2}$$

for some positive definite covariance matrix Σ. If $K=4$ we can test for Granger causality running from X_2 to X_1 by considering the equation

$$X_{1,t} = \alpha_0 + \sum_{i=1}^{p} \alpha_i X_{1,t-i} + \sum_{i=1}^{p} \beta_i X_{2,t-i} + \sum_{i=1}^{p} \gamma_i X_{3,t-i} + \sum_{i=1}^{p} \delta_i X_{4,t-i} + \varepsilon_t. \tag{4.3}$$

This approach generalises a bivariate model in Yang et al. (2005). The null hypothesis of no Granger causality from X_2 to X_1 is a test of the hypothesis $\beta_1 = ... = \beta_p = 0$. The test determines whether or not the X_2 process has significant predictive power for X_1 once we take into account information already included in the joint history of X_1, X_3, X_4. We estimate equation (4.3) using OLS and adopting the method of Newey and West (1987), to correct for heteroscedasticity and autocorrelation, test the hypothesis $\beta_1 = ... = \beta_p = 0$ using a chi-squared test.

(Generalized) Forecast error variance decomposition (G)FEVD. The chi-squared test above allows one to draw conclusions regarding causality. However, we are also interested in the economic relationships between variables in (4.3) over and above statistical significance. Sims (1980) devised the forecast error variance decomposition – a method which can be used to provide insights beyond Granger causality. The method explores the interrelationships between economic variables by explicitly accounting for contemporaneous correlation between variables – a non-diagonal covariance matrix in (4.2). However, the othogonalized FEVD conceived by Sims (1980) is known to be sensitive to the ordering of the variables. In contrast, the GFEVD, developed by Pesaran and Shin (1998) and applied by Yang et al. (2005) among others, is known to be invariant to the ordering of the variables and so is more suited to practical applications.

The GFEVD can be constructed as follows. X_t in equation (4.1) can be written in terms of an infinite moving average process:

$$X_t = \sum_{i=0}^{\infty} C_i \varepsilon_{t-i} .$$

The n step-ahead GFEVD is defined as

$$\theta_{ij}^{(g)}(n) = \frac{\sigma_{jj}^{-1} \sum_{k=0}^{n} \left(e_i' C_k \Sigma e_j\right)^2}{\sum_{k=0}^{n} e_i' C_k \Sigma C_k' e_j} \quad \text{for } i, j=1,\ldots,K,$$

where σ_{jj} denotes the j^{th} diagonal entry of the residual covariance matrix Σ, and e_i is a $K \times 1$vector with 1 in the j^{th} row and 0s elsewhere. Subsequently, if we renormalise so that

$$\sum_{j=1}^{K} \theta_{ij}^{(g)}(n) = 1,$$

then the GFEVD expresses the percentage of the generalized forecast error variance of variable i which can be attributed to variable j. Hence the GFEVD provides an added sense of scale, it is a measure of cumulative system effects downstream of an initial shock, and thus it provides a more refined notion of causality than Granger causality (Yang et al. (2005)).

4.2 Stability and change point analysis

In this subsection we develop a methodology for testing for change points within the lagged regression (4.1). Our aim is to ensure the stability and robustness of the estimates obtained so that the results obtained are not biased by estimation across a structural break. Consider the standard linear regression model for a sequence of n observations $(y_1, \ldots, y_n)$:

$$y_i = x_i^T \beta_i + u_i,$$

where β_i is a p-dimensional vector of parameters. One way to test for a structural break is to test the hypothesis

$$H_0: \beta_i = \beta_0 \ (i=1,\ldots,n),$$

against the alternative

$$H_1: \beta_i = \begin{cases} \beta_0 & 1 \le i \le i_0 \\ \beta_1 & i > i_0, \end{cases}$$

with $\beta_0 \neq \beta_1$. Suppose the break-point i_0 is known. The approach taken by Chow (1960) was to test for structural change using the conventional F-statistic

$$F_{i_0} = \frac{RSS(H_1) - RSS(H_0)}{RSS(H_1)/(n-2p)}, \tag{4.4}$$

where RSS denotes the residual sum of squares computed according to the hypotheses H_0 and H_1. However, the utility of this approach is limited by the assumption of a known change point. As discussed in Zeilis et al. (2002) one may calculate the F-statistic (4.4) for $i_0=2,\ldots,n$ and combine the sequence of F-statistics generated into a single numerical value. This has the effect of condensing information in the sequence of F-statistics in (4.4) into a single test statistic, thus avoiding multiple testing and providing a more robust approach[5]. This is the approach taken in Andrews (1993), Andrews and Ploberger (1994) and Andrews et al. (1996). Brief examples illustrating practical applications of Andrews' tests, and other types of structural change test, can be found in Zeileis et al. (2002), Section 5. These papers describe various different ways of aggregating the F-statistics (4.4) into a single test statistic. Here we restrict to a sup-F statistic defined as

$$\sup F = \sup_{i_0} F_{i_0}. \tag{4.5}$$

Approximate p-values corresponding to (4.5), and related tests, can be calculated using the method of Hansen (1997). As laid out above, the Andrews' test (4.5) can only detect one break-point per regression. However, this can be resolved as follows. Plot the sequence of F-statistics in (4.4) and compare against the critical value corresponding to (4.5). Values above this threshold give evidence of a structural break. The maximum of the F-statistics in (4.4) gives the date of the change point. Non-uniqueness of this maximal value suggests multiple change points.

[5] As an illustration we note that the critical values for the test (4.5) are larger than the conventional critical F-values corresponding to the test for a break at known i_0 in (4.4).

5. Results

5.1 Stability and change point analysis

Initially, augmented Dickey-Fuller tests were applied to the spot and futures volatility series and to the unexpected components of trading volume and open interest. In all cases the null hypothesis of non-stationarity was rejected and we may reasonably proceed to a VAR analysis.

Coffee markets may be affected by a variety of weather events and other external influences. This list of potential externalities includes production quotas for coffee, which were finally suspended on September 30th 1994 (source: ICO). We thus avoid this issue by taking data from after this date and our sample runs from October 3rd 1994 to April 12th 2010. Over the sample period in question the ICO website[6] lists frosts in 1994 and 2000 and droughts in 1994, 1999, 2000, 2003 and 2005. In addition, changes to the Robusta futures contract on LIFFE were made in 2008 and are also liable to affect the way in which spot and futures markets interact. Thus, in order to correctly characterise the interdependence between the economic variables in our study we must account for the possibility that these relationships may change over time.

In the sequel we consider Andrews' sup *F*-test for structural change. Values of the *F*-statistic in excess of the critical level indicate a change point. The maximum value of the sequence of *F*-statistics indicates the proximal date of the change point. Sample output from the procedure is shown in Figure 5. Additional Figures and *p*-values for the test of the null hypothesis of no structural change can be obtained from the authors by request. The results may be interpreted as follows. A change point is found in 1999. This is due to a severe drought affecting coffee production in Brazil, with up to 40% of the region's harvest destroyed. A change point is also found in 2008 and appears linked to changes made to the Robusta futures contract on LIFFE.

To avoid estimating models across a structural break, and thus producing potentially biased results, we therefore split out data into three Periods: Period 1 October 3rd 1994-December 30th 1998, Period 2 January 4th 1999- December 31st 2007, Period 3 January 2nd 2008- April 12th 2010.

5.2 VAR Analysis

The results in this section suggest a bi-directional causal relationship exists between spot and futures markets. However, results for Granger causality tests (Tables 2, 4, 6) and the GFEVD (Tables 3, 5, 7) show that the effect is not constant over time. Initially futures market volatility is seen to exert a greater influence over spot volatility than the other way round. However, the impact of spot volatility upon futures market volatility increases over time and in the final period spot volatility is seen to drive futures market volatility. Detailed summaries of findings in each sub-period are listed below.

Period 1 1994-1998. Results in Table 2 show that spot volatility is Granger caused by futures market volatility for both futures markets. Additionally, we also have some evidence that

[6] http://www.ico.org/frosts_droughts.asp

Brazilian spot volatility is Granger caused by unexpected open interest on Coffee C. Similarly, Robusta spot volatility is Granger caused by unexpected volume on Coffee C. There is also some evidence that unexpected open interest on Coffee C Granger causes Mild spot volatility (p=0.067), and that unexpected volume on Coffee C Granger causes Brazilian spot volatility ($p=0.063$). The results also give an indication of bi-directional causality between spot and futures markets, with volatility on Coffee C Granger caused by spot volatility for both Colombian and Robusta varieties. The finding that volatility in the spot market for Robusta influences the futures market for Coffee C is particularly notable and may appear a little surprising. However, Robusta production accounts for more than a third of total world coffee production[7] and so some informational content in their price might be expected, even though the Coffee C futures contract does not directly reference Robusta beans. With the exception of the Brazilian market, spot volatility also causes unexpected open interest on Coffee C. Colombian spot volatility is also seen to Granger cause unexpected trading activity (volume and open interest) on the Robusta futures market. There is also some evidence ($p=0.064$) suggestion that Mild spot volatility Granger causes unexpected volume on the Robusta futures market.

The GFEVD shown in Table 3 provides a slightly different picture but a degree of bi-directional causality between spot and futures markets remains. Futures volatility appears to drive spot volatility, explaining a large percentage of the variation that occurs in spot volatility, whilst spot volatility explains only relatively small amounts of the variation in futures market volatility. Instead, futures volatility appears more closely connected to unexpected trading volume. Unexpected volume accounts for around 13% of the variation of futures market volatility for Coffee C and between 6-8% for Robusta. Some evidence of the interdependence between speculative and hedging behaviour is apparent: a combination of unexpected open interest and futures market volatility accounts for approximately 14% of the variation in unexpected trading volume on Coffee C, and around 11-12% for Robusta.

Period 2 1999-2007. A combination of Granger causality tests and the GFEVD indicates a bi-directional causal relationship between futures market volatility and spot market volatility. However, the evidence for this is stronger using the Granger causality tests rather than the GFEVD. Significant or borderline significant p-values, shown in Table 4, gives some indication of bi-direction causality between spot and futures market volatility on all markets - with the exception that Robusta spot volatility does not Granger cause Robusta futures volatility. Additionally, we have some evidence that Mild spot volatility Granger causes unexpected open interest on Coffee C (p=0.052) and unexpected open interest on the Robusta futures market (p=0.053). Further, with the exception of Robusta, some evidence that spot volatility Granger causes unexpected trading volume on the Robusta futures contract is found. However, in the case of Brazilian spot volatility the result is only significant at the 10% level.

The GFEVD in Table 5 shows differences from the previous period although results show that the effect of futures volatility on Coffee C upon spot volatility is very similar to Period 1. Spot volatility is now seen to have an effect on futures market volatility as a combination of spot volatility and unexpected trading volume accounts for 10-20% of the variation in futures market volatility on Coffee C and 11-15% of that on Robusta. Differences emerge between the two futures markets. On the Robusta futures market, unexpected volume and unexpected open interest appear to be largely self-determined. However, on Coffee C unexpected trading

[7] Source – International Coffee Organisation

activity appears more nuanced. Unexpected volume accounts for roughly 12% of the variation in unexpected open interest and a combination of unexpected open interest and futures market volatility accounts for around 14% of the variation in unexpected trading volume.

Period 3 2008-2010. Table 6 provides mixed evidence on the degree of interdependence between spot and futures markets where the referenced bean type is not common. Granger causality tests indicate that unexpected volume and unexpected open interest on the Robusta futures contract are only caused by Robusta spot volatility. However, volatility in the Robusta futures contract is still Granger caused by spot market volatility for the different varieties of Arabica. Granger causality running from Robusta spot volatility to futures market activity and volatility on Coffee C remains. Robusta spot volatility is Granger caused by futures volatility on Coffee C, with some evidence of a dependence on unexpected trading volume on Coffee C (p=0.070). In contrast, Robusta futures volatility does not Granger cause volatility on any of the spot markets of the Arabica varieties. There is also evidence for interdependence between spot and futures markets when both reference the same variety of coffee. Robusta spot volatility is Granger caused by unexpected trading volume and futures volatility on the Robusta futures market. Bi-directional Granger causality occurs between futures volatility on Coffee C and Brazilian spot market volatility, and there remains some evidence, p=0.096, that unexpected open interest on Coffee C Granger causes Brazilian spot volatility. Further, unexpected open interest on Coffee C is Granger caused by Colombian spot volatility.

The GFEVD shown in Table 7 also shows important differences from earlier periods. Futures market volatility explains a similar amount of variation in spot volatility as before. However, the proportion of variation in futures market volatility explained by spot volatility has dramatically increased. Generally spot volatility explains more of the variation in futures market volatility than the other way round. This suggests, for the first time, that spot markets that are driving futures markets rather than the other way round. Some bi-directional causality between unexpected volume and unexpected open interest is apparent. Unexpected open interest on Coffee C accounts for 12-13% of the variation in unexpected trading volume. Similarly unexpected trading volume on Coffee C accounts for 15-16% of the variation in unexpected open interest. Further, a combination of unexpected open interest and futures volatility accounts for around 10% of the variation in unexpected trading volume on the Robusta futures market.

6 Conclusions

This paper discusses the interdependence between spot and futures markets for coffee. The results are of interest both for a contribution to an extensive financial literature on the interplay between spot and futures markets and for potential policy implications linked to commodity markets in LDCs. Moreover, this paper develops the empirical approach found in the literature by both the implementation of a multivariate Granger causality test and an examination of the effect of external shocks (adverse harvests and changes in futures contract specifications) upon the interaction between spot and futures markets.

Performing a VAR analysis evidence is found of a bi-directional causal relationship between spot and futures markets. However, the way in which spot and futures markets interact does not remain static and can change over time in response to exogenous shocks. Some interdependence between unexpected volume and unexpected open interest is also found. Statistical tests for structural change reveal two change points, each associated with external shocks which lead to changes in the behaviour of economic agents in spot and futures markets for coffee. These external shocks consist of a severe drought affecting coffee production in Brazil in 1999 and modifications made to the Robusta futures contract on LIFFE in 2008. Given the results of the change point tests, we partition our sample accordingly in a subsequent VAR analysis. Results suggest that, despite some evidence of bi-directional causality, futures market volatility dominates spot volatility in Periods 1-2. However, in Period 3 it is spot volatility which appears to dominate futures market volatility. These results suggest that futures markets are becoming increasingly efficient over time. The impact of spot markets upon futures markets appears to be growing over time: futures markets for coffee appear to be increasingly driven by risks associated with the underlying spot price. In conclusion spot markets have seen an increasing effect, both in terms of statistical and economic terms, upon the volatility of futures prices. Conversely however, evidence of a statistically significant effect of futures markets on the volatility of spot prices has declined. The exception is the Robusta spot market, which remains influenced by futures markets to a significant extent.

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Appendix I: Tables and Figures

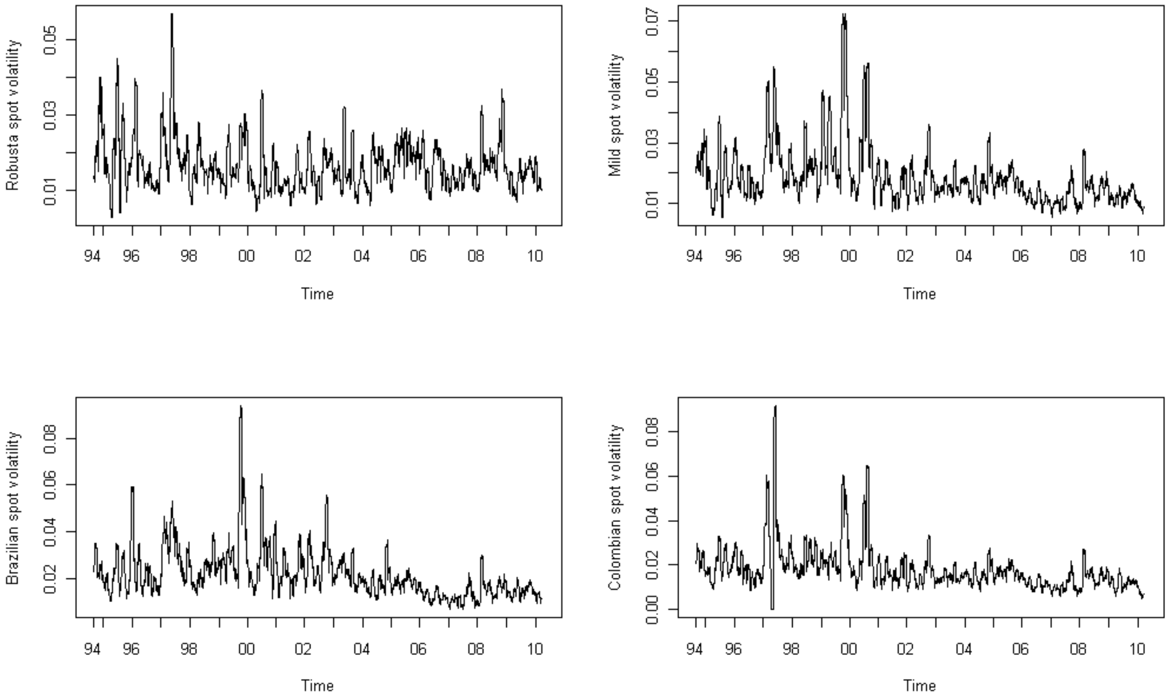

Figure 1: Plot of spot market historical volatility. Standard deviation of log-returns based on a moving window of 21 trading days.

Market type	**Market**	**Mean volatility (Standard deviation)**	**Mean log-return (Standard deviation)**
Spot	Mild	0.0188 (0.00994)	-6.865×10^{-5} (0.0212)
	Brazilian	0.0218 (0.01084)	-1.243×10^{-4} (0.0242)
	Colombian	0.0183 (0.01019)	-2.419×10^{-5} (0.0208)
	Robusta	0.0168 (0.00698)	-2.365×10^{-4} (0.0182)
Futures	Coffee C	0.0236 (0.00928)	-1.181×10^{-4} (0.0252)
	Robusta Futures	0.0201 (0.00819)	-2.741×10^{-4} (0.0217)

Table 1: Summary statistics of volatility and log-returns series by market.

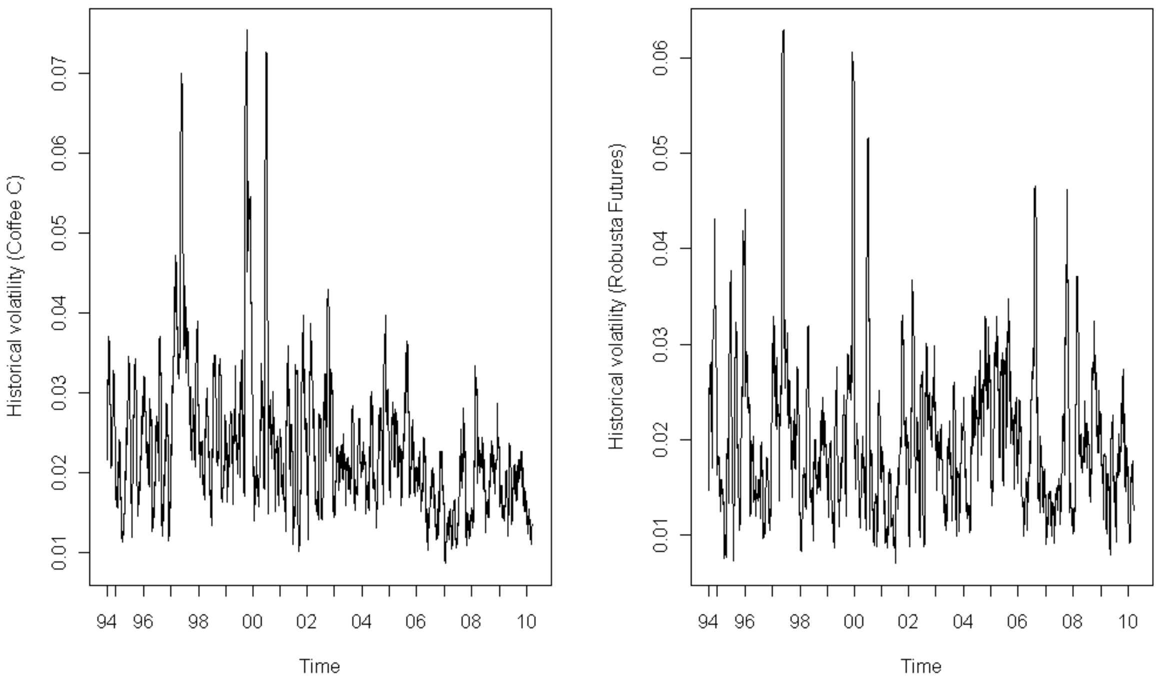

Figure 2: Plot of futures market historical volatility. Standard deviation of log-returns based on a moving window of 21 trading days.

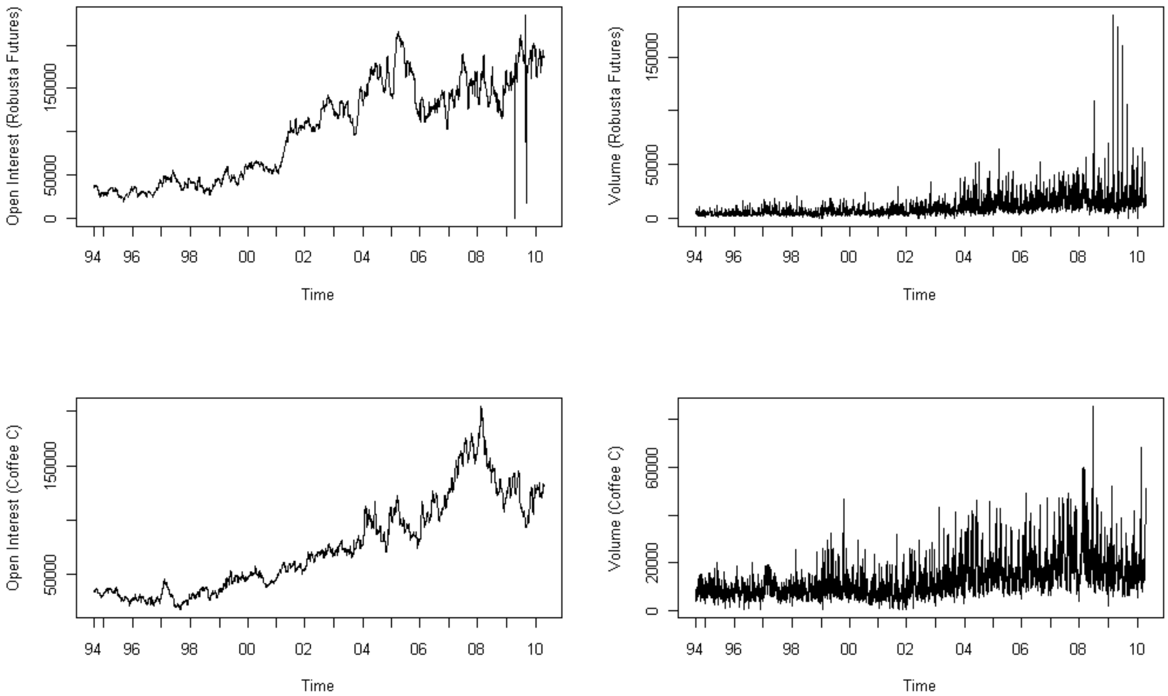

Figure 3: Plot of open interest and trading volume by futures market.

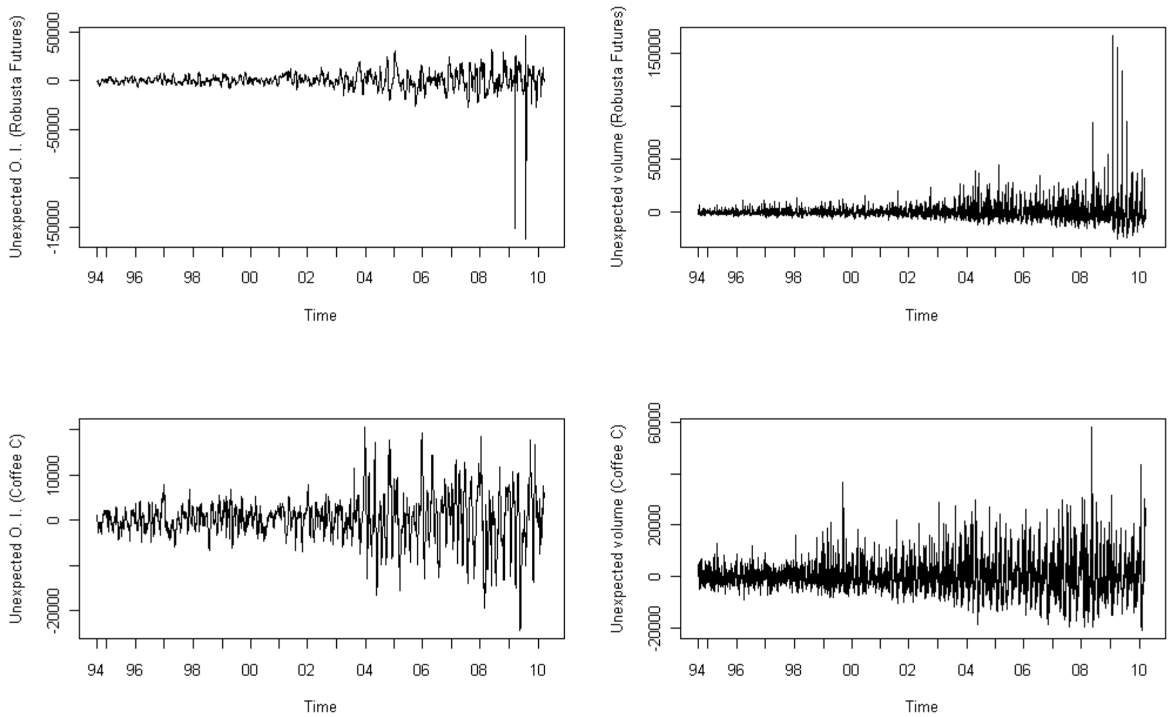

Figure 4: Plot of unexpected components of open interest and trading volume by futures market.

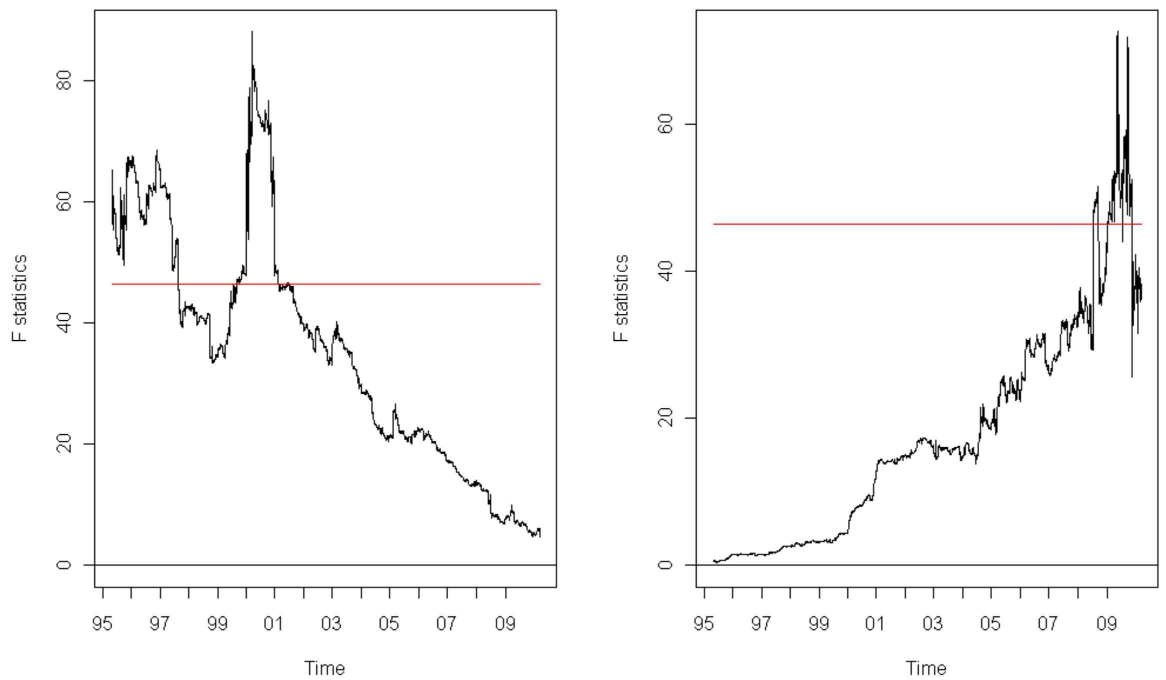

Figure 5: Sample output for Andrews' sup-*F* test of structural change for VAR models. Left panel: Endogenous= Unexpected Open Interest (Coffee C), Exogneous=Spot Volatility (Mild). Right panel: Endogenous=Spot Volatility (Mild), Exogneous=Unexpected Trading Volume (Robusta Futures).

Futures Market	Spot Market	Spot volatility causes			Spot volatility is caused by		
		Unexpected Volume	Unexpected Open Interest	Futures Volatility	Unexpected Volume	Unexpected Open Interest	Futures Volatility
Coffee C	Mild	0.201	0.011	0.311	0.136	0.067	0.000
	Brazilian	0.194	0.692	0.191	0.063	0.005	0.000
	Colombian	0.367	0.000	0.000	0.519	0.860	0.000
	Robusta	0.727	0.000	0.017	0.049	0.670	0.000
Robusta Futures	Mild	0.064	0.705	0.401	0.541	0.970	0.000
	Brazilian	0.829	0.204	0.319	0.653	0.430	0.000
	Colombian	0.000	0.050	0.148	0.867	0.755	0.000
	Robusta	0.397	0.450	0.152	0.302	0.301	0.000

Table 2: *p*-values for Granger causality tests: Period 1 (October 3rd 1994-December 30th 1998).

	Futures Market	Spot Market			
		Mild	Brazilian	Colombian	Robusta
Spot volatility caused by	Coffee C				
Spot volatility		0.501	0.472	0.508	0.712
Unexpected volume		0.096	0.144	0.088	0.036
Unexpected open interest		0.009	0.039	0.001	0.005
Futures volatility		0.393	0.344	0.403	0.247
Unexpected volume caused by					
Spot volatility		0.010	0.008	0.008	0.007
Unexpected volume		0.843	0.855	0.852	0.849
Unexpected open interest		0.063	0.059	0.060	0.063
Futures volatility		0.083	0.078	0.078	0.081
Unexpected Open Interest caused by					
Spot volatility		0.031	0.044	0.017	0.013
Unexpected volume		0.018	0.016	0.016	0.016
Unexpected open interest		0.863	0.862	0.869	0.867
Futures volatility		0.087	0.077	0.098	0.104
Futures volatility caused by					
Spot volatility		0.026	0.040	0.017	0.040
Unexpected volume		0.134	0.130	0.126	0.130
Unexpected open interest		0.001	0.001	0.001	0.001
Futures volatility		0.839	0.828	0.856	0.829
Spot volatility caused by	Robusta Futures				
Spot volatility		0.562	0.612	0.526	0.271
Unexpected volume		0.081	0.069	0.057	0.093
Unexpected open interest		0.015	0.036	0.015	0.012
Futures volatility		0.342	0.283	0.403	0.623
Unexpected volume caused by					
Spot volatility		0.024	0.015	0.037	0.010
Unexpected volume		0.857	0.868	0.850	0.867
Unexpected open interest		0.048	0.049	0.046	0.049
Futures volatility		0.071	0.068	0.067	0.073
Unexpected Open Interest caused by					
Spot volatility		0.009	0.010	0.021	0.017
Unexpected volume		0.014	0.013	0.016	0.015
Unexpected open interest		0.950	0.957	0.930	0.937
Futures volatility		0.028	0.019	0.033	0.031
Futures volatility caused by					
Spot volatility		0.027	0.060	0.014	0.005
Unexpected volume		0.086	0.087	0.061	0.080
Unexpected open interest		0.023	0.021	0.015	0.019
Futures volatility		0.864	0.830	0.910	0.896

Table 3: 21 day-ahead Generalized Forecast Error Variance Decomposition for Period 1 (October 3rd 1994-December 30th 1998) by spot and futures market.

Futures Market	Spot Market	Spot volatility causes			Spot volatility is caused by		
		Unexpected Volume	Unexpected Open Interest	Futures Volatility	Unexpected Volume	Unexpected Open Interest	Futures Volatility
Coffee C	Mild	0.205	0.052	0.009	0.380	0.471	0.007
	Brazilian	0.922	0.760	0.000	0.545	0.270	0.000
	Colombian	0.361	0.273	0.021	0.544	0.387	0.000
	Robusta	0.828	0.560	0.068	0.604	0.739	0.000
Robusta Futures	Mild	0.003	0.053	0.024	0.419	0.498	0.024
	Brazilian	0.094	0.736	0.021	0.356	0.570	0.007
	Colombian	0.048	0.540	0.000	0.389	0.475	0.002
	Robusta	0.693	0.760	0.829	0.235	0.532	0.000

Table 4: *p*-values for Granger causality tests: Period 2 (January 4th 1999- December 31st 2007).

	Futures Market	Spot Market			
		Mild	Brazilian	Colombian	Robusta
Spot volatility caused by	Coffee C				
Spot volatility		0.557	0.471	0.523	0.716
Unexpected volume		0.065	0.065	0.054	0.043
Unexpected open interest		0.007	0.010	0.005	0.002
Futures volatility		0.371	0.454	0.417	0.239
Unexpected volume caused by					
Spot volatility		0.011	0.015	0.015	0.014
Unexpected volume		0.849	0.843	0.842	0.842
Unexpected open interest		0.075	0.074	0.074	0.074
Futures volatility		0.066	0.068	0.069	0.070
Unexpected Open Interest caused by					
Spot volatility		0.003	0.003	0.001	0.024
Unexpected volume		0.118	0.119	0.119	0.122
Unexpected open interest		0.868	0.866	0.867	0.839
Futures volatility		0.012	0.013	0.012	0.015
Futures volatility caused by					
Spot volatility		0.106	0.134	0.109	0.011
Unexpected volume		0.081	0.077	0.080	0.088
Unexpected open interest		0.002	0.002	0.002	0.001
Futures volatility		0.811	0.786	0.809	0.900
Spot volatility caused by	Robusta Futures				
Spot volatility		0.936	0.915	0.927	0.636
Unexpected volume		0.022	0.021	0.021	0.064
Unexpected open interest		0.003	0.006	0.003	0.004
Futures volatility		0.039	0.058	0.049	0.297
Unexpected volume caused by					
Spot volatility		0.004	0.006	0.008	0.025
Unexpected volume		0.942	0.940	0.938	0.924
Unexpected open interest		0.018	0.018	0.018	0.016
Futures volatility		0.036	0.036	0.036	0.035
Unexpected Open Interest caused by					
Spot volatility		0.001	0.002	0.002	0.018
Unexpected volume		0.018	0.018	0.018	0.023
Unexpected open interest		0.978	0.977	0.977	0.957
Futures volatility		0.003	0.003	0.002	0.002
Futures volatility caused by					
Spot volatility		0.058	0.071	0.081	0.106
Unexpected volume		0.053	0.052	0.051	0.050
Unexpected open interest		0.008	0.008	0.008	0.007
Futures volatility		0.880	0.869	0.860	0.836

Table 5: 21 day-ahead Generalized Forecast Error Variance Decomposition for Period 2 (January 4th 1999- December 31st 2007) by spot and futures market.

Futures Market	Spot Market	Spot volatility causes			Spot volatility is caused by		
		Unexpected Volume	Unexpected Open Interest	Futures Volatility	Unexpected Volume	Unexpected Open Interest	Futures Volatility
Coffee C	Mild	0.956	0.134	0.218	0.359	0.282	0.449
	Brazilian	0.911	0.103	0.007	0.279	0.096	0.026
	Colombian	0.403	0.038	0.171	0.350	0.429	0.160
	Robusta	0.032	0.020	0.002	0.070	0.213	0.000
Robusta Futures	Mild	0.795	0.250	0.000	0.418	0.355	0.936
	Brazilian	0.686	0.182	0.001	0.387	0.204	0.932
	Colombian	0.809	0.147	0.000	0.320	0.416	0.135
	Robusta	0.054	0.001	0.165	0.036	0.393	0.000

Table 6: *p*-values for Granger causality tests: Period 3 (January 2nd 2008- April 12th 2010).

	Futures Market	Spot Market			
		Mild	Brazilian	Colombian	Robusta
Spot volatility caused by	Coffee C				
Spot volatility		0.521	0.488	0.583	0.781
Unexpected volume		0.015	0.015	0.011	0.011
Unexpected open interest		0.056	0.078	0.039	0.095
Futures volatility		0.408	0.419	0.367	0.114
Unexpected volume caused by					
Spot volatility		0.042	0.045	0.029	0.020
Unexpected volume		0.799	0.790	0.804	0.811
Unexpected open interest		0.117	0.122	0.126	0.127
Futures volatility		0.042	0.042	0.041	0.042
Unexpected Open Interest caused by					
Spot volatility		0.049	0.072	0.058	0.019
Unexpected volume		0.164	0.164	0.148	0.156
Unexpected open interest		0.756	0.729	0.768	0.795
Futures volatility		0.031	0.036	0.026	0.029
Futures volatility caused by					
Spot volatility		0.441	0.374	0.409	0.135
Unexpected volume		0.017	0.021	0.017	0.025
Unexpected open interest		0.062	0.083	0.065	0.105
Futures volatility		0.480	0.522	0.508	0.735
Spot volatility caused by	Robusta Futures				
Spot volatility		0.724	0.692	0.803	0.561
Unexpected volume		0.003	0.006	0.002	0.007
Unexpected open interest		0.041	0.039	0.019	0.038
Futures volatility		0.233	0.262	0.176	0.394
Unexpected volume caused by					
Spot volatility		0.008	0.012	0.008	0.011
Unexpected volume		0.888	0.886	0.882	0.885
Unexpected open interest		0.053	0.053	0.054	0.054
Futures volatility		0.051	0.049	0.055	0.049
Unexpected Open Interest caused by					
Spot volatility		0.022	0.028	0.016	0.007
Unexpected volume		0.061	0.062	0.063	0.077
Unexpected open interest		0.901	0.893	0.906	0.896
Futures volatility		0.016	0.017	0.015	0.021
Futures volatility caused by					
Spot volatility		0.380	0.339	0.341	0.135
Unexpected volume		0.021	0.029	0.024	0.041
Unexpected open interest		0.017	0.017	0.017	0.024
Futures volatility		0.582	0.615	0.618	0.801

Table 7: 21 day-ahead Generalized Forecast Error Variance Decomposition for Period 3 (January 2nd 2008- April 12th 2010) by spot and futures market.