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Efficiency and unbiasedness of corn futures markets:

New evidence across the financial crisis*

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Abstract

Recent years witnessed commodity prices increases which have fostered research-works on their predictability and a renewed interest of practitioners and policy makers. The objective of this paper is to test the predictive ability of futures prices on the underlying spot prices by taking corn, which is one of the most important agricultural commodities in terms of trading volumes and for its role in the dietary regime of many countries. We consider the corn futures on the CBOT in the period May 1998-December 2011 so as to extend previous studies on this market and to assess a possible effect of the financial crisis. Our results do not emphasize a role for the latter and, although we do not find evidence of efficiency and unbiasedness, the futures corn price turns out to be the best predictor of the spot price if compared with most used alternatives.

Keywords: futures prices, corn futures, efficiency, unbiasedness

JEL Codes: C53, G13, Q14

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1. Introduction

Recent years have witnessed a revival of the debate on the generalized increase of commodity prices and their volatility.[1] The increase in the world population can be considered as partly responsible for this, because it implies an increase in the demand of raw materials, especially the agricultural ones. Moreover, some situations of political instability and adverse weather conditions (e.g. Russia and Ukraine in 2010, USA and Mexico in 2011) have contributed to the phenomenon together with the increased production of biofuel.

However, taking into account the relationship between the spot and futures prices of the commodities another determinant has been underscored, i.e. the increasing number of non-commercial investors, such as financial funds, who are active in futures on commodity that until the early 2000s were considered just consumption and not investment goods. These new market participants are motivated by the possibility to diversify their portfolio risk due to the low correlation between commodity and stock prices and by the possibility to hedge inflation risk. As a consequence, monthly trading volumes and open interests triplicated during the period 2005-2008 for all agricultural futures (Robles *et al.* (2009) and CME Group, 2012). The increasing influence of non-commercial operators may thus imply a progressive separation between the price formation mechanism and the productive system.

The dynamics of commodity prices is particularly relevant if we think of their relationship with macroeconomic fluctuations (notable examples are the oil price shocks in the 70s). Hence the possibility to predict future spot prices has always interested researchers, practitioners and policy makers. If the existence of

[1] A parallel renewed interest on commodity futures pricing is also present in the literature (e.g. Realdon, 2012).

commodity futures markets on one hand has been sometimes accused of being destabilizing for the spot market prices, on the other it allows to exploit the relationship between the two prices for predictive purposes (see Torricelli (1989, 1994) for a discussion of these issues).

The objective of this paper is to test the predictive ability of futures prices on the underlying spot prices. To this end we take the market for corn, since corn is one of the most important agricultural commodities both in terms of trading volumes and for the importance in the dietary regime of many countries. We consider the period May 1998-December 2011 so as to extend Mc Kenzie and Holten (2002) and to assess a possible effect of the latter financial crisis.

The paper is organized as follows. In the next Section we recall the testing approach and the results of the literature on the predictive content of futures prices as for agricultural commodities. In Section 3 we illustrate the dataset and provide descriptive statistics on the corn spot and futures markets. In Section 4 we present the result of our analyses of efficiency and unbiasedness of futures prices, while in Section 5 we assess the possible impact of the recent financial crisis. In Section 6 we implement the in and out of sample analysis. After comparing our results with the literature in Section 7, in the last Section we provide concluding comments.

2. Efficiency and unbiasedness of futures prices: the literature on agricultural commodities

The literature on the issue is very vast and conclusions are disparate. First of all it is important to underscore that the concept of efficiency and unbiasedness of futures prices are empirically difficult to distinguish because theoretically intertwined. In fact, market efficiency implies that futures prices equal expected future spot prices plus or minus a (constant or time-varying) risk premium, whereas futures prices are said to be unbiased predictors of future spot prices only if markets are efficient and there is no risk premium. In other words, testing for unbiasedness of futures prices is equivalent to testing the joint hypothesis of efficiency and risk neutrality. Formally, it follows that unbiasedness requires testing the joint hypothesis of $\alpha = 0$ and $\beta = 1$ in the following regression:

$$S_t - S_{t-k} = \alpha + \beta(F_{t-k} - S_{t-k}) + \varepsilon_t \quad (1)$$

where

S_t is the spot price at time t

S_{t-k} is the spot price at time $t - k$

F_{t-k} is the futures price

ε_t is the error term.

As stressed by McKenzie and Holt (2002), testing the joint hypothesis does not allow to distinguish between the two concepts and rejection of the joint null may be due to market inefficiency ($\beta \neq 1$), or to a constant risk premium even in the presence of market efficiency ($\alpha \neq 0$ and $\beta = 1$) or to a time-varying risk premium that prevents unbiasedness of futures prices.

Moreover, it has to be taken into account that markets may be efficient and unbiased in the long run, but they may present inefficincies and pricing biases in the short run. To account for this, two different types of econometric analyses are performed in the literature, i.e. the cointegration analysis in Equation (2) and the Error Correction Model (ECM) in Equation (3):

$$u_t = S_t - \alpha - \delta F_{t-1} \tag{2}$$

$$\Delta S_t = -\rho u_{t-1} + \beta \Delta F_{t-1} + \sum_{i=2}^{m} \beta_i \Delta F_{t-i} + \sum_{j=1}^{k} \psi_j \Delta S_{t-j} + v_t \tag{3}$$

where

u_t stationary

u_{t-1} is the error correction term at time $t-1$

α and δ are the cointegration terms

$\Delta S_t = S_t - S_{t-1}$

$\Delta F_{t-1} = F_{t-1} - F_{t-2}$

v_t is a white noise.

To test the short run efficiency Mc Kenzie and Holt (2001) implement the ECM in (3) also with a GQARCH thus obtaining the following GQARCH-M-ECM:

$$\Delta S_t = -\rho u_{t-1} + \beta \Delta F_{t-1} + \sum_{i=2}^{m} \beta_i \Delta F_{t-i} + \sum_{j=1}^{k} \psi_j \Delta S_{t-j} + \theta\sqrt{h_t} + v_t \tag{4a}$$

$$v_t = e_t\sqrt{h_t}\ ;\ e_t \sim IN(0,1) \tag{4b}$$

$$h_t = w + \sum_{i=2}^{r} \gamma_i h_{t-i} + \sum_{j=1}^{s} a_{jj} \mathrm{v}_{t-j}^2 + \sum_{j=1}^{s} a_j \mathrm{v}_{t-j} + \sum_{j \neq k}^{s} a_{jk} \mathrm{v}_{t-j} \mathrm{v}_{t-k} \tag{4c}$$

Where h_t is the conditional variance of the spot price.

Table 1 sums up main results in the literature on agricultural futures and highlights different testing approaches and different conclusions obtained also according to the specific market under investigation. These differences can be explained resting on the different trading volumes, since the market is likely to be inefficient if there are only a few operators and arbitrage conditions are more likely to remain unexploited. Chinn and Coibion (2010) show in fact an inverse correlation between market depth and unbiasedness of futures prices.

TABLE 1: The efficiency of agricultural futures market: the literature

PAPER	PERIOD	MARKET	METHOD	EFFICIENCY
Chinn and Coibion (2010)	1/1999-10/2009	**Corn CME**	Simple Regression	**NO**
Chinn and Coibion (2010)	1/1999-10/2009	**Corn CME**	GARCH	**NO**
McKenzie and Holt (2002)	9/1959-10/2000	**Corn CBOT**	Cointegration	**YES**
McKenzie and Holt (2002)	9/1959-10/2000	**Corn CBOT**	ECM	**NO**
McKenzie and Holt (2002)	9/1959-10/2000	**Corn CBOT**	GQARCH-M-ECM	**NO**
Beck (1994)	1966-1986	**Corn CBOT**	ECM	**YES**
Chinn and Coibion (2010)	1/1999-10/2009	**Soybean CME**	Simple Regression	**YES**
Chinn and Coibion (2010)	1/1999-10/2009	**Soybean CME**	GARCH	**NO**
Kellard *et al.* (1999)	12/1979-11/1996	**Soybean CBOT**	ECM	**YES**
McKenzie and Holt (2002)	9/1959-10/2000	**Soy meal CBOT**	Cointegration	**YES**
McKenzie and Holt (2002)	9/1959-10/2000	**Soy meal CBOT**	ECM	**NO**
McKenzie and	9/1959-	**Soy meal**	GQARCH-M-	**YES**

Holt (2002)	10/2000	**CBOT**	ECM	
Chinn and Coibion (2010)	1/1999-10/2009	**Wheat CME**	Simple Regration	**NO**
Chinn and Coibion (2010)	1/1999-10/2009	**Wheat CME**	GARCH	**NO**
McKenzie and Holt (2002)	9/1966-10/2000	**Hogs CME**	Cointegration	**YES**
McKenzie and Holt (2002)	9/1966-10/2000	**Hogs CME**	ECM	**NO**
McKenzie and Holt (2002)	9/1966-10/2000	**Hogs CME**	GQARCH-M-ECM	**YES**
Kellard *et al.* (1999)	5/1982-10/1996	**Hogs CME**	Cointegration	**NO**
Kellard *et al.* (1999)	5/1982-10/1996	**Hogs CME**	ECM	**NO**
McKenzie and Holt (2002)	9/1965-10/2000	**Live cattle CME**	Cointegration	**YES**
McKenzie and Holt (2002)	9/1965-10/2000	**Live cattle CME**	ECM	**NO**
McKenzie and Holt (2002)	9/1965-10/2000	**Live cattle CME**	GQARCH-M-ECM	**NO**
Kellard *et al.* (1999)	5/1982-10/1996	**Live cattle CME**	Cointegration	**YES**
Kellard *et al.* (1999)	5/1982-10/1996	**Live cattle CME**	ECM	**NO**

3. The Dataset

3.1 The construction of the dataset

To the end of the present analysis we consider the futures contracts traded on Chicago Board of Trade (CBOT), which is well known for its activity in grain futures markets including corn.[2] Futures settlement prices are downloaded from Datastream, which provide price series as from May 1998. The time span considered is thus May 1998-December 2011 so as to include the recent financial crises.

As for spot prices, since there is rarely a full overlapping between the futures specifics and the underlying, we have estimated them in line with the literature as the mean of futures prices in the maturity month.[3] Corn futures on the CBOT have a bimonthly maturity but for the end-of-the year maturity as shown in Table 2.

TABLE 2: Expiration months of the corn futures contracts

Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
		✓		✓		✓		✓			✓

Source: CBOT website

In order to avoid overlapping of the observations and the resulting autocorrelation of residuals, we have taken a two-month forecast horizon and then used the futures price two month before the contract maturity. This choice, together with the different length of the end-of-year contract, creates a displacement issue for spot and futures price of the end-of-year maturity. To make this clearer, let us develop the Error Correction Model (ECM) in Equation (3):

$$(S_t - S_{t-1}) = -\rho(S_{t-1} - F_{t-2}) + \beta(F_{t-1} - F_{t-2}) + \cdots$$

and consider it for the months creating the issue:

$$(S_{12} - S_{09}) = -\rho(S_{09} - F_{07}) + \beta(F_{10} - F_{07}) + \cdots \quad (5.a)$$

$$(S_{03} - S_{12}) = -\rho(S_{12} - F_{10}) + \beta(F_{01} - F_{10}) + \cdots \quad (5.b)$$

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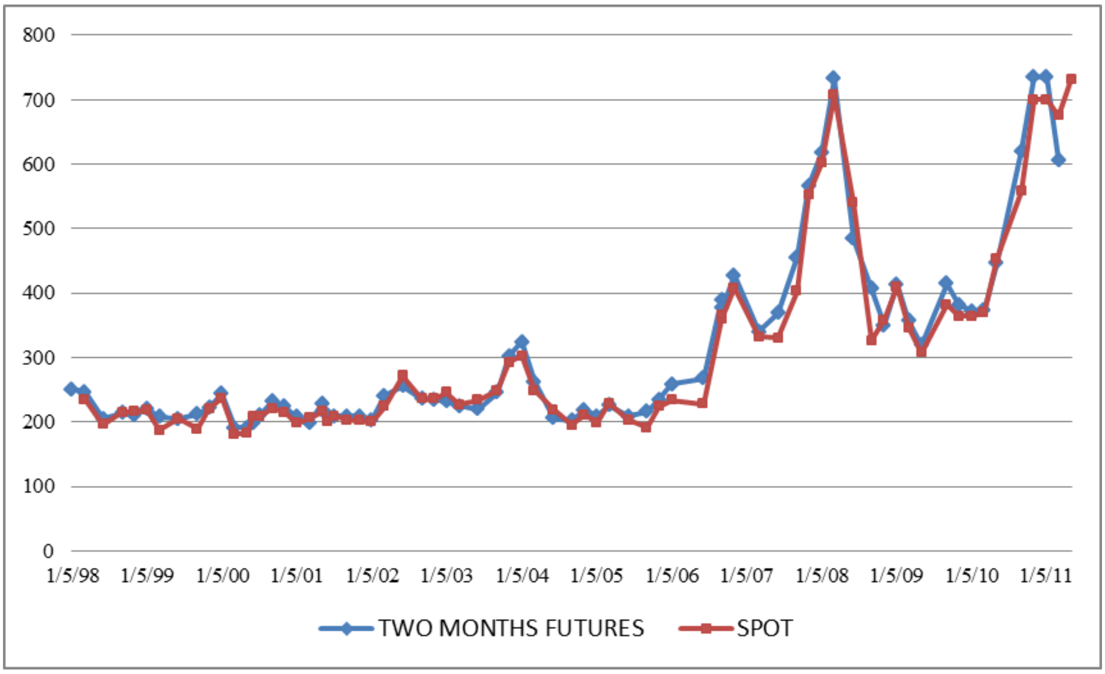
[2] The CBOT merged with the Chicago Mercantile Exchange (CME) in 2007.

[3] In fact the theory shows that $S_T = F_{T,T}$ and commodity futures have a 15-day time span for delivery.

Bold terms in (5.a) e (5.b) highlight the need for tackling the issue. We do it by taking the following assumption: October spot prices are taken to be equal to the September ones and January spot prices are taken to be equal to the December ones.

3.2 Descriptive analyses

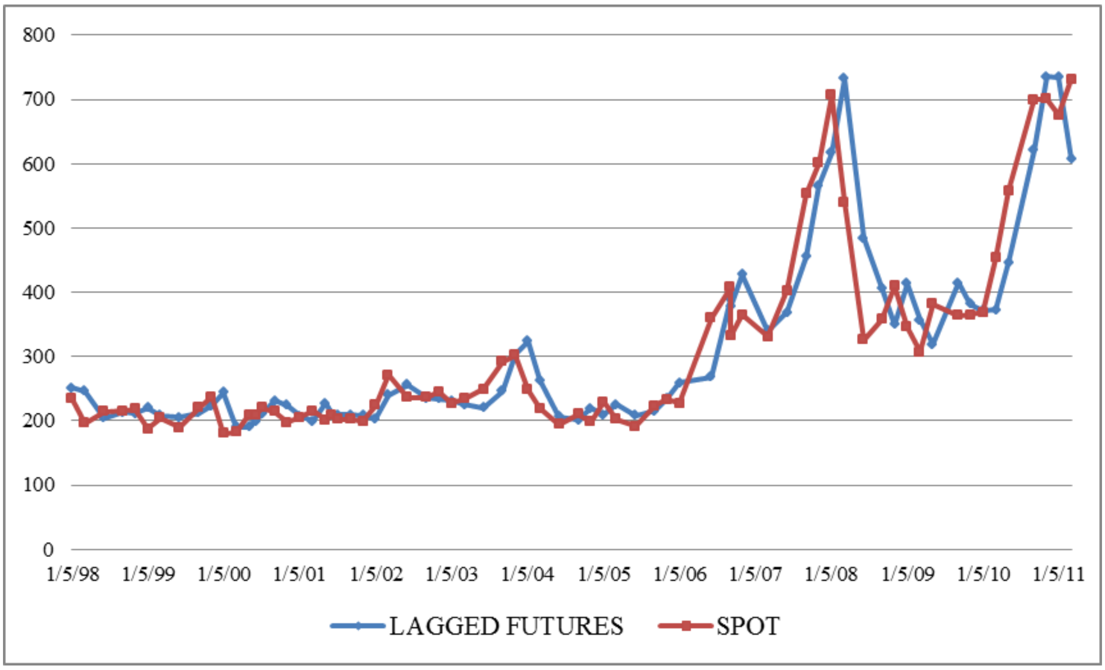
The dynamics of futures and spot prices reported in Graph 1 shows a similar pattern of the two series. Moreover it highlights that, after a period of relatively stable prices (1998-2006), both show an increased and higher volatility with a first peak in July 2008 (706.5 and 732 cents/$ per bushel for the spot and futures price respectively), a second peak for futures in March (735 cents/$ per bushel) and a final peak in September 2011 for the spot price only (731 cents/$ per bushel). The financial crisis thus seems to have played a role in determining the price level, the volatilities and the similarity of the patterns of the two series, whereby differences between them are more apparent form 2006 onwards.



GRAPH 1: Trend of two months futures price and spot price (in cents/$ per bushel)

Since we finally aim at detecting the predictive content of futures price, in Graph 2 we plot the spot prices and the one-period lagged futures prices. Although the dynamics are similar, there is a difference between the lagged futures prices and the spot ones that the former should in theory predict.

Given that 2006 seems to mark a break, we split the sample and calculate summary statistics over the whole sample, before and after the crisis (Table 3). From an average futures price of about 225 cents/$ per bushel in the pre-crisis period, the same increases by nearly 40% to 310 cents/$ per bushel. The same holds true for spot prices. To be noted that on average futures prices are higher than spot prices. As for standard deviations, they signal a much higher volatility in the post-crisis period (5 times higher than in the pre-crisis period)

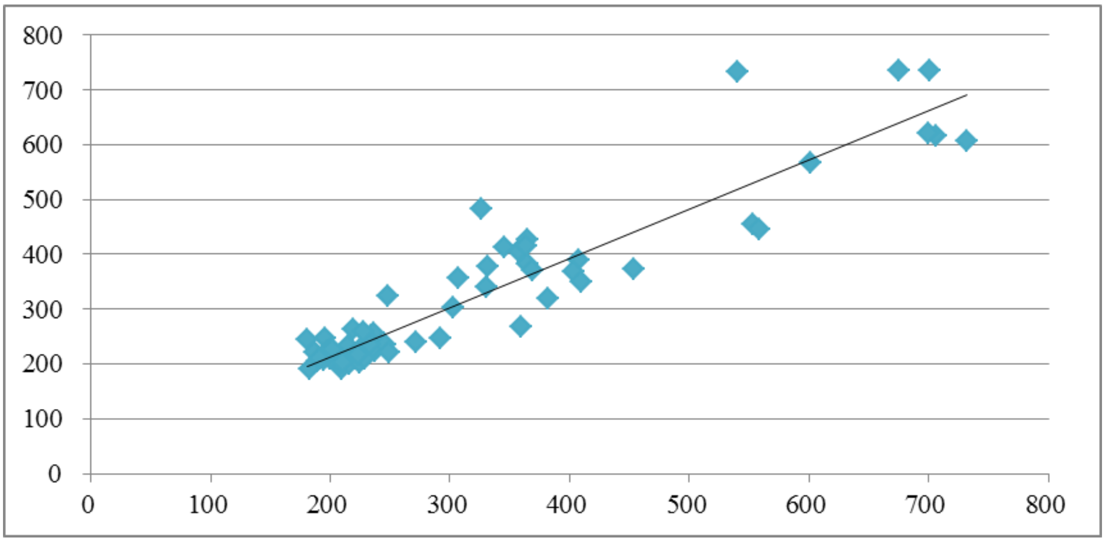


GRAPH 2: Trend of two months futures price lagged for one period and spot price (in cents/$ per bushel)

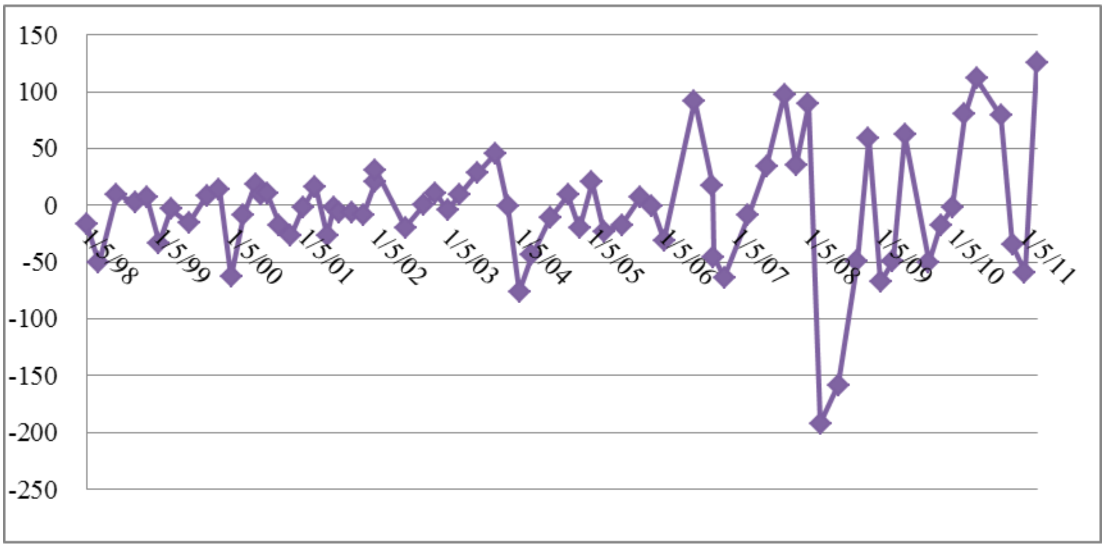
TABLE 3: Means and standard deviations of corn prices in different sub periods

	FUTURES	**SPOT**
Mean (1998-2011)	309.70	307.24
Mean pre-crisis (1998-2006)	224.88	219.19
Mean post-crisis (2007-2011)	470.48	465.73
Std.dev (1998-2011)	141.94	147.66
Std.dev pre-crisis (1998-2006)	26.93	25.75
Std.dev post-crisis (2007-2011)	134.07	144.11

Although the relationship between the spot and futures time series is apparent, we have additionally implemented two graphs. The scatter plot in Graph 3 confirms a significant relationship between the spot price and the lagged futures one. When we look at the plot of $(Spot_t - Futures_{t-1})$ in Graph 4, it appears to be likely stationary, given a tendency to mean reverte around zero. We will investigate the stationarity in connection with the analyses performed in the next Section.



GRAPH 3: Scatter plot of spot prices and futures prices lagged for one period



GRAPH 4: Difference between spot prices and futures prices lagged for one period

4 Tests of efficiency and unbiasedness

In this Section, in line with Mc Kenzie and Holten (2002), we present the results on the efficiency and the unbiasedness of the corn futures market separating the long run analysis, based on cointegration, from the short run one, based on an ECM. Recalling that cointegration is a necessary condition for market efficiency and unbiasedness of the futures price, we start with it.

4.1 Cointegration analysis

In order to check for cointegration[4] of the spot and futures prices, we implement Johansen test to estimate the following equation:

$$S_t = \alpha + \delta F_{t-1} + u_t \quad (6)$$

Table 4 reports results, which are obtained considering two lags both for spot prices at time t and futures prices at time t-1, and considering a constant in the cointegration relation[5].

TABLE 4: Johansen test

Rank	Eigenvalue	Trace test	P-value	Max test	P-value
r = 0	0.86622	136.12	[0.0000]	134.77	[0.0000]
r = 1	0.019963	1.3511	[0.8864]	1.3511	[0.8855]

The trace and the maximal eigenvalue test together prove that there is a cointegration vector, i.e. the linear combination is I(0).

We can now estimate the cointegration parameters. To this end, we estimate the following VAR:

$$\Pi = \alpha\beta' \quad (7)$$

---

[4] In all the analyses we take prices in logarithm (multiplied by 100). Preliminary to the cointegration test we have verified by means of the ADF test that the two series are both cointegrated of order 1. Results are available upon request.

[5] In order to choose for the optimal number of lag, we have implemented the Akaike Information Criterion (AIC) and obtained 2 as the optimal lag (results are available upon request). As for a discussion of the constant issue in the cointegration test, See Johansen (1991).

where:

α is the weight matrix

β is the matrix of the cointegration vector.

Table 5 reports results for α and β, also normalized with the spot price.

TABLE 5: Estimates of cointegrating vector and adjustment coefficients

	Spot(t)	**Futures(t-1)**	**Constant**
β	-0.078476	0.076860	0.67985
β **normalized**	1.0000	-0.97940	-8.6631
α	3.1206	-11.751	
α **normalized**	-0.24489	0.92219	

Hence the cointegration relation is:

$$S_t = 8{,}6631 + 0{,}97940 F_{t-1} + u_t$$

Since the Johansen test proves the existence of a significant relationship between spot and futures prices, we cannot reject market efficiency in the long run.

In order to check for unbiasedness of the futures price as a predictor of the spot one, we recall that it requires the absence of the risk premium and that the predictor perfectly predicts the spot price. Thus we impose the following linear constraints to Equation (6):

$$\alpha = 0 \text{ and } \delta = 1 \tag{8}$$

TABLE 6: Restrictions imposed on the cointegrating terms

Restrictions	Test statistic	P-value
$\alpha = 0$	0.684271	0.40812
$\delta = 1$	1.21974	0.269411
$\delta = 1$; $\alpha = 0$	18.9311	7.74752e-005

Notes: Statistics are likelihood ratios distributed as a χ^2 with two degree of freedom.

Table 6 reports results on these restrictions tested separately and jointly. The null $\alpha = 0$ cannot be rejected and hence we can discard the possibility of a constant positive risk-premium. As for the null $\delta = 1$, although it is accepted, the very low p-value for the joint hypothesis of $\delta = 1$ and $\alpha = 0$ implies rejection of unbiasedness of the futures price. Hence, the rejection of the unbiasedness can be attributed either to market inefficiency or to a time varying positive risk premium that hinders the possibility of predicting the future spot price.

4.2 Error correction model (ECM)

Cointegration is a necessary but not sufficient condition for market efficiency and unbiasedness of the futures price. To go deeper into the issue, and because of the non-stationarity of spot and futures price, we implement the ECM to evaluate the short-run market efficiency. Recalling the Equation (3):

$$\Delta S_t = -\rho u_{t-1} + \beta \Delta F_{t-1} + \sum_{i=2}^{m} \beta_i \Delta F_{t-i} + \sum_{j=1}^{k} \psi_j \Delta S_{t-j} + v_t$$

This model was estimated with one lag of ΔS_{t-1} and ΔF_{t-1} according to the optimal lag length provided by AIC (two and hence one in first-differences). The results, presented in Table 7, indicate that the coefficient ρ is not significant in contrast with cointegration assessment. Since also β is not significant, the change in the futures price is not associated with the change in the spot price, a result which is contrary to the hypothesis of market efficiency.

TABLE 7: ECM estimation

	Coefficients	**Test statistic**	**p-value**
u_{t-1}	-0.276555 (0.3727)	-0.7419	0.4608
ΔF_{t-1}	0.0211184 (0,3754)	0.05626	0.9553
ΔS_{t-1}	0.424036 (0.3378)	1.255	0.2139
Std. dev	14.5839		
Log likelihood	-276.3716		
AIC	558.7431		
Durbin-Watson	1.9477		

Given the results discussed above, it seems unnecessary to impose linear constraints to Equation (3) to test the efficiency and the unbiasedness constraints. However, for the sake of completeness, Table 8, we report results of the restrictions for short-run market efficiency and unbiasedness, which are respectively given by constraint (9) and (10) to the ECM:

$$\rho = 1, \rho\delta = \beta \neq 0, \text{ e } \beta_i = \psi_j = 0 \quad (9)$$

$$\rho = 1, \beta = 1, \text{ e } \beta_i = \psi_j = 0 \quad (10)$$

TABLE 8: Test of efficiency and unbiasedness

Restrictions	Test statistic	p-value
$\rho = 1, \rho\delta = \beta \neq 0,$ $\beta_i = \psi_j = 0$	125.157	5.91813e-027
$\rho = 1, \beta = 1,$ $\beta_i = \psi_j = 0$	127.157	3.81662e-027

Notes: Wald test is used to estimate the restrictions

The p-values indicate the impossibility to state that the market is efficient and that the futures price is a good predictor of expected spot price. Thus, at this stage of the analysis, we can say that unbiasedness is caused market inefficiency (vs. a time varying risk premium).

To test the robustness of our results, we have enforced tests on residuals. Specifically, we have implemented the White test for the heteroscedasticity, the Breusch-Godfrey test for the autocorrelation in the error and the ARCH test (see Table 9).

TABLE 9: Tests on the ECM residuals

Test	Test statistic	p-value
White test	20.4146	0.00887632
Breusch-Godfrey test	0.603429	0.72646
ARCH test	2.15869	0.90454

Notes: Autocorrelation and ARCH test are tested until the six lag

With regard to the presence of autocorrelation and ARCH effects on residuals, both hypotheses are widely rejected. Since we observe heteroscedasticity in residual, as the White test highlights, we re-estimate the ECM using weighted least squares so as to weight the observations with the inverse of the conditional variance square root of the error v_t.

TABLE 10: ECM estimation using weighted least squares

	Coefficient	**Test statistic**	**p-value**
u_{t-1}	-0.791361** (0.3148)	-2.513	0.0145
ΔF_{t-1}	0.763758* (0.4231)	1.805	0.0757
ΔS_{t-1}	0.580783* (0.3218)	1.805	0.0757
Std. dev	9.9565		
Log-likelihood	-251.2329		
AIC	508.4658		
Durbin-Watson	1.6126		

**,* indicate, respectively, a significance of 5% and 10%

Table 10 shows that the results of the new estimates reverse conclusions of the previous OLS model. In fact, we find that all the coefficients are significant, which proves a short-run cointegration relationship exists.

Therefore we have to reconsider the problem of efficiency and unbiasedness by imposing once again the restrictions, as reported in Table 11.

TABLE 11: Test of efficiency and unbiasedness

Restrictions	Test statistic	p-value
$\boldsymbol{\rho = 1}$	0.439038	0.50993
$\boldsymbol{\rho = 1}$, $\boldsymbol{\rho\delta = \beta \neq 0}$, $\boldsymbol{\beta_i = \psi_j = 0}$	46.0608	4.42638e-016
$\boldsymbol{\rho = 1}$, $\boldsymbol{\beta = 1}$, $\boldsymbol{\beta_i = \psi_j = 0}$	7.09441	0.000338923

Also in this case, even if $\boldsymbol{\rho}$ is significant, we cannot accept the further restrictions needed to demonstrate the corn futures efficiency. In particular the change in the spot price contributes to the forecast of expected spot price, which goes against the market efficiency and futures price unbiasedness.

To sum up, even taking into account the effect of heteroscedasticity, the latter results confirms market inefficiency. Some caution in the interpretation of our results is in order due to the limited number of data, which can decrease the reliability of asymptotic tests, and to the problems in the observations frequency (see discussion of eq. (5a,b)).

5. The financial crisis and futures market efficiency

In the descriptive analyses in Section 3.2 we have underscored a possible effect of the latter financial crisis on market dynamics and efficiency, which appear to be higher in the pre-crisis period. By inspection of Graph 1, a structural break appear to have happened. In order to test for it, we have the Quandt Likelihood Ratio (QLR) statistics over both series (with two lags).

TABLE 12: QLR test

	SPOT	FUTURES
Date (with F test max)	01:2006	01:2006
F test	1.86089	0.832752
Critical value 10%	4.09	4.09

Results of the QLR test in Table 12 do not confirm the presence of a structural break. However, to account for a possible effects of the crisis which corresponded to a period of higher volatility we have performed our analyses again over the sub period 1998-2006. To be noted that the sample reduce to 46 observation per series, an instance that has to be seriously considered in the interpretation of the results.

TABLE 13: Johansen test, period 1998-2006

Rank	Eigenvalue	Trace test	P-value	Max test	P-value
r = 0	0.83918	82.311	[0.0000]	78.581	[0.0000]
r = 1	0.083088	3.7300	[0.4656]	3.7300	[0.4646]

Cointegration analyses is performed as in Section 4.1 [6]. Results in Table 13 highlight the existence of a cointegration vector (see also Table 14) thus confirming cointegration as in the case of the whole sample. As for unbiasedness, the analyses based on restrictions (9) and (10) provide the results (reported in Table 15) which reaffirm the absence of a constant risk premium.

[6] Preliminary to the cointegration analysis we have performed stationarity analysis obtaining the same results (available upon request) as for the whole sample.

TABLE 14: Estimates of cointegrating vector and adjustment coefficients

	Spot(t)	**Futures(t-1)**	**Constant**
β	-0.092961	0.10252	-5.3813
β **normalized**	1.0000	-1.1028	57.887
α	1.6973	-8.8149	
α **normalized**	-0.15779	0.81945	

TABLE 15: Restrictions imposed on the cointegrating terms

Restrictions	**Test statistic**	**P-value**
$\alpha = 0$	1.15889	0.281696
$\delta = 1$	1.06662	0.301709
$\delta = 1\ ; \alpha = 0$	10.1833	0.006148

As for futures prices, the constraints $\delta = 1\ ; \alpha = 0$ are rejected but the p-value amount to 0.006 only. Thus rejection of the unbiasedness is not so clearcut in the pre-crises subperiod. This induces to think that the financial crisis has influenced market efficiency.

Results in Table 16, reporting the ECM, point to reject market efficiency and the futures price unbiasedness in line with the conclusions obtained for the whole sample.

Concluding, the inefficiency results obtained also for the more stable period 1998-2006 tend to exclude that the financial crisis played a role in determining inefficiency.

TABLE 16: ECM, period 1998-2006

	Coefficient	**Test statistic**	**p-value**
u_{t-1}	-0.108122 (0.401281)	-0.2694	0.7889
ΔF_{t-1}	-0.0632194 (0.447057)	-0.1414	0.8882
ΔS_{t-1}	-0,0551455 (0,417510)	-0.1321	0.8956
Std. dev	12.22571		
Log-likelihood	-171.4825		
AIC	348.9650		
Durbin-Watson	1.662202		

6. In and out of sample analyses

The aim of this paragraph is to compare the forecast performance of the futures prices with three possible alternatives: the random walk, in which the forecast is equal to the current spot price plus a normally distributed white noise, the ECM and the ECM-WLS.

First of all we split the sample into two: in-sample (1998:05-2004:12) and out-of-sample (2005:01-2011:12), so that the rolling analysis can be implemented.

We evaluate the forecast performance by calculating the mean square error (MSE) and the root mean square error (RMSE) defined, respectively, as (11) and (12):

$$MSE = E\left[\left(S_T - \hat{S}_{T|t}\right)^2\right] \quad (11)$$

$$RMSE = \sqrt{E\left[\left(S_T - \hat{S}_{T|t}\right)^2\right]} \quad (12)$$

In order to sharpen the analysis, we have calculated a third parameter, called relative MSE, in which the forecast performance of futures prices are compared with the alternatives mentioned above. The relative MSE is defined as follows:

$$Relative\ MSE = \frac{MSE_x}{MSE_{futures}} \quad (13)$$

where

MSE_x is the MSE of the alternative x

$MSE_{futures}$ is the MSE of futures price

Thus, for the futures price this index is one by definition, for the alternatives if the index is greater (smaller) than one, the futures prices is a better (worse) forecast of the expected spot price.

TABLE 17: Forecast performance

	MSE	**RMSE**	**Relative MSE**
FUTURES	4982.59	70.59	1.00
RANDOM WALK	6012.80	77.54	1.206
ECM	6015.298	77.56	1.207
ECM-WLS	6239.53	78.99	1.252

Table 17 shows the results. The futures prices always provide better forecasts than the other methods, whereby the ECM-WLS is the worst, the random walk and the ECM results are almost equivalent. Although being the best alternative, futures prices have a high RMSE thus confirming the inefficiency of the market. Moreover, it is interesting to note the difference between ECM-WLS and ECM in terms of the MSE. Indeed, though the fitting of the ECM-WLS model is greater than the ECM (see log likelihood in Table 7 and 10), the forecast performance of the latter model is better.

7. A comparison with the literature

In conclusion we aim to assess the consistency of our results with those presented earlier with special reference to the corn market. Specifically, three are the main reference papers: Chinn and Coibion (2010), Beck (1994) and McKenzie and Holt (2002). Table 18 compares the results of these analyses with ours.

TABLE 18: Comparison of main results on the corn market

	Chinn and Coibion (2010)	**Beck (1994)**	**McKenzie and Holt (2002)**	**Our analysis**
Method	OLS e GARCH	ECM	ECM e ARCH(1)-ECM	ECM
Market	CME	CBOT	CBOT	CBOT
Period	1990-2009	1966-1986	1959-1995	1998-2011
Efficiency (forecast horizon)	**NO**(3 months) **NO**(6 months)	**YES**(2 months) **NO**(6 months)	**NO**(2 months)	**NO**(2 months)

Chinn and Coibion (2010), based on the assumption of stationarity of the price series, have used different econometric techniques and hence their analyses are not directly comparable. However they also conclude about the corn market inefficiency on both horizons considered.

Beck (1994) and McKenzie and Holt (2002) are more directly comparable since they perform cointegration analyses. Beck (1994) considers both a 6- and a 2-month forecast horizon and obtains long run inefficiency results. However, when implementing ECM he finds unbiasedness of the futures price over the 2-month horizon, but not over the over the 6-month one. McKenzie and Holt (2002), who consider only the two month forecast horizon, find long run market efficiency and unbiasedness but reject it for the short run .

The partial differences between our results and the cited literature may mainly stem for the different time period considered, that corresponds to quite different market conditions. In fact we consider a more recent period, which does not overlap with those of the other research-work and is quite distant with respect to Beck(1994). To go deeper into this, in Table 19 we compare the ECM parameters that turn out to be significant in the Beck (1994), McKenzie and Holt (2002) and our analysis.

TABLE 19: ECM estimates: a comparison

	Constant	**Error correction term**	ΔF_{t-1}	ΔS_{t-1}
Beck (1994)	-0.03	-1.06	1.22	-
McKenzie and Holt (2002)	-	-1.16	1.29	-
Our analysis	-	-0.79	0.76	0.58

Beside the significance of the change in the spot price, our coefficients are quite lower than in the other two papers implying a much lower impact on the spot price of changes in the futures price or in the long run equilibrium

As for the in and out of sample analyses, we can compare results with Reeve and Vigfusson (2011), Chinn and Coibion (2010) e McKenzie and Holt (2002). Reeve and Vigfusson (2011) confront the predictive ability of the futures price to that of the random walk with and without drift. They conclude that the futures price outperforms both alternatives on each horizon considered (3 month and one year). The same is true for Chinn and Coibion (2010) who take into consideration also an ARIMA model that is not capable however of outperforming the futures price. By contrast, McKenzie and Holt (2002) compare futures with ECM and ARCH(1)-ECM, whereby the latter prove to be the best alternative.

8. Conclusions

In this paper we tested the predictive ability of futures prices on the underlying spot prices in the market for corn, taken not only for its relevant trading volumes but also for its importance in the dietary regime of many countries. We considered the period May 1998-December 2011 so as to extend previous studies on this market and to be able to assess a possible effect of the latter financial crisis.

Cointegration analysis provides two main conclusions. Johansen test proves the existence of a significant relationship between spot and futures prices so that we cannot reject market efficiency in the long run. However, when we test restrictions to check for unbiasedness, we obtain a rejection of the unbiasedness that can be attributed either to market inefficiency or to a time varying positive risk premium that hinders the possibility of predicting the future spot price. To go deeper into the issue, based on the non-stationarity of spot and futures price, we implement the ECM to evaluate the short-run market efficiency, accounting also for heteroschadsticity of residuals. Our results indicate that the market is not efficient and the futures is a biased estimator of the spot price. We can thus conclude that unbiasedness is caused market inefficiency (vs. a time varying risk premium). We also check for a role of the latter financial crisis in determining a decreased in efficiency, but we do not find significant results.

Most interestingly, even if corn futures prices emerge from our results as biased predictors of spot prices, our forecast analyses proves that they outperform other possible alternatives, i.e. the random walk, the ECM and the ECM-WLS, which is of great interest not only to researchers, but also to practitioners and policy makers.

Finally, we believe that our results may contribute to the debate on the financialization process taking place in commodity markets (e.g. Irwin et al., 2009), since commodity futures have emerged as a popular asset class for many financial institutions. We plan to explore these connections in the future.

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