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Volatility Spillovers between Foreign Exchange, Commodity and Freight Futures Prices: Implications for Hedging Strategies

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Abstract

In many studies the assumption is made that traders only encounter one type of price risk. In reality, however, traders are exposed to multiple price risks, and often have several relevant derivative instruments available with which to hedge price uncertainty. In this study, commodity, foreign exchange, and freight futures contracts are analyzed for their effectiveness in reducing price uncertainty for international grain traders. A theoretical model is developed for a representative European importer to depict a realistic trading problem encountered by an international grain trading corporation exposed to more than one type of price risk. The traditional method of estimating hedge ratios by Ordinary Least Squares (OLS) is compared to the Seemingly Unrelated Regression (SUR) and the multivariate GARCH (MGARCH) methodology, which takes into account time-varying variances and covariances between the cash and futures markets. Explicit modeling of the time-variation in futures hedge ratios via the MGARCH methodology, using all derivatives and taking into account dependencies between markets results in a significant reduction in price risk for grain traders. The results also confirm that the unique, but underutilized, freight futures market is a potentially useful mechanism for reducing price uncertainty for international grain traders. The research undertaken in this study provides valuable information about reducing price uncertainty for international grain traders and gives a better understanding of the linkages between closely related markets.

Key words: dynamic hedging, multivariate GARCH, foreign exchange, freight and commodity futures.

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1.INTRODUCTION

One notion of optimal hedging implies a trader may optimally select the proportion of futures positions to cover an exposed cash position in order to minimize price risk. These proportions are commonly known as optimal hedge ratios. Empirical and theoretical models, to date, have focused on a wide range of issues relating to estimating optimal hedge ratios. For instance, Benninga, Eldor and Zilcha (BEZ) and Lence (1995, 1996) addressed issues relating to the assumptions imbedded in optimal hedge ratio estimation. Several recent papers have concentrated on developing 'dynamic models' by relaxing the assumption of constant conditional second moments in spot and futures prices (e.g., Baillie and Myers; Myers; and Sephton). A number of recent studies, have examined how 'domestic' companies might manage their risks by using various derivative instruments (e.g., Fackler and McNew; Lapan and Moschini; Vukina, Li and Holthausen; and Li and Vukina), and some have focused on international hedging scenarios (e.g., Fung and Lai, Zilcha and Broll). Interestingly, with the exception of Hauser and Neff, all prior international studies of exporting or importing have ignored freight price risk and the possibility of utilizing freight futures to help reduce that risk for firms engaged in international commodity exchange.[1]

In most studies on managing risks with the assistance of hedging ratios , (both empirical and theoretical) however, the recommendations are based on the implicit assumption that the international traders only encounter one type of risk. That is, the study of risk is generally confined to hedging the unknown future price of the underlying commodity of interest. In reality,

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[1] Hauser and Neff did incorporate freight rate futures in their analysis of hedging multiple risks in international trade. A major finding was that freight futures did little or nothing to reduce price uncertainty for international grain traders. Their analysis was developed under the questionable assumption that conditional second moments are constant. Moreover, it was assumed that all asset prices were independent.

however, traders typically face multiple sources of uncertainty and so several hedging ratios may be of interest. For instance, a trader may not only be exposed to the price risk associated with the underlying commodity but may also confront foreign exchange rate risk if the payment is denominated in a foreign currency, or transportation price risk if the trader is responsible for shipment.

This research builds upon previous work to examine, for the first time, the effectiveness of several different financial derivatives, (foreign exchange, commodity and the BIFFEX freight futures contract), in helping to reduce price uncertainty for international grain traders using a multivariate generalized autoregressive conditional heteroskedasticty (MGARCH) model.[2] Extending the model to a time-varying framework (such as MGARCH models) complicates the estimation and so the estimation procedure becomes more complex when the hedging scenario takes into account multiple risks. Consequently, combining a time-varying framework with multiple risks has received only limited attention (e.g., Kroner and Claessens, Gagnon, Lypney and McCurdy).

The model developed here is unique in that it accounts for dynamic price volatility spillovers between markets and takes into account the effect of freight price and foreign exchange rate uncertainty, an aspect of international price risk management largely ignored in previous studies. In this paper a theoretical model is derived to determine appropriate hedging strategies for a European based wheat importer, where both freight futures contracts, foreign exchange contracts and wheat futures contracts are used. It is assumed that a hypothetical importer receives

[2] The Baltic International Freight Futures Exchange (BIFFEX) opened on May 1, 1985. This unique futures market was designed to allow participants in dry bulk shipping markets access to a mechanism for hedging freight price risk. It still remains as the only futures contract ever written on a service.

weekly wheat shipments from the U.S. Gulf to Rotterdam.[3] Three sources of price uncertainty for the grain importer are the Rotterdam wheat price and the ocean freight rate, assuming that the importer pays for freight services and the foreign exchange rate. Exchange rate uncertainty is an issue for the European based grain importers, as both freight and wheat prices are denominated in U.S. dollars.

Because the prices facing the importer are multiplied by exchange rates, minimizing the variance of the importer's portfolio implies that the variances and covariances are functions of products of random variables. This makes the theoretical importer's model, and hence optimization, more complicated, yet more realistic, than previous studies on reducing price uncertainty. To investigate the empirical implications of dynamic hedging for a representative importer, the MGARCH model is formulated in the least restrictive way. Specifically the positive semidefinite formulation as proposed originally by Baba, Engle, Kraft, and Kroner (BEKK) (1989) and used by Baillie and Myers (1991) and by Gagnon et al. (1998) is used to formulate optimal hedge ratios.

2. IMPORTER'S THEORETICAL HEDGING MODEL

The hedging behavior of a representative importer is modeled under the assumption of price uncertainty. Implicit throughout is the assumption that the quantity shipped is held constant. A European based importer has at least three futures contracts at her disposal with which to hedge the relevant price uncertainty: the conventional futures price contract for grain, the relatively new BIFFEX freight futures contract for freight price uncertainty, and the foreign exchange futures contract for foreign exchange uncertainty. As both the Chicago Board of Trade

[3] Weekly prices are available for both locations. The U.S. Gulf – Rott route (*R*1) receives the joint largest weighting (10%) in the current Baltic Freight Index (forming the basis of trading on the freight futures market).

(CBOT) wheat futures contracts and the London International Financial Futures Exchange (LIFFE) BIFFEX contracts are denominated in U.S. dollars, a European importer would be exposed to foreign exchange risk if she entered into these contracts. Also, as the Rotterdam wheat price and the cash price of freight (R1) are denominated in U.S. dollars, an extra layer of foreign exchange exposure lies within the trader's cash market exposure.

Ignoring the potential usefulness of any futures contracts, the importer's unhedged price outcome in Rotterdam can be expressed as:

$$IP_t = R_t * DC_t - R1_t * DC_t - \partial_t, \qquad (1)$$

where IP_t is the importer's price, R_t is the Rotterdam cash price of wheat, $R1_t$ is the cash price of freight from the U.S. Gulf to Rotterdam, and DC_t is the U.S. dollar/Deutschemark ($/DM) cash foreign exchange rate, and ∂_t represents other (non-stochastic) transactions costs. Alternatively, the hedged price outcome for the importer may be modeled as:

$$IHP_t = IP_t + b_1(C_{t-1} * DC_{t-1} - C_t * DC_t) + b_2(B_{t-1} * DC_{t-1} - B_t * DC_t) + b_3(DF_{t-1} * R_{t-1} - DF_t * R_t), (2)$$

where B is the BIFFEX freight futures price, C is the CBOT wheat futures price, DF is the $/DM futures foreign exchange rate, and b_i is the proportion of futures contracts either bought or sold in the futures markets respectively (positive if short, negative if long). Any prices denoted with a t-1 subscript are known constants at time t, whereas any prices denoted with a t subscript denote stochastic variables.

We would expect the European importer to go long CBOT contracts to offset any unexpected increases in the Rotterdam price of wheat. The trader would also go long in the BIFFEX freight futures market, *B*, to offset any increases in the cost of freight ($R1_t$), and would go short in foreign exchange contracts to purchase U.S. dollars to pay for the wheat and freight.

At time t, the European importer would pay IP_t for the wheat purchased in Rotterdam. Part of the uncertainty could be hedged by buying futures contracts at time *t-1* for price C_{t-1}. The proportion hedged would be b_1. As the futures contracts are denominated in U.S. dollars, the value of the futures contracts must be converted from Deutschemarks to U.S. dollars by multiplying the value by the current spot rate, DC_{t-1}. At time t the grain trader would receive IP_t for the wheat he did not hedge. But assuming that the contracts don't expire at the delivery date (the trader would have to deliver in this case), he would not accept delivery on the futures contracts. Instead at time t, the grain trader would sell back the futures contracts at price C_t, convert any proceeds into Deutschemarks by multiplying by the spot exchange rate, DC_t, and buy the entire hedged position in Rotterdam in U.S. dollars. Therefore if $C_{t-1}*DC_{t-1} < C_t*DC_t$, the trader would make money on the transaction. Alternatively, if $C_{t-1}*DC_{t-1} > C_t*DC_t$, or $C_{t-1}*DC_{t-1} = C_t*DC_t$, the trader will lose, or neither gain nor lose money on the transaction. For ocean freight, the grain trader would go long (buy freight futures contracts) at time *t-1* and resell the contracts at time *t*, if the trader were responsible for paying for the freight services. If $B_{t-1}*DC_{t-1} < B_t*DC_t$ the trader would make money on the transaction. The last term in (2) determines the optimal number of foreign exchange futures contracts to be used for hedging foreign exchange rate risk. The Rotterdam prices of wheat are multiplied by the Deutschmark futures contract prices to put them in equivalent units as the other two hedge ratios, as the hedge units must be determined *a* *priori* in practice. As the trader would originally go short foreign exchange futures contracts, if $DF_{t-1}*R_{t-1} > DF_t*R_t$, the trader would make money on the transaction.

It is assumed in this paper that the trader would choose the appropriate futures positions in the commodity, freight and foreign currency units in order to minimize the variability of the net price paid in Rotterdam. The variance of the importer's net price equation (2) can be expressed as:

$$\text{Var}(IHP_t) = \sigma^2_{RDC} + \sigma^2_{R1DC} + b_1^2\sigma^2_{CDC} + b_2^2\sigma^2_{BDC} + b_3^2\sigma_{DFR} - 2\sigma_{RDC,R1DC} - 2b_1\sigma_{RDC,CDC} - b_2\sigma_{RDC,BDC} - 2b_3\sigma_{RDC,DFR} + 2b_1\sigma_{R1DC,CDC} + 2b_2\sigma_{R1DC,BDC} + 2b_3\sigma_{R1DC,DFR} + 2b_1b_2\sigma_{CDC,BDC} + 2b_1b_3\sigma_{CDC,DFR} + 2b_2b_3\sigma_{BDC,DFR} \quad (3)$$

where for instance: σ^2_{RDC} is the variance of the product of Rotterdam price multiplied by the \$/DM exchange rate, and $\sigma_{RDC,R1DC}$ is the covariance between the product of the Rotterdam price multiplied by the \$/DM exchange rate and the cash price of freight (R1) multiplied by the \$/DM exchange rate. The expressions for the variances and covariances above are complicated because they are functions of random variables that are not independent of one another. However, Bohrnstedt and Goldberger (BG) derive the exact variance of a product *xy* and present the exact covariance of two products *xy* and *uv* and their formulas are used in this study. Taking the derivatives of (3) with respect to b_1, b_2 and b_3 yield the first-order necessary conditions for a risk minimizing hedge and solving for the optimal hedge ratios yields the following analytical solutions:

$$b_1 = (-\sigma_{RDC,CDC}(\sigma_{BDC,DFR})^2 + \sigma_{R1DC,CDC}(\sigma_{BDC,DFR})^2 + \sigma_{RDC,CDC}\sigma^2_{BDC}\sigma^2_{DFR} - \sigma_{R1DC,CDC}\sigma_{BDC}\sigma_{DFR} - \sigma_{CDC,BDC}\sigma_{RDC,BDC}\sigma_{DFR} + \sigma_{CDC,BDC}\sigma_{R1DC,BDC}\sigma^2_{DFR} + \sigma_{CDC,BDC}\sigma_{BDC,DFR}\sigma_{RDC,DFR} - \sigma_{CDC,BDC}\sigma_{BDC,DFR}\sigma_{R1DC,DFR} - \sigma_{CDC,DFR}\sigma_{BDC,DFR}\sigma_{R1DC,BDC} + \sigma_{CDC,DFR}\sigma_{BDC,DFR}\sigma_{RDC,BDC} - \sigma_{CDC,DFR}\sigma_{RDC,DFR}\sigma^2_{BDC} + \sigma_{CDC,DFR}\sigma_{R1DC,DFR}\sigma^2_{BDC}) / \Delta, \quad (4)$$

and

$$b_2 = -(\sigma_{CDC,DFR}\sigma_{CDC,BDC}\sigma_{RDC,DFR} + \sigma_{CDC,DFR}\sigma_{CDC,BDC}\sigma_{R1DC,DFR} + \sigma_{BDC,DFR}\sigma^2_{CDC}\sigma_{RDC,DFR} - \sigma_{BDC,DFR}\sigma^2_{CDC}\sigma_{R1DC,DFR} - \sigma_{BDC,DFR}\sigma_{CDC,DFR}\sigma_{RDC,CDC} + \sigma_{BDC,DFR}\sigma_{CDC,DFR}\sigma_{R1DC,CDC} - \sigma_{RDC,BDC}\sigma^2_{CDC}\sigma^2_{DFR} + \sigma_{RDC,BDC}(\sigma_{CDC,DFR})^2 + \sigma_{R1DC,BDC}\sigma^2_{CDC}\sigma^2_{DFR} + \sigma_{R1DC,BDC}(\sigma_{CDC,DFR})^2 + \sigma_{CDC,BDC}\sigma_{RDC,CDC}\sigma^2_{DFR} - \sigma_{CDC,BDC}\sigma_{R1DC,CDC}\sigma^2_{DFR}) / \Delta \text{, and} \quad (5)$$

$$b_3 = (-\sigma_{CDC,DFR}\sigma_{RDC,CDC}\sigma^2_{BDC} + \sigma_{CDC,DFR}\sigma_{R1DC,CDC}\sigma^2_{BDC} - \sigma_{CDC,DFR}\sigma_{CDC,BDC}\sigma_{RDC,BDC} - \sigma_{CDC,DFR}\sigma_{CDC,BDC}\sigma_{R1DC,BDC} - \sigma_{R1DC,CDC}\sigma_{CDC,BDC}\sigma_{BDC,DFR} + \sigma_{RDC,CDC}\sigma_{CDC,BDC}\sigma_{BDC,DFR} + \sigma_{BDC,DFR}\sigma^2_{CDC}\sigma_{R1DC,BDC} - (\sigma_{CDC,BDC})^2\sigma_{RDC,DFR} + (\sigma_{CDC,BDC})^2\sigma_{R1DC,DFR} - \sigma_{BDC,DFR}\sigma^2_{CDC}\sigma_{RDC,BDC} + \sigma_{RDC,DFR}\sigma^2_{CDC}\sigma^2_{BDC} - \sigma_{R1DC,DFR}\sigma^2_{CDC}\sigma^2_{BDC}) / \Delta \text{, where} \quad (6)$$

$$\Delta = 2\sigma_{RDC,DFR}\sigma_{CDC,BDC}\sigma_{BDC,DFR} - (\sigma_{BDC,DFR})^2\sigma^2_{CDC} + \sigma^2_{BDC}\sigma^2_{CDC}\sigma^2_{DFR} - \sigma^2_{BDC}(\sigma_{CDC,DFR})^2 - (\sigma_{CDC,BDC})^2\sigma^2_{DFR} \text{ .} \quad (7)$$

Therefore, the components of each of these optimal hedge ratios are simply the variances and covariances of spot and futures prices that can be retrieved from the MGARCH model for each time period and applied to the variance and covariance expressions provided by (BG).

3. DATA

Weekly data necessary to undertake the study were collected from the Baltic Exchange, the London International Financial Futures Exchange (LIFFE), the Chicago Board of Trade (CBOT), Datastream International, Bridge Financial Services and Clarkson Research Services of London. Data covers the period May 17th 1985 – August 23rd 1996 for in-sample analysis, and August 39th 1997 – Jan 17th 1998 were retained for an out-of-sample analysis. The few missing values (less than 5% of the total) were replaced with predicted values from a cubic spline interpolation. [4]

4. PRELIMINARY TIME SERIES ANALYSIS

The presence of a unit root was tested for in each series by performing Augmented Dickey-Fuller (ADF) tests. The ADF test results confirm that each series is associated with a unit root. The same weekly prices were also used to test for the presence of GARCH effects in conditional second moments. In all cases, time-varying conditional heteroskedacity was identified and subsequently accounted for by using Bollerslev's GARCH(1,1) process, under the assumption of normality, and, following Baillie and Myers, by utilizing the conditional Student's t density. Tests for departures from normality indicated that in most instances the normality assumption was not violated. Tests for residual autocorrelation in the standardized and the squared standardized residuals failed to detect any serious misspecifications of the GARCH components of the univariate models. Finally, Johansen cointegration tests were performed for the various pairs of cash and futures prices. The results indicated that except the foreign exchange prices, all pairs of cash and futures prices are indeed cointegrated. All preliminary time-series results are available upon request.

5. ECONOMETRIC SPECIFICATION

As the grain importer has available three derivative instruments in which to hedge the price uncertainty, accounting for time-varying covariability between futures and cash prices using a time-varying conditional variance-covariance framework (MGARCH) may lead to efficiency gains in terms of risk reduction. Therefore, in order to maximize the potential to pick up any covariation between the cash and futures markets, the positive semi-definite formulation (BEKK)

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[4] Further details on data and the data sources are omitted to conserve space but are available from the authors upon

of the MGARCH model was applied. This specification permits time-variation in the conditional correlations as well as the conditional variances. Moreover, this functional form ensures that the conditional variances are always non-negative. In order to implement the model, it is necessary to jointly model the first two moments of the cash and futures prices that would be used by the importer. Time series diagnostics led to the following specification:

$$\Delta R1_t = a_0 + \sum_{i=1}^{6} a_i \Delta R1_{t-i} + \sum_{i=1}^{6} a_{i+6} \Delta B_{t-i} + t_1 Z1_{t-1} + e_{R1t} \quad (8)$$

$$\Delta B_t = b_0 + \sum_{i=1}^{6} b_i \Delta R1_{t-i} + \sum_{i=1}^{6} b_{i+6} \Delta B_{t-i} + t_2 Z1_{t-1} + e_{Bt} \quad (9)$$

$$\Delta R_t = p_0 + \sum_{i=1}^{6} p_i \Delta R_{t-i} + \sum_{i=1}^{6} p_{i+6} \Delta C_{t-i} + t_3 Z2_{t-1} + e_{Rt} \quad (10)$$

$$\Delta C_t = d_0 + \sum_{i=1}^{6} d_i \Delta R_{t-i} + \sum_{i=1}^{6} d_{i+6} \Delta C_{t-i} + t_4 Z2_{t-1} + e_{Ct} \quad (11)$$

$$\Delta DC_t = g_0 + e_{DMCt} \quad (12)$$

$$\Delta DF_t = q_0 + e_{DMFt} \quad (13)$$

$$[e_{R1t}, e_{Bt}, e_{Rt}, e_{Ct}, e_{DCt}, e_{DFt}] \mid \Omega_{t-1} \sim N(O, H_t) \text{ where } H_t = W^T W + A^T e_{t-1} e^T_{t-1} A + B^T H_{t-1} B \quad (14)$$

All data are differenced due to the non-stationarity of each series, and all equations (except the DC and DF equations) contain an error correction term (Zi_{t-1}) designed to capture the cointegrating relationships mentioned previously. All mean equations in the system were estimated as an AR(6) process, except the foreign exchange rate equations which were best described as simple martingale processes.[5] The positive definite formulation was applied to the model as

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request.

[5] Following Tong (1996), the MGARCH structure used in this paper has an AR representation in the mean equation to capture residual serial correlation. An AR(6) process was found to be sufficient in equations (8-11) (using Box Pierce Q statistics) to render the residuals white noise. Evidence of autocorrelation in futures prices is not uncommon, (Matthews and Holthausen and Rauseer and Carter).

represented by equations (14). The disturbance vector ε_{it} are assumed to have a conditional normal distribution with the time dependent covariance matrix H_t. In (14), W is a symmetric (6x6) parameter matrix and A and B are unrestricted (6x6) parameter matrices.

Results were obtained from the systems of equations (8-14) by using the nonlinear maximum likelihood (ML) estimation routine (Davidon-Fletcher-Powell algorithm) offered by GQOPT (FORTRAN). Modelling Ht within the MGARCH framework entails estimation of 58 conditional mean equation parameters, and 93 variance-covariance parameters and so the results are excluded to conserve space (but are also available upon request). The results illustrate however that many off-diagonal terms in the A and B matrices associated with Ht are statistically significant. Results of several diagnostic tests for the MGARCH model failed to detect any serious misspecifications of the conditional mean and variance dynamics in the model suggesting that the MGARCH model performs very well in capturing both the conditional mean and variance-covariance dynamics of the cash and futures data.

6. OPTIMAL HEDGE RESULTS

The optimal hedge ratios derived previously (4-6) are nonlinear functions of the variances and the covariances of spot and futures prices. They can be retrieved from the MGARCH model for each time period for the representative importer. Each variance and covariance expression is itself a function of the means and central product moments of the cash and futures prices as described previously but can be calculated and used to form the three hedge ratios illustrated in (4), (5) and (6). For comparative purposes, simple Ordinary Least Squares (OLS) and Seemingly Unrelated Regression (SUR) hedge ratios are also estimated for the freight, wheat and foreign exchange market. The SUR model will facilitate a determination of how much advantage (if any) there is to estimating hedge ratios jointly while restricting the variances and covariances to be constant. Hedge ratio simulations for the representative importer is undertaken over two time horizons: one in-sample, the other out-of-sample (described in the data section). Only results from the out-of-sample forecasts are presented in this paper because in reality traders are more concerned with what will occur in the future than what occurred in the past.[6] Table 1 illustrates that the average hedge ratios and illustrates that the MGARCH and SUR methodologies appear to differ significantly from those generated by the OLS method. Variance reductions in all three models using one step ahead forecasts are very encouraging. Moreover, using the MGARCH model improves performance over the unhedged scenario by approximately 70.35% in terms of incremental variance reduction (IVR), whereas the OLS method only improve over the unhedged scenario by approximately 61% in the full hedge scenario. The SUR model which partially takes into account time-variation through updated forecasts, improves over the unhedged scenario by approximately 68%. When the freight futures are not included in the importer's trading portfolio (the partial hedge) performance declines vis-à-vis the unhedged scenario. Specifically, the OLS conditional variance is reduced to approximately 55%, implying that the marginal effectiveness of the freight futures market is approximately 6% in terms of risk reduction. For the MGARCH and SUR formulation, exclusion of the freight market also implies an increase in price risk of approximately 7%. Such results confirm that the unique "service oriented" freight futures market is a significant factor in helping to reduce price risk for grain importers.

The marginal contribution of the CBOT contracts varies considerably depending upon which model is used. Ignoring this derivative in the MGARCH model implies an increase in price variation of less than 1%, whereas excluding the contract from the OLS and SUR models implies

[6] In-sample results are excluded to conserve space but did produce qualitatively similar results to the out-of-sample

an increase in variation of approximately 18% and 27% respectively. Ignoring the potential usefulness of the foreign exchange contract is perhaps the most detrimental omission for a grain importer. Its marginal contribution ranges from approximately 61% using the MGARCH model, 64% using the SUR model, to approximately 83% in the OLS model. The IVR against the OLS model confirm previously published results suggesting the importance of incorporating time-varying covariability in optimal hedge ratio estimation. Moreover, the results also suggest that, although taking into account covariability and updating forecasts of cash and futures prices has a positive effect on reducing risk as shown in the SUR model results, it is the incorporation of time-variation covariability between the cash and futures prices that leads to considerable gains in terms of risk reduction.

7. SUMMARY

An evaluation of the performance of hedge ratios generated by the MGARCH, and SUR and OLS methodologies implies that the time-varying hedge ratios are statistically different from the constant hedge ratios. Also, as noted by Gagnon et al. (1998), estimation procedures which measure hedge ratios for each hedging instrument in isolation tend to over-estimate the number of futures contracts required to hedge the cash position. Results from the importer's model estimated here confirm this phenomenon.

Perhaps more interesting, is the superlative performance of the MGARCH hedge ratios over the OLS and SUR methodologies. As well, an evaluation of the marginal contribution of the BIFFEX freight futures market signifies the importance of this unique futures market in reducing price uncertainty for an importer of U.S. grain. Also, the foreign exchange derivative contract appears to be an extremely important contributory factor in helping to reduce price uncertainty for

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analysis. All results are available upon request.

the grain importer. Surprising, is the lack of importance of the CBOT contract for the grain importer. The average hedge ratio for the CBOT contract hovers slightly above zero (for the SUR and MGARCH models), suggesting that hedging the price of the wheat is relatively unimportant in this framework. The consequent marginal contribution in reducing uncertainty is therefore negligible. It might be inferred that hedging the other two types of uncertainty (freight and foreign exchange) provides a natural hedge for the grain price exposure. That is, accounting for the observed significant time-varying covariability between these related markets suggests that locking in to freight and foreign exchange futures contracts naturally hedges the wheat price exposure.

The findings and methodology employed in this paper are unique in several ways. Firstly, no previous study has reported estimates for a six-equation formulation of the BEKK specification of the MGARCH model. Secondly, previous work examining linkages between freight, commodity, and foreign exchange rate prices has assumed independence of the cash and futures prices. Results reported here illustrate that such an assumption is erroneous and that implementing more realistic assumptions regarding the co-dependency of the prices yields significant rewards in terms of reduction of price uncertainty for international grain traders. Finally, contrary to other studies that evaluated the potential usefulness of the BIFFEX freight market, this model illustrates the importance of the market, and may explain why such a unique, yet underutilized derivative market still remains popular among traders after fourteen years of existence.

Table 1: Importer's average hedge ratios: out-of-sample

	Freight hedge ratio	Wheat hedge ratio	FOREX hedge ratio
OLS	-0.326	-0.409	0.922
	(0.000)	(0.000)	(0.000)
SUR	-0.363	0.010	0.859
	(0.001)	(0.000)	(0.000)
MGARCH	-0.328	0.023	0.824
	(0.011)	(0.029)	(0.020)

Figures in parenthesis are variances.

Table 2: Importer's hedge ratio performance: out-of-sample

Model	Average Variance of Portfolio	I.V.R. vis-à-vis Unhedged Portfolio	I.V.R. vis-à-vis OLS Portfolio
Full Model using all three derivatives: BIFFEX, CBOT and FOREX			
Unhedged	18943.29	0.000%	-
OLS	7333.83	61.29%	61.29%
SUR	6108.53	67.75%	16.71%
MGARCH	5617.46	70.35%	23.40%
Partial Model (A) Using two derivatives, excluding the BIFFEX			
Unhedged	18943.29	0.000%	-
OLS	8502.18	55.12%	55.12%
SUR	7426.99	60.79%	12.65%
MGARCH	6860.77	63.78%	19.31%
Partial Model (B) Using two derivatives, excluding the CBOT			
Unhedged	18943.29	0.000%	-
OLS	10758.23	43.21%	43.21%
SUR	11288.55	40.41%	-4.93%
MGARCH	5828.89	69.23%	45.81%
Partial Model (C) Using two derivatives, excluding the FOREX			
Unhedged	18943.29	0.000%	-
OLS	23023.28	-21.50%	-21.50%
SUR	18238.3	3.72%	20.78%
MGARCH	17138.07	9.5%	25.56%

The full model utilizes all three derivative contracts available to the importer. The partial models exclude one of the three derivatives. The incremental variance reduction (I.V.R.) vis-à-vis the unhedged portfolio measures the reduction in variance of the models against the unhedged model. The I.V.R. vis-à-vis the OLS model measures the reduction in variance for the OLS model against the unhedged portfolio, and the MGARCH model against the OLS model.

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