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Offshore Commodity and Currency Hedging Strategy with Hedging Costs

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Abstract

This study explores the role of hedging costs in offshore hedging to minimize the risks associated with fluctuations in commodity export prices and exchange rates in international grain trade. The study focuses on three areas: (1) the effects of hedging costs in both commodity and currency futures hedging, (2) the relationship between hedging cost and trade volume of a grain, and (3) a prescriptive hedging strategy for Japanese wheat importers in the commodity and currency futures markets.

A demand system for futures hedging is presented and the effect of hedging cost on the model is analyzed. The model is applied to a representative wheat importer in Japan. Demand for futures is estimated under different levels of hedging costs in both commodity and currency futures markets. The empirical results show that the hedging costs are significant in both markets. The demand for hedging increases when the hedging costs decrease. When hedging costs are incorporated into the model, the two futures hedging have a substitute relationship.

Keywords: international grain trade, risk management, offshore futures hedging, hedging cost.

Highlights

The study explores the role of hedging cost in commodity and currency futures markets and implications for offshore hedgers who attempt to minimize the risks associated with commodity price and exchange rate changes in international trade. In the model, hedging products are treated as *goods* and the hedging costs as *prices* of the goods so that a *Marshallian* type of demand system is derived.

The study focuses on the effects of costs in both commodity and currency futures hedging and reinterprets the implications of existing offshore hedging studies by including hedging costs in the analysis. The hedging model developed in this study is applied to Japanese grain importers.

The empirical results indicate that hedging costs are significant in both markets. The demand for hedging increases when own cost is reduced. When hedging costs are incorporated into the model, the two means of futures hedging have a substitute relationship, associated with covariances between the two markets.

The results have several implications. First, reducing hedging costs in the Chicago Board of Trade would induce more hedgers into the market from abroad, resulting in reduced risk for offshore traders who import grains from the United States. Second, the substitution effect of the hedging demand implies that when a hedger faces a high cost in the commodity futures market, he can switch some portion of the commodity hedging to the currency futures market in order to manage risk from commodity price changes, and *vice versa*. However, the marginal rate of substitution depends on the covariance between the commodity market and currency market. Third, Japanese wheat importers face risks from changes in both export prices and exchange rates. The empirical results show that hedge ratios are slightly higher in the currency futures market than in the commodity futures market, suggesting that in recent years there has been higher risk in the currency market than in the wheat export market. Prescriptive optimal hedge ratios in both markets might be important information to Japanese wheat importers.

Offshore Commodity and Currency Hedging Strategy with Hedging Costs

Hyun J. Jin and Won W. Koo*

Introduction

This study explores the role of hedging cost in offshore hedging intended to minimize the risks associated with changes in commodity price and exchange rate in international trade. The primary objectives of this study are to analyze the hedgers' demands for both commodity and exchange rate futures and to evaluate the effects of hedging costs on the optimal hedge ratios in the two markets. In this hedging model, hedging products are treated as *goods* and the hedging costs as *prices* of the goods so that a *Marshallian* type of demand system is derived.

The paper germinates from two main areas of study. One area of study concerns hedging cost [Hirshleifer (1988); Lence (1995, 1996); Locke and Venkatesh (1997); Wang, Yau, and Baptiste (1997); and Frechette (2000, 2001)]. Lence and Frechette found that transaction costs and opportunity costs are reasons for driving hedgers from the market and reducing optimal hedge ratios. They concluded that optimal hedge ratios vary with hedging costs. Frechette (2001) included costs in a hedging study which analyzed both commodity futures and options as management tools for corn buyers and concluded that, from the demander's perspective, futures and options are substitute goods and the cost of each affects the demand for both hedging goods.

The other area of study involves risk management for international trade using futures hedging [Thompson and Bond (1987); Fung and Lai (1991); Kroner and Sultan (1993); Hauser and Neff (1993); and Haigh and Holt (2000, 2001)]. These studies, however, did not give attention to the hedging cost. By synthesizing the two lines of study, we produce an offshore hedging demand model with careful attention to hedging costs. The offshore hedging demand models used in past analyses are rebuilt and thus their results are reinterpreted in this study by incorporating hedging costs.

Our hedging model is applied to a case study of Japanese grain importers, and provides guidance on managing risks they face by using the hedging products in both markets and calibrating the impact of hedging costs. Providing prescriptive optimal hedge ratios in both markets with hedging costs is shown to be important to Japanese wheat importers.

This study also analyzes the relationship between hedging cost and the volume of offshore trade. Reduced hedging costs could induce more hedgers from abroad to participate in the futures market, resulting in reduced risk for offshore traders who import grains from the United States. If offshore grain importers face similar risk levels in importing grain from different sources, reducing hedging cost in the representative commodity futures market in the United States will stimulate increased hedging demand and therefore increased import demand from the United States.

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This study develops a demand system for futures hedging in both commodity and currency futures markets and analyzes the effect of hedging cost on the model and, in turn, on the volume of offshore trade. The model is applied to a representative grain importer in Japan who purchases wheat as an input for wheat flour products. Demands for futures are estimated under different levels of hedging costs in both commodity and currency futures markets.

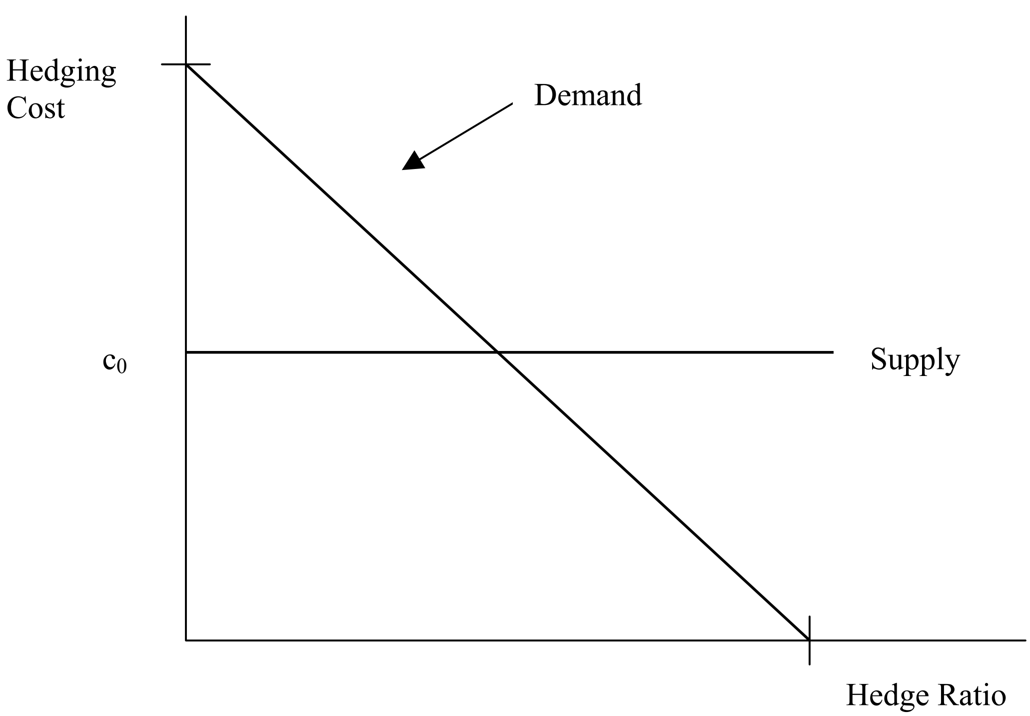
An Offshore Hedging Demand Model

Consider two countries: exporting country, A, and importing country, B. Assume that country A exports wheat and has a commodity futures market and a commodity cash market, which are comprised of risk-averse hedgers and risk-neutral speculators. Also assume that country B has wheat importers who have risk-averse utility, and also has currency cash and futures markets. The wheat importers in country B can access both the commodity futures market in country A and the currency futures market in country B in order to avoid risks from cash price and exchange rate variations.

It is also assumed that there are only two time periods: time *0* and time *1*. Hedgers place hedging at $t = 0$ and lift or revise it at $t = 1$. For international traders, the time can be any unit ranging from months to years. Assume there is no multi-period trading. Thus, hedgers buy contracts that are the closest to hedger's desired hedging date. Hedgers' only goal is to reduce risks from price and exchange rate variation from $t = 0$ to $t = 1$.

Since the marginal hedging costs in this model are treated as prices for hedging, hedgers face a downward demand curve for hedging products as shown in Figure 1.

Figure 1.
Equilibrium in the Supply and Demand for Hedging



The hedging costs are assumed to be constant, and thus represent both marginal and average costs. The supply of futures hedging is assumed to be equal to or fixed at the marginal cost.

Hedging costs may include transaction costs, brokers' fees, opportunity costs, learning costs, etc. For example, to get started in a futures market, one must own or lease a membership at the exchange. An individual may trade in the market if he knows someone who owns a membership, or he may use a broker. The majority of investments in futures contracts are done through brokers who in turn use members of the exchange to process orders. The members charge a fee and the brokers are paid according to trading volume. Alternatively, if one participates in the futures market by acquiring a membership, the new member needs to have publications, information, and advice. These activities are accompanied by some significant costs.

Thus, whether a trader uses a broker or seeks a market membership, he will be confronted with some considerable expenses; this is the transaction cost of futures hedging. In addition, to control a futures contract, one must put up a portion of the contract's face value called "margin." When a trader engages in a long hedging, he needs to pay for the futures contract or put up a margin. Using money for the margin or cash paid method entails opportunity cost, especially if the funds are borrowed by a loan.

Hedging cost, including the transaction and opportunity costs, is therefore not negligible. However, the majority of studies choose to ignore this factor. One must note that the assumption of a lack of hedging cost originated from the desire to simplify models, and not from an economic reason.

For a representative grain importer, hedging in the commodity futures market in the exporting country may cost more than hedging for an equivalent unit in the currency futures market in his country. This implies that the availability of hedging opportunities is important and related to the costs. Importers may give more weight to hedging in the currency futures market than in the commodity futures market, ceteris paribus. Thus, introducing hedging costs in an offshore hedging model is necessary and may change hedge ratios in both futures markets.

Consider the case of a representative grain importer in country B who needs to buy an agricultural product as an input from country A at period *1*. His objective is to minimize the total cost for the input or to maximize expected profits from engaging in purchase of the input and hedging in the futures markets.

This can be written as follows:

$$E_t[\Pi_{t+1}] = -X_{t+1}\ \tilde{P}_{t+1}\ \tilde{R}_{t+1} + H_t\,(\tilde{F}_{t+1}\ \tilde{R}_{t+1} - F_t\, R_t - c_t) + G_t\,(\tilde{S}_{t+1} - S_t - \tau_t), \tag{1}$$

where E_t – mathematical expectation operator,

P_t – commodity export price in the exporting country A at time *t*,

F_t – commodity futures price in the importing country B at time *t*,

S_t – currency futures price in the importing country B at time *t*,

R_t – exchange rate of importing country's currency against exporting country's currency at time *t*,

X_{t+1} – amount of a grain to be purchased at time *1* (this factor can be considered to be given since our objective is to estimate optimal hedge ratios for a specific amount of the grain),

H_t – amount of futures contract to be bought in the commodity futures market,

G_t – amount of futures contract to be purchased in the currency futures market,

r – coefficient of absolute risk aversion,

c – *price* of hedging, i.e., hedging cost faced by the hedgers in the commodity futures market,

τ – *price* of hedging, i.e., hedging cost faced by the hedgers in the currency futures market.

The first term on the right-hand side is the total cost for purchasing grain from country A at time *1*, the second term is the return from engaging in the commodity futures market, and the last term is the gain from purchasing currency hedging. In this objective function, P_{t+1}, F_{t+1}, R_{t+1}, and S_{t+1} are treated as random variables as denoted by the tilda symbol.

The currency futures prices in the last term of Equation (1) are multiplied by the grain export prices to translate the currency futures hedge ratio into a unit equivalent to the commodity futures hedge ratio. After this process, dividing Equation (1) by X_{t+1} yields the following:

$$E_t[\pi_{t+1}] = -\tilde{P}_{t+1}\ \tilde{R}_{t+1} + h_t\,(\tilde{F}_{t+1}\ \tilde{R}_{t+1} - F_t\, R_t - c_t) + g_t\,(\tilde{S}_{t+1}\ \tilde{P}_{t+1} - S_t\, P_t - \tau_t), \tag{2}$$

where $h = H/X$ and $g = G/X$, which are hedge ratios in the commodity and currency futures markets, respectively. The objective of the importer becomes a maximization of *per unit* expected profits, and the choice variable is hedge ratio rather than quantities hedged.

This study adopts the *mean-variance framework* to construct an offshore hedging model. The objective of the decision maker is to maximize expected per-unit profits with respect to *h* and *g*, subject to the variance of the profits. The objective function of the representative hedger is

$$w_t = E_t[\pi_{t+1}] - r\, V_t(\pi_{t+1}), \tag{3}$$

where $V_t(\cdot)$ denotes a volatility variable that measures the risk accompanying the profits. The coefficient of absolute risk aversion, $r = U''/2U'$, is supposed to have a positive sign and be fixed at a specific level. It is assumed that the utility function of the representative grain importer is continuous, monotonic increasing, and strictly concave.

Corresponding to the objective function (2), the estimated variance of returns at time *1* is

$$V_t(\pi_{t+1}) = V_t(\widetilde{P}\,\widetilde{R}) + h^2\,V_t(\widetilde{F}\,\widetilde{R}) + g^2\,V_t(\widetilde{S}\,\widetilde{P}) - 2h\,CV_t(\widetilde{P}\,\widetilde{R},\widetilde{F}\,\widetilde{R}) - 2g\,CV_t(\widetilde{P}\,\widetilde{R},\widetilde{S}\,\widetilde{P}) + 2hg\,CV_t(\widetilde{F}\,\widetilde{R},\widetilde{S}\,\widetilde{P}), \tag{4}$$

where $CV_t(\cdot)$ is the covariance operator. After substituting Equation (4) into the mean-variance framework (3), maximizing the objective function with respect to *h* and *g* generates first order conditions as follows:

$$\widetilde{F}_{T+1}\,\widetilde{R}_{t+1} - F_t\,R_t - c_t - r[2h\,V_t(\widetilde{F}\,\widetilde{R}) - 2\,CV_t(\widetilde{P}\,\widetilde{R},\widetilde{F}\,\widetilde{R}) + 2g\,V_t(\widetilde{F}\,\widetilde{R},\widetilde{S}\,\widetilde{P})] = 0, \tag{5a}$$

$$\widetilde{S}_{t+1}\,\widetilde{P}_{t+1} - S_t\,P_t - \tau_t - r[2g\,V_t(\widetilde{S}\,\widetilde{P}) - 2\,V_t(\widetilde{P}\,\widetilde{R},\widetilde{S}\,\widetilde{P}) + 2h\,CV_t(\widetilde{F}\,\widetilde{R},\widetilde{S}\,\widetilde{P})] = 0. \tag{5b}$$

The second order condition is satisfied by the assumption of strict concavity of the utility function $U(\cdot)$.

If we solve the first order conditions with respect to *h* and *g*, we obtain the following optimal hedge ratios for commodity and currency futures:

$$h^* = -\left(\frac{1}{2r(V_t(\widetilde{F}\widetilde{R})\,V_t(\widetilde{S}\widetilde{P}) - CV_t(\widetilde{F}\widetilde{R},\widetilde{S}\widetilde{P})^2)}\right)\{CV_t(\widetilde{F}\,\widetilde{R},\widetilde{S}\,\widetilde{P})\,\widetilde{S}\,\widetilde{P} + 2r\,CV_t(\widetilde{P}\,\widetilde{R},\widetilde{S}\,\widetilde{P})\,CV_t(\widetilde{F}\,\widetilde{R},\widetilde{S}\,\widetilde{P}) - CV_t(\widetilde{F}\,\widetilde{R},\widetilde{S}\,\widetilde{P})\,P\,S + c\,V_t(\widetilde{S}\,\widetilde{P}) - \widetilde{F}\,\widetilde{R}\,V_t(\widetilde{S}\,\widetilde{P}) - 2r\,CV_t(\widetilde{P}\,\widetilde{R},\widetilde{F}\,\widetilde{R})\,V_t(\widetilde{S}\,\widetilde{P}) + F\,R\,V_t(\widetilde{S}\,\widetilde{P}) - \tau\,CV_t(\widetilde{F}\,\widetilde{R},\widetilde{S}\,\widetilde{P})\}, \tag{6a}$$

$$g^* = -\left(\frac{1}{2r(CV_t(\widetilde{F}\widetilde{R},\widetilde{S}\widetilde{P})^2 - V_t(\widetilde{F}\widetilde{R})\,V_t(\widetilde{S}\widetilde{P}))}\right)\{-CV_t(\widetilde{F}\,\widetilde{R},\widetilde{S}\,\widetilde{P})\,\widetilde{F}\,\widetilde{R} - 2r\,CV_t(\widetilde{P}\,\widetilde{R},\widetilde{F}\,\widetilde{R})\,CV_t(\widetilde{F}\,\widetilde{R},\widetilde{S}\,\widetilde{P}) + CV_t(\widetilde{F}\,\widetilde{R},\widetilde{S}\,\widetilde{P})\,F\,R - \tau\,V_t(\widetilde{F}\,\widetilde{R}) + \widetilde{S}\,\widetilde{P}\,V_t(\widetilde{F}\,\widetilde{R}) + 2r\,CV_t(\widetilde{P}\,\widetilde{R},\widetilde{S}\,\widetilde{P})\,V_t(\widetilde{F}\,\widetilde{R}) - P\,S\,V_t(\widetilde{F}\,\widetilde{R}) + c\,CV_t(\widetilde{F}\,\widetilde{R},\widetilde{S}\,\widetilde{P})\}. \tag{6b}$$

In the optimal hedge ratios, both commodity hedging cost (*c*) and currency hedging cost (τ) are included. The relationship between the commodity and currency futures markets depends on both markets' hedging costs; this relationship can be captured by the sign of the partial derivatives for the optimal hedge ratios with respect to the costs. The signs of partial derivatives are

$$\partial h^*/\partial c \le 0, \qquad \partial h^*/\partial \tau \ge 0, \qquad \partial g^*/\partial c \ge 0, \qquad \partial g^*/\partial \tau \le 0. \tag{7}$$

See Appendix for details of the derivations.

The inequality (7) shows that the own-price effects are positive and cross-price effects are negative. Inequality (7) has two implications. First, hedging cost is not negligible in determining the hedging demand for international traders. The cost plays a significant role as the *price* for hedging goods. The amount hedged will decrease as the marginal hedging cost increases. Therefore, defining and reducing hedging cost is a good approach to increasing offshore hedging demand in the futures markets. Second, commodity futures and currency futures are, within limit, substitute goods, depending on the size of covariance between commodity prices and exchange rates. The amount hedged with one futures product will decrease when the marginal cost within the other futures market falls.

Note that the sizes as well as signs of the cross-price effects are equal, implying that the demand for offshore hedging satisfies the symmetry condition of a demand system. The question of which futures demand is more sensitive to its own cost changes remains obscure, depending on the size of $V_t(\tilde{F}\ \tilde{R})$ and $V_t(\tilde{S}\ \tilde{P})$. The model implies that reducing the marginal cost of commodity futures hedging in the Chicago Board of Trade (CBOT) could induce more offshore hedgers to participate in the market who either did not have any hedging position before or have a hedging position only in the currency futures market, reducing the risk in importing grains from the United States.

Application to Japanese Wheat Importers

Wheat Statistics of Japan

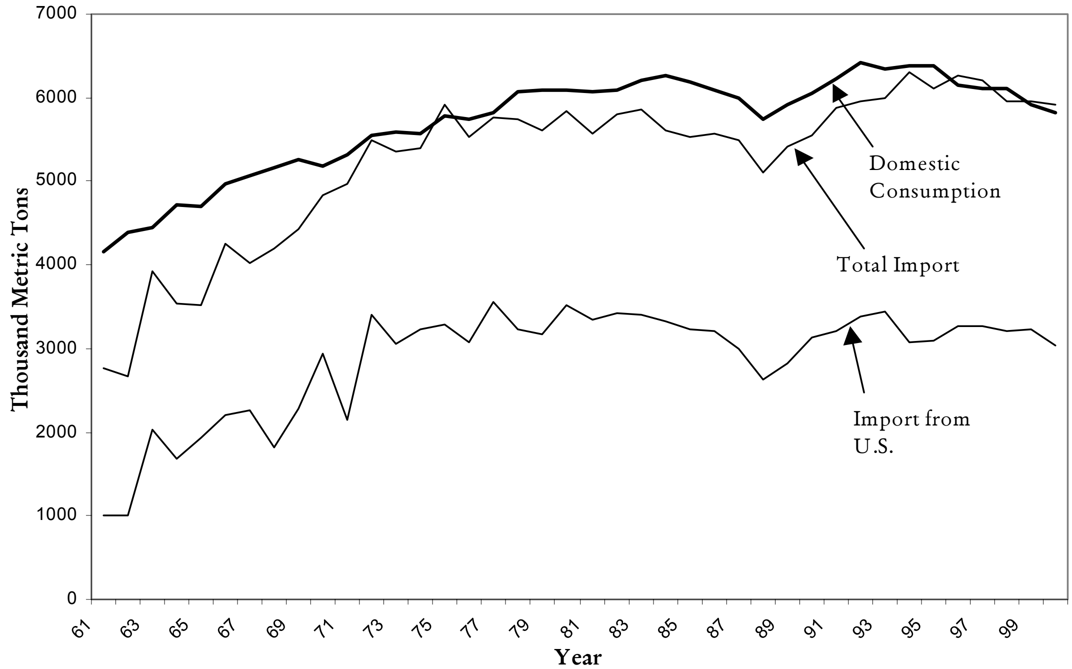
In this section, the newly constructed hedging demand model is applied to Japanese traders who import wheat from the United States. To avoid risks from variations in both commodity export prices and exchange rates when buying wheat at time *1*, importers need a long hedging.

In this empirical analysis, the United States acts as an exporting country in which the central commodity export market is Portland and the central commodity futures market is the CBOT. The CBOT is selected as a representative grain futures market in the United States because of its relative importance in international grain markets and because there is no futures trading for wheat in Japan. Japan acts as an importing country in which the currency futures market is the Tokyo International Financial Futures Exchange (TIFFE).

Wheat is one of the most important sources of food for Japanese consumers, and domestic consumption has been continuously increasing. In 2000, Japan consumed 5,824 thousand metric tons of wheat, while its domestic production was just 3.76 thousand metric tons. Thus, to fill the gap between the demand for domestic consumption and the domestic production of wheat, Japan relies upon imports for more than 99% of her wheat consumption. Japan imported 5,911 thousand metric tons in fiscal-year 2000; among the imported wheat, 51.4% was shipped from the United States.

Figure 2 shows total domestic consumption, total import, and import from the United States from 1961 to 2000. Total wheat consumption reached its highest point in 1993 and has gradually decreased since then. However, the total import has steadily increased for the sample period due mainly to decreased domestic production of wheat in Japan. Import from the United States has remained the same since 1973.

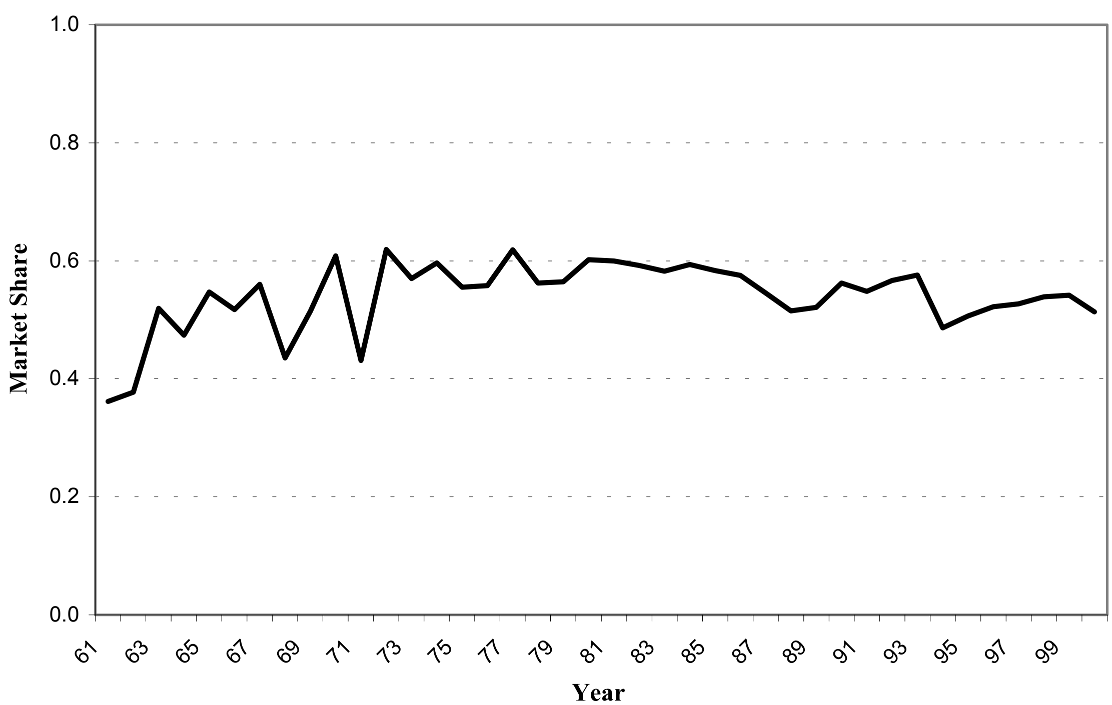
Figure 2.
Wheat Statistics of Japan:
Domestic Consumption, Total Import, and Import from United States.



Note: Data source is the Economic Research Service (ERS) of U.S. Department of Agriculture.

Figure 3 shows that the U.S. market share of wheat in Japan has remained at around 50%, implying that Japan is a loyal importer from the United States, and that small risks in U.S. wheat export prices and exchange rates will result in large losses in trade for Japanese grain importers.

Figure 3.
U.S. Wheat Trade Share in Japan



Note: Data source is the Foreign Agricultural Trade of the United States (FATUS), ERS of the U.S. Department of Agriculture.

Data

The data used for this study consist of wheat export prices in Portland, the nearby wheat futures prices in the CBOT, the exchange rates of the Japan currency against the U.S. dollar, and the nearby Japan currency futures prices in the TIFFE[1]. The wheat export prices were obtained from the ERS of the U.S. Department of Agriculture, the nearby wheat futures prices were provided by the Great Pacific Trading Company, the exchange rates were furnished by the ERS of the U.S. Department of Agriculture and the International Monetary Fund, and the Japan currency futures prices were provided by the TIFFE. The data are compiled monthly; the unit for commodity prices is cents per bushel, and the unit for the currency prices is yen per dollar. These data are available from January 1991 to February 2001.

Assume that the futures prices, $\tilde{F}$ and $\tilde{S}$, are unbiased. The expected values of commodity cash prices, commodity futures prices, exchange rates, and currency futures prices are calculated through an adaptive expectation model. Here, Autoregressive (AR) models are used for the adaptive expectation. The lags, *p*, in the AR models were chosen by criteria such as the *t*-statistic, the adjusted R^2, and the Akaike Information Criteria (AIC). After selecting the AR terms using *t*-statistics at 5% significance level, the adjusted R^2 statistic and AIC were examined for chosen AR(*p*) models.

The Autoregressive Conditional Heteroskedasticity-Lagrange Multiplier (ARCH-LM) Test and the Breusch-Godfrey LM (BGLM) test were performed for the selected AR(*p*) models[2]. In addition, other AR specifications by adding or deleting the constant, a trend, or other lags were made to compare them with chosen AR models. The ARCH-LM test was conducted to check conditional heteroskedasticity in errors and the BGLM test searched for serial correlation in errors.

Finally, the variance-covariance matrix for the expected prices and exchange rates was calculated. The descriptive statistics for the data set are presented in Table 1. It is assumed that hedgers know the variance-covariance before the sample period and that the variance is fixed over the sample period.

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[1] When a futures contract comes close to maturity, the nearby contract was used to compile the data because increased volume of trading may induce larger volatility of the prices. Thus, a jump is made to the prices of the successive contract before the month of maturity.

[2] The null hypothesis of the ARCH-LM test is that there is no ARCH in errors, and that of the BGLM test is that there is no serial correlation up to lag order *p* in errors. The test statistic of ARCH-LM is calculated by $T \cdot R^2$, where the statistic is distributed with a Chi-square χ^2_p, T is the number of observations, R^2 is the coefficient of determination from the auxiliary regression, and *p* is the number of variables in the right-hand side of the auxiliary equation. The test was completed by collecting the residuals from a chosen model, AR(*p*), and performing regression between squared residual and lagged-squared residuals. The test-statistic of the BG-LM test is calculated in a step similar to the ARCH-LM, except that R^2 is the coefficient of determination from the auxiliary regression between the residual and lagged residuals.

Table 1.
Descriptive Statistics for the Data Set

Series	*Mean*	*Standard Deviation*	*Skewness*	*Kurtosis*	*Normality Test*
Wheat Export Prices ($/bu)	3.863	0.773	0.532	2.640	6.269 (0.043)
Wheat Futures Prices ($/bu)	3.447	0.746	0.872	3.566	16.699 (0.000)
Exchange Rates (yen/$)	114.856	13.620	0.093	2.440	1.725 (0.422)
Currency Futures Prices (yen/$)	114.678	13.038	0.262	2.239	4.230 (0.120)

Note: Positive (negative) skewness means that the distribution has a long right (left) tail. The kurtosis of the normal distribution is 3. If the kurtosis exceeds 3, the distribution is peaked and has a thicker tail relative to the normal. If the kurtosis is less than 3, the distribution is flat and has a thinner tail relative to the normal. The normality test was completed using the Jarque-Bera statistic where the null hypothesis is that series follow a normal distribution; the values in the parenthesis are the reported p-values such that a small probability value leads to the rejection of the null hypothesis of a normal distribution.

Empirical Results

Using the hedging demand equations, (6a) and (6b), the optimal hedge ratios were estimated, as shown in Table 2. Since pinpointing exact costs of hedging activities is difficult and is also beyond the scope of this study, cost ranges were set up from 0.5 cents to 2.5 cents per bushel for the wheat futures and from 0.5 to 2.25 cents per dollar for the currency futures.

Table 2.
Optimal Hedge Ratios, h^* and g^*

c \ τ	*0.50*	*0.75*	*1.00*	*1.25*	*1.50*	*1.75*	*2.00*	*2.25*
0.50	36127 .49247	.37244 .49226	.38361 .49206	.39477 .49185	.40594 .49164	.41711 .49144	.42827 .49123	.43944 .49102
0.75	.34508 .50364	.35625 .50343	.36742 .50322	.37858 .50302	.38975 .50281	.40092 .50260	.41208 .50240	.42325 .50219
1.00	.32889 .51481	.34006 .51460	.35123 .51439	.36239 .51418	.37356 .51398	.38473 .51377	.39589 .51356	.40706 .51335
1.25	.31270 .52597	.32387 .52576	.33503 .52556	.34620 .52535	.35737 .52514	.36853 .52494	.37970 .52473	.39087 .52452
1.50	.29651 .53714	.30768 .53694	.31884 .53672	.33001 .53652	.34118 .53631	.35234 .53610	.36351 .53590	.37468 .53569
1.75	.28032 .54831	.29149 .54810	.30265 .54789	.31382 .54768	.32499 .54748	.33615 .54727	.34732 .54706	.35849 .54685
2.00	.26413 .55947	.27530 .55926	.28646 .55906	.29763 .55885	.30880 .55864	.31996 .55844	.33113 .55823	.34230 .55802
2.25	.24794 .57064	.25910 .57043	.27027 .57022	.28144 .57002	.29260 .56981	.30377 .56960	.31494 .56940	.32610 .56919
2.50	.23175 .58181	.24291 .58160	.25408 .58139	.26525 .58118	.27641 .58098	.28758 .58077	.29875 .58056	.30991 .58035

Note: In each cell, optimal commodity futures hedge ratios, h^*, are listed above optimal currency futures hedge ratios, g^*. Columns denote changes of currency hedging costs in the TIFFE, ranging from 0.50 to 2.25 cents per dollar. Rows represent changes of commodity hedging costs in the CBOT, ranging from 0.50 to 2.50 cents per bushel.

Frechette (2000) stated that a reasonable value of hedging cost could be 0.5 cents per bushel for corn. If we consider incorporating a margin and other costs for offshore hedgers, the cost could be higher than 0.5 cents. So, a reasonable cost range of wheat futures hedging is from 0.5 to 2.5 cents per bushel. In a similar fashion, the cost range of currency futures hedging is set from 0.5 to 2.5 yen per dollar. Converting yen to cents yields a range approximately from 0.5 to 2.25 cents per dollar[3].

One needs to set the coefficient of absolute risk aversion, *r,* to cover a range of possible risk preferences. In previous studies of offshore hedging, efforts to define the true value of *r* have remained elusive. Several studies, for example Kroner and Sultan (1993) and Gagnon, Lypny, and McCurdy (1998), have used a value $r = 4$, based on empirical studies for stock market volatility without any adjustment for offshore hedging.

[3] The average exchange ratio between yen and dollar for the sample period is 114. If we convert the currency hedging cost in the TIFFE, the range was from 0.44 to 2.17. However, to make the unit of the currency hedging cost similar to the commodity futures hedging cost, the approximate (from 0.5 to 2.25) is used.

Lapan and Moschini (1994); Lence (1995); Frechette (2000); and Jin and Frechette (2002) were used as guides to select values for the coefficient. We adjusted the values of absolute risk aversion in these studies by considering data frequency, monetary unit, the framework of mean-variance utility, and input-based quantity, to select a value of absolute risk aversion of 0.2 per each cent. This value can be considered to be moderate risk aversion[4]. The coefficient of risk aversion can be increased or decreased to cover other possible ranges of risk preference. Expanding this analysis to other risk aversions and broader cost ranges is straightforward. Higher hedge ratios in both futures markets can be expected when the value of the risk aversion coefficient is increased and hedging costs are lowered, and *vice versa*.

To estimate the optimal hedge ratios, the variance-covariance matrix of $\tilde{F}\ \tilde{R}$, $\tilde{S}\ \tilde{P}$, $\tilde{P}\ \tilde{R}$ has been calculated using the variance-covariance decomposition under multivariate normality by Haigh and Holt (2001). The results of optimal hedge ratios in the futures markets are displayed in Table 2. Each cell denotes optimal hedge ratios in both futures markets when the hedging costs are fixed at specific levels. For example, assuming that the commodity hedging cost is 1.25 cents per bushel and the currency hedging cost is also 1.25 cents per dollar, then the optimal commodity hedge ratio is 0.34620 and the optimal currency hedge ratio is 0.52535. This result indicates that the representative Japanese wheat importer needs to buy wheat futures contracts which are 34.62% of the wheat needed to be purchased at time *1* and currency futures contracts which are 52.53% of the dollars needed to purchase wheat at time *1*.

The optimal hedge ratios change with different hedging costs. If we fix the currency hedging cost and increase the commodity hedging cost, the optimal commodity hedge ratios decrease. For example, assume that the currency hedging cost is 1.25 cents per dollar. If we increase the wheat hedging cost from 0.50 to 2.50 cents per bushel, the optimal commodity hedge ratios decrease from 0.39477 to 0.26525, confirming a negative own-price effect of the hedging demand system. On the other hand, the optimal currency hedge ratios increase from 0.49185 to 0.58118, confirming a positive cross-price effect of the demand system.

Although changes in each cell are not dramatic, i.e., changes in hedge ratios are not large, the results suggest that hedging cost is important in the offshore hedging strategy. When we consider that Japanese grain traders import 3 million metric tons in aggregate from United States, small percentage changes in the optimal hedge ratio could result in large differences in the hedging performance. The negative own-price effects and positive cross-price effects on the hedging demand system confirm the substitute relationship between the two futures hedging methods under positive hedging costs in both markets.

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[4] Lapan and Moschini (1994) and Lence (1995) suggested that risk aversion ranges from 0 to 20 per year for a soybean farmer. To adjust the risk aversion coefficient to fit the case of international traders, we considered the following four factors - (1) converting an annual value to a monthly value, (2) in cents, (3) on the framework of mean-variance utility, r = -U"/2U", and (4) on an assumption that an input-based quantity for a representative importer is at least twenty times larger than an output-based quantity for a farmer. According to those factors, a final scaling factor of roughly 0.05 is produced by (1) multiplying by 12, (2) dividing by 100, (3) dividing by 2, and (4) multiplying by (20/12), where the last factor was divided by twelve to make it monthly unit. Thus, the range of r corresponds to approximately 0 to 2, and reasonable values for low, moderate, and high risk-aversions are 0.02, 0.20, and 2.00 respectively.

Figure 4 shows optimal commodity hedge ratios for corresponding costs. The demand curve is linear due to the mean-variance utility. It has a negative slope, suggesting less willingness to hedge as cost increases. That is, as the commodity hedging cost increases, the optimal commodity hedge ratio decreases, *ceteris paribus*.

In turn, as we increase the currency hedging cost, the commodity hedging demand curve moves outward, denoting the cross-price effect and implying a substitute relationship between the two futures hedging. The eight curves represent commodity hedging demand under eight different currency hedging costs, ranging from 0.5 to 2.25 cents per dollar and noted as *a* to *h* in Figure 4.

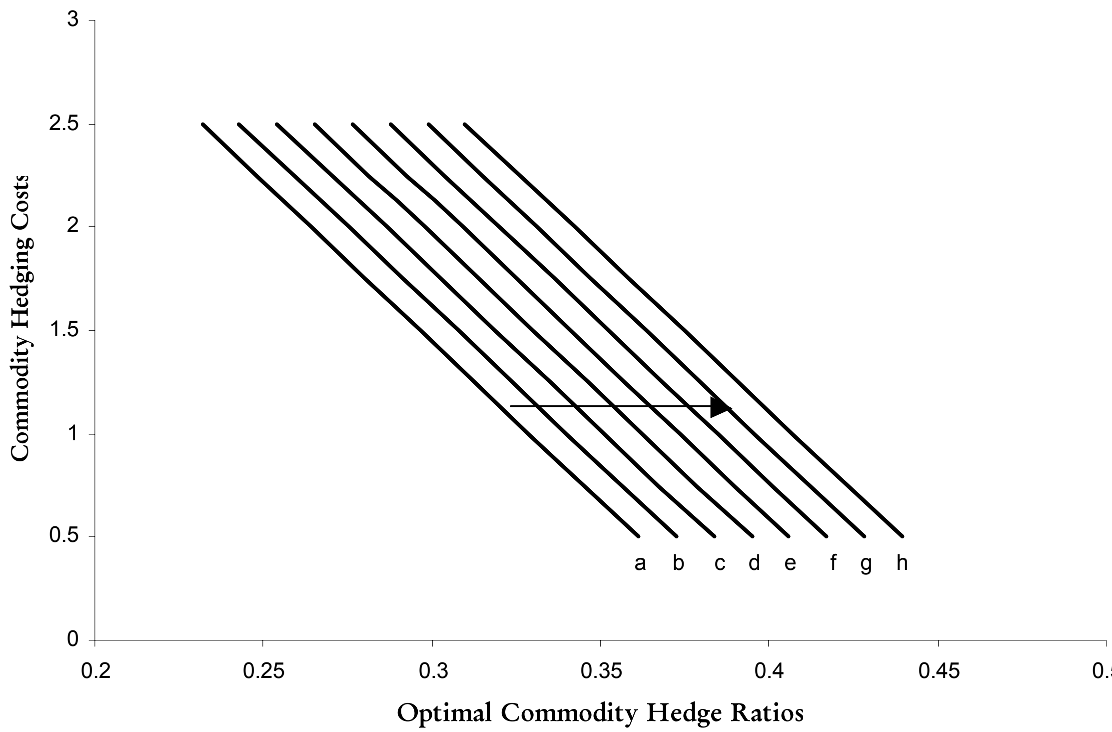
A demand curve for currency hedging, similar to the commodity hedging demand curve, was also drawn. The currency demand curve also has a negative slope, but it is less sensitive to its own-price changes than the commodity hedging demand curve.

Figure 5 shows the demands for wheat and currency hedging when we fix each cost at a specific level. The demand curve for wheat hedging is drawn by fixing the currency hedging cost and changing the commodity hedging cost from 0.50 to 2.50 cents per bushel. The dotted line which crosses with the commodity hedging demand curve is an expansion path, denoting a direction of shifts of the commodity hedging demand curves due to cross-price effects if we change the currency hedging cost. The currency demand curve and its expansion path are also drawn in a similar fashion. Both expansion paths have the same slope, suggesting the same cross-price elasticity and confirming the symmetry condition of the demand system. Figure 5 also shows that the wheat hedging demand is moderately sensitive to its cost, while the currency hedging demand is relatively insensitive. The elasticity of the wheat hedging demand is -0.2462, and that of the currency hedging demand is -0.0019.

One noticeable result is that the optimal currency hedge ratio when both costs equal 2.25 is larger than when both costs equal 0.5, while the optimal commodity hedge ratio works in the opposite manner (Table 2). This is counter-intuitive because higher hedging costs usually induce lower hedge ratios. The results are explained by the fact that the currency hedging demand has smaller own-price elasticity than cross-price elasticity. That is, when both costs increase simultaneously, an increase in the optimal currency hedge ratio caused by the cross-price effect is larger than a decrease caused by its own-price effect.

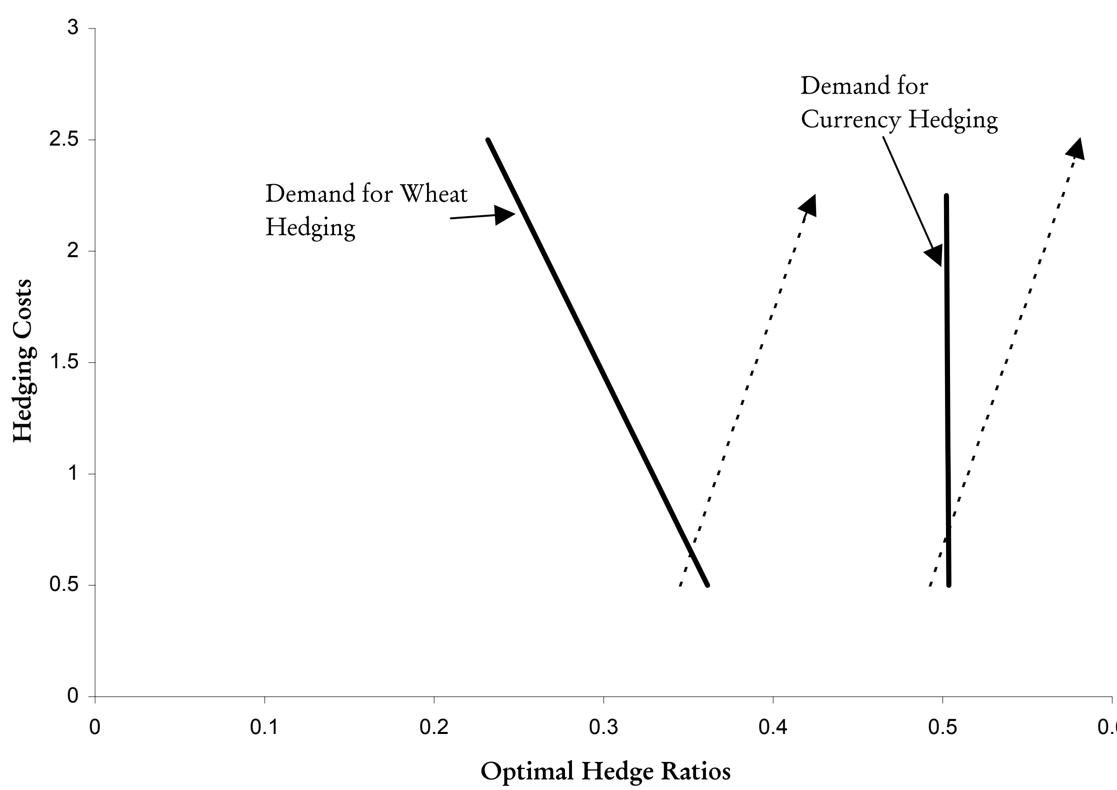
In this study, the coefficient of absolute risk aversion, *r,* is set at 0.2 per cent. However, changing the value of risk aversion results in dramatic changes in the optimal hedge ratios for both markets. We proceeded to expand the empirical analysis to other risk aversions and discovered that higher hedge ratios in both futures markets are acquired when the value of the risk aversion coefficient increases, and *vice versa*. Optimal hedge ratios were also estimated when one of the markets had zero or infinite hedging cost to check if there were kinks in the demand curves.

Figure 4.
Demand for Commodity Hedging and the Cross-Price Effect



Note: The arrows indicate shifts of the commodity hedging demand curve as we change the currency hedging cost. The linearity of the curves is due to the mean-variance approach.

Figure 5.
Demands for Wheat and Currency Hedging, and Cross-Price Effects



Implications & Conclusions

This study indicates that hedging costs are significant in both markets. The demands for hedging increase when hedging costs are reduced. When positive hedging costs are incorporated, the two methods of futures hedging have a limited substitute relationship, associated with covariances between the two markets.

The results have several implications. First, reducing commodity hedging cost in the CBOT would induce more hedgers from abroad to become involved in the market, reducing the risk for offshore traders who import grains from the United States. Tailoring the hedging opportunity by reducing cost will stimulate hedging demand and therefore increase import demand for grains from the United States. If importers can find a proper tool to manage the export price risk using the futures market, they may maintain or increase imports from the United States, even though U.S. wheat export prices are more volatile than those of other exporting countries.

Second, the substitution effect of the hedging demand implies that when a hedger faces a high cost in the commodity futures market, he can switch some portion of the hedging to the currency futures market in order to manage risk from commodity price changes and *vice versa*. However, the marginal rate of substitution depends on the covariance between the commodity market and currency market.

Third, Japanese wheat importers face risks from changes in both export prices and exchange rates. They need risk management tools to avoid the existing danger. The empirical results show that hedge ratios are slightly higher in the currency futures market than in the commodity futures market, suggesting that there has been higher risk within recent years in the currency market than in the wheat export market.

There are some limits to this study. Attention was not given to the supply side of the futures hedging; it was assumed to be given, or at least fixed. However, the hedging costs will differ for each offshore trader. A sophisticated offshore hedger will face relatively lower hedging cost, whereas the learning cost of a novice will be higher. Thus, for a more accurate analysis of the impacts of hedging costs, a detailed study of the hedging cost needs to be completed. This study is also limited by the exclusion of other risk management tools, as it is unlikely that offshore traders would use only the two means of futures hedging in real situations. They could use other risk management tools such as insurances, commodity options, or currency options. Future research which includes other risk management tools may contribute to more effective strategies for international traders.

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Appendix

The partial derivatives for the optimal hedge ratios with respect to the costs are

(A1a) $$\partial h^{*}/\partial c = -\left(\frac{\mathrm{V_t}(\tilde{\mathrm{S}}\,\tilde{\mathrm{P}})}{2r(\mathrm{V_t}(\tilde{\mathrm{F}}\,\tilde{\mathrm{R}})\,\mathrm{V_t}(\tilde{\mathrm{S}}\,\tilde{\mathrm{P}}) - \mathrm{CV_t}(\tilde{\mathrm{F}}\,\tilde{\mathrm{R}},\tilde{\mathrm{S}}\,\tilde{\mathrm{P}})^2)}\right),$$

(A1b) $$\partial h^{*}/\partial \tau = -\left(\frac{-\,\mathrm{CV_t}(\tilde{\mathrm{F}}\,\tilde{\mathrm{R}},\tilde{\mathrm{S}}\,\tilde{\mathrm{P}})}{2r(\mathrm{V_t}(\tilde{\mathrm{F}}\,\tilde{\mathrm{R}})\,\mathrm{V_t}(\tilde{\mathrm{S}}\,\tilde{\mathrm{P}}) - \mathrm{CV_t}(\tilde{\mathrm{F}}\,\tilde{\mathrm{R}},\tilde{\mathrm{S}}\,\tilde{\mathrm{P}})^2)}\right),$$

(A1c) $$\partial g^{*}/\partial c = -\left(\frac{\mathrm{CV_t}(\tilde{\mathrm{F}}\,\tilde{\mathrm{R}},\tilde{\mathrm{S}}\,\tilde{\mathrm{P}})}{2r(\mathrm{CV_t}(\tilde{\mathrm{F}}\,\tilde{\mathrm{R}},\tilde{\mathrm{S}}\,\tilde{\mathrm{P}})^2 - \mathrm{V_t}(\tilde{\mathrm{F}}\,\tilde{\mathrm{R}})\,\mathrm{V_t}(\tilde{\mathrm{S}}\,\tilde{\mathrm{P}}))}\right),$$

(A1d) $$\partial g^{*}/\partial \tau = -\left(\frac{-\,\mathrm{V_t}(\tilde{\mathrm{F}}\,\tilde{\mathrm{R}})}{2r(\mathrm{CV_t}(\tilde{\mathrm{F}}\,\tilde{\mathrm{R}},\tilde{\mathrm{S}}\,\tilde{\mathrm{P}})^2 - \mathrm{V_t}(\tilde{\mathrm{F}}\,\tilde{\mathrm{R}})\,\mathrm{V_t}(\tilde{\mathrm{S}}\,\tilde{\mathrm{P}}))}\right).$$

To define the signs of the derivatives, one needs to know the signs of $\mathrm{CV_t}(\tilde{F}\,\tilde{R},\tilde{S}\,\tilde{P})$ and $2\mathrm{r}[\mathrm{V_t}(\tilde{F}\,\tilde{R})\,\mathrm{V_t}(\tilde{P}\,\tilde{R}) - \mathrm{CV_t}(\tilde{F}\,\tilde{R},\tilde{S}\,\tilde{P})^2]$. Decomposing $\mathrm{CV_t}(\tilde{F}\,\tilde{R},\tilde{S}\,\tilde{P})$ produces the following equation:

(A2) $$\mathrm{CV_t}(\tilde{F}\,\tilde{R},\tilde{S}\,\tilde{P}) = \mathrm{E}[\tilde{F}\,\tilde{R}\,\tilde{S}\,\tilde{P}] - \mathrm{E}[\tilde{F}\,\tilde{R}]\,\mathrm{E}[\tilde{S}\,\tilde{P}],$$

where $\mathrm{E}[\tilde{F}\,\tilde{R}] = \mathrm{CV_t}(\tilde{F},\tilde{R}) + \mathrm{E}[\tilde{F}]\,\mathrm{E}[\tilde{R}]$ and $\mathrm{E}[\tilde{S}\,\tilde{P}]$ comprises the similar components. If we substitute the relation into Equation (A2), we have

(A3) $$\mathrm{CV_t}(\tilde{F}\,\tilde{R},\tilde{S}\,\tilde{P}) = \mathrm{E}[\tilde{F}\,\tilde{R}\,\tilde{S}\,\tilde{P}] - (\mathrm{CV_t}(\tilde{F},\tilde{R}) + \mathrm{E}[\tilde{F}]\,\mathrm{E}[\tilde{R}])\,(\mathrm{CV_t}(\tilde{S},\tilde{P}) + \mathrm{E}[\tilde{S}]\,\mathrm{E}[\tilde{P}]),$$

where we expect the signs of $\mathrm{CV_t}(\tilde{F},\tilde{R})$ and $\mathrm{CV_t}(\tilde{S},\tilde{P})$ to be negative on the basis of economic theory.

For example, Thompson and Bond (1987) argued that the sign of price-exchange rate covariance is negative. Following them, at least three different theoretical studies support their argument. First, Chambers and Just (1979) and Chambers (1984) say that spot commodity prices are directly affected by changes in the value of the U.S. dollar. For example, a rise in dollar-denominated commodity prices is related to a U.S. dollar devaluation. Second, Lucas (1980) and Katseli-Papaefsratiou (1980) suggest that in a small, open economy, changes in world commodity prices have a significant effect on the exchange rate of the economy. Third, the studies of Frankel (1981) and Bond (1984) suggest that monetary shocks may alter both commodity prices and exchange rates via interest rates. If interest rates rise in a short-term, commodity prices will be pushed down due to inventory effects, and the currency will be strengthened through induced capital inflow.

These studies suggest that the sign of covariance between commodity prices and exchange rates is negative. Note that the sign of covariance between spot and futures prices of a product is usually expected to be positive. Therefore, it is likely that the signs of $CV_t(\tilde{F}, \tilde{R})$ and $CV_t(\tilde{S}, \tilde{P})$ are negative. However, the absolute value of the covariance cannot exceed the magnitude of $E[\tilde{F}]\,E[\tilde{R}]$ and $E[\tilde{S}]\,E[\tilde{P}]$ because expected values of the products, $E[\tilde{F}\,\tilde{R}]$ and $E[\tilde{S}\,\tilde{P}]$, are less than or equal to zero. The sign of $CV_t(\tilde{F}\,\tilde{R}, \tilde{S}\,\tilde{P})$ is therefore positive.

On the other hand, we can define the sign of $2r[V_t(\tilde{F}\,\tilde{R})\,V_t(\tilde{P}\,\tilde{R}) - CV_t(\tilde{F}\,\tilde{R}, \tilde{S}\,\tilde{P})^2]$ through the statistical relationship between *covariance* and c*orrelation*. The covariance between $\tilde{F}\,\tilde{R}$ and $\tilde{S}\,\tilde{P}$ is expressed as follows:

(A4) $$CV_t(\tilde{F}\,\tilde{R}, \tilde{S}\,\tilde{P}) = \rho_{FR,SP}\sqrt{V_t(\tilde{F}\tilde{R})}\ \sqrt{V_t(\tilde{S}\tilde{P})},$$

where $\rho_{FR,SP}$ is the correlation coefficient between $\tilde{F}\,\tilde{R}$ and $\tilde{S}\,\tilde{P}$. The following relation holds unless $\rho_{FR,SP} = \pm 1$, which would lead to corner solutions.

(A5) $$V_t(\tilde{F}\,\tilde{R})\,V_t(\tilde{P}\,\tilde{R}) - CV_t(\tilde{F}\,\tilde{R}, \tilde{S}\,\tilde{P})^2 = \frac{CV_t(\tilde{F}\,\tilde{R}, \tilde{S}\,\tilde{P})^2}{\rho_{FR,SP}^{\,2}} - CV_t(\tilde{F}\,\tilde{R}, \tilde{S}\,\tilde{P})^2 > 0.$$

Note that the coefficient of risk-aversion is positive. Thus, denominators in the partial derivatives (A1a) and (A1b) are positive while those in (A1c) and (A1d) are negative. Finally, we have the signs of the partial derivatives as follows:

(A6) $$\partial h^*/\partial c \le 0, \qquad \partial h^*/\partial \tau \ge 0, \qquad \partial g^*/\partial c \ge 0, \qquad \partial g^*/\partial \tau \le 0.$$