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Financial speculation in energy and agriculture futures markets: A multivariate GARCH approach

Abstract: This paper analyses futures prices of four energy commodities (crude oil, heating oil, gasoline and natural gas) and five agricultural commodities (corn, oats, soybean oil, soybeans and wheat), over the period 1986-2010. Using DCC multivariate GARCH models, it provides new evidence on four research questions: 1) Are macroeconomic factors relevant in explaining returns of energy and non-energy commodities? 2) Is financial speculation significantly related to returns in futures markets? 3) Are there significant relationships among returns, either in their mean or variance, across different markets? 4) Is speculation in one market affecting returns in other markets? Results suggest that the S&P 500 index and the exchange rate significantly affect returns. Financial speculation, proxied by Working's T index, is poorly significant in modelling returns of commodities. Moreover, spillovers between commodities are present and the conditional correlations among energy and agricultural commodities display a spike around 2008.

JEL Codes: C32; G13; Q11; Q43.
Keywords: Energy; Agricultural commodities; Futures markets; Financial speculation; Multivariate GARCH.

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1. Introduction

The last decades have witnessed a number of changes in commodities futures markets. The oil market has continuously grown, becoming the world's biggest commodity market and turning from a primarily physical product activity into a sophisticated financial market (Chang et al. 2011). The increasing presence of hedgers, as well as speculators, has led to allegations that speculation drives crude oil prices, and speculators, index funds and hedge funds have been responsible for the increase in energy and food prices from 2004 onwards (Masters 2008). The literature however has provided, so far, little empirical evidence in support of this claim.

Speculators have historically been present in non-energy commodities futures markets as well: it is therefore reasonable, while testing the role of speculators and any possible impact on commodities' returns, to extend the analysis to both energy and non-energy commodities.

Moreover, the common behaviour displayed by energy and non-energy commodities prices in recent times, characterized by a steep rise around year 2008 which has been followed by a sharp decrease during the "great recession", has posed the question of the linkage between these markets, and the spillovers that may be present.

This paper contributes to the existing literature by shedding some light on several compelling issues. More precisely, it focusses on four research questions. First, are macroeconomic factors relevant in explaining returns of energy and non-energy commodities? Second, is financial speculation significantly related to returns in futures markets? Third, are there significant relationships among returns, either in their mean or variance, across different markets? Finally, is speculation in one market affecting returns in other markets? Or, in other words, are there spillovers across markets in speculation?

Our empirical exercise considers weekly data over the time period 1986:3 to 2010:52. We collect data on returns of four energy commodities (gasoline, heating oil, natural gas and crude oil) and four non-energy commodities (corn, oats, soybeans and wheat). Additionally, we include in our analysis a biofuel, soybean oil, to investigate if the relationship among the latter and energy commodities is stronger than what can be found between energy and food commodities. We consider a generalized autoregressive conditional heteroskedasticity (GARCH) model to estimate commodities' returns: we first discuss an univariate analysis, where returns are explained by macroeconomic variables and a measure of speculation. Then, we present multivariate GARCH models to investigate the presence of spillovers across commodities.

Our results suggest that macroeconomic variables are relevant in explaining commodities' returns, more precisely the Standard & Poor's (S&P) 500 index has a positive and significant coefficient, while the multilateral exchange rate has a negative effect, as expected. As concerns the second research question, we observe that speculation, measured by the Working's T index, does not seem to significantly affect returns. As for the third issue, we observe that returns of other commodities are generally not significant in the mean equations (with the exception of natural gas and crude oil in the returns of other energy commodities). We find however that the dynamic conditional correlations among commodities are time varying and higher in recent years. Interestingly, correlations between soybean oil and energy commodities, as well as correlations between agricultural commodities and a factor of energy ones, present a spike around 2008. Finally, as speculation is generally poorly significant, we do not detect a relevant impact on other markets' returns.

The remainder of this paper is structured as follows. Section 2 discusses the debate on the impact of speculation in futures markets and the presence of spillovers across commodities. Section 3 presents the data and some descriptive statistics. Section 4 describes the econometric model while Section 5 presents the results. Finally, Section 6 concludes.

2. Literature review

Some commentators (Frankel 2008a, Mitchell 2008, Verleger 2009, Smith 2009) suggest that the causes of price increases have to be identified in economic fundamentals as low interest rates in the USA, which forced to look for other investment opportunities. Another factor is the rapid economic growth worldwide, especially in China and India, which has been accompanied by growing demand for food commodities. Instability among oil producers, especially in the Middle East, and therefore uncertainty in the supply of oil has to be accounted for as well. Finally, misguided ethanol subsidies have increased biofuel production and might have affected prices. Baffes and Haniotis (2010) add to the latter argument claiming that the future path of commodities prices is uncertain due to the strict relationship between energy and non-energy prices. In particular, this relationship has increased considerably in the recent boom, indicating that events and policy changes happening in one market affect other markets. Gilbert (2010) finds that, in the last years, oil prices have had more influence on food ones. He claims however that this is the result of common causation rather than of a direct causal link.

More recently, several researchers and analysts suggested that the increasing presence of speculators in commodity future markets could explain the spike in prices in the 2007-2008 period (see, among many, Eckaus 2008, Masters 2008, Soros 2008). Indeed, Medlock III and Jaffe (2009) show that non-commercial agents in 2009 represented about 50% of total open interest in the oil market, compared to about 20% prior to 2002. Moreover, the open interest held by speculators moved from a lagging indicator of price to a leading indicator around January 2006, suggesting a possible cause in oil prices increase. Khan (2009) argues that speculation played a role as the price of crude oil and the price of gold, which used to move together until 2000, display a gap from 2002 onwards. Robles et al. (2009) find some evidence that speculative activity Granger-causes current commodity prices of wheat, maize, soybeans and rice. Du et al. (2011) show that scalping and speculation affect positively crude oil price volatility. Moreover, after 2006, they find that the oil price shock has triggered price changes in corn and wheat markets, potentially because of an increase in ethanol production.

Other authors instead do not find a statistically significant relationship between commodity prices and index funds, which are held responsible for speculation. Index Investment Data (IID) have been made available by CFTC from December 2007. Using these data Irwin and Sanders (2012) find little evidence that IID positions influence returns or volatility in 19 commodity futures markets. Authors interested in analysing the previous period proxied index funds activity using data on swap dealers. Empirical tests provide no evidence that position changes by any trader group influence price changes in both energy and non-energy commodities futures markets (Brunetti and Büyükşahin 2009, Stoll and Whaley 2010, Büyükşahin and Harris 2011, Bastianin et al. 2012).

Sanders et al. (2010) study agricultural futures markets over the period 1995-2008 and show that the Working's T (1960) index, traditionally adopted to measure excess speculation (see Section 3 for a formal definition), has remained stable or below historical levels in recent years. However, they suggest that this result might be due to the nature of the index itself: the recent rise in long speculative positions has been paralleled by an increase in short hedging, thus implying an overall decrease in the Working's T index. Till (2009) reaches the same conclusion for oil futures market over the period 2006-2009.

Other authors suggest that the crude oil price spike and collapse in 2007-08, while being mainly driven by increasing world demand, can not be explained by macroeconomic factors only and suggest that speculation played a role (Kaufmann and Ulman 2009, Kaufmann 2011). We follow this approach, and in the subsequent econometric analysis we investigate the role of macroeconomic variables *and* speculation on futures' returns.

The asset pricing literature provides empirical evidence of the ability of few macroeconomic variables to forecast returns on commodities futures. The first is the return on the 90-day Treasury bill, which represents the short-term discount rate free of a risk premium. The T-bill tends to be lower during economic recessions and higher during periods of growth. Thus, it is expected to be negatively correlated with real economic output growth. A negative relationship between real commodity prices and real interest rates has been confirmed empirically (Frankel 2008b). The second variable is the equity dividend yield: futures commodity prices are expected to reflect the systemic risk embedded within the evolution of stock market conditions (Chevallier 2009). A third variable is the "junk bond premium", which is the premium on long-term corporate bonds rated BAA by Moody's over the AAA rated ones. This difference represents the monetary compensation for risk. Recent works on petroleum futures returns and carbon futures returns (Sadorsky 2002, Chevallier 2009) find however that these macroeconomic risk variables are poorly significant. Finally, exchange rates are thought to be closely related to commodities futures prices, although the direction of the causality among these variables is still debated. Indeed, Chen et al. (2010) show that exchange rates have robust forecasting power over global commodity prices and that commodity prices Granger-cause exchange rates in-sample.[1]

Another issue we tackle with the present econometric exercise is the relationship among commodities prices and price changes. The literature has largely debated on this. Several authors find cointegration among commodity prices (see among many Malliaris and Urrutia 1996, Chaudhuri 2001, Natanelov et al. 2011).

Pindyck and Rotemberg (1990) analyze monthly returns of 7 commodities (wheat, cotton, copper, gold, crude oil, lumber and cocoa) from 1960 to 1985. The commodities are chosen to be neither substitutes nor complements, neither co-produced and neither inputs for others' production and they are thus expected to be uncorrelated. However, the authors find that the residuals of a regression of these commodities' prices on macroeconomic variables are highly correlated, meaning that prices move together even after accounting for a set of macroeconomic variables. This "excess co-movement" is possibly explained by the so called "herd" behaviour of financial traders. Subsequently, several papers have challenged the excess co-movement hypothesis (Leybourne et al. 1994, Deb et al. 1996, Ai et al. 2006).

More recently the literature has concentrated on possible linkages between energy and non-energy commodities. Indeed, crude oil is an important input in agricultural production, either in the form of diesel, fertilizers or pesticides. Baffes (2007) measures the effect of crude oil prices on the prices of 35 internationally traded primary commodities for the 1960–2005 period, finding that the pass-through of crude oil price changes to the overall non-energy commodity index is 0.16: a 10% increase in the price of crude oil brings a 1.6% increase in the non-energy commodity prices. Extending the sample up to 2008 Baffes (2010) finds that a 10% increase in energy prices brings a

[1] Given the weekly frequency of data adopted in the econometric exercise we are not able to include other macroeconomic controls, such as industrial production or unemployment rate (which are available a monthly frequency).

2.8% increase in non-energy prices, suggesting that the 2008 financial crisis has strengthened the relationship between energy and non-energy prices.

Researchers have focussed recently also on a specific class of commodities, biofules, and on the possible linkages between biofuels and other food commodities. Natanelov et al. (2011) show a lack of cointegration between corn and crude oil price between mid 2004 and July 2006, which is due to policy interventions on biofules. However, after surpassing a certain threshold in crude oil price the two series are cointegrated. Ciaian and Kancs (2011) show that the interdependencies among crude oil and agricultural commodities (included corn and soybean) are increasing over time, while Du and McPhail (2012) find that after 2008 ethanol, gasoline, and corn prices are more closely linked.

3. Data description

We collect data on futures prices for four energy commodities (light sweet crude oil, heating oil, gasoline and natural gas) and five agricultural commodities (corn, oats, soybean oil, soybeans and wheat). All the energy commodities are traded on the New York Mercantile Exchange (NYMEX), while the agricultural ones are traded on Chicago Board of Trade (corn, oats, soybean oil and soybeans) and Kansas City Board of Trade (wheat). Daily data are retrieved from Datastream and turned into weekly averages of futures prices[2] for each commodity. Indeed, data necessary to build the speculation index are provided by the Commitments of Traders (COT) reports of U.S. Commodity Futures Trading Commission (CFTC) on a weekly basis, thus we have to adopt this data frequency.[3] CFTC collects every week the open interest for specific categories of traders: commercial (hedgers)[4] and non-commercial (speculators and arbitrageurs),[5] distinguishing between short and long positions. The period considered spans from 1986:3 to 2010:52.[6]

[2] We use the continuous futures price series, calculated by Thomson Financial. They start at the nearest contract month which forms the first values for the continuous series and switch over on 1st day of new trading month.

[3] Notice that daily data exist, but are not publicly available.

[4] Commercial agents are also active in the spot market. In this category CFTC includes producers, merchants, processors and users, i.e. who use futures markets to manage or hedge risks associated with the physical activity of commodities, and swap dealers, i.e. all the agents who use these markets to manage or hedge the risk associated with swap transactions.

[5] Non-commercial agents are in futures markets to make profits from selling and buying futures contracts. In this category CFTC includes money managers, i.e. a category which includes a registered commodity trading advisor (CTA), a registered commodity pool operator (CPO) or an unregistered fund identified by CFTC, and other reportables, i.e. any trader that is not identified in the previous categories.

[6] From January 1986 to September 1992 CFTC reports data with bi-monthly frequency. Missing data are replaced by the average between the previous and the following observation. As a robustness check, we estimate the models in the period running from September 1992 to December 2010. Results are unaffected. These estimates are reported in the statistical appendix, available from the authors upon request.

The data collected allow to calculate the Working's T index, which is a measure of speculative activity that proxies the excess of speculation relative to hedging activity. This index is calculated as the ratio of non-commercial positions to total commercial positions:

$$\begin{cases} 1+\dfrac{SS}{HS+HL} & if \quad HS \geq HL \\ 1+\dfrac{SL}{HS+HL} & if \quad HS < HL \end{cases} \tag{1}$$

where *SS* is speculation short, *SL* is speculation long, *HS* is hedging short and *HL* is hedging long.
It should be noted that the calculation of the Working's T index crucially depends on the classification of the market operators between hedgers and speculators. CFTC also provides data for "Non Reportable" agents,[7] which are not classified into any of the two categories. However, open interest held by these subjects should be included in the computation of the index. Several rules to treat them are at hand. One could consider them as being all hedgers or, more likely, all speculators. Indeed, hedgers are generally known by CFTC and are less likely to be among non reportables. We follow an intermediate approach, assuming that 70% of them are speculators and 30% are hedgers. However, we calculate the speculation index also in the two "extreme" hypotheses and perform the econometric exercise with these variables.[8]
To control for macroeconomic factors we collect daily (5 days) data, which we turn into weekly averages, on Moody's AAA and BAA corporate bond yield, 3-month Treasury bill, S&P 500 index and a weighted exchange rate index of the U.S. dollar against a subset of broad index currencies outside U.S. for the period 01/02/1986 - 12/31/2010 from the Federal Reserve Economic Data (FRED) provided by the Federal Reserve of St. Louis.[9]
Descriptive statistics of the variables are reported in Table 1. Futures prices and macroeconomic variables contain a unit root, as the Augmented Dickey-Fuller (ADF) test statistics does not reject the null hypothesis for almost all series in the dataset. Therefore, for each commodity we consider

[7] CFTC defines this category as follows: "The long and short open interest shown as "Non Reportable Positions" is derived by subtracting total long and short "Reportable Positions" from the total open interest. Accordingly, for "Non Reportable Positions", the number of traders involved and the commercial/non-commercial classification of each trader are unknown." (see http://www.cftc.gov/MarketReports/CommitmentsofTraders/ExplanatoryNotes/index.htm) Notice that threshold levels for non-reportables have changed over time. As long as non-reportables are included in the computation of the Working's T index and our results using different rules to attribute non-reportables (see more infra) to the different trading categories are robust, we might expect that the change in thresholds does not impair our results.

[8] Results are similar using alternative definitions of the Working's T index. They can be found in the statistical appendix available from the authors upon request.

[9] The trade weighted exchange index is defined as a weighted average of the foreign exchange value of the U.S. dollar against a subset of the broad index currencies that circulate widely outside the country of issue. Major currency index includes the Euro Area, Canada, Japan, United Kingdom, Switzerland, Australia, and Sweden. According to this definition, a decrease of the index corresponds to a depreciation of the U.S. dollar.

the return r_{it}, which is defined as $\log(P_{it} / P_{it-1})$, where P_{it} and P_{it-1} are the prices of commodity *i* at weeks *t* and *t-1*, respectively. This transformation allows to obtain stationarity, as shown in the second panel of Table 1.

The third panel shows that Working's T index ranges from mean values of 10.5% (in gasoline) to 26.8% (in soybeans) and, in the entire sample, it reaches maximum values of around more than 50% (in natural gas and oats). The index is stationary in levels and therefore is not transformed.

However, the long time span considered in our sample may, on average, conceal the role of speculation in recent times. We report summary statistics for two different periods: 1986-2003 and 2004-2010 to inspect if any change of this index occurred across different commodities over time. The choice is driven by the consideration that the sharp increase in oil prices is generally acknowledged to begin in 2004 (Smith 2009): in this year the oil demand exceptionally reaches a record level of almost three millions barrels a day[10] and the S&P GSCI (Goldman Sachs Commodity Index) sharply accelerates. Results are reported in Table 2. First, we observe that in the 1986-2003 period energy commodities display lower mean values than non-energy ones. Second, mean values are generally lower in the 2004-2010 period, with the notable exception of natural gas, crude oil and wheat: excess speculation has increased in recent times for these commodities. The tests of the equality of means reported in Table 2 suggest that these differences are statistically significant.

The contemporaneous rise in agricultural and energy prices poses the question of the linkages between these markets and the spillovers that may take place: preliminary evidence is provided by the correlations between the variables employed in the estimation.[11] The highest correlations are those between returns of energy commodities (generally higher that 0.7), while soybean oil, notwithstanding its widespread use as fuel, is poorly correlated with them. Correlations between returns and Working's T indexes are in almost all cases not significant, suggesting that the relationship linking these variables is weak and anticipating the result found in the econometric analysis that speculation is not relevant in explaining futures returns. Correlations between speculation indexes are generally not large and mixed in sign.

4. The econometric specification

We aim at modelling the returns of commodities' futures prices. As a preliminary step, we test for stationarity of all the series, and take the log difference if necessary (see Table 1).

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[10] See U.S. Energy Information Administration (2008).

[11] The correlation matrix is not reported but is available in the statistical appendix.

Then, we estimate the following equation:

$$r_{it} = \alpha_0 + \alpha_1 int\_rate_t + \alpha_2 junk\_bond\_yield_t + \alpha_3 S\&P_t + \alpha_4 exc\_rate_t + \alpha_5 WT_{it} + \varepsilon_{it} \tag{2}$$

where the dependent variable is the return in commodity market *i* at time *t*. The macroeconomic context is summarized by the returns of 3-month treasury bills (int_rate_t), the junk bond yield, the returns of the S&P 500 index ($S\&P_t$) and the exchange rate between U.S. dollar and other currencies, and the speculation present in markets, represented by the Working's T (WT_{it}) for the market *i* at time *t*. We consider nine markets and the time period spans from 1986:3 to 2010:52.[12]

We first estimate the model with ordinary least squares (OLS) and test for autoregressive conditional heteroskedasticity (ARCH) effects in the residuals. If such effects are present, we revert to a generalized conditional heteroskedasticity (GARCH) model. If the GARCH term is statistically significant, we opt for a GARCH(1,1) model, controlling that the second moment and log moment conditions are respected. We also test for autocorrelation in the residuals and include an auto regressive term if necessary.

As will be shown in the next section, the GARCH(1,1) model with an AR(1) term is the preferred specification to model the returns. Therefore, we end up estimating a model where the conditional mean equation is:

$$r_{it} = \gamma_0 + \gamma_1 int\_rate_t + \gamma_2 junk\_bond\_yield_t + \gamma_3 S\&P_t + \gamma_4 exc\_rate_t + \gamma_5 WT_{it} + \gamma_6 r_{it-1} + \varepsilon_{it} \tag{3.a}$$

and the conditional variance is defined as:

$$\sigma_{it}^2 = s_i + \sum_{j=1}^{p_i} \alpha_j \varepsilon_{it-j}^2 + \sum_{j=1}^{q_i} \beta_j \sigma_{it-j}^2 \tag{3.b}$$

where the variance σ_{it}^2 of the regression model's disturbances is a linear function of lagged values of the squared regression disturbances and of its past value: *p* defines the order of the ARCH term, and *q* of the GARCH term. In the econometric exercise, we estimate a model where $p=q=1$.

The univariate analysis is however limited in its scope: the common trend in futures prices suggests that a multivariate approach should be implemented to investigate the presence of spillovers, both in the mean and in the variance equation. Indeed, a multivariate-GARCH model captures the effects on current volatility of own innovation and lagged volatility shock originated in a given market, as

[12] For heating oil data are available from 1986:22, for natural gas from 1990:14.

well as cross innovation and volatility spillovers from other futures markets. This allows to better understand volatility, as well as volatility persistence, in interconnected markets.

A general multivariate GARCH model is defined as:

$$r_t = Cx_t + \varepsilon_t \tag{4.a}$$

$$\varepsilon_t = H_t^{1/2} \upsilon_t \tag{4.b}$$

$$H_t = D_t^{1/2} R_t D_t^{1/2} \tag{4.c}$$

where r_t is an $m \times 1$ vector of dependent variables, C is an $m \times k$ matrix of parameters, x_t is a $k \times 1$ vector of independent variables, which contains, following the results obtained in the univariate analysis, first lags of the returns r_{t-1}, $H_t^{1/2}$ is the Cholesky factor of the time varying conditional covariance matrix of the disturbances H_t and υ_t is a $m \times 1$ vector of i.i.d. innovations with zero mean and unit variance and D_t is a diagonal matrix of conditional variances in which each σ_{it}^2 evolves according to a univariate GARCH process defined as in the univariate analysis as $\sigma_{it}^2 = s_i + \sum_{j=1}^{p_i} \alpha_j \varepsilon_{it-j}^2 + \sum_{j=1}^{q_i} \beta_j \sigma_{it-j}^2$ (again we present the results specifying p=q=1) and R_t is defined as:

$$R_t = diag(Q_t)^{-1/2} Q_t diag(Q_t)^{-1/2} \tag{4.d}$$

$$Q_t = (1 - \lambda_1 - \lambda_2) R + \lambda_1 \tilde{\varepsilon}_{t-1} \tilde{\varepsilon}_{t-1}^{'} + \lambda_2 Q_{t-1} \tag{4.e}$$

where R_t is a matrix of time-varying conditional quasicorrelations, $\tilde{\varepsilon}_t$ is an m $\times 1$ vector of standardized residuals ($D_t^{-1/2} \varepsilon_t$) and λ_1 and λ_2 are the two parameters that determine the dynamics of conditional quasicorrelations. They are both non-negative, and they must satisfy the condition $0 \le \lambda_1 + \lambda_2 < 1$. When Q_t is stationary, the R matrix is a weighted average of the unconditional covariance matrix of the standardized residuals $\tilde{\varepsilon}_t$ and the unconditional mean of Q_t. As the two matrices are different, the R matrix is neither the unconditional correlation matrix, nor the unconditional mean of Q_t. As a consequence, the parameters in R are known as quasicorrelations (Engle 2009).

As i =1,…,9 we would ideally consider a multivariate GARCH model where m = 9. While the constant conditional correlation assumption allows to estimate large systems as it reduces the number of parameters to be estimated, several studies on crude oil returns have shown that this hypothesis is unrealistic as conditional correlations are generally found to be time varying (Lanza et al. 2006, Manera et al. 2006, Chang et al. 2009). Indeed, as will be shown in the next section, this hypothesis does not fit our data, both in energy and agricultural markets. Therefore, we present the results obtained with the dynamic conditional correlation (DCC) model, which drops the latter assumption. A minor shortcoming of this model is that the complexity involved, in terms of number of coefficients to be estimated, might imply some problems in the maximization of the likelihood function.

As a consequence, we present our results dividing the commodities into two subgroups. In the first one, labelled "fuels", we include the four energy commodities and the soybean oil: in this way, we are able to investigate possible spillovers between energy markets and a biofuel. The second one includes the five agricultural commodities: this allows to test the presence of spillovers between food commodities and a biofuel, as discussed in the literature.[13]

Several authors suggest that spillovers might be present between energy and agricultural markets as well (Mitchell 2008, Baffes 2007, 2010, Du et al. 2011, Baffes and Haniotis 2010). To test this hypothesis, we extend the second system of equations (i.e. "agricultural" commodities) by including a sixth endogenous variable. We could include returns in crude oil market to investigate if and how energy markets influence agricultural commodities. It has been highlighted however that other energy commodities are relevant in the formation of agricultural prices. For example, natural gas is the basis for nitrogen fertilizer production. As a consequence, we prefer to summarize dynamics in energy futures markets by means of a principal factor analysis. Notice that the factor is constructed using information contained in the four purely "energy" commodities, i.e. not including soybean oil. As a consequence, the latter system allows to separately consider the spillover between energy markets, a biofuel and food commodities.

5. Results

Estimation results for the univariate specification are shown in Table 3. For all the commodities, the Lagrange multiplier test for ARCH effects indicates the presence of ARCH effects in the residuals of the OLS estimate of the model. Thus, we move to a GARCH(1,1) specification. Additionally, the Ljung-Box test (not reported) on the GARCH(1,1) model shows that the residuals contain autocorrelation up to order 1. However, introducing an AR(1) term in the models eliminates autocorrelation of the residuals, as shown by the Ljung-Box test reported.

[13] Notice that we do not include corn among biofuels. Ethanol production from corn was negligible before 2002 and although it has increased in recent times, corn is still mainly devoted to human and livestock consumption (Trostle 2008).

The speculation index is negative or not significant. This result contrasts with claims that speculation has affected returns in a positive way. A negative sign implies that an increase in excess speculations corresponds to a decrease in returns.

As for the macroeconomic controls, we observe that the S&P 500 index is positive and generally significant, and that the exchange rate is negative and generally significant, suggesting that a depreciation of U.S. dollar compared to other currencies increases futures prices and is thus correlated with positive returns. As expected, the ARCH (α) and GARCH (β) terms are always statistically significant: the ARCH estimates are generally small (between 0.072 for soybean oil and 0.173 for soybeans) and the GARCH estimates are generally high and close to one (between 0.741 for heating oil and 0.892 for wheat). This indicates a near long memory process: a shock in the volatility series impacts on futures volatility over a long horizon.[14] Notice that our results are robust to alternative econometric specifications, such as GARCH-in-mean, exponential GARCH and threshold GARCH.[15]

To analyze the spillovers between different commodities and the linkages between different futures markets we move to a system where the returns are jointly estimated, allowing for conditional variances. Additionally, we can check if the speculation index of one commodity influences returns of other ones.

Starting from a GARCH(1,1)-AR(1) specification that is supported for all commodities in the univariate case, we consider a DCC multivariate GARCH. This model is preferred to the CCC specification, as the conditional correlations obtained are clearly not constant over time (more *infra*).[16] In each equation the returns of each commodity are regressed on the macroeconomics controls, on the lagged dependent variable[17] and on the lagged returns of the other commodities. Finally, we include among the regressors the own speculative index as well as the Working's T of all the other commodities, to investigate if speculation in one market is significant in other markets.

The results for the group of "fuels" commodities are presented in Tables 4.a and 4.b. Table 4.a reports the results for the mean and variance equations. Among macroeconomic variables, the S&P index is always positive and significant and the exchange rate is generally negative and significant. We observe, with the exception of gasoline and heating oil, that lagged values of the dependent variable are positive and significant, suggesting persistence in returns. Moreover, lagged returns in crude oil and natural gas positively affect returns of the other commodities. The estimates suggest

[14] As $\alpha + \beta < 1$ for all commodities, the second moment and log-moment conditions are satisfied in all markets, and this is a sufficient condition for consistency and asymptotic normality of the QMLE estimator (McAleer at al. 2007).
[15] A summary of results using alternative specifications is available in the statistical appendix.
[16] The results obtained with a CCC specification for the mean equation are very similar to the DCC ones. Therefore, they are not reported but are available in the statistical appendix.
[17] We include only one lag as the univariate case supports an AR(1) model.

that speculation is widely not significant: the Working's T index in own market is generally negative, confirming the results obtained in the univariate analysis. The ARCH (α) and GARCH (β) terms are always positive and statistically significant and their sum is smaller than one. Again, the ARCH estimates are small and the GARCH estimates are generally high, confirming the presence of a near long memory process. We estimate the models assuming a multivariate Student's T distribution for the error terms. The degrees of freedom of the distribution are estimated and reported at the bottom of Table 4.a. The DCC model reduces to the CCC if the λ parameters are both equal to zero: we test the null hypothesis that $\lambda_1 = \lambda_2 = 0$ and the test strongly rejects the null, thus supporting the dynamic specification. As concerns the time-varying conditional correlations, we find that correlations between soybean oil and the other energy commodities present high values around the year 2008, i.e. in the peak period of prices (see Figure 1).[18] Descriptive statistics on the conditional correlations are reported in Table 4.b: the highest mean value observed is between heating oil and crude oil (0.773) followed by the one between gasoline and crude oil (0.723) and between gasoline and heating oil (0.706). The lowest mean values are those related to soybean oil.[19] Besides, all the correlations vary dramatically displaying also negative values and having a large range of variation. For example, if we consider the correlation between heating oil and crude oil, a maximum value of 0.875 means that, on the corresponding week (13th week of 1998), heating oil and crude oil returns would have brought almost the same risk. On the contrary, a minimum value of -0.206 (50th week of 2000) between natural gas and crude oil means that shocks to these two commodities are not perfect substitutes in terms of risk.

Results for the "agriculture" group of commodities are reported in Tables 5.a-5.b. Among macroeconomic controls, only the S&P return and the exchange rate display significant coefficients, with the expected signs. We do not observe spillovers in the mean equation: only the own lagged return shows positive and significant coefficients. Measures of speculation are poorly significant: exclusively the Working's T indexes for corn and soybean oil are significant and negative.[20]

The conditional correlations implied by the DCC model reported in Table 5.b are generally high. Contrary to the "fuels" DCC, we do not observe marked peaks in recent times. The minimum values of the correlations are, within this group, always positive, meaning that the substitution in risk is absent in these futures markets.

Finally, we discuss the results for the extended group, which includes agricultural commodities and a factor summarizing the four energy variables, which has been obtained using the principal factor

[18] For the full set of dynamic conditional correlation plots refer to the statistical appendix.

[19] These values are on average slightly smaller than the correlations obtained in the CCC model which are reported in the statistical appendix

[20] Notice that results for this group are on a longer time span relative to the "fuels" group. Results on the same interval are unchanged and are reported in the statistical appendix.

method to analyze the correlation matrix among the returns of the four energy commodities. Results reported in Tables 6.a-6.b confirm previous evidence concerning the five agricultural commodities. However, we observe no evident spillover in the mean equation among food commodities, a biofuel and the energy factor.

The dynamic conditional correlations, reported in Table 6.b, are generally positive. Interestingly, the correlations between the energy factor and the other commodities are mainly low, with the highest value being the correlation with soybean oil (0.143). Figure 1 reports the dynamic conditional correlations, and shows that, while being on average small, the conditional correlations with the energy factor display a peak around year 2008. The descriptive statistics reported in Table 6.b show that negative values exist only when considering correlations with the energy factor: negative correlations indicate that high volatility values in the energy markets correspond to low volatility levels in the markets for agricultural commodities.

5.1 Sensitivity over time

Our sample has a long time span, so it is interesting to see if spillover effects in the volatility of commodity returns become more marked in recent years. This is shown in Table 7.a, where are reported mean tests on dynamic conditional correlations of "fuels" group. Mean values are statistically different at 1% level in the two samples. In particular, values after 2004 are higher and mean values between energy commodities and soybean oil are almost doubled in the second period. This result confirms the increasing interaction between markets, especially when biofuels are considered. Table 7.b shows that, also for the "agriculture" group, mean values have increased after 2004, but, this time, the increase is less sharp and the relationship with biofuels is less marked. Finally, Table 7.c confirms that, also in this last group, mean values of dynamic conditional correlations between agricultural commodities and the energy factor are more than doubled after 2004.

We investigate if there are changes in mean equations before and after 2004 in the results of DCC estimations.[21] As regards the "fuels" group it is relevant to notice that the influence of crude oil (with reference to its past returns and its Working's T index) on other commodities and, in particular, on soybean oil, appears to be significant only after 2004, suggesting that spillovers in the mean equation happen mostly in the last period. Interestingly, we find that the conditional correlations increase in size after 2004 and that the correlations between fuels and soybean oil become significant and positive, confirming again spillover effects in recent times. Results for the "agriculture" group do not show marked differences before and after 2004. Finally, looking at the

[21] These results, as well as those with CCC model, are reported in the statistical appendix.

“agriculture” system enriched with the energy factor, we observe that the correlations between the energy factor and the agricultural commodities and biofuel become significant only after 2004. These last results support once again the increasing interaction between different markets and are in line with similar results obtained adopting alternative econometric approaches (Natanelov et al. 2011, Ciaian and Kancs 2011, Du and McPhill 2012).

6. Conclusions

The recent spike in commodities prices in 2008 has lead to claims that prices are driven by speculators. Moreover, as the rise has affected both energy and food commodities a generalized financialization of commodities futures markets has been held responsible. Another channel for the transmission of price shocks has been alleged to be the increasing relevance of biofules, which interconnect energy and food markets. However, most of the evidence in support of these hypotheses is based on descriptive statistics.

We collect data on futures prices for four energy commodities and five agricultural commodities (including a biofuel, soybean oil) over the period 1986-2010 at weekly frequency and measure financial speculation by means of the Working’s T (1960) index. With this sample we aim at answering to four research questions. First, we look at the role of macroeconomic factors as possible drivers of returns of energy and agricultural commodities. Second, we consider whether financial speculation is significantly related to returns in futures markets. Third, we focus on the relationship among returns across different markets both with respect to the mean and the variance. Moreover, we investigate if and how speculation in one market affects returns in other markets.

Descriptive evidence shows that the Working’s T index has significantly increased after 2004 only in crude oil, natural gas and wheat futures markets. Additionally, the correlations with commodities returns are generally not significant.

The econometric exercise presents an univariate analysis where commodity returns are modelled according to a GARCH(1,1)-AR(1) term. Working’s T index is negative or not significant: a negative sign implies that an increase in excess speculation corresponds to a decrease in returns. This result contrasts with the claims in the literature that speculation has affected returns in a positive way (Eckaus 2008, Masters 2008, Soros 2008). Among macroeconomic factors, S&P500 index is positive and significant and the exchange rate is negative and generally significant, suggesting that a depreciation of U.S. dollar increases futures prices.

To analyze spillovers between commodities and different futures markets we present results from multivariate GARCH models. We group the commodities into two subgroups, “fuels” (gasoline, heating oil, natural gas, crude oil and soybean oil) and “agriculture” (corn, oats, soybeans, wheat and soybean oil). As in the univariate case, S&P500 index is always positive and significant and the exchange rate is generally negative and significant.

Thus, as concerns our first research question, some macroeconomic variables seem to significantly affect the returns in commodities futures. With respect to our second research question, estimates suggest that speculation is generally not relevant. As for the third issue, i.e. possible spillovers across commodities, both in the mean and variance equation, we observe that lagged returns of crude oil and natural gas positively affect returns of the other energy commodities. Looking at volatilities, it is interesting to note that correlations between soybean oil and the other energy commodities and those between agricultural and energy factor present higher values around 2008, i.e. in the peak period of prices. Negative correlations between agriculture commodities and the energy factor suggest that high (low) volatilities in the agricultural markets correspond to low (high) volatility in the energy market. Moreover, when we distinguish between time periods, we notice that mean values of dynamic conditional correlations always increase after 2004 and, in fuels markets, they even double. Finally, speculation in one market does not seem to significantly affect returns in other markets.

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Tables and Figures

Table 1: Summary statistics on weekly observations

	Obs	Mean	Std. Dev.	Min	Max	Unit Root Test
FUTURES PRICES						
Gasoline	1299	0.970	0.640	0.318	3.538	-0.737
Heating Oil	1279	0.960	0.689	0.302	4.039	-0.403
Natural Gas	1079	4.056	2.563	1.100	14.462	-2.098
Crude Oil	1298	34.292	24.520	11.048	142.800	-0.294
Soybean Oil	1299	0.249	0.090	0.134	0.670	0.192
Corn	1299	2.721	0.899	1.439	7.473	-0.386
Oats	1299	1.734	0.630	0.957	4.591	-1.121
Soybeans	1299	6.759	2.057	4.211	16.279	-0.647
Wheat	1299	4.033	1.494	2.376	12.682	-0.860
RETURNS						
Gasoline	1298	0.001	0.046	-0.183	0.253	-30.778***
Heating Oil	1278	0.001	0.041	-0.181	0.199	-30.293***
Natural Gas	1078	0.001	0.061	-0.215	0.255	-27.278***
Crude Oil	1297	0.001	0.043	-0.213	0.199	-31.352***
Soybean Oil	1298	0.001	0.028	-0.154	0.138	-28.171***
Corn	1298	0.001	0.031	-0.178	0.199	-29.192***
Oats	1298	0.001	0.040	-0.146	0.243	-29.659***
Soybeans	1298	0.001	0.028	-0.156	0.124	-29.086***
Wheat	1298	0.001	0.029	-0.148	0.142	-29.488***
WORKING'S T						
Gasoline	1299	1.105	0.046	1.036	1.386	-5.667***
Heating Oil	1279	1.154	0.051	1.050	1.340	-5.550***
Natural Gas	1079	1.128	0.083	1.021	1.517	-4.304***
Crude Oil	1298	1.140	0.039	1.051	1.278	-5.097***
Soybean Oil	1299	1.183	0.065	1.051	1.364	-6.806***
Corn	1299	1.250	0.047	1.146	1.401	-5.366***
Oats	1299	1.180	0.091	1.040	1.592	-5.608***
Soybeans	1299	1.268	0.068	1.113	1.492	-5.063***
Wheat	1299	1.194	0.053	1.028	1.404	-6.714***
MACROECONOMIC VARIABLES						
T-bill	1300	4.087	2.198	0.020	9.033	-0.448
Dlog(T-bill)	1299	-0.003	0.083	-0.787	0.799	-26.943***
S&P 500	1300	826.488	416.504	206.274	1559.282	-1.131
Dlog(S&P 500)	1299	0.001	0.020	-0.178	0.096	-30.260***
Junk Bond Yield	1300	0.984	0.412	0.520	3.456	-2.042
Dlog(Junk Bond Yield)	1299	-0.001	0.036	-0.170	0.381	-26.701***
Exchange Rate	1300	90.490	9.943	69.590	120.960	-2.556
Dlog(Exchange Rate)	1299	-0.001	0.008	-0.041	0.034	-27.801***

Notes: "Unit Root Test" reports the Augmented Dickey-Fuller statistics for the null hypothesis that there is a unit root in the variable. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively.

Table 2: Summary statistics on Working's T index

Commodity		Obs		Mean			Std. Dev.		Min		Max	
		1986-2003	2004-2010	1986-2003	2004-2010	t-stat	1986-2003	2004-2010	1986-2003	2004-2010	1986-2003	2004-2010
ENERGY	Gasoline	935	364	1.116	1.076	15.070***	0.049	0.020	1.036	1.042	1.386	1.155
	Heating Oil	915	364	1.161	1.136	8.189***	0.053	0.039	1.050	1.072	1.340	1.259
	Natural Gas	715	364	1.084	1.213	-35.554***	0.044	0.075	1.021	1.097	1.517	1.478
	Crude Oil	935	363	1.135	1.150	-6.004***	0.043	0.027	1.051	1.090	1.278	1.232
AGRICULTURE	Soybean Oil	935	364	1.203	1.133	19.992***	0.058	0.053	1.051	1.054	1.364	1.267
	Corn	935	364	1.262	1.219	16.148***	0.043	0.043	1.172	1.146	1.401	1.319
	Oats	935	364	1.193	1.146	8.690***	0.093	0.076	1.053	1.040	1.592	1.435
	Soybeans	935	364	1.288	1.217	19.124***	0.065	0.047	1.113	1.113	1.492	1.327
	Wheat	935	364	1.181	1.225	-14.383***	0.044	0.061	1.028	1.102	1.404	1.382

Notes: t-stat is the mean test; * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 3: Estimates of the univariate specification

		Gasoline	Heating Oil	Natural Gas	Crude Oil	Soybean Oil	Corn	Oats	Soybeans	Wheat
Mean Equation	Tbill	0.039**	0.028**	0.016	0.022	0.013	0.018*	-0.001	0.010	0.011
		(0.015)	(0.012)	(0.017)	(0.014)	(0.009)	(0.011)	(0.012)	(0.010)	(0.011)
	Junk Bond Yield	-0.050	-0.023	0.056	-0.033	-0.012	-0.011	-0.017	-0.021	-0.003
		(0.032)	(0.027)	(0.050)	(0.027)	(0.019)	(0.021)	(0.028)	(0.018)	(0.019)
	S&P 500	0.068	0.106**	0.152*	0.134***	0.103***	0.073**	0.065	0.094***	0.038
		(0.054)	(0.050)	(0.082)	(0.050)	(0.035)	(0.036)	(0.049)	(0.033)	(0.036)
	Exchange Rate	-0.347***	-0.564***	-0.135	-0.385***	-0.267***	-0.159*	-0.268**	-0.197***	-0.118
		(0.134)	(0.115)	(0.189)	(0.121)	(0.089)	(0.087)	(0.119)	(0.073)	(0.084)
	Working's T	-0.083***	-0.080***	-0.057**	0.008	-0.052***	-0.027	-0.002	-0.026**	-0.020
		(0.029)	(0.021)	(0.025)	(0.027)	(0.012)	(0.018)	(0.012)	(0.010)	(0.016)
	AR(1)	0.179***	0.161***	0.199***	0.156***	0.208***	0.201***	0.174***	0.201***	0.209***
		(0.028)	(0.030)	(0.033)	(0.029)	(0.028)	(0.028)	(0.028)	(0.030)	(0.028)
	Constant	-0.093***	0.094***	0.066**	-0.008	0.063***	0.035	0.002	0.034**	0.024
		(0.032)	(0.024)	(0.028)	(0.031)	(0.014)	(0.022)	(0.014)	(0.013)	(0.019)
Variance Equation	ARCH(1)	0.114***	0.166***	0.153***	0.130***	0.072***	0.151***	0.115***	0.173***	0.087***
		(0.025)	(0.029)	(0.037)	(0.027)	(0.019)	(0.030)	(0.032)	(0.029)	(0.018)
	GARCH(1)	0.828***	0.741***	0.765***	0.825***	0.875***	0.793***	0.766***	0.794***	0.892***
		(0.037)	(0.046)	(0.053)	(0.034)	(0.035)	(0.038)	(0.063)	(0.030)	(0.022)
	Constant	0.000***	0.000***	0.000***	0.000***	0.000**	0.000***	0.000***	0.000***	0.000**
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	LM test for ARCH	68.025***	167.973***	8.678***	56.957***	29.917***	23.701***	88.460***	30.089***	32.350***
	Ljung-Box Q test (lag 1)	2.072	0.042	0.568	0.543	0.557	0.022	0.529	0.038	0.404
	Log Likelihood	2286	2405	1560	2402	2922	2816	2442	2997	2888
	AIC	-4550	-4788	-3099	-4782	-5821	-5611	-4862	-5971	-5754
	BIC	-4493	-4732	-3044	-4725	-5764	-5554	-4805	-5914	-5698
	N. of Obs.	1298	1278	1078	1297	1298	1298	1298	1298	1298

Notes: The error distribution is a Student's T. Standard errors in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 4.a: DCC model on "fuels" group

		Gasoline	Heating Oil	Natural Gas	Crude Oil	Soybean Oil
Mean Equation	Tbill	0.038**	0.020	0.005	0.021	0.007
		(0.016)	(0.013)	(0.018)	(0.015)	(0.011)
	Junk Bond Yield	-0.037	-0.019	0.035	-0.046	-0.001
		(0.033)	(0.028)	(0.046)	(0.030)	(0.020)
	S&P 500	0.134*	0.150**	0.196**	0.141**	0.148***
		(0.069)	(0.060)	(0.089)	(0.064)	(0.042)
	Exchange Rate	-0.411***	-0.578***	-0.147	-0.555***	-0.337***
		(0.150)	(0.129)	(0.210)	(0.133)	(0.098)
	Gasoline(-1)	0.063	-0.042	-0.091	-0.022	0.034
		(0.045)	(0.037)	(0.056)	(0.038)	(0.025)
	Heating Oil(-1)	-0.116**	-0.027	-0.019	-0.064	-0.014
		(0.055)	(0.051)	(0.070)	(0.052)	(0.031)
	Natural Gas(-1)	0.042**	0.064***	0.193***	0.060***	-0.036***
		(0.020)	(0.018)	(0.034)	(0.018)	(0.012)
	Crude Oil(-1)	0.183***	0.206***	0.114*	0.192***	-0.021
		(0.057)	(0.050)	(0.067)	(0.054)	(0.031)
	Soybean Oil(-1)	-0.009	-0.048	-0.063	-0.053	0.186***
		(0.045)	(0.038)	(0.061)	(0.039)	(0.032)
	Working's T Gasoline	-0.097**	0.015	0.090	-0.055	0.006
		(0.045)	(0.038)	(0.065)	(0.038)	(0.029)
	Working's T Heating Oil	0.000	-0.062**	-0.058	-0.031	-0.029
		(0.031)	(0.027)	(0.045)	(0.027)	(0.020)
	Working's T Natural Gas	0.007	0.002	-0.051*	-0.001	-0.002
		(0.021)	(0.018)	(0.027)	(0.019)	(0.014)
	Working's T Crude Oil	-0.008	0.023	0.031	0.029	0.022
		(0.051)	(0.044)	(0.063)	(0.045)	(0.030)
	Working's T Soybean Oil	-0.016	-0.014	-0.062**	-0.010	-0.042***
		(0.019)	(0.016)	(0.028)	(0.017)	(0.011)
	Constant	0.128**	0.045	0.064	0.078	0.054*
		(0.056)	(0.048)	(0.076)	(0.050)	(0.033)
Variance Equation	ARCH(1)	0.091***	0.093***	0.145***	0.105***	0.154***
		(0.021)	(0.017)	(0.032)	(0.016)	(0.047)
	GARCH(1)	0.828***	0.850***	0.760***	0.844***	0.696***
		(0.042)	(0.028)	(0.044)	(0.020)	(0.108)
	Constant	0.000***	0.000***	0.000***	0.000***	0.000**
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	F-stat on Working's T	13.770**	8.790	8.630	10.310*	18.910***
	Log Likelihood			11136		
	AIC			-22067		
	BIC			-21554		
	Degree of Freedom			9.724***		
				(1.065)		
	Lambda 1			0.050***		
				(0.009)		
	Lambda 2			0.816***		
				(0.038)		
	Test for Lambda 1 = Lambda 2 = 0 (Chi2(2))			1400.520***		
	N. of Obs.	1076	1076	1076	1076	1076

Notes: The error distribution is a multivariate Student's T. Standard errors in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 4.b: Descriptive statistics of dynamic conditional correlations on "fuels" group

Returns	N. of Obs.	Mean	Std. Dev.	Min	Max	Skew.	Kurt.
Gasoline, Heating Oil	1076	0.706	0.064	0.100	0.852	-2.256	16.889
Gasoline, Natural Gas	1076	0.219	0.084	-0.199	0.568	-0.341	4.721
Gasoline, Crude Oil	1076	0.723	0.059	0.102	0.855	-3.086	25.343
Gasoline, Soybean Oil	1076	0.130	0.089	-0.112	0.490	0.533	4.279
Heating Oil, Natural Gas	1076	0.330	0.075	0.047	0.574	-0.267	3.317
Heating Oil, Crude Oil	1076	0.773	0.059	0.108	0.875	-4.115	35.206
Heating Oil, Soybean Oil	1076	0.164	0.097	-0.136	0.466	0.296	3.523
Natural Gas, Crude Oil	1076	0.219	0.082	-0.206	0.430	-0.832	5.120
Natural Gas, Soybean Oil	1076	0.129	0.076	-0.090	0.419	0.287	3.203
Crude Oil, Soybean Oil	1076	0.126	0.094	-0.146	0.519	0.478	4.175

Table 5.a: DCC model on “agriculture” group

		Corn	Oats	Soybeans	Wheat	Soybean Oil
Mean Equation	Tbill	0.014	-0.003	0.017	0.013	0.016
		(0.012)	(0.014)	(0.011)	(0.011)	(0.011)
	Junk Bond Yield	-0.010	-0.024	-0.017	-0.011	-0.024
		(0.018)	(0.025)	(0.015)	(0.017)	(0.019)
	S&P 500	0.068*	0.076	0.088***	0.038	0.091**
		(0.036)	(0.049)	(0.031)	(0.034)	(0.036)
	Exchange Rate	-0.129	-0.175	-0.156**	-0.144*	-0.258***
		(0.083)	(0.120)	(0.071)	(0.081)	(0.086)
	Corn(-1)	0.170***	-0.032	0.026	-0.031	0.037
		(0.037)	(0.047)	(0.029)	(0.033)	(0.032)
	Oats(-1)	0.022	0.189***	0.016	0.025	-0.003
		(0.021)	(0.032)	(0.017)	(0.019)	(0.020)
	Soybeans(-1)	-0.051	-0.010	0.135***	-0.015	-0.038
		(0.041)	(0.055)	(0.038)	(0.038)	(0.039)
	Wheat(-1)	-0.014	0.036	-0.024	0.175***	0.008
		(0.029)	(0.040)	(0.024)	(0.031)	(0.027)
	Soybean Oil(-1)	0.024	-0.019	0.020	0.032	0.193***
		(0.035)	(0.050)	(0.030)	(0.033)	(0.035)
	Working's T Corn	-0.020	-0.047**	-0.000	-0.039***	0.007
		(0.016)	(0.022)	(0.013)	(0.015)	(0.015)
	Working's T Oats	0.002	0.011	0.003	-0.004	-0.001
		(0.008)	(0.010)	(0.006)	(0.007)	(0.007)
	Working's T Soybeans	0.004	-0.002	-0.006	0.004	-0.008
		(0.012)	(0.017)	(0.010)	(0.011)	(0.011)
	Working's T Wheat	-0.007	0.006	0.002	-0.010	0.000
		(0.013)	(0.018)	(0.012)	(0.013)	(0.013)
	Working's T Soybean Oil	-0.012	0.003	-0.028***	0.012	-0.030***
		(0.013)	(0.017)	(0.011)	(0.013)	(0.012)
	Constant	0.040	0.037	0.036	0.045*	0.039
		(0.026)	(0.035)	(0.022)	(0.025)	(0.024)
Variance Equation	ARCH(1)	0.109***	0.096***	0.124***	0.088***	0.054***
		(0.020)	(0.024)	(0.017)	(0.021)	(0.012)
	GARCH(1)	0.831***	0.781***	0.846***	0.882***	0.909***
		(0.029)	(0.060)	(0.019)	(0.029)	(0.022)
	Constant	0.000***	0.000***	0.000***	0.000**	0.000***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	F-stat on Working's T	3.320	6.170	11.360**	9.100	11.340**
	Log Likelihood			15274		
	AIC			-30342		
	BIC			-29810		
	Degree of Freedom			7.715***		
				(0.669)		
	Lambda 1			0.022***		
				(0.006)		
	Lambda 2			0.928***		
				(0.025)		
	Test for Lambda 1 = Lambda 2 = 0 (Chi2(2))			5267.510***		
	N. of Obs.	1297	1297	1297	1297	1297

Notes: The error distribution is a multivariate Student’s T. Standard errors in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 5.b: Descriptive statistics of dynamic conditional correlations on "agriculture" group

Returns	N. of Obs.	Mean	Std. Dev.	Min	Max	Skew.	Kurt.
Corn, Oats	1297	0.481	0.077	0.025	0.647	-1.465	6.377
Corn, Soybeans	1297	0.607	0.069	0.031	0.733	-2.925	20.214
Corn, Wheat	1297	0.510	0.075	0.026	0.677	-1.672	8.814
Corn, Soybean Oil	1297	0.485	0.068	0.025	0.636	-1.305	8.234
Oats, Soybeans	1297	0.377	0.070	0.019	0.583	-0.527	4.830
Oats, Wheat	1297	0.355	0.070	0.018	0.599	-0.405	3.815
Oats, Soybean Oil	1297	0.342	0.067	0.018	0.564	-0.368	4.573
Soybeans, Wheat	1297	0.341	0.076	0.018	0.518	-0.833	4.050
Soybeans, Soybean Oil	1297	0.687	0.069	0.035	0.811	-3.906	29.986
Wheat, Soybean Oil	1297	0.284	0.069	0.015	0.457	-0.584	3.730

Table 6.a: DCC model on "agriculture + factor of energy variables" group

		Corn	Oats	Soybeans	Wheat	Soybean Oil	Energy factor
Mean Equation	Tbill	0.013	-0.007	0.015	0.013	0.012	0.786**
		(0.012)	(0.014)	(0.011)	(0.011)	(0.010)	(0.332)
	Junk Bond Yield	0.006	-0.017	-0.012	-0.005	-0.017	-0.775
		(0.020)	(0.029)	(0.017)	(0.020)	(0.020)	(0.666)
	S&P 500	0.105**	0.071	0.125***	0.028	0.138***	3.676**
		(0.044)	(0.058)	(0.038)	(0.045)	(0.041)	(1.428)
	Exchange Rate	-0.188*	-0.206	-0.193**	-0.275***	-0.276***	-12.973***
		(0.096)	(0.137)	(0.082)	(0.104)	(0.095)	(3.038)
	Corn(-1)	0.165***	-0.046	0.039	0.023	0.036	0.480
		(0.041)	(0.052)	(0.034)	(0.041)	(0.034)	(1.093)
	Oats(-1)	-0.004	0.172***	0.000	-0.001	-0.009	-0.287
		(0.024)	(0.036)	(0.020)	(0.024)	(0.022)	(0.721)
	Soybeans(-1)	-0.039	0.000	0.125***	-0.035	-0.029	1.441
		(0.046)	(0.059)	(0.043)	(0.046)	(0.041)	(1.362)
	Wheat(-1)	-0.003	0.039	-0.015	0.171***	0.014	1.491*
		(0.031)	(0.042)	(0.026)	(0.036)	(0.028)	(0.886)
	Soybean Oil(-1)	0.004	-0.013	0.022	0.009	0.180***	-3.017**
		(0.040)	(0.055)	(0.035)	(0.041)	(0.039)	(1.287)
	Energy factor(-1)	-0.001	-0.000	0.000	-0.001*	-0.000	0.174***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.031)
	Working's T Corn	-0.018	-0.051**	0.004	-0.035*	0.007	-1.278**
		(0.018)	(0.024)	(0.015)	(0.018)	(0.017)	(0.540)
	Working's T Oats	-0.002	0.026	-0.006	-0.004	-0.006	0.494
		(0.012)	(0.016)	(0.011)	(0.013)	(0.012)	(0.372)
	Working's T Soybeans	-0.005	0.005	-0.020	0.008	-0.014	-0.171
		(0.015)	(0.022)	(0.013)	(0.016)	(0.014)	(0.480)
	Working's T Wheat	-0.022	-0.010	0.011	-0.019	0.006	0.381
		(0.017)	(0.023)	(0.014)	(0.017)	(0.015)	(0.490)
	Working's T Soybean Oil	-0.010	0.003	-0.029**	0.007	-0.032***	-0.035
		(0.014)	(0.019)	(0.012)	(0.014)	(0.012)	(0.428)
	Working's T Gasoline	0.005	0.019	0.017	0.048	-0.013	-0.690
		(0.027)	(0.040)	(0.023)	(0.030)	(0.028)	(0.897)
	Working's T Heating Oil	0.016	-0.001	0.002	-0.025	-0.007	-0.994
		(0.021)	(0.029)	(0.018)	(0.023)	(0.020)	(0.652)
	Working's T Natural Gas	0.024	0.015	-0.002	0.014	-0.009	-0.567
		(0.016)	(0.021)	(0.013)	(0.016)	(0.015)	(0.474)
	Working's T Crude Oil	-0.039	-0.035	-0.018	-0.039	0.014	0.739
		(0.031)	(0.045)	(0.026)	(0.032)	(0.030)	(1.045)
	Constant	0.061	0.039	0.052	0.059	0.065	2.542*
		(0.046)	(0.058)	(0.038)	(0.045)	(0.041)	(1.412)
Variance Equation	ARCH(1)	0.104***	0.075***	0.115***	0.089***	0.050***	0.144***
		(0.020)	(0.024)	(0.017)	(0.024)	(0.014)	(0.032)
	GARCH(1)	0.840***	0.826***	0.849***	0.861***	0.906***	0.805***
		(0.031)	(0.062)	(0.020)	(0.043)	(0.027)	(0.042)
	Constant	0.000***	0.000**	0.000***	0.000**	0.000**	0.050***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.019)
	F-stat on Working's T	9.180	8.170	14.450	11.390	14.790*	17.760**
	Log Likelihood			11330			
	AIC			-22347			
	BIC			-21570			
	Degree of Freedom			9.671***			
				(0.961)			
	Lambda 1			0.016***			
				(0.004)			
	Lambda 2			0.952***			
				(0.013)			
	Test for Lambda 1 = Lambda 2 = 0 (Chi2(2))			13481.110***			
	N. of Obs.	1076	1076	1076	1076	1076	1076

Notes: The error distribution is a multivariate Student's T. Standard errors in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 6.b: Descriptive statistics for dynamic conditional correlations on "agriculture + factor of energy variables" group

Returns	N. of Obs.	Mean	Std. Dev.	Min	Max	Skew.	Kurt.
Corn, Oats	1076	0.488	0.073	0.016	0.605	-2.218	10.706
Corn, Soybeans	1076	0.592	0.075	0.019	0.703	-3.233	19.297
Corn, Wheat	1076	0.514	0.080	0.017	0.665	-2.102	11.044
Corn, Soybean Oil	1076	0.464	0.068	0.015	0.592	-1.909	10.613
Corn, Energy factor	1076	0.060	0.062	-0.057	0.306	1.063	4.500
Oats, Soybeans	1076	0.345	0.060	0.011	0.539	-0.676	5.206
Oats, Wheat	1076	0.357	0.067	0.012	0.496	-0.990	5.836
Oats, Soybean Oil	1076	0.318	0.055	0.010	0.522	-0.454	5.572
Oats, Energy factor	1076	0.072	0.060	-0.111	0.248	0.188	3.007
Soybeans, Wheat	1076	0.329	0.070	0.011	0.477	-0.916	4.410
Soybeans, Soybean Oil	1076	0.680	0.081	0.022	0.798	-3.657	23.293
Soybeans, Energy factor	1076	0.119	0.068	-0.026	0.380	0.977	4.372
Wheat, Soybean Oil	1076	0.284	0.064	0.010	0.447	-0.555	4.163
Wheat, Energy factor	1076	0.091	0.052	-0.056	0.239	0.298	2.506
Soybean Oil, Energy factor	1076	0.143	0.083	-0.024	0.435	1.138	4.114

Table 7.a: Mean tests on dynamic conditional correlations of "fuels" group

Returns	Obs.		Mean		t-stat
	Before 2004	After 2004	Before 2004	After 2004	
Gasoline, Heating Oil	713	363	0.692	0.733	-10.340***
Gasoline, Natural Gas	713	363	0.203	0.250	-8.946***
Gasoline, Crude Oil	713	363	0.717	0.733	-4.290***
Gasoline, Soybean Oil	713	363	0.104	0.182	-15.046***
Heating Oil, Natural Gas	713	363	0.320	0.350	-6.355***
Heating Oil, Crude Oil	713	363	0.767	0.786	-5.262***
Heating Oil, Soybean Oil	713	363	0.134	0.223	-15.924***
Natural Gas, Crude Oil	713	363	0.211	0.236	-4.678***
Natural Gas, Soybean Oil	713	363	0.115	0.157	-8.784***
Crude Oil, Soybean Oil	713	363	0.097	0.183	-15.981***

Notes: * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 7.b: Mean tests on dynamic conditional correlations of “agriculture” group

Returns	Obs.		Mean		t-stat
	Before 2004	After 2004	Before 2004	After 2004	
Corn, Oats	933	364	0.476	0.493	-3.646***
Corn, Soybeans	933	364	0.609	0.604	0.982
Corn, Wheat	933	364	0.504	0.526	-4.660***
Corn, Soybean Oil	933	364	0.481	0.495	-3.381***
Oats, Soybeans	933	364	0.377	0.378	-0.122
Oats, Wheat	933	364	0.347	0.377	-7.029***
Oats, Soybean Oil	933	364	0.334	0.362	-7.037***
Soybeans, Wheat	933	364	0.340	0.343	-0.539
Soybeans, Soybean Oil	933	364	0.678	0.711	-7.761***
Wheat, Soybean Oil	933	364	0.277	0.302	-5.863***

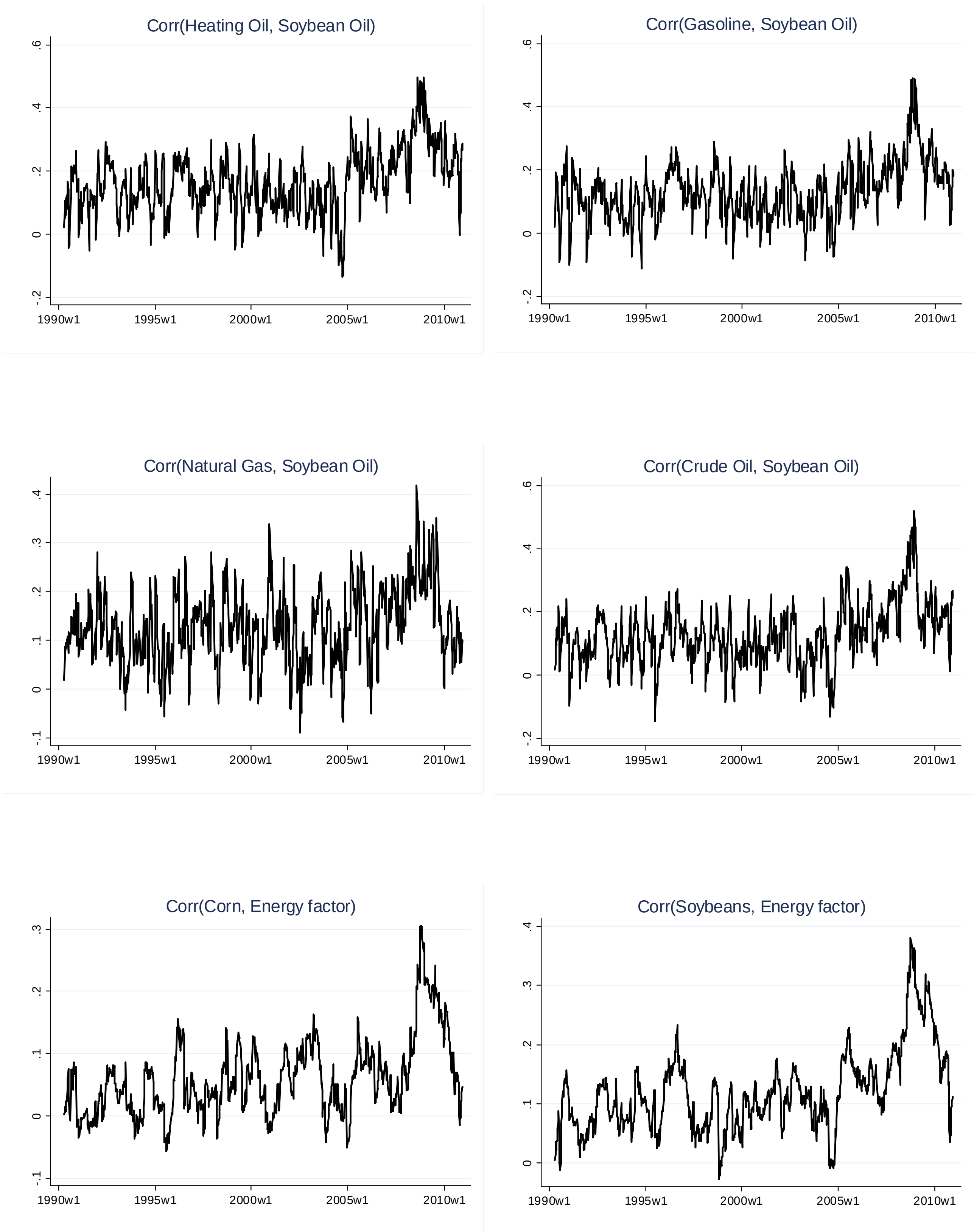
Notes: * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

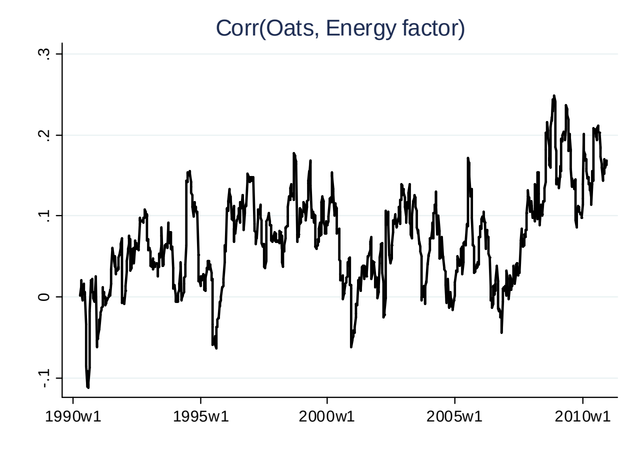
Table 7.c: Mean tests on dynamic conditional correlations of “agriculture + factor of energy variables” group

Returns	Obs.		Mean		t-stat
	Before 2004	After 2004	Before 2004	After 2004	
Corn, Oats	713	363	0.482	0.499	-3.748***
Corn, Soybeans	713	363	0.591	0.594	-0.568
Corn, Wheat	713	363	0.506	0.530	-4.739***
Corn, Soybean Oil	713	363	0.455	0.480	-5.716***
Corn, Energy factor	713	363	0.043	0.092	-13.260***
Oats, Soybeans	713	363	0.341	0.352	-3.099***
Oats, Wheat	713	363	0.344	0.382	-9.207***
Oats, Soybean Oil	713	363	0.305	0.343	-11.055***
Oats, Energy factor	713	363	0.059	0.096	-9.869***
Soybeans, Wheat	713	363	0.326	0.335	-1.868*
Soybeans, Soybean Oil	713	363	0.667	0.708	-8.377***
Soybeans, Energy factor	713	363	0.093	0.170	-20.795***
Wheat, Soybean Oil	713	363	0.274	0.304	-7.442***
Wheat, Energy factor	713	363	0.082	0.110	-8.477***
Soybean Oil, Energy factor	713	363	0.104	0.218	-27.458***

Notes: * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Figure 1: Selected dynamic conditional correlations graphs

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.1
.2
.3
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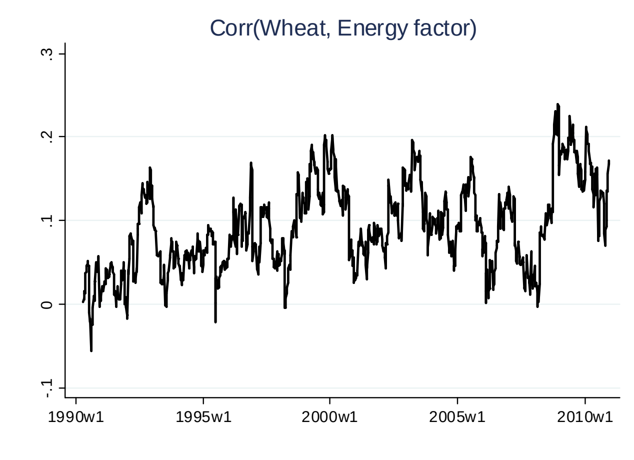
1995w1
2000w1
2005w1
2010w1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.1
.2
.3
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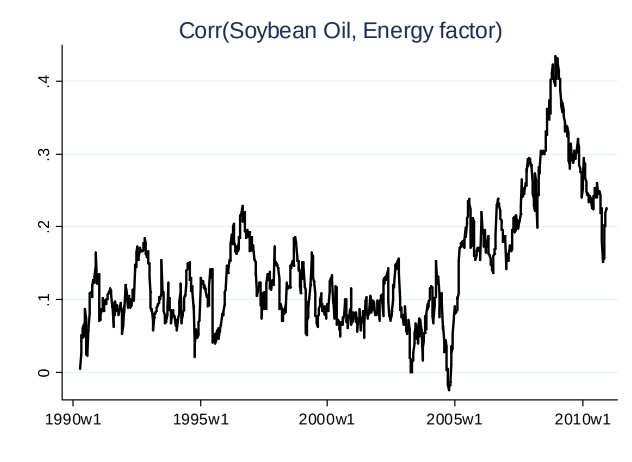
1995w1
2000w1
2005w1
2010w1


Corr(Soybean Oil, Energy factor)
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.1
.2
.3
.4
1990w1
1995w1
2000w1
2005w1
2010w1