

PRICE UNCERTAINTY AND OPTIMAL HEDGING IN THE AGRICULTURAL MARKET

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Abstract

The increased volatility of the agricultural prices has detrimental effects on the economic welfare and raises concerns regarding poverty and malnutrition at a global level. Financial risk management can be an efficient solution for limiting the effects of international agricultural price volatility. The paper analyzes the behavior of the U.S. wheat and corn prices, emphasizing their highly volatile and unpredictable nature. Given the existence of the basis risk, the estimation of the optimal hedge ratio is needed in order to provide an efficient hedging strategy against price risks. The role of public authorities in this context can consist in promoting education in the fields of hedging and understanding the agricultural price volatility risk. We estimate static and time varying optimal hedge ratios for wheat and corn through several methods. Based on the out of sample hedging effectiveness given by the variance reduction, the methods are compared and the results show that the time varying hedge ratios estimated through rolling window OLS and GARCH methods outperform the static counterparts.

Keywords: price uncertainty, hedging, agricultural commodity prices, futures price, volatility.

1. Introduction

The high volatility that characterized the agricultural commodity prices starting with the beginning of 2008 caused concerns regarding poverty and malnutrition at a global level. After the sharp increase in prices, in the second part of 2008 the prices retreated significantly as a result of better weather conditions, but factors like biofuel demand, population and income growth continue to pressure for increased levels in prices and volatility. Also, the volatility has important consequences on resources allocation and general welfare. Resulting in an increased risk associated to the economic environment, the volatility may cause a reduced level of participation in certain economic activities and will affect the level of investment.

Lampietti *et al.* (2011) proposed different strategies that could reduce the vulnerability to the agricultural price shocks: the strengthening of safety nets, the improvement of access to family planning services, promoting education, investments in research to increase productivity, the reduction of exposure to market volatility through more efficient supply chains and better use of financial instruments for hedging. Given their importance, all the above measures could be implemented or promoted by the administrative authorities.

Galtier (2013) shows that price instability can be managed through two non-exclusive approaches: by reducing it or by buffering its effects. Each of these two approaches can be implemented either through public intervention or market-based strategies. In this case, there can be identified four 'pure' strategies to manage price instability. The first strategy consists in stabilizing prices through market-based actions. In this case, through trade is facilitated the compensation of surpluses and deficits between regions or countries and through storage between different time periods. The second strategy consists in reducing the effects of price instability through market-based actions and is based on hedging the financial risks caused by market fluctuations. Thus, this strategy relies on futures markets and on instruments such as futures contracts or options that allow the hedger to receive financial compensation in the case of a price surge or drop. The third strategy regards stabilizing prices through public intervention in order to hold the price between a floor and a ceiling by regulating the quantity available on the market. The goals of this strategy can be achieved by regulating exports and imports through different taxes or subsidies or by using public buffer stocks. The fourth strategy consists in reducing the effects of price instability by means of public intervention and is based on resources transferred to vulnerable households in order to help them maintain their consumption level in case of shocks. These instruments can be split into emergency aids and structural safety nets.

Dethier and Effenberger (2012) noticed that trade and market interventions to stabilize agricultural prices had limited success or failed. Even in the case when these unilateral interventions of the public authorities succeeded in stabilizing domestic prices, they had the effect of increasing the volatility of international prices, and that led to vicious circles of similar responses by authorities of other countries. The same authors emphasized that price transmission from international to domestic markets

varies across countries and commodities, while trade restrictions and other policy interventions lead to imperfect price transmission. In order to stabilize domestic prices, countries made use of market interventions for limiting price transmission from international markets. As an example, international commodity agreements were very common in the 1970s. These agreements were setting price-bands supported by stocks that were released when prices hit the higher bound of the range or accumulated when prices were near the floor and they soon failed. Wright (2009) shows that prices tend to be either at the floor or at the ceiling of the defined range, an event that is in contrast to the goal of stabilizing prices around the middle of the band. Srinivasan and Jha (2001) estimated that buffer stocks in the wheat market lead to higher volatility than would in the case of liberalized trade for India. Thus, the efficiency of using buffer stocks to manage agricultural price volatility is limited.

In these conditions financial risk management can be an efficient solution for limiting the effects of international agricultural price volatility on domestic prices. The role of public authorities in this context can be mainly to promote education in the fields of hedging and understanding the agricultural price volatility risk. Also, another role of the public authorities can consist in promoting the development of domestic futures markets in order to increase the hedging efficiency. A domestic futures market, with underlyings that are close to the specifications of the physical traded agricultural goods in the country allows for a higher correlation between spot and futures prices and thus to a higher hedging efficiency.

The easiest way to hedge price risk is through futures contracts for the linearity of the payoff. The naive recommendation is to hedge on the futures market an equal quantity with the physical exposure. If the spot and futures prices would move exactly in the same direction and with the same magnitude, the changes in the spot price would be perfectly offset by the changes in the futures price and the naive one to one hedge ratio would eliminate the price risk. But the spot and futures prices are not perfectly correlated, causing therefore the basis risk. In this case, it is needed to estimate the optimal hedge ratio that minimizes the risk of the hedged position.

Our paper analyzes the behavior of wheat and corn U.S. prices for a period of 15 years. The futures prices are for the contracts traded on the Chicago Board of Trade exchange, the world largest exchange for agricultural products. The market was chosen for its importance at the global level. After discussing the volatile behavior of agricultural prices, the static and time varying optimal hedge ratios are estimated through several methods. Based on the out of sample hedging effectiveness given by the variance reduction, the methods are compared. The results show that the agricultural prices are highly volatile and unpredictable. Also, the time varying hedge ratios, estimated through rolling window OLS and GARCH methods outperform the static counterparts. The objectives of the paper are twofold: firstly, it highlights the volatile nature of agricultural prices for a better understanding of the risk and as a motive for hedging and, secondly, it presents different methods to estimate the optimal hedge ratio in order to achieve a higher hedging efficiency. These objectives can be seen in

the context of the public authorities' role in promoting education in the fields of hedging and understanding the agricultural price volatility risk.

The paper is organized as follows: the second section presents the main findings regarding the relationship between volatility, welfare and investments, regarding the estimation of the optimal hedge ratio and briefly presents the agricultural policies of the European Union. The third part discusses the methodology and the models used for the optimal hedge ratio estimation. Next are presented the results of the analysis, while the last section concludes.

2. Literature review

The negative impact of price volatility on growth and poverty was analyzed by Ramey and Ramey (1995) and Rodrick (1999), the authors showing that the most detrimental effects are on emergent states. The empirical studies that analyze the relationship between uncertainty and the level of investment show mixed results. Carruth, Dickerson and Henley (2000) emphasize that some researchers signaled a strong and negative correlation between uncertainty and investment, while others concluded that there is no significant relationship among the two variables. For example, in the first category are the studies of Huizinga (1993), Ghosal and Lougani (1996) and Guiso and Parigi (1999), while in the second category we can find the studies conducted by Campa and Goldberg (1995) and Leahy and Whited (1996).

Based on a study of Japanese firms, Ogawa and Suzuki (2000) analyzed the impact of industry uncertainty on investment decisions and found that the two mentioned variables are negatively correlated. Also, Bulan (2005) analyzed the relationship between the price volatility of stocks and the level of investments in U.S. firms and concluded that they are strongly and negatively correlated. Elder and Serletis (2009) found a negative correlation between the volatility in oil prices and the level of investments in Canada. Elder and Serletis (2010) found the same result for the U.S. market, showing also the economic activity has an exacerbated response to the negative oil price shocks, while the response to a positive shock is dampened. Yoon and Ratti (2011) suggest that the stability in energy prices conducts to a greater stability in firm-level investment.

In order to protect against the price volatility an efficient hedging is needed. The optimal hedge ratio (OHR) is derived by maximizing the utility or by minimizing a certain risk measure. Cecchetti, Cumby and Figlewski (1988) and Bessembinder and Lemmon (2002) used different utility functions of return and risk in order to estimate the OHR. Lence (1995; 1996) had a focus on the agricultural market in deriving the utility maximizing hedge ratio. The models that derive the OHR by minimizing the variance are easy to estimate and, therefore, their use is extensive in the literature. Ederington (1979) estimated the OHR using the ordinary least squares (OLS) regression. The static hedge ratios can also be derived by other methods, such as the error-correction model (Chou, Fan and Lee, 1996) or the auto-regressive distributed lag (ARDL) model, introduced by Chen, Lee and Shrestha (2004).

Other authors estimate time varying hedge ratios. Kroner and Sultan (1993) proposed the generalized autoregressive conditional heteroscedasticity (GARCH) models to estimate the OHR and this method gained popularity among researchers. The hedge ratios are easier to be estimated through rolling window OLS (RW OLS) techniques and provide good results in terms of hedging effectiveness. Lien, Tse and Tsui (2002) found that a constant correlation GARCH model does not provide an improvement of the effectiveness compared to the RW OLS. Bystrom (2003), in a study focused on the electricity market, showed that the static OLS hedge ratio can perform better than the RW OLS or the GARCH time varying ratios. Moon, Yu and Hong (2009) found a better performance of the RW OLS on the Korean stock market. Other studies combine GARCH techniques with regime switching models. For example, Lee and Yoder (2007) applied a Markov regime switching model to estimate time varying hedge ratios for the corn and nickel markets. The same method was used by Alizadeh, Nomikos and Pouliasis (2008) for the crude oil market. Kostika and Markellos (2013) proposed the autoregressive conditional density (ARCD) model for the OHR estimation. Alizadeh, Nomikos and Pouliasis (2008) also studied the relationship between the time varying OHR and the basis. They found that there is a positive relationship between the OHR volatility and the magnitude of the basis.

The Common Agricultural Policy (CAP), introduced in 1962 and revised several times after, represents the agricultural policy of the European Union and it implements a system of agricultural subsidies and other programs. The general objectives of the CAP are set in the Treaty establishing the European Economic Community (Treaty of Rome), article 33. These objectives are:

- to increase agricultural productivity by promoting technical progress and by ensuring the rational development of agricultural production and the optimum utilization of the factors of production, in particular labor;
- to ensure a fair standard of living for the agricultural community, in particular by increasing the individual earnings of persons engaged in agriculture;
- to stabilize markets;
- to assure the availability of supplies;
- to ensure that supplies reach consumers at reasonable prices.

The CAP evolved through several reforms. For example, the reform in 2003 introduced the Single Payment Scheme. Also, the intervention mechanisms diminished significantly. As an example, the Commission intervenes only on wheat, butter and skimmed milk powder.

3. Methodology and econometric models

The first step of the analysis consists in examining the evolution of the wheat and corn prices for the observed period. The database used is represented by the weekly spot and futures prices of wheat and corn, traded at the Chicago Board of Trade (CBOT) exchange during the period between 05.11.1997 – 31.10.2012 (15 years and 783 weekly observations). The day of the week for the price is Wednesday and if

Wednesday was not a business day, then the next good business day was taken into consideration. The spot price is represented by the No. 2 Soft Red Winter wheat price for wheat and by the No. 2 Yellow corn price for corn. For the futures prices it is considered the nearby contract, with rollover at the beginning of the expiration month in order to avoid the effects of the low liquidity before the contract expires. Also, the prices are expressed in USD/bushel.

Initially, the descriptive statistics of the weekly prices and relative variations (spot and futures) are given: mean, median, maximum, minimum, skewness, kurtosis, standard deviation and the annualized volatility. For simplifying reasons, we will refer to the relative variations in prices as weekly returns. In order to compute the annualized volatility, the following formula was applied:

$$Volatility = \sigma_r \sqrt{52} \quad (1)$$

where σ_r is the standard deviation of the weekly returns and 52 represents the number of weeks in a year.

The use of non-stationary data in the regressions can lead to spurious results (Cotter and Hanly, 2006). In order to test the stationarity of the time series, the Augmented Dickey-Fuller (ADF) unit root test was applied. Also, for testing the cointegration between the spot and futures prices, the Johansen cointegration test was considered. As Juhl, Kawaller and Koch (2012) show, the proper specification of the model used to estimate the optimal hedge ratio depends on the involved time series characteristics.

The weekly returns are computed as the difference between the price logarithms of two consecutive weeks:

$$r_{X_t} = \log(X_t) - \log(X_{t-1}) \quad (2)$$

where X represents the spot or the futures price.

A scatter chart between the actual and the lagged value of the return was plotted in order to evaluate if there is a relationship between the two variables, as a test for the price evolution predictability. Also, an auto-regressive model with one lag AR(1) was applied for this purpose. The AR(1) has the following form:

$$r_{S_t} = \rho \cdot r_{S_{t-1}} + \varepsilon_t \quad (3)$$

If the AR(1) would be validated, there would be a relationship between the actual and lagged returns and the evolution of the price could be predicted based on past information. The invalidation of the AR(1) model would lead to the conclusion of price evolution unpredictability.

In order to emphasize the volatile behavior of the wheat and corn spot price evolution, we estimated and plotted the conditional standard deviation using a GARCH (1,1) model having the following form:

$$r_{S_t} = c + \varepsilon_t \quad (4)$$

$$\sigma_t^2 = \omega + a\varepsilon_{t-1}^2 + b\sigma_{t-1}^2 \quad (5)$$

where σ_t^2 is the conditional variance at time t and ε_t is the error term from the mean equation.

The conditional standard deviation is given by the square root of the conditional variance and it is a proxy for the spot price volatility at different moments in time.

In order to highlight the basis risk that a hedger is exposed to, the basis between the futures and spot price is computed, together with its statistics for wheat and corn. The value of the basis is represented by the difference between the logarithms of the futures and spot prices:

$$Basis_t = \log(F_t) - \log(S_t) \quad (6)$$

The basis risk is the reason to estimate the optimal hedge ratio (OHR). The OHR can be static or time varying. We estimate the static OHR by three methods (OLS, ECM and ARDL) and the time varying OHR by two methods (RW OLS and bivariate GARCH).

The static OLS OHR is given by the following regression:

$$r_{S_t} = \alpha + h_{OLS} r_{F_t} + e_t \quad (7)$$

where h_{OLS} is the estimation of the OHR using the OLS method and e_t is the error term.

The long-run relationship between the spot and futures prices in the ECM is given by the following equation:

$$\log(S_t) = a + b \log(F_t) + \varepsilon_t \quad (8)$$

The static ECM OHR is given by the following regression:

$$r_{S_t} = \alpha + \lambda \hat{\varepsilon}_{t-1} + h_{ECM} r_{F_t} + e_t \quad (9)$$

where $\hat{\varepsilon}_{t-1} = \log(S_{t-1}) - [\hat{a} + \hat{b} \log(F_{t-1})]$ is the lagged error term from the long-run relationship and e_t is the error term. The coefficient h_{ECM} is the estimation of the OHR using the ECM.

The ARDL model was proposed by Chen, Lee and Shrestha (2004) to estimate the OHR, based on the simultaneous equations models considered by Hsiao (1997) and Pesaran (1997):

$$r_{S_t} = \alpha_1 + \alpha_2 \log(S_{t-1}) + \alpha_3 \log(F_{t-1}) + h_{ARDL} r_{F_t} + e_t \quad (10)$$

where h_{ARDL} is the estimation of the OHR using the ARDL model and e_t is the error term.

The time varying OHR are estimated by the RW OLS and bivariate GARCH methods. The RW OLS consists in the re-estimation of the OLS regression after each passing period by augmenting the estimation period with the new data and simultaneously dropping the oldest data. The RW OLS equation has the following form:

$$r_{S_t} = \alpha + (h_{OLS_t} | \Omega_{t-n+1,t}) r_{F_t} + e_t \quad (11)$$

Where $h_{OLS_t} | \Omega_{t-n+1,t}$ is the time varying OHR estimated through the RW OLS method, based on the information available from the moment $t-n+1$ to the moment t and n represents the number of periods of the rolling window.

The second time varying OHR is estimated using a bivariate cointegration GARCH (1,1) model. The conditional mean and conditional variance-covariance equations are given by:

$$r_{S_t} = \omega_S + \beta_S (S_{t-1} - \mathcal{Y}_{t-1}) + e_{S_t} \quad (12)$$

$$r_{F_t} = \omega_F + \beta_F (S_{t-1} - \mathcal{Y}_{t-1}) + e_{F_t} \quad (13)$$

$$\sigma_{S_t}^2 = c_S + a_S e_{S_{t-1}}^2 + b_S \sigma_{S_{t-1}}^2 \quad (14)$$

$$\sigma_{F_t}^2 = c_F + a_F e_{F_{t-1}}^2 + b_F \sigma_{F_{t-1}}^2 \quad (15)$$

$$\sigma_{SF_t} = \rho_t \cdot \sigma_{S_t} \cdot \sigma_{F_t} \quad (16)$$

where $S_{t-1} - \mathcal{Y}_{t-1}$ is the lagged error term of the cointegrating relationship $S_t = \mathcal{Y}_t + \varepsilon_t$.

The OHR is given by the conditional covariance and the conditional variance of the futures returns:

$$h_{BGARCH_t} = \sigma_{SF_t} / \sigma_{F_t}^2 \quad (17)$$

In order to assess the hedging efficiency of each OHR, we compute the Ederington (1979) hedging effectiveness indicator (EHE) that shows how much variance of the unhedged spot position is eliminated through hedging and is given by the following relation:

$$EHE = \frac{Var(r_S) - Var(r_H)}{Var(r_S)} \quad (18)$$

The methodology also consists in splitting the database in two parts. The first part, the sample period, covers the data from 05.11.1997 to 06.06.2007 (501 price observations and 500 weekly returns). Based on this period, the static OHR using OLS, ECM and ARDL methods are computed. Also, the sample period is used to estimate the first RW OLS OHR and the parameters of the BGARCH (1,1) model. The out of sample period covers the data from 13.06.2007 to 31.10.2012 and is used to test the hedging effectiveness of the various static and time varying OHR. Based on this period are estimated the time varying OHR (through RW OLS and BGARCH), are computed the variances of the hedged and unhedged positions and the EHE indicators for each OHR (estimated through static OLS, ECM, ARDL, RW OLS and BGARCH). The final step consists in comparing the models from the perspective of the EHE indicators.

4. Results

The evolution of wheat and corn spot prices is shown in Figure 1. It can be observed that the two prices are correlated and exhibit a stochastic and volatile evolution. Until 2007, both prices were in the range of 2-4 USD/bushel. As a result of the unfavorable weather conditions, the wheat price spiked in late 2007 and early 2008 from 4 USD/bushel to a maximum near 12 USD/bushel. Thus, in a period of less than a year, the wheat price tripled. After reaching its maximum level, the wheat price retreated in 2008 and, during the Lehman Brothers episode of the financial crisis from October 2008, was again under the level of 4 USD/bushel. After the crisis, the wheat price continued its surge, up to the level of 8 USD/bushel in 2012.

Although with less aggressive fluctuations, the corn price exhibits a high volatility as well. From levels of around 3 USD/bushel in the summer of 2007, the corn price reached a level of 7 USD/bushel in the summer of 2008 and retreated again to the level of 3 USD/bushel during the financial crisis. After the crisis, the corn price followed the wheat price evolution, reaching a level of 7.5 USD/bushel in October 2012.

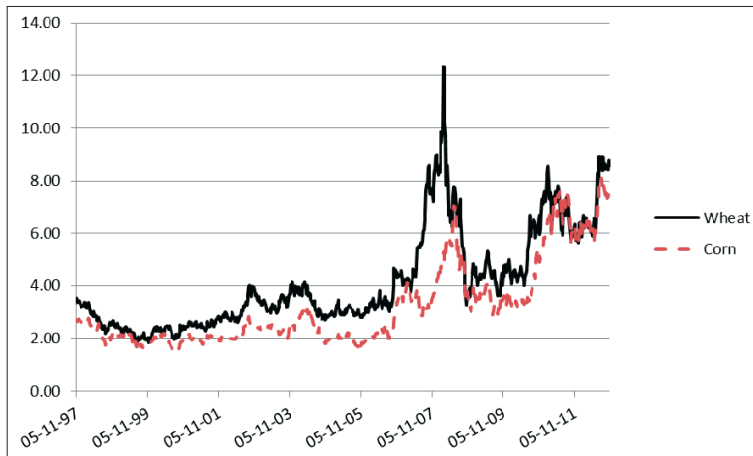


Figure 1: Wheat and corn spot price evolution

Source: Authors' own calculations

The descriptive statistics of spot and futures prices of wheat and corn are depicted in Table 1. It can be observed that the futures price is, on average, higher than the spot price in both cases and the wheat price is higher than the corn price.

The extreme values of the prices represent proofs of the high volatility. As an example, the ratio between the maximum and minimum value of the spot price during the analyzed period is 6.74 for wheat and 5.20 for corn. Also, the maximum and minimum weekly returns of the spot prices are around +/-20%. The annualized volatility is in all cases greater than 30% and the spot prices are more volatile than the futures prices. The levels of the Skewness and Kurtosis suggest that the distributions are asymmetric and leptokurtic. Thus, the hypothesis of normal distribution for prices and returns is rejected.

Table 1: Descriptive statistics

	Wheat				Corn			
	Spot		Futures		Spot		Futures	
	Price	Return	Price	Return	Price	Return	Price	Return
Mean	4.15	0.11%	4.52	0.11%	3.22	0.13%	3.38	0.13%
Median	3.43	0.00%	3.62	-0.14%	2.47	0.17%	2.50	0.00%
Maximum	12.33	23.69%	12.83	22.71%	8.08	17.36%	8.30	15.30%
Minimum	1.83	-22.37%	2.27	-17.74%	1.56	-18.39%	1.75	-16.89%
Skewness	1.20	0.15	1.09	0.35	1.34	-0.05	1.26	-0.02
Kurtosis	3.83	4.46	3.38	4.33	3.71	4.70	3.38	4.16
St dev	1.90	5.00%	2.03	4.52%	1.63	4.45%	1.66	4.24%
Volatility	36.03%		32.59%		32.07%		30.61%	

Source: Authors' own calculations

The use of non-stationary data in the regressions can lead to spurious results (Cotter and Hanly, 2006). In order to test the stationarity of the time series, the Augmented Dickey-Fuller (ADF) unit root test was applied. The results show that the spot and futures prices are non-stationary processes, but the returns are stationary (see Table 2).

Table 2: ADF test results

		Spot		Futures	
		t-stat	p-value	t-stat	p-value
Wheat	Level	-1.5104	0.5280	-1.3837	0.5914
	Log return	-28.9537	0.0000	-29.3874	0.0000
Corn	Level	-0.4228	0.9027	-0.4844	0.8915
	Log return	-28.5827	0.0000	-29.8490	0.0000
Critical values: 1%: -3.438; 5%: -2.865; 10%: -2.569					

Source: Authors' own calculations

In order to test the cointegration between the spot and futures prices, the Johansen test was applied (see Table 3). The results of the test show that there is a cointegration relationship between spot and futures prices for the case of wheat and corn.

Table 3: Johansen cointegration test results

	No cointegrating vector	At most one
Wheat	14.9199	1.5577
Corn	21.0807	0.0647
Critical values: None: 1%: 20.04; 5%: 15.41; At most one: 1%: 6.65; 5%: 3.76		

Source: Authors' own calculations

The results of the ADF and Johansen tests suggest that the regressions that estimate the OHR should be applied on the returns series and that a model that takes into

account the cointegration between the spot and futures prices should provide better results than the simple OLS method.

Figure 2 shows the evolution of wheat and corn spot returns. During the analyzed period, the magnitude of the weekly returns varies, with greater movements for the last years.

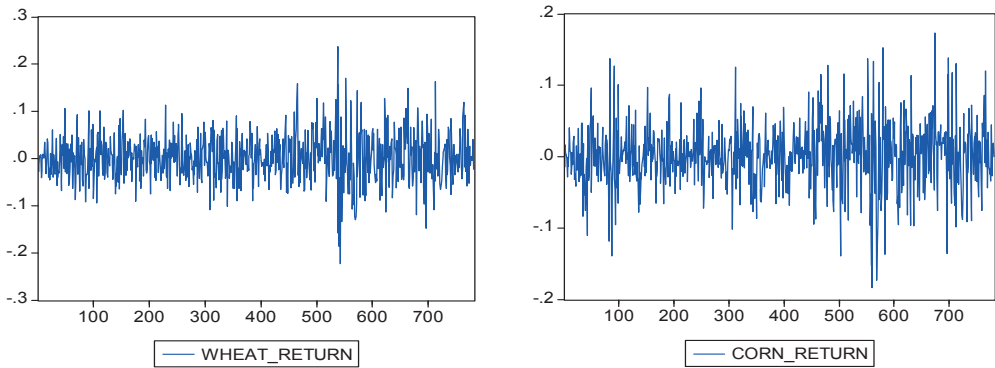


Figure 2: Wheat and corn weekly spot returns

Source: Authors' own calculations

The actual and lagged weekly returns are plotted in Figure 3. As the pairs are fairly distributed among the four quadrants, we can conclude that there is no specific relationship between actual and lagged return for the cases of wheat and corn and the evolution of the price cannot be forecasted based on the past movements.

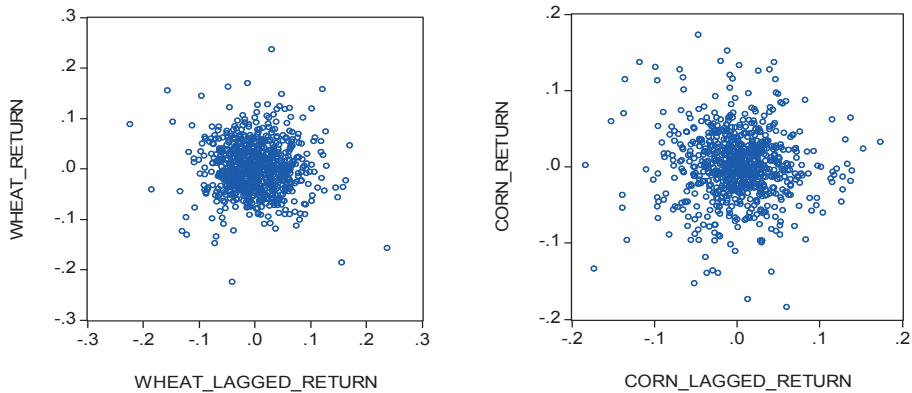


Figure 3: Wheat and corn actual and lagged weekly spot returns

Source: Authors' own calculations

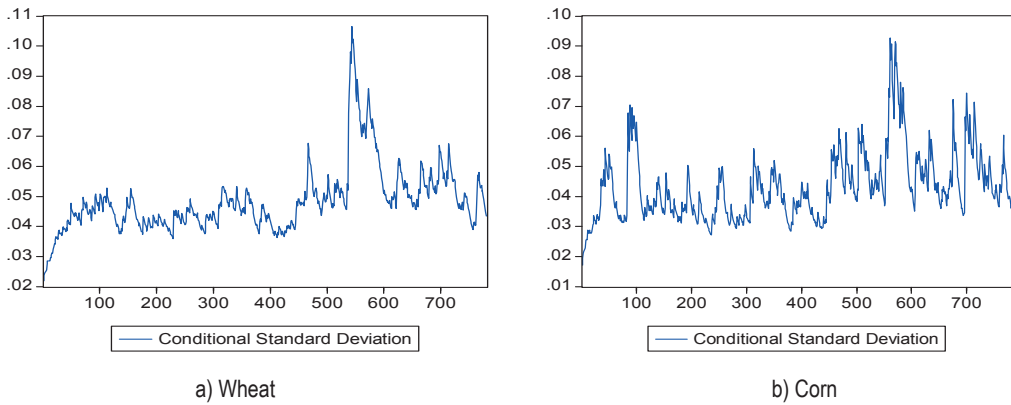
In order to test for the predictive nature of the wheat and corn spot price evolution, an AR(1) model was applied for the weekly returns series. The results invalidate the AR(1) model (see Table 4), suggesting the fact that the spot price evolution is unpredictable for both wheat and corn cases.

Table 4: AR(1) model results

	Coefficient	Std. error	t-stat	p-value	R-squared
Wheat	-0.0360	0.0358	-1.0072	0.3141	0.0007
Corn	-0.0228	0.0358	-0.6370	0.5243	0.0004

Source: Authors' own calculations

In order to emphasize the volatile behavior of the wheat and corn spot price evolution, we estimated and plotted the conditional standard deviation using a GARCH (1,1) model. As it can be seen in Figure 4, the prices exhibit a relatively increased volatility and the periods of high and medium volatility alternate.

**Figure 4:** Conditional standard deviations

Source: Authors' own calculations

In order to highlight the basis risk that a hedger is exposed to, the basis between the futures and spot price is computed. Figure 5 shows that the basis exhibits a stochastic and volatile evolution in both wheat and corn cases.

The futures price is generally higher than the spot price, the backwardation being rather the exception for the agricultural market. The basis is characterized by extreme volatility periods when the futures price is close to the spot price alternating with periods when futures price is more than 10% higher than the spot price. The volatile evolution of the basis represents the main argument for the estimation of the OHR.

The futures price is, on average, with 8.67% higher than the spot price for wheat and with 5.28% for corn (see Table 5), while the median is relatively close to the mean value. The extreme values and the standard deviations highlight the magnitude of the basis risk. The wheat basis varies from a minimum of -7.52% to a maximum of 45.72, while the corn basis varies from -8.36% to 26.83%. The standard deviations are close to the mean value, suggesting a high volatility of the basis. These statistics show that the basis risk is large in the agricultural market.

We estimate the static OHR by OLS, ECM and ARDL methods. The static OHR are lower than the unit value in the case of wheat as in the case of corn (see Table 6). There

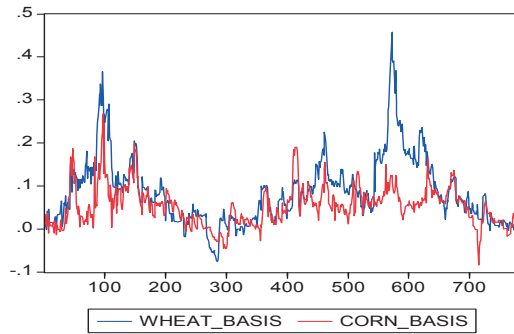


Figure 5: Wheat and corn basis

Source: Authors' own calculations

Table 5: Basis statistics

	Wheat	Corn
Mean	8.67%	5.28%
Median	7.61%	5.33%
Maximum	45.72%	26.83%
Minimum	-7.52%	-8.36%
St dev	7.87%	4.54%

Source: Authors' own calculations

can be also noticed that there are no significant differences among the OHR estimated through these three methods and the ARDL OHR tends to be slightly higher than the OLS and ECM counterparts.

The OHR for wheat is higher than the one for corn. The time varying OHR are significantly higher than the static ones. For wheat, both methods (RW OLS and bivariate GARCH) estimate OHR with an average greater than the unit value. Also, for both commodities, the averages of the OHR estimated with bivariate GARCH model are higher than those estimated with the RW OLS method.

Table 6: Optimal hedge ratios

Asset/Model	OLS	ECM	ARDL	RW OLS (average)	GARCH (average)
Wheat	0.952	0.952	0.953	1.043	1.091
Corn	0.849	0.856	0.858	0.944	1.013

Source: Authors' own calculations

Table 7 synthesizes the estimated parameters of the bivariate GARCH (1,1) model. For each commodity and type of price (spot or futures), the sum of the ARCH and GARCH terms is close to the unit value, suggesting that the volatility shocks are quite persistent in time.

Table 7: Bivariate GARCH (1,1) results

	Wheat		Corn	
	Coefficient	Std. error	Coefficient	Std. error
ω_S	-0.0001	0.0247	0.0014	0.0015
β_S	-0.0584*	0.0019	-0.0654*	0.0311
c_S	0.0001	0.0000	0.0001*	0.0001
a_S	0.0210	0.0145	0.1289**	0.0412
b_S	0.9447**	0.0343	0.7858**	0.0666
ω_F	0.0005	0.0018	0.0007	0.0017
β_F	-0.0169	0.0225	0.0116	0.0325
c_F	0.0001	0.0001	0.0002	0.0001
a_F	0.0138	0.0201	0.0403	0.0315
b_F	0.9249**	0.1094	0.8325**	0.1174

Note: ** and * indicate significance at 1% and 5% level.

Source: Authors' own calculations

We computed the Ederington (1979) hedging effectiveness (EHE) indicators for the out of sample period. The EHE indicator show how much variance of the initial spot exposure is reduced through hedging. A higher EHE indicated a more efficient hedging. The results show that the time varying hedge ratios outperform the static ones in terms of variance reduction for both wheat and corn (see Table 8).

Table 8: Hedging effectiveness indicators

Asset/Model	OLS	ECM	ARDL	RW OLS	GARCH
Wheat	0.8988	0.8987	0.8989	0.9071	0.9201
Corn	0.9005	0.9026	0.9031	0.9182	0.9122

Source: Authors' own calculations

For the wheat market the most efficient method to estimate the OHR is the bivariate GARCH (1,1) model, the time varying OHR reducing 92.01% of the spot exposure variance. This represents an important improvement, compared to the hedging effectiveness of the static OHR of only 89.87%-89.89%. For the corn case, the most efficient method to estimate the OHR is the RW OLS, with a hedging effectiveness of 91.82%.

5. Conclusions

The high volatility that characterizes the agricultural commodity prices starting with the beginning of 2008 caused detrimental effects on economic welfare and concerns regarding poverty and malnutrition at a global level. Hedging using financial instruments represents a strategy that could reduce the vulnerability to the agricultural price shocks. The easiest way to hedge price risk is through futures contracts for the linearity of the payoff and, because of the basis risk, the estimation of the OHR is needed.

Our paper analyzes the wheat and corn U.S. market for a period of 15 years. The results show that agricultural prices exhibit high levels of volatility and are unpredictable. Given the importance of the subject and the volatile behavior of the agricultural prices, it is important for administrative authorities to promote efficient hedging strategies.

We estimate static and time varying hedge ratios using methods such as the OLS, ECM, ARDL, RW OLS and the bivariate GARCH model. We find that the time varying hedge ratios outperform the static ones in terms of variance reduction. For the wheat market the most efficient method to estimate the OHR is the bivariate GARCH model, while for the corn case, the most efficient method to estimate the OHR proved to be the RW OLS.

The findings of the paper can be helpful for the public authorities in their role of promoting the understanding of the agricultural price volatility risk. Also, the methodology presented for estimating the optimal hedging ratio can have importance in the context of promoting education in the financial risk management field.

References:

1. Alizadeh, A.H., Nomikos, N.K. and Pouliasis, P.K., 'A Markov Regime Switching Approach for Hedging Energy Commodities', 2008, *Journal of Banking and Finance*, vol. 32, no. 9, pp. 1970-1983.
2. Bessembinder, H. and Lemmon, M.L., 'Equilibrium Pricing and Optimal Hedging in Electricity Forward Markets', 2002, *The Journal of Finance*, vol. 57, no. 3, pp. 1347-1382.
3. Bystrom, H.N.E., 'The Hedging Performance of Electricity Futures on the Nordic Power Exchange', 2003, *Applied Economics*, vol. 35, no. 1, pp. 1-11.
4. Bulan, L.T., 'Real Options, Irreversible Investment and Firm Uncertainty. New Evidence from U.S. Firms', 2005, *Review of Financial Economics*, vol. 14, no. 3-4, pp. 255-279.
5. Campa, J. and Goldberg, L., 'Investment in Manufacturing, Exchange Rates and External Exposure', 1995, *Journal of International Economics*, vol. 38, no. 3-4, pp. 297-320.
6. Carruth, A., Dickerson, A. and Henley, A., 'What Do We Know about Investment Under Uncertainty?', 2000, *Journal of Economic Surveys*, vol. 14, no. 2, pp. 119-153.
7. Cecchetti, S.G., Cumby, R.E. and Figlewski, S., 'Estimation of the Optimal Futures Hedge', 1988, *Review of Economics and Statistics*, vol. 70, no. 4, pp. 623-630.
8. Chen, S.S., Lee, C.F. and Shrestha, K., 'An Empirical Analysis of the Relationship between the Hedge Ratio and Hedging Horizon: A Simultaneous Estimation of the Short- and Long-Run Hedge Ratios', 2004, *Journal of Futures Markets*, vol. 24, no. 4, pp. 359-386.
9. Chou, W.L., Fan, K.K. and Lee, C.F., 'Hedging with the Nikkei Index Futures: The Conventional Model versus the Error Correction Model', 1996, *The Quarterly Review of Economics and Finance*, vol. 36, no. 4, pp. 495-505.
10. Cotter, J. and Hanly, J., 'Revaluating Hedging Performance', 2006, *The Journal of Futures Markets*, vol. 26, no. 7, pp. 677-702.
11. Dethier, J.-J. and Effenberger, A., 'Agriculture and Development: A Brief Review of the Literature', 2012, *Economic Systems*, vol. 36, no. 2, pp. 175-205.
12. Ederington, L.H., 'The Hedging Performance of the New Futures Markets', 1979, *Journal of Finance*, vol. 34, no. 1, pp. 157-170.

13. Elder, J. and Serletis, A., 'Oil Price Uncertainty', 2010, *Journal of Money, Credit and Banking*, vol. 42, no. 6, pp. 1137-1159.
14. Elder, J. and Serletis, A., 'Oil Price Uncertainty in Canada', 2009, *Energy Economics*, vol. 31, no. 6, pp. 852-856.
15. European Economic Community, Treaty Establishing the European Economic Community, EEC Treaty, (Treaty of Rome), 1957.
16. Galtier, F., 'Managing Food Price Instability: Critical Assessment of the Dominant Doctrine', 2013, *Global Food Security*, vol. 2, no. 2, pp. 72-81.
17. Ghosal, V. and Lougani, P., 'Product Market Competition and the Impact of Price Uncertainty on Investment: Some Evidence from US Manufacturing Industries', 1996, *Journal of Industrial Economics*, vol. 44, no. 2, pp. 217-228.
18. Guiso, L. and Parigi, G., 'Investment and Demand Uncertainty', 1999, *Quarterly Journal of Economics*, vol. 114, no. 1, pp. 185-227.
19. Hsiao, C., 'Cointegration and Dynamic Simultaneous Equations Model', 1997, *Econometrica*, vol. 65, no. 3, pp. 647-670.
20. Huizinga, J., 'Inflation Uncertainty, Relative Price Uncertainty, and Investment in US Manufacturing', 1993, *Journal of Money, Credit and Banking*, vol. 25, no. 3, pp. 521-549.
21. Juhl, T., Kawaller, I.G. and Koch, P.D., 'The Effect of the Hedge Horizon on Optimal Hedge Size and Effectiveness When Prices are Cointegrated', 2012, *Journal of Futures Markets*, vol. 32, no. 9, pp. 837-876.
22. Kostika, E. and Markellos, R.N., 'Optimal Hedge Ratio Estimation and Effectiveness Using ARCD', 2013, *Journal of Forecasting*, vol. 32, no. 1, pp. 41-50.
23. Kroner, K.F. and Sultan, J., 'Time-varying Distributions and Dynamic Hedging with Foreign Currency Futures', 1993, *Journal of Financial and Quantitative Analysis*, vol. 28, pp. 535-551.
24. Lampietti, J.A., Michaels, S., Magnan, N., McCalla, A.F., Saade, M. and Khouri, N., 'A Strategic Framework for Improving Food Security in Arab Countries', 2011, *Food Security*, vol. 3, no. 1, pp. 7-22.
25. Leahy, J.V. and Whited, T.M., 'The Effect of Uncertainty on Investment: Some Stylized Facts', 1996, *Journal of Money, Credit and Banking*, vol. 28, no. 1, pp. 64-83.
26. Lee, H.-T. and Yoder, J.K., 'A Bivariate Markov Regime Switching GARCH Approach to Estimate Time Varying Minimum Variance Hedge Ratios', 2007, *Applied Economics*, vol. 39, no. 10, pp. 1253-1265.
27. Lence, S.H., 'The Economic Value of Minimum Variance Hedges', 1995, *American Journal of Agricultural Economics*, vol. 77, no. 2, pp. 353-364.
28. Lence, S.H., 'Relaxing the Assumptions of Minimum Variance Hedging', 1996, *Journal of Agricultural and Resource Economics*, vol. 21, no. 1, pp. 39-55.
29. Lien, D., Tse, Y.K. and Tsui, A.K.C., 'Evaluating the Hedging Performance of the Constant Correlation GARCH Model', 2002, *Applied Financial Economics*, vol. 12, no. 11, pp. 791-798.
30. Moon, G.-H., Yu, W.-C. and Hong, C.-H., 'Dynamic Hedging Performance with the Evaluation of Multivariate GARCH Models: Evidence from KOSTAR Index Futures', 2009, *Applied Economics Letters*, vol. 16, no. 9, pp. 913-919.
31. Ogawa, K. and Suzuki, K., 'Uncertainty and Investment: Some Evidence from the Panel Data of Japanese Manufacturing Firms', 2000, *The Japanese Economic Review*, vol. 51, no. 2, pp. 170-192.

32. Pesaran, M.H., 'The Role of Economic Theory in Modeling the Long Run', 1997, *The Economic Journal*, vol. 107, no. 440, pp. 178-191.
33. Ramey, G. and Ramey, V.A., 'Cross-Country Evidence on the Link between Volatility and Growth', 1995, *The American Economic Review*, vol. 85, no. 5, pp. 1138-1151.
34. Rodrick D., 'Where Did All the Growth Go? External Shocks. Social Conflict and Growth Collapse', 1999, *Journal of Economic Growth*, vol. 4, no. 4, pp. 385-412.
35. Srinivasan, P.V., Jha, S., 'Liberalized Trade and Domestic Price Stability. The Case of Rice and Wheat in India', 2001, *Journal of Development Economics*, vol. 65, no. 2, pp. 417-441.
36. Wright, B., 'International Grain Reserves and Other Instruments to Address Volatility in Grain Markets', Policy Research Working Paper 5028, World Bank, Washington, DC, 2009.
37. Yoon, K.H. and Ratti, R.A., 'Energy Price Uncertainty, Energy Intensity and Firm Investment', 2011, *Energy Economics*, vol. 33, no. 1, pp. 67-78.