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Optimal Hedging Ratio for Pakistan's Wheat Imports

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ABSTRACT

In this paper, optimal hedging ratio is calculated for Pakistan's wheat imports from USA. Price risk faced by various market participants is estimated. Slope coefficient from OLS regression is used to calculate optimal hedging ratio (OHR). Results indicate that FOB and CIF prices of wheat are significantly volatile and need proper management of associated risk. While optimal hedging ratio of wheat using FOB prices at US ports against Minneapolis Grain Exchange and Kansas City Board of Exchange were 0.925 and 0.867.

Key Words: Stationarity; Unit root test; Optimal hedging ratio; Import; Wheat

INTRODUCTION

In Pakistan, wheat being the main staple food is also the most sensitive crop and even small changes in its price and availability are perceived to have profound effects on national economy. This un-certainty in prices can turn large profits into huge losses to both producers and overall economy (Faruqee *et al.,* 1997). Pakistan had not been a hundred % food sufficient country in the past, so it had been importing substantial amounts of wheat from various countries especially from USA. During the last 13 years, Pakistan has spent (on an average) about Rs. 11759 million annually on wheat imports (Government of Pakistan, 2003).

Many studies have been conducted on the usefulness of hedging instruments as risk management tool including Claessens and Varangis (1993), Claessens *et al*. (1993), Lidfeldt and Anderson (1994), Morgan *et al.* (1994), Nilsson (2001), and Silva *et al.* (2003). Large number of studies has focused on developing countries. In general, these studies conclude that hedging reduces commodity price risk and is better than other risk mitigating tools. Faruqee *et al*. (1997) investigated the feasibility of using hedging instruments as risk management tool in the wheat market of Pakistan. Their results support the common deduction of using futures market as effective risk management tool.

Three hedge strategies have been proposed for using derivative instruments such as futures to hedge a portfolio of risky assets: the traditional one to one hedge, the beta hedge, and the minimum variance hedge. All three strategies require determining the optimal hedge ratio h* (OHR). The traditional one to one hedge strategy involves the adoption of a fixed hedge h = -1 which consists of taking a futures position that is equal in magnitude, but opposite in sign, to the spot position. If price changes in the futures market can exactly predict variations in the future markets, the adoption of a one to one strategy will successfully eliminate the price risk.

The beta hedge strategy is quite similar but it is used when the cash portfolio to be hedged does not exactly match the portfolio underlying the futures contract. So this time, the optimal hedge ratio is calculated as the negative of the beta of the cash portfolio. Naturally, if the cash portfolio is that, which underlies the futures position, the two strategies will give the same value for the hedge ratio.

However, in practice the prices on the spot and futures markets do not move exactly together and a hedge ratio derived from the traditional or beta hedge strategy would not hedge the price risk. Since the futures contract is more volatile than the price of underlying commodity, the use of a portfolio beta as a sensitivity adjustment would result in a portfolio being over-hedged. So the minimum variance (MV) hedge ratio is employed to cope with this imperfect correlation.

Several techniques have been proposed to estimate the minimum variance hedge ratio with futures contracts. While these techniques hold theoretical appeal, there is no univocal evidence as to their effectiveness. Only the GARCH (generalized autoregressive conditional heteroscedasticity) model has been found to outperform the OLS model and the improvement is not really consistent (Casillo, 2004). Lien *et al.* (2002) used a constant correlation model in relation to ten spot and futures markets covering currency, commodity and stock index futures. He asserted that if conditional heteroscedasticity was a characteristic of many price series, there was no definitive conclusion about the superior hedging performances of the GARCH model. Therefore, he obtained and compared the performances of the MV hedge ratio from an OLS and a CC-GARCH showing that the GARCH strategy was not able to outperform the OLS strategy. Moreover, given the high transaction costs associated with the GARCH strategy, the authors argued that it should not be considered for hedging purposes but just for data description.

The prices of agricultural commodities are expected to show higher variations in the post WTO era. We use price data obtained from the years when WTO agreements have been implemented. So, this study is undertaken to find out whether futures market can still be used as risk minimizing tool. The slope coefficient from OLS regression is employed as optimal hedging ratio. The study compliments the results from Faruqee *et al.* (1997), who conducted a similar study but on the data belonging to pre WTO period.

MATERIALS AND METHODS

Standard deviation and coefficient of variation were employed to calculate the price variability and risk management needs. Dickey-Fuller test was employed to estimate the presence of non-stationarity of data. To calculate the optimal hedging ratio of Pakistan's wheat imports from U.S. two futures contracts i.e. (a) Soft White Wheat traded on the Minneapolis Grain Exchange and (b) Hard Red Winter Wheat traded on the Kansas City Board of Trade were used. These contracts were chosen because they cover wheat whose characteristics are closest to those of wheat commonly imported by Pakistan. Monthly data for both the contracts from January 1996 to December 2003, providing a total 96 observations was collected. Before running the regression, time series price data was subjected to stationarity testing. The optimal hedge ratio was computed against three different import (cash) prices i.e. the U.S. dollar FOB (free on board) price of Western White Wheat at U.S. Ports, the price of wheat delivered at Karachi, and the Karachi price in Pakistani rupees.

Empirical method. Minimum variance (MV) model has been proposed by Johnson (1960) and Stein (1961) and developed by Ederington (1979), who employs portfolio theory to identify the hedge ratio (h*) as:

$$h^*_{t-1} = -(\sigma^2_{W,F,t} / \sigma^2_{F,t}) \qquad (1)$$

Where $\sigma^2_{F,t}$ represents the conditional variance of the futures contract and $\sigma^2_{S,F,t}$ is the conditional covariance between the wheat futures and the spot position on wheat. The negative sign just means that the hedging of a long stock position requires a short position in the corresponding futures contract.

In order to show how the above can be derived let W_t and F_t be the logarithms of wheat cash and wheat futures prices, respectively. The starting point necessary to derive the model is represented by the two equations that express the actual returns offered from the two assets at time t,

$$\Delta W_t = W_t - W_{t-1} = R_{s,t} \text{ and } \Delta F_t = F_t - F_{t-1} = R_{f,t}$$

Hence, the expected return at time t-1 of a portfolio (P) consisting of a long position in Q_W unit of the wheat and Q_f units of the corresponding futures contract, is given by:

$$E_{t-1}(P_t) = Q_w E_{t-1}(\Delta W_t) - Q_f E_{t-1}(\Delta F_t) \qquad (2)$$

Where the price changes are assumed to be stochastic and the spot position Q_W is given.

The resulting variance associated to this portfolio is:

$$\sigma^2_{p,t} = Q\,\sigma^2_{W,t} + Q\,\sigma^2_{F,t} - 2\,Q_{W,t-1}\,Q_{f,t-1}\,\sigma_{W,F,t} \qquad (3)$$

With $\sigma^2_{W,t}$ and $\sigma^2_{F,t}$ representing the conditional variance of the cash and futures positions. If the goal is to maximize investor's expected utility we need to define its utility function, which is the risk-return trade-off, in order to go on. Following Kahl's formulation, Brooks *et al.* (2002) has shown that if the investor has the following linear utility function,

$$U(E_{t-1}(P_t), \sigma^2_{p,t}) = E_{t-1}(P_t) - \psi\,\sigma^2_{p,t} \qquad (4)$$

Where ψ is the degree of risk aversion, then agent's maximisation problem can be expressed as,

$$\text{Max } U(E_{t-1}(P_t), \sigma^2_{p,t}) = Q_s E_{t-1}(\Delta W_t) - Q_f E_{t-1}(\Delta F_t) +$$
$$-\psi(\sigma^2_{W,t} + Q\,\sigma^2_{F,t} - 2\,Q_{W,t-1}\,Q_{f,t-1}\,\sigma_{W,F,t}) \qquad (5)$$

Substituting, we can derive the solution that permits to maximize the utility function, that is the condition for an optimum,

$$-\frac{Q_f}{Q_w} = \frac{\sigma_{wf}}{\sigma^2{}_f} - \frac{\delta_f}{Q_w \nu \sigma^2{}_f} \qquad (6)$$

That can also be written as:

$$Q_f = \left(\delta_f \big/ \nu\sigma^2{}_f\right) - Q_w\left(\sigma_{wf} \big/ \sigma^2{}_f\right) \qquad (7)$$

Assuming that ψ is indefinitely high (i.e. $\psi \to \infty$) the investor futures position does not depend on the risk parameter because the ratio "$\delta F / \nu\sigma^2_f$" becomes insignificant. In that case the hedge ratio is:

$$h^* = Q_f / Q_w = -\sigma_{w,f} / \sigma^2_f = \rho(\sigma_w / \sigma_f) \qquad (8)$$

Where ρ is the correlation coefficient between cash (W) and futures (F) prices. Substituting this expression into the portfolio variance equation, we obtain the variance of return for the minimum risk hedge ratio,

$$\sigma = \sigma(1 - \rho) \qquad (9)$$

Therefore, the return on a hedged position will normally be subject to the risk caused by unanticipated changes in the relative price between the position being hedged and the futures contract. The formula clearly expresses that only when there is a perfect correlation, the risk can be completely eliminated by hedging. If the spot and futures prices are co-integrated and the conditional variance-covariance matrix is time invariant, it has been shown that a constant optimal hedge ratio can be obtained from the slope coefficient h in the regression:

$$\Delta Wt = \alpha + h^* \Delta Ft + \varepsilon t \quad (10)$$

This method of the Ordinary Least Squares regression in which the coefficient estimate for the future price gives the hedge ratio by regressing the spot on the future price, has been employed in the past by various studies, like Ederington (1979), Malliaris and Urrutia (1991) and Benet (1992).

However, as recognized by Cecchetti *et al.* (1988) and Castellino (1990) the minimum variance (MV) hedge ratio is in general inconsistent with the mean-variance framework. In order to be consistent the MV hedge ratio has to implicitly assume that either expected returns on the futures contract needs to be zero or that investors are infinitely risk averse, as shown above, which means that they will renounce an infinite amount of expected return in exchange for an indefinitely small risk reduction. Such an assumption is undoubtedly unrealistic; nevertheless the minimum variance hedge ratio is useful in order to provide a benchmark for the hedging performances.

Although, this method has suffered various criticisms by Pindyck (1984), Poterba and Summer (1986), Bollerslev (1986), Baillie and Gennaro (1990). Moreover, in recent literature; Baillie and Myers (1991), Myers (1991), Sephton (1993), Park and Switzer (1995) has proposed the use of hedging strategies based on the GARCH (generalized autoregressive conditional heteroscedasticity) class of models, which allow the conditional variances and covariances used as inputs to the hedge ratio to be time-varying. Finally, other researchers have proposed more complex techniques and some special case of the above techniques for the estimation of the OHR. Among these we mention the random coefficient autoregressive offered by Bera *et al.* (1997), the Fractional Co-integrated Error Correction model by Lien and Tse (1999), the Exponentially Weighted Moving Average Estimator by Harris and Shen (2002), and the asymmetric GARCH by Brooks *et al.* (2002). Nevertheless, whether a distinctive superior hedge ratio estimation methodology exists is a question that is still under debate.

Many time series are non-stationary and in general, OLS regressions between such data are spurious. The validity of calculating OHR using regression requires that cash price series be stationary. The presence of a unit root in the autoregressive representation of a time series leads to non-stationarity, and such series, referred to as being integrated of order one [*I* (I)], must be first-differenced to render them stationary. Where *I* (1) series move together and their linear combination is stationary, they are referred to as being co-integrated and the problem of spurious regression does not arise. We begin by testing for the presence of unit roots in the individual time series using the augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1981; Said & Dickey, 1984), both with and without a deterministic trend. The number of lags in the ADF-equation is chosen to ensure that serial correlation is absent using the Breusch-Godfrey statistic (Greene, 2000, p. 541).

RESULTS AND DISCUSSION

Measuring the price volatility. As depicted by the results presented in Table I the government denominated prices i.e. procurement and release price exhibit considerably low variation. Since 1990, wholesale prices at Lahore and Multan have exhibited some variations, with coefficient of variation of 9.3 and 11.2, respectively. However, when we look at international prices, they show significantly large volatility than domestic prices. The U.S. dollar price of wheat at U.S. Gulf port has a coefficient of variation of 17.9% and when freight charges are added, the figure becomes 17.1. Further, when Karachi U.S. dollar price is converted into price in rupees, the variability of the price rises to great extent with a coefficient of variation 32.4%. So, the net result is displayed in large volatility of international wheat price in rupees.

Lastly, the coefficient of variation of the subsidy series is 75%, implying that in a typical year, subsidy payments will be 75% above or below the average payment.

Stationarity of data. Most time series data exhibit trends and are called non-stationary (Nelson & Plosser, 1982). Augmented Dickey-Fuller (ADF) test is used to test for the unit roots in the series in logarithms. Lags are added so that Breuch-Gogfrey LM-statistics (Greene, 2000, p. 541) rejects serial correlation up to fourth order. Table II presents the results of the ADF-tests performed with and without a linear trend. In the non-trended model, unit roots appear in FOS, CS and CRS. While FUS, FOH, CH, CRH and FUH appears to have no unit roots. However, in trended model all the variables show unit roots. Therefore, we can conclude that all the series are non-stationary.

Where:

FOS = FOB U.S. dollar price of Soft White Western Wheat at U.S. Gulf port

CS = CIF U.S. dollar price of Soft White Western Wheat at Karachi port

CRS = CIF rupees price of Soft White Western Wheat at Karachi port

FUS = Futures U.S. dollar price of Minneapolis Grain Exchange futures contract

FOH = FOB U.S. dollar price of Hard Red Winter Wheat at Northwestern ports

CH = CIF U.S. dollar price of Hard Red Winter Wheat at Karachi port

CRH = CIF rupees price of Hard Red Winter Wheat at Karachi port

FUH = Futures U.S. dollar price of Kansas City Board of Trade futures contract.

All the series become stationary after 1st differencing (Table III). This shows that they are I (1).

Optimal hedging ratio. If there is no (or little) basis risk and if changes in futures prices explain all changes in cash prices, hedgers should cover all cash transactions with futures contracts. When there is a basis risk, however, hedgers should generally cover only a portion of their cash position. Statistical analysis of cash and futures prices can determine the hedge ration, an important policy variable.

Table I. Measure of Price Variability in Pakistan, January 1990-June 2003

Price per ton	Mean	Standard Deviation	Coefficient of Variation (percent)
Procurement Price (rupees)	2918	241.1	8.3
Release Price (rupees)	2985	365.4	12.2
Wholesale Price (rupees)			
Lahore	2988	277.6	9.3
Multan	3166	354.7	11.2
FOB U.S. Gulf (US$)	141.5	25.3	17.9
CIF Karachi (US$)	165.1	28.2	17.01
CIF Karachi (rupees)	6,540	2115.6	32.4
Govt. Import Subsidy (rupees)	1472	1101	74.77

Note: Subsidy data is from 19884-85 to 2002-03. Price data is deflated by consumer price index.
Source: Govt. of Pakistan (various issues), Agricultural Prices Commission of Pakistan (various issues) and International Wheat Council (various issues)

Table II. DF Test for Unit Roots

Variables	Test Statistics for Non-trended Model	Test Statistics for Trended Model	Trend	$\varnothing_3$
FOS	-2.43	-1.90	1.16	3.21
CS	-2.31	-1.79	1.64	4.09
CRS	-	-	-	-
FUS	-3.27	-2.66	-.02	5.29
FOH	-3.36	-2.82	2.06	6.81
CH	-3.12	-2.57	1.57	2.84
CRH	-	-	-	-
FUH	-2.94	-2.62	0.72	7.93
C.V.	-2.89	-3.45	2.79	6.49

Note: Results are at 95% confidence level.

Table III. First Differenced Series

Variables	Test Statistics for Non-trended Model	Test Statistics for Trended Model
FOS	-7.85	-8.18
CS	-8.38	-8.61
CRS	-	-
FUS	-7.65	-7.99
FOH	-7.80	-8.17
CH	-7.32	-8.01
CRH	-	-
FUH	-7.80	-8.17
C.V.	-3.45	-2.89

Note: Results are at 95% confidence level.

For traders wishing to reduce risk by hedging with futures contracts, the proportion of the spot position held as futures contracts - the hedging ratio - is critical. The optimal hedging ratio is the unconditional covariance between spot and futures prices relative to the un-conditional variance of the futures price (Johnson, 1960; Stein, 1961).

In Pakistan, the instability of wheat import costs depends on the variability of both the volume of imports and price of imports. However, because the government controls the volume of imports, fluctuating prices are the main source of risk management strategies. The hedging decision can be viewed as a portfolio selection problem in which the hedger selects the optimal proportions of un-hedged (cash) and hedged (futures) wheat imports. In this case, risk management strategies aim to minimize the variance in the value of the portfolio of hedged and un-hedged imports.

Assuming risk minimization, hedging the U.S. dollar FOB wheat price at U.S. Gulf port using the Minneapolis Grain Exchange yielded a hedge ratio of 0.92 (Table IV). This means that if the government wishes to purchase, say, 2 million tons of wheat, it would need to cover 1.84 million metric tons with futures contracts, or roughly 13, 522 contracts (assuming about 136 tons per contract).

For U.S. dollar CIF price hedge ratio is 0.906 and for CIF rupees price at Karachi is 0.748. The hedge ratio declines for the Kansas City Board of Trade wheat contract. Hedging the U.S. dollar FOB wheat price at Pacific Northwest Port using the Kansas City wheat contract yielded a hedge ratio of 0.867 (Table IV). In this case, if the government wishes to purchase, say, 1 million tons of wheat, it would need to cover 0.867 million metric tons with futures contracts. For U.S. dollar CIF price hedge ratio is 0.862 and for CIF rupees price at Karachi, it is 0.685.

It can be concisely argued that the highest potential effectiveness of hedging Pakistani wheat purchase is exhibited by soft white wheat contract that is traded on the Minneapolis Grain Exchange. This inference is made in consideration of its low basis risk and high value of hedge ratio.

CONCLUSIONS

As predicted by various researchers, like other agricultural commodities wheat prices are still volatile enough that associated risk must be managed somehow. Various international wheat prices have shown high volatility for Pakistan. Optimal hedge ratios calculated by minimum variance (MV) method are very high, which suggests that futures markets should be used to minimize price risk associated with wheat imports for Pakistan. We have just shown the suitability of using U.S. futures markets for wheat trade by Pakistan. However, government should take necessary steps to set up local commodity futures markets, so that domestic market participants can also benefit from them as risk minimization tool.

Table IV. Hedge Ratio in Pakistan, 1996-03

Contract and Price	Hedge Ratio [a]
Minneapolis Soft White Wheat No. 1	
FOB U.S. dollar price at U.S Gulf Port	0.925
CIF U.S. dollar price at Karachi	0.906
CIF rupees price at Karachi	0.748
Kansas City Hard Red Winter Wheat No. 2	
FOB U.S. dollar price at Pacific Northwest Ports	0.869
CIF U.S. dollar price at Karachi	0.862
CIF rupees price at Karachi	0.685

Note: a. Slope coefficient regression between first differences of cash and nearby futures prices.
Source: International Grain Council (various issues), Minneapolis Grain Exchange, Kansas City Board of Trade, and Agricultural Prices Commission of Pakistan (various issues).

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