THE DYNAMIC HEDGING EFFECTIVENESS FOR SOYBEAN FARMERS OF MATO GROSSO WITH FUTURES CONTRACTS OF BM&F

Efetividade do Hedge Dinâmico para produtores de soja em Mato Grosso utilizando contratos futuros da BM&F

ABSTRACT

Dynamic hedging effectiveness for soybean farmers in Rondonópolis (MT) with futures contracts of BM&F is calculated through optimal hedge determination, using the bivariate GARCH BEKK model, which considers the conditional correlations of the prices series, comparing the results with the minimum variance model effectiveness, calculated by OLS, the unhedged and the naïve hedge positions. The financial effectiveness of the dynamic hedge model is superior and can be used by farmers for several decision making purposes such as price discovery, hedging calibration, cash flow projections, market timing, among others.

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RESUMO

As taxas ótimas de hedge para os produtores de soja em Rondonópolis (MT), através de contratos futuros da BM&F, são comparadas através das duas principais abordagens para a determinação de hedge ótimo, o modelo de mínima variância, por MQO, e o modelo GARCH BEKK bivariado, o qual considera as correlações condicionais das séries. A efetividade financeira do modelo de hedge dinâmico apresenta-se superior, e pode ser usada pelos produtores para uma série de tomada de decisões tais como descoberta de preços, ajuste de taxa de hedge, projeções de fluxo de caixa, no processo de *market timing* entre outras.

Palavras-chave: hedge dinâmico; mínima variância; soja; Mato Grosso.

Keywords: dynamic hedge; minimum variance; soybeans; Mato Grosso.

1 INTRODUCTION

In the last three decades Brazilian agribusiness has played a pivotal role in foreign exchange generation and regional economic development, particularly in the Central-Western Region. With the continuous growth in size, competitiveness and complexity of the agricultural sector in the last few years, information has become a strategic input for decision making in the production, as well as the marketing phases.

Within this framework, the soybean supply chain became particularly relevant to the Brazilian agribusiness. In the last ten years, the harvested area of the grain has grown at an annual average rate of 8,1%, boosted by an expanding foreign demand, turning the country a major supplier of the commodity worldwide (MAPA, 2007).

Soybean cultivation was introduced in Brazil before the 50´s and in the 70 and 80´s a rapid growth happened, stabilizing through the 80´s. In the 90´s and 2000 there was a large increase in the crop production, turning the country the second producer worldwide (SANCHES; MICHELLON; ROESSING, 2004).

There are associated price volatility risks for the soybean production, with a negative impact over the industry revenues. One possibility for offsetting the price risks is through futures contracts, which have been, however, underutilized by Brazilian producers (MARQUES; MELLO; MARTINES-FILHO, 2008).

The research question addressed in this article is the measurement of the hedging effectiveness of the dynamic hedge ratios, evaluating its performance *vis-à-vis* other hedging strategies, for the soybean farmers in Rondonópolis (MT), using futures contracts of BM&F. The results have many applications in the supply chain of the crop, particularly in the price discovery process, hedging ratio calibration, cash flow projections, financial leverage and marketing decisions, as well as in the expansion of futures contracts usage in the local futures exchange, BM&F – Bolsa de Mercadorias e Futuros.

The survey questions are: i. how to calculate the hedging ratios effectiveness through the bivariate GARCH BEKK and the minimum variance models; ii. what is the hedging effectiveness of the dynamic hedge ratios compared with the unhedged, the "naïve" and traditional model, by OLS, portfolio positions ; and, iii. what are the intrinsic properties of the dynamic hedging ratios time series, such as the existence of unit root.

The results contribute to the academic research in futures markets, using a state-of-the-art model to obtain the dynamic hedge ratios for Brazil´s most traded agricultural commodity, applied to the largest producer region.

The article is divided as follows: section 2 reviews the literature in the field, section 3 describes the OLS, the GARCH BEKK and other hedging methodologies, the parametric tests and the data set, section 4 presents and discusses the results and section 5 concludes the study.

2 LITERATURE REVIEW

Most of the current literature about hedging strategies studies the optimal hedge ratios, i.e., the ratio between spot and futures markets position of price risk minimizing agent using futures contracts.

Hedge is defined in the literature as the strategy of agents willing to transfer risk among themselves, primarily hedgers and speculators. When a hedger offsets its price risk, he becomes exposed to basis risk, which is the instability between spot (in the price reference market) and futures prices (LEUTHOLD ET AL., 1989).

Marques et al. (2008) described hedging in the futures market as the agent holding contrary spot and futures markets positions, taking the futures contracts settlement date as reference for trading.

Collins (1997) indicated that most of the hedging literature focuses on how the market players can use this financial tool to offset their risks, therefore optimizing their price, output, income and profit objectives. As such, several hedging strategy models have been studied throughout time, which fundamentally converge to decision models for the hedging effectiveness, considering most influencing factors as close as possible to the agents realities.

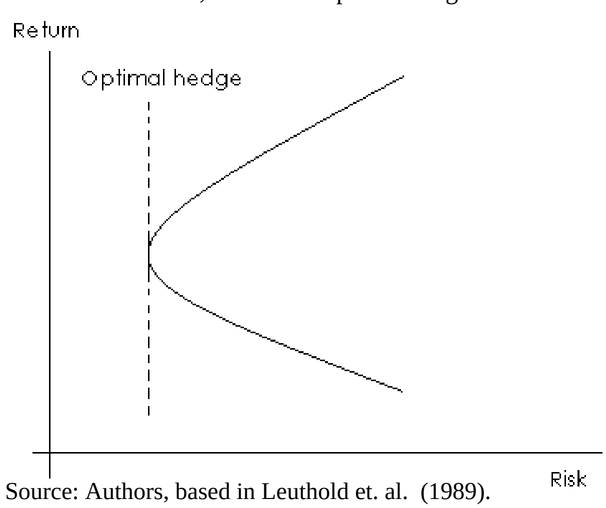
The risk offsetting proportion, i.e., the ratio of the agent´s position, the number of contracts, in the futures market relative to his spot market position defines the hedge ratio, which is an outstanding reference in the literature. Carter (1999) demonstrated that most of the literature concerning hedge in the past fifty years investigates the optimal hedge ratio.

Some models study the expected utility in hedging, such as Johnson (1960), Stein (1961) and Grant (1989), using the minimum variance framework to obtain the optimal hedge ratio. Others include some degree of flexibility, as in Lence (1996), to proxy the decision making process of the agents. All this research effort focuses the optimal hedge ratios.

Considering the agent´s decision making process, one of his goals is the risk minimization of his overall position in the commodity market, as in a portfolio evaluation. Therefore, the optimal hedge ratio can be different of one, as a part of the output is hedged in the futures market and the balance is spot traded. Finding this optimal hedge ratio, the minimum variance hedge, is the fundamental goal when one trades in the futures markets (HULL, 2003).

Figure 1 shows the optimal hedge position, or minimum variance, in a risk and return framework:

FIGURE 1 – Risk, return and optimal hedge ratio



Source: Authors, based in Leuthold et. al. (1989).

As in Figure 1, the minimum variance hedge, the optimal hedge ratio, is the quotient between the futures and spot markets position that yields the highest utility considering the agent‘s risk and return preferences, i.e., the position in both markets that maximizes return and minimizes the expected return variance.

There are studies in Brazil approaching the optimal hedge, such as Silva et al. (2003), who evaluated the hedging effectiveness of soybean oil, meal and grain in CBOT and BM&F, finding that a cross-hedging strategy with grain futures in BM&F has a low degree of effectiveness for the oil and meal, while the equivalent contracts in CBOT showed better results.

Santos et al. (2008) investigated the minimum variance hedge in BM&F for the Central-Western soybean production, between October of 2002 and December of 2005, concluding that 44% of the output of the Goiás soybean could be hedged with futures contracts to offset 35% of its price risk.

Martins and Aguiar (2004) studied the futures contracts timeframes in CBOT to discover those with higher degree of hedging effectiveness for the Brazilian soybean output cycle, concluding that the contracts settled in the second half of the year, in particular the months of July and August, were the most effective. Also found a higher effectiveness in the regions closer to the exporting ports of São Paulo and Paraná.

The Brazilian studies approached the optimal hedge strategy following a particular methodology. As such, a necessary consequent step is to compare the two main methodological hedging frameworks, the minimum variance and the generalized autoregressive conditional heteroskedasticity (GARCH) models, applied to a sample region of soybean market in Brazil, which is the contribution of the present article.

3 METHODOLOGYAND DATA

Two methodologies were considered for the optimal hedge ratios of the soybean farmers in Rondonópolis (MT) through futures contracts in BM&F, within a time period. The first method was ordinary least squares (OLS), based in the constant covariances matrix hypothesis. The second was the GARCH BEKK model, which considers the time dependence of the covariances matrix, yielding a dynamic hedge ratio for each time period considered.

The hedging effectiveness was calculated for both the minimum variance and the dynamic hedge ratios, on a portfolio optimization framework, comparing with an unhedged and a “naïve” hedge positions. Also, the unit root was tested for the resulting dynamic hedge ratios for time series analytical purposes.

3.1 Minimum Variance Hedge Model

For Hull (2003) the optimal hedge ratio describes the futures and spot markets position of an agent that minimizes price variance if he is a risk averter. This ratio is given by:

$$\frac{COV(\Delta S_t, \Delta F_t)}{Var(\Delta F_t)} \tag{1}$$

where:

ΔS_t = spot prices first difference;
$\alpha, \beta =$ linear parameters of the model;
ΔF_t = futures prices first difference.

Leuthold et al. (1989) showed that these variables are calculated through the ordinary least squares (OLS) estimation of:

$$\Delta S_t = \alpha + \beta \Delta F_t \tag{2}$$

In equation 2 the estimated β indicates the total output ratio that should be traded in the futures markets yielding the least variance, the minimum variance optimal hedge ratio. The standard OLS test of R^2, the coefficient of determination, indicates the hedging effectiveness, the decrease in the price variance of the agent´s total position, given by the sum of his spot and futures markets positions (HULL, 2003).

However, the minimum variance optimal hedge methodology must be evaluated with limits, as there are evidences, such as serial correlation and heteroskedasticity, that results are dependent of the commodity price variation conditional distributions, which will change in time when the conditional distribution varies, with a high degree of probability.

In this regard, the White´s heteroskedasticity and the Ljung-Box serial correlation tests were calculated, to analyse if the covariances matrix conditional distribution is non-constant and the GARCH BEKK model can be applied to calculate better conditional variation adjusted hedge ratios.

3.2 The ARCH-GARCH Models

A time series is a sequentially ordered data set, referred to a timeframe or not. The main objective of a time series analysis is to find the characteristics of its generating stochastic process in order to predict its future values (GUJARATI, 2007).

Agricultural prices and financial series are characterized by high volatility, as well as small and large prediction errors. This behavior is a consequence of shifts in monetary and fiscal policies, exogenous demand and supply shocks, intrinsic commodities properties and marketing conditions, among others (CARTER, 1999).

Therefore the heterogeneity of the prediction errors variance can be characterized as the existence of autocorrelation, which is dependent of the orthogonality of the regression, implying the heteroskedastical behavior of the prevision errors variance, observed in several prices and financial series.

In his seminal article, Engle (1982) studied the variance of the prediction errors in highly volatile time series, leading to the autoregressive conditional heteroscedasticity (ARCH) models, on which the conditional variance is dependent of the series past values and modeled through a quadratic form.

For an ARCH (1) type of model, the error variance ε_t will depend of a constant plus the term ε_{t-1}^2, which is the main characteristic of the ARCH models. For generalization purposes, given a time series Y_t, an ARCH (r) model can be defined as:

$$\begin{aligned} Y_t &= \beta_0 + \beta_1 X_{1K} + \ldots + \beta_k X_{Kt} + \varepsilon_t \\ Var(\varepsilon_t) &= \sigma_t^2 = \alpha_0 + \alpha_1 Y_{t-1}^2 + \alpha_2 Y_{t-2}^2 + \ldots + \alpha_r Y_{t-r}^2 \end{aligned} \quad (3)$$

For the ARCH (r) model to have a positive and stationary (weak) variance, according to Morettin and Toloi (2004), the following conditions for the errors variance model must be satisfied:

$$\begin{aligned} &\alpha_0 > 0, \alpha_i > 0 \\ &\forall i = 1,2,3..p \\ &\sum \alpha_1 < 1 \end{aligned} \quad (4)$$

Engle (1982) considered the error term ε_t as Gaussian, with zero mean and unitary variance, independent and identically distributed (i.i.d.) variable. The ARCH approach for price series (particularly for commodities), as well as financial series, is presented in the literature because those series are not auto-correlated.

The ARCH models can be extended through the generalized autoregressive conditional heteroskedasticity (GARCH) approach, which increases the time series informational set, yielding a more parcimonious formulation, compared with an AR or MA modeling (BOLLERSLEV, 1986). Hence, a GARCH (r,m) volatility models feature less parameters than an ARCH (r).

Recent literature showed that a GARCH (1,1) model is the most robust specification for a financial time series. Baba et al. (1990), Karolyi (1995) and Yang and Allen (2004) demonstrated that a GARCH (1,1) model, having fewer parametric restrictions, is preferable to the over-parametrized models.

A GARCH (1,1) process can be described as follows:

$$\begin{aligned} Y_t &= \beta_0 + \beta_1 X_{1t} + \ldots + \beta_{kt} X_{kt} + \varepsilon_t \\ Var(\varepsilon_t) &= \sigma_t^t = \omega + \alpha_1 Y_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \end{aligned} \quad (5)$$

As described in Morettin and Toloi (2004), the stationarity conditions of a GARCH (1,1) model, as well as its positive valued variance condition process, can be resumed as:

$$\begin{aligned} &\omega > 0, \alpha_1 > 0 \\ &\beta_1 > 0 \\ &\alpha_1 + \beta_1 < 1 \end{aligned} \quad (6)$$

The sum of the α_1 and β_1 coefficients describes the time series volatility shock persistence, an interesting characteristic of this class of models.

When $\alpha_1 + \beta_1$ is low in value, an initial shock in a series volatility will rapidly dissipate. However when the sum is closer to the unitary upper bound, the shock will demand more time for the volatility to converge to its historical average.

There are situations in which the sum could reach above the unitary value, resulting in a residual conditional variance of ε_t with unit root, when an initial shock in the series volatility will not converge to its historical average (ENDERS, 2004).

The parameter estimation of the GARCH models was calculated through the conditional maximum likelihood method, using the GARCH BEKK model, as described in Baba et al. (1990) and Bittencourt et al. (2006).

The BEKK (q, p, k) model, with the conditional covariances matrix H_t, given the informational set available in t, can be defined as:

$$\varepsilon_t = H_t^{1/2} v_t, \quad (7)$$

$$H_t = C'C + \sum_{i=1}^{q} A_i' \varepsilon_{t-1} \varepsilon_{t-i}' A_i + \sum_{j=1}^{p} B_j' H_{t-j} B_j \quad (8)$$

Where C, A, B are (k x k) parameters matrices, with k=2, in the bivariate case, C is an upper triangular matrix, p and q are the model orders and k is the number of series used.

As Karolyi (1995) ilustrated, the BEKK model has a particularity in its specification, the generalized configurations, allowing cross impacts between the conditional variances and covariances of the variables, while not demanding a large number of parameter estimations.

The model is estimated through the Quasi-maximum Likelihood Method, adopting the errors Gaussian assumption. Jeantheau (1998) demonstrated the strong consistency of quasi-maximum likelihood estimators in multivariate GARCH models, even if the data is approximately non-normal, thus justifying the approach.

In the BEKK model, the optimal hedge ratio can be defined, when the return is equal to the log differences of the commodity prices, as:

$$b_{t-1} = Cov(\Delta p_{t-1}, \Delta f_t \mid \Omega_{t-1}) / Var(\Delta f_t \mid \Omega_{t-1}) \tag{9}$$

Where b_{t-1} indicates the optimal hedge ratio and p_t and f_t are the logs of spot and futures prices respectively.

Baillie and Myers (1998) and Benninga et al. (1984) showed that variance minimization implies a high degree of risk aversion. However, if the expected return of the hedge is zero, then the minimum variance hedge rule will be the maximum expected hedge utility rule, generalizing the use of the minimum variance approach.

Given the spot and futures prices bivariate model, an optimal hedge ratio vector can be obtained through the conditional covariance matrix H_t, as:

$$b_{t-1} = h_{21,t} / h_{22,t} \tag{10}$$

Where $h_{ij,t}$ is the i-*e*th row and j-*e*th column element of the conditional covariance matrix H_t. The optimal dynamic hedge ratio, in sampled estimates, can be obtained with H_t, and its matrix representation is:

$$\begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{bmatrix} \begin{bmatrix} c_{11} & c_{21} \\ 0 & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}' \begin{bmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \tag{11}$$

3.3 Hedging effectiveness

For the minimum variance and dynamic hedge ratios, calculated through the OLS and GARCH BEKK models respectively, the hedging effectiveness will be derived from the time varying and constant portfolios using the output of the models, as in Brooks et al. (2002).

For the dynamic hedge ratios portfolio, at time *t-1* the expected return $E_{t-1}(R_t)$, of the portfolio comprising one unit of commodity and β units of the futures contract may be written as:

$$E_{t-1}(R_t) = E_{t-1}(\Delta S_t) - \beta_{t-1} E_{t-1}(\Delta F_t) \tag{12}$$

Where β_{t-1} is the hedge ratio determined at time *t-1*, for use in period *t*. The variance of the expected return ($\sigma_{p,t}$) of the portfolio is:

$$\sigma_{p,t} = \sigma_{s,t} + \beta_{t-1}^2 \sigma_{F,t} - 2\beta_{t-1}\sigma_{SF,t} \tag{13}$$

where:

$\sigma_{p,t}$ = the conditional variance of the portfolio;
$\sigma_{s,t}$ = the conditional variance of the portfolio spot position;
$\sigma_{F,t}$ = the conditional variance of the portfolio futures position;
$\sigma_{SF,t}$ = the conditional covariance between the spot and futures position; and
β_{t-1} = the optimal hedge ratio.

For hedging effectiveness comparison, four different commodity portfolios were dimensioned. First, the unhedged portfolio, where there is only a long position in the commodity spot market.

Second, the "naïve" hedged, taking one short futures contract for every spot market unit, making β equals minus one, but not allowing the hedge to time-vary. The "naïve" hedge proxy the basis risk only portfolio.

Basis is defined as the difference between spot and futures prices, as follows:

$$B_t = S_t - F_t \tag{14}$$

Where B_t = basis, S_t = spot price and F_t = futures price. Therefore:

$$E_{t-1}(\Delta B_t) = E_{t-1}(\Delta S_t) + E_{t-1}(\Delta F_t) \quad (15)$$

Which is equivalent to equation 12, with ΔB_t = ΔR_t and $\beta = -1$.

In the third portfolio, the minimum variance hedge, there are the spot and the optimal OLS time invariant hedge ratio positions. And last, the dynamic hedged portfolio, where the spot and dynamic time variant positions are input, using the optimal hedge ratios of the GARCH BEKK model.

The return and variance were calculated for all four portfolios in order to infer which yields the highest degree of effectiveness, measured by the variance reduction *vis-á-vis* the expected return.

Descriptive statistics evaluation, Augmented Dickey-Fuller (ADF) unit roots and Engle-Granger cointegration tests were performed in both spot and futures price series levels. The ADF unit root test was also performed on the dynamic hedge ratios, given by the GARCH-BEKK model, to verify its stationarity, to evaluate the use of ARMA modeling for *ex-ante* previsions.

3.4 Data

Three sets of data were used. The first one was the spot market soybean daily prices in Rondonopolis (MT), source: ESALQ/CEPEA. The prices are quoted in R$/60 kg bags and were transformed in US dollars to compare with the futures prices of BM&F contracts quotes. The second was the futures prices series of the soybean contract traded in BM&F, which has the following specifications:

Carchano e Pardo (2009) showed that among five different methodologies to construct index futures contracts continuous series, for trading as well as academic research purposes, there are not significant differences between the resultant series, indicating that the least complex method can be applied.

In order to obtain a continuous soybean futures price series for the BM&F contract, the settlement month and its last trading date were considered to construct successive non-overlapping time intervals. The rollover date, the point of time when contract series are switched to the next one, is the 9th business day before the first day of the contract settlement month, as defined in the contract specifications in Table 1.

For example, the last day for the April contract will be the 9th business day before April 1st, when a new interval will be initiated with the prices for the May contract. Therefore, March will have both price series for the April and May contracts, with rollover on the 9th business day before April 1st. For a single year, the continuous futures prices time series intervals were constructed as follows:

The third was the Reais/US dollars daily exchange rate series, given by the PTAX-800 selling quotes, of Banco Central do Brasil, used to convert the spot prices, quoted in Reais, in Rondonópolis (MT) to US dollars, in order to compare with the futures contracts in BM&F.

Estimation period was March 03rd, 2004 up to June 16th, 2009, totaling 1.321 observations of daily quotes. When there was a discrepancy of dates, i.e., local holidays, the price in date *t* was linearly interpolated between the previous and the next values. The return was calculated by the logarithm difference between two successive values, for both spot and futures series.

The software used was E-VIEWS, version 6, which holds the GARCH BEKK model built-in features.

4 DISCUSSION AND RESULTS

The daily spot, in Rondonópolis (MT), and futures prices series, in BM&F, are shown below, both series plotted at the level:

TABLE 1 – BM&F Soybean Futures Contracts Main Specifications

ITEM	SPECIFICATION
Commodity	Brazilian soybean, export type, graded through MAPA specifications
Quote	Usdollars for 60 kgs bag
Trade Unit	27 metric tons or 450 bags of 60 kgs
Settlement Months	March, april, may, june, july, august, september and november
Settlement and Last Trading Date	9th business day before the first day of settlement month
Point of delivery and price reference	Paranaguá (PR)
Daily Settlement	Based in the settlement price as per the Exchange´s rules

Source: BM&F-BOVESPA (2009)

The summary statistics, unit root and cointegration tests for the level spot and futures price series are explicit as follows:

The ADF unit root tests results do not make possible to reject the null hypothesis of non-stationarity for the spot and futures price series. The returns are skewed to the left, leptokurtic, both features in accordance with results presented for financial and commodity price time series.

The Engle and Granger results in Table 3 demonstrate that the null hypothesis of non-stationarity in the residuals of the cointegrating regression is rejected and there is a long term relationship between soybean spot and future daily price series.

The results for the minimum variance hedge, calculated by OLS are:

The minimum variance hedge, β, equals the ΔF_t coefficient, reaching 0.499, which is the position in soybean futures contracts in BM&F necessary to offset the price risk of the spot position. The minimum variance hedge effectiveness is given by the R^2 statistics, 0.188.

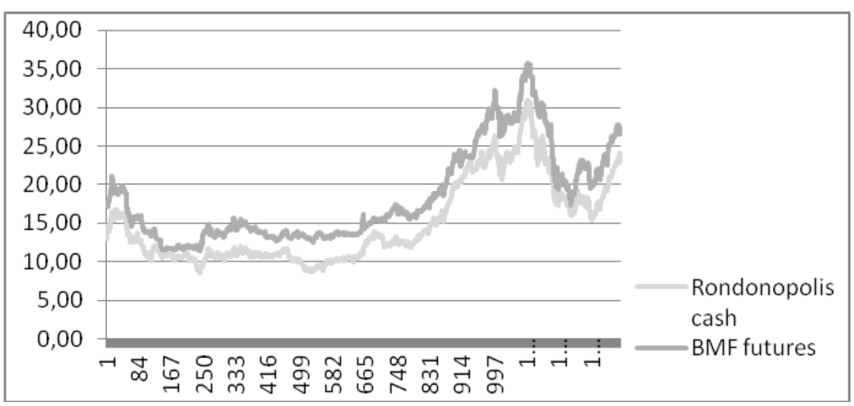
The diagnostic tests for the minimum variance hedge model (White´s and Ljung-Box), to detect volatility clustering and heteroskedasticity, peculiar of financial and commodity price series, are listed as follows:

TABLE 2 –Soybean Futures Contracts Continuous Price Series

MONTH	FUTURES CONTRACTS MONTHS*
January	March
February	March / April
March	April / May
April	May / June
May	June / July
June	July / August
July	August / September
August	September / November
September	November
October	November / March
November	March
December	March

Note: The reference day for the price series rollover date is the 9th business day before the contract month first day.
Source: Authors, with BM&F soybean contract specifications.

FIGURE 2 – Soybean Daily Prices Spot Market in Rondonópolis (MT), Futures in BM&F (USdollars/60 kg bag) – Dates: Mar.01/04 to Jun.16/09



Source: BM&F (2009)

TABLE 3 – Spot and Futures Soybean Daily Prices summary Statistics and Cointegration Tests

Unit Root Tests	ADF			
F_t	-0.6012			
S_t	-0.5692			
Summary Statistics	Mean	Variance	Skewness	Excess Kurtosis
ΔF_t	0.032	2.887	-0.932	9.812
ΔS_t	0.037	3.831	-0.364	5.984
Engle-Granger Cointegration Test	ϕ_0	ϕ_1	ADF	
S_t as dependent variable	-0.003	0.510	-5.231	

Note: ADF: Augmented Dickey-Fuller test; $\Delta S_t = \ln(S_t / S_{t-1}), \Delta F_t = \ln(F_t / F_{t-1})$

Source: authors

TABLE 4 – Minimum Variance Hedge OLS Regression Parameters

Variable	Coefficient	Standard-Error	"t" statistics	Probability
C	0.018	0.049	0.363	0.717
ΔF_t	0.499	0.029	17.445	0.000
R^2	0.188			

Note: β = minimum variance hedge is the Δf_t coefficient and R^2 its effectiveness.

Source: authors

TABLE 5 – Diagnostic Tests for the Minimum Variance (OLS) Hedge Model

TEST Autocorrelation: Ljung-Box		Test Statistics	P-Value
ΔF_t	Q(05)	4.584	0.469 *
	Q(10)	9.671	0.470 *
	Q(15)	13.786	0.542 *
ΔS_t	Q(05)	2.417	0.789 *
	Q(10)	6.880	0.737 *
	Q(15)	8.811	0.887 *
Heteroskedasticity : White´s		73.539 **	

Note: Rejects the null hypothesis of autocorrelation at the 5, 10 and 15 % significance levels; (**) accepts the null hypothesis of homoskedasticity at the 5, 10 and 15% significance levels. Source: authors

The Ljung-Box test results allow the rejection of the null hypothesis of non-autocorrelation in the residual of the OLS model.

However, the White´s test indicates the existence of heteroskedasticity, resulting in an inappropriate hedge ratio, given by OLS. Therefore, the best approach is to use a model considering this feature, such as the GARCH BEKK bivariate.

The output for the GARCH BEKK bivariate model is:

In Table 6, the C(1), C(2) parameters are the spot and futures price coefficients, A_i is the ARCH term matrix, B_j is the GARCH matrix. The parameters of A_i e B_j are used for volatility transmission. In Figure 3 the minimum variance and the dynamic hedge ratios, calculated through the OLS and GARCK BEKK models, respectively, are shown:

The unit root test for the dynamic hedge ratio series is listed below:

As in Table 7, the dynamic hedge ratios are stationary, once ADF test result is below the 1, 5 and 10% critical values. Therefore the null hypothesis of a unit root in the dynamic hedge series can be rejected and there is not temporal dependency among the observations, and an ARMA model can be used for previsions of future time paths.

For hedging effectiveness comparison, four portfolios were constructed, with an unhedged position, a "naïve", the minimum variance and dynamic hedges, as follows:

The unhedged portfolio corresponds to a single long position in the spot market. The return and variance show the Rondonópolis (MT) soybean price series performance. All the other portfolios return and variance relative performances are compared with the unhedged.

By Table 8, the "naïve" hedge portfolio, holding a long spot and a short futures markets position simultaneously, decreases the return but does not affect the variance. This behavior proxy pure basis risk speculation, i.e., the expected return is neutral and variance depends only of the basis itself.

Composed of a long spot and a short futures markets position, the later equals the spot position multiplied by β, the minimum variance hedge portfolio decreases both the return and variance. The variance reduction corresponds to daily basis price risk neutralization and is larger than the "naïve" portfolio variance decrease.

The dynamic hedge portfolio, which has a long spot market position and a β time varying futures market short position, does not alter significantly the return of the unhedged portfolio, but has quite the same impact on variance reduction as the minimum variance, as shown in Table 8.

This means that the dynamic hedge portfolio holds the largest hedging effectiveness, outperforming all the others, both in terms of constant expected return and price risk minimization, measured by variance reduction. Another relevant feature of the dynamic hedge portfolio is the stationarity of, which can be used for prevision through an ARMA model. Also, as it is time varying, the associated financial costs are less than the other hedges.

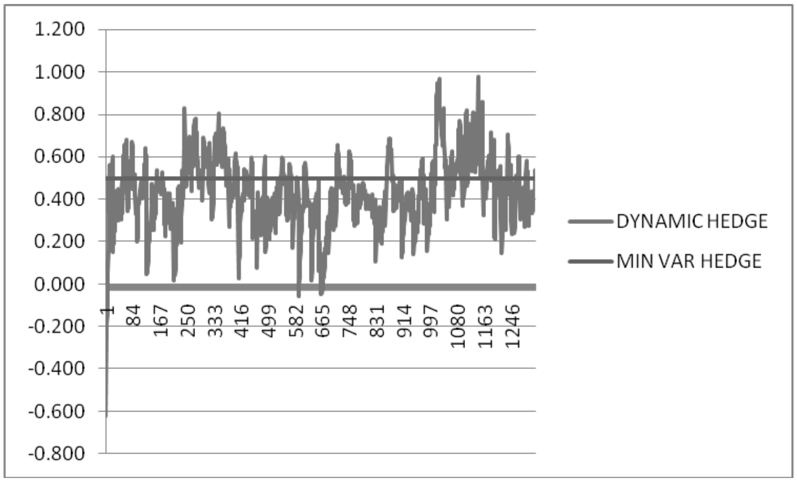
TABLE 6 – GARCH BEKK Bivariate Model Parameter Estimation

Parameters	Estimation	Standard-Error
C(1)	0.067	0.049
C(2)	0.027	0.039
M(1,1)	0.199	0.046
M(1,2)	0.077	0.015
M(2,2)	0.237	0.040
A1(1,1)	0.253	0.017
A1(2,2)	0.328	0.013
B1(1,1)	0.938	0.009
B1(2,2)	0.898	0.012

Note: Covariance specification: BEKK; $GARCH = M + A1 * RESID(-1) * A1 + B1 * GARCH(-1)$; M is an Indefinite matrix, A1, B1 are diagonal matrices.

Source: authors

FIGURE 4 – Minimum Variance and Dynamic Hedge Ratios Soybean Spot and Futures Prices Output: OLS and GARCH BEKK Bivariate Model



Source: authors

TABLE 7 – Unit Root Test for the Dynamic Hedge Ratios GARCH BEKK Bivariate Model Output

		Test Values	Probability
Augmented Dickey-Fuller test		-9.2383	0.0000
Test critical values:	1% level	-3.4351	
	5% level	-2.8635	
	10% level	-2.5679	

Source: authors

TABLE 8 – Hedging Effectiveness Summary Statistics for Portfolio Return and Variance (in % Change) of Daily Quotes

Parameters	Unhedged	Naïve	Min Variance Hedge	Dynamic Hedge
□	0	-1	0.499	Time varying
Return	0.034	0.002	0.018	0.033
Variance	3.831	3.837	3.112	3.127
Relativization		Naïve	Min Variance Hedge	Dynamic Hedge
Return		94.1%	-47.1%	-2.9%
Variance		0.2%	-18.8%	-18.4%

Source: authors

5 SUMMARYAND CONCLUSIONS

The optimal hedge considers the price risk offset and the expected return from the simultaneous spot and futures markets positions. The hedger wants to carry a combination of his assets positions in a portfolio comprising of commitments in the commodity spot and futures markets that maximizes his utility function. Finding this best resources allocation is the hedger main objective. The function of the futures markets is to provide a financial tool capable of delivering the portfolio optimal combination.

The hedging strategies encompass several alternatives, ranging from the simple unhedged, long only, to the dynamic, time varying, positions, as described earlier. Each alternative impacts the risk, measured by the variance, and expected return differently. The hedger continuous efforts are geared toward finding which portfolio combination of spot and futures markets positions better suits his needs and perceptions. Particularly, for the soybean farmers of Rondonópolis (MT), bearing high basis risk, this effort is compensated by the optimal hedging results.

Compared with the unhedged, "naïve" and minimum variance hedges, the dynamic hedge is the most effective to minimize price risk and optimize expected return for the Rondonópolis (MT) soybean production. This result is in line with other studies of dynamic hedge ratios for other commodities and is widely approached for academic research.

There are several economic and financial impacts of the dynamic hedge strategy on the Rondonópolis (MT) soybean farmers using the BM&F futures contracts, which will positively affect their decision making process, such as price discovery, hedging calibration, cash flow projections, market timing, among others.

A dynamic, time varying, hedge, considering the intrinsic characteristics of the price series volatility, has a major contribution in offsetting the Rondonópolis (MT) soybean price risk, which is a seasonal, storable commodity, affected by a high basis risk. That will contribute for a better resources allocation by the industry, increasing the returns throughout the whole supply chain, making all agents better-off.

In this study, the daily quotes used bear a lot of noise. For future researches longer periods, adjusted to the farmers reality should be studied, as well as new dynamic hedging models, the overall cost input for the hedge trades, turning the approaches as close as possible to the Brazilian soybean farmers reality.

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