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Price Uncertainty within the Grain Export Marketing Channel

R.J. Hauser and D. Neff*

Results of a survey conducted by the USDA (Caron) indicate that the largest "exporting" risk perceived by U.S. grain merchandisers is caused by changes in the flat price of grain. The largest "logistical" risk was associated with ocean charters. The objectives of the present study are to (1) measure these perceived risks in terms of price uncertainty facing exporters and importers of U.S. corn and soybeans at various stages of the marketing channel, (2) estimate the extent to which the uncertainty can be reduced through small portfolio diversification, and (3) compare price uncertainty levels facing exporters versus importers in an attempt to deduce behavioral incentives at each marketing stage.

Procedure

Corn and soybean shipments from Illinois to Rotterdam during 1981-89 are considered. It is assumed that the exporter can sell grain at either Illinois, the Gulf, or Rotterdam. The sources of price uncertainty facing the exporter at each location are:

Location	Source of Price Uncertainty
Illinois	Illinois grain price
Gulf	Gulf price, barge rate
Rotterdam	Rotterdam price, barge rate, ocean-vessel rate

Price uncertainty facing the exporter who sells in Illinois is associated only with the future Illinois price. At the port stage (Gulf), the uncertainty is measured as a function of future Gulf price and the cost of transporting grain from Illinois to the Gulf (barge rate). Likewise, at the import site, the uncertainty is associated with the Rotterdam price and transport costs.

The importer's purchasing scenarios are defined as:

Location	Source of Price Uncertainty
Illinois	Illinois price, barge rate, ocean rate, exchange rate
Gulf	Gulf price, ocean rate, exchange rate
Rotterdam	Rotterdam price, exchange rate

The importer must pay the location's grain price plus transportation costs. All payments are made in U.S. dollars, meaning that the importer also faces exchange rate uncertainty.

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Two time periods are considered: January 1981-June 1985 and July 1985-December 1989. The nine years of 1981-89 were divided into these two 4.5 year periods because trading of ocean-freight futures at the Baltic International Freight Futures Exchange (BIFFEX) in London began on May 1, 1985.

Uncertainty Estimates

Uncertainty is defined here as the variance (or standard deviation) of the difference between expected and realized outcomes. For a given commodity (c), location (l), time period (i), and hedging scenario (h), the price uncertainty can be described as:

$$\mathrm{VAR}(P_{cliht} - {}_{t-1}E[P_{cliht}]) \tag{1}$$

where VAR is the variance operator; P is the realized outcome; c=1,2; l=1,2,3; i=1,2; h=1,2,...,n, where n depends on values of l and i; t=1,2,...,27 for i=1(1981-85) and t=1,2,...,28 for i=2(1985-89); and ${}_{t-1}E[P_{cliht}]$ is the expectation of P_{cliht} at time t-1. Realized and expected outcomes are estimated in 8-week intervals; i.e., about 6 observations per year.

For the exporter, the unhedged price outcome at each location is calculated as:

$$\text{Illinois:}\quad P_t = IL_t \tag{2}$$
$$\text{Gulf:}\quad P_t = GF_t - BR_t \tag{3}$$
$$\text{Rotterdam:}\quad P_t = RT_t - OC_t - BR_t \tag{4}$$

where IL is the commodity price in Illinois; GF is the commodity price at the export port (Gulf); BR is the barge rate of transportation for grain shipments from Illinois to the Gulf; RT is the commodity price at Rotterdam; and OC is the ocean rate for the Gulf-to-Rotterdam shipment. All prices and rates are in U.S. cents per cwt.

The outcomes estimated by equations (2)-(4) represent a "net price" received by an "exporter" who originates the commodity in Illinois and sells the commodity at either the origination point (eqn. 2), the Gulf (eqn. 3), or Rotterdam (eqn. 4). This net price clearly does not include all costs. For example, handling costs and the trucking cost from the Illinois elevator to the river are not included. These other costs, however, are presumably close to constant (or deterministic) over an 8 week period and therefore add little uncertainty.

The hedged price outcome for the exporter is:

$$HP_t = P_t + b_1(F_{t-1} - F_t) + b_2(O_{t-1} - O_t) \tag{5}$$

where P_t is defined by either (2), (3), or (4); HP_t is the realized outcome when other instruments (futures contracts) are used to form a small portfolio; F_t is the commodity futures price at time t; O_t is the ocean freight futures price; and b_1 and b_2 are the number of short positions per cash position (hedge ratio) held in commodity futures and ocean futures, respectively. When the selling location is Illinois or the Gulf, $b_2 = 0$. Other values of b_1 and b_2 will be defined later.

For the importer, the unhedged price outcome at each location is:

$$\text{Rotterdam:} \quad P_t = RT_t * SE_t$$

$$\text{Gulf:} \quad P_t = (GF_t + OC_t)SE_t \tag{6}$$

$$\text{Illinois:} \quad P_t = (IL_t + BR_t + OC_t)SE_t \tag{7}$$

$$\tag{8}$$

where SE_t is the exchange rate in Deutschemarks (DM) per U.S. dollar.

It is assumed that the importer can receive the commodity at either Rotterdam (eqn. 6), the Gulf (eqn. 7), or Illinois (eqn. 8). The price outcome, P_t, is in DM units.

The hedged price outcome for the importer is:

$$HP_t = P_t + b_1(F_{t-1} - F_t)SE_t + b_2(O_{t-1} - O_t)SE_t + b_3(E_{t-1} - E_t)\,{}_{t-1}E[P_t]/E_{t-1} \tag{9}$$

where P_t is defined by either (6), (7), or (8); and E_t is the exchange rate futures in DM/\$. The last term in (9) contains ${}_{t-1}E[P_t]/E_{t-1}$, which determines the number of dollars hedged under a full hedge (i.e., when $b_3 = 1$).

Expectation Estimates

Our measurement of uncertainty (eqn. 1) requires expectations of (2)-(9). For (2)-(4), the expectation of P_t is estimated as the sum of the expected values of each term on the right hand side. The expectation of (4), for example, is the expected (forecasted) Rotterdam price minus the expected ocean rate minus the expected barge rate.

One general procedure is used to estimate the expectation of commodity prices at each location, exchange rate, and ocean rate. This expectation is based on price spreads between futures contracts. Price spreads reflect the market's estimate of the equilibrium return for holding a long position in the underlying cash good or service. Therefore, under the assumption of unbiased futures, the futures spread provides a market estimate of the expected change in spot price.

The expected change in spot price used here is based on the nearby and next nearby futures prices. At time t, the annualized rate of return (r) implied by the next nearby price minus the nearby price is calculated. The expected spot price for time t+1 is then found by

$${}_tE[S_{t+1}] = S_t e^{rd}$$

where S_t is the spot price at time t, e is the exponential function, and d is 56/365, the annualized time between t and t+1.

Although a futures market does not exist for barge freight, a similar procedure to that described above is used to estimate expected barge rates by using information from the St. Louis Merchants Exchange Call Session for southbound barge-grain freight. Forward rates resolved at the Call Session also provide a market estimate of expected rate changes. Hauser and Buck (p. 11) use this information to estimate the market's expectation of rate seasonality. The resulting seasonality indices are used here to find expected barge rates by adjusting the current barge rate forward according to the appropriate index.

Since trading in ocean-freight futures did not begin until mid 1985, the market's implied rate of change in ocean rates could not be calculated during the 1981-85 period. Therefore, a naive expectation model is assumed for ocean rates for 1981-85. That is, the ocean rate in period t is the expected rate for period t+1.

The sum of individual variable expectations yields the expectation of (2), (3), or (4), representing the expectation of unhedged price. The expectation of (5) is the expectation of hedged price. It is assumed that the futures price is the agent's unbiased expectation of futures price; e.g., ${}_{t-1}E[F_t] = F_{t-1}$. Consequently, the expected hedged outcome corresponding to (2)-(4) is equal to the respective expected unhedged outcome. In other words, the expected net price of a particular hedged scenario is the same as the expected net price when not hedging.

Equations (6)-(8) include products of variables, and thus expectation estimates must consider covariances. It is assumed here that the exchange rate (SE_t) and other prices (RT, GF, IL, BR, OC) are independent. Therefore, expectations of (6)-(8) are found by simply inserting the expected values of each variable into the equations. The expected hedged price (eqn. 9) is again equal to the expected unhedged price.

Hedge Ratio Estimates

Hedge ratios (b_i values) for (5) and (9) are based on either a "full" hedge or an "optimal" hedge. Under full hedging, b_i is one. The optimal hedge ratio is based on Myers and Thompson's approach of first specifying futures and cash price determination processes, and then using the errors from these processes to estimate the variances needed to calculate the ratio.

The assumptions underlying the agent's expectation models are also used to specify the price determination models for cash and futures prices. Under the unbiased-futures assumption the general model is (Myers and Thompson, p. 863):

$$p_t = X_{t-1}\alpha + u_t \tag{10}$$

$$f_t = f_{t-1} + v_t \tag{11}$$

where p_t is the cash price, f_t is futures price, u_t and v_t are serially uncorrelated errors, and X_{t-1} is a vector of variables which help predict p_t. The generalized optimal hedge ratio estimator is the OLS estimate of δ in:

$$p_t = \delta\Delta f_t + X_{t-1}\alpha + e_t \tag{12}$$

For the present analysis, (12) is estimated under the assumption that X_{t-1} is equal to the expected price outcome and that more than one type of futures instruments (commodity, ocean, and exchange) can be considered, depending on the scenario. For example, the OLS specification used to find optimal hedge ratios for soybean futures and ocean-rate futures for the exporter selling at Rotterdam is:

$$P_t = b_1\Delta F_t + b_2\Delta O_t + {}_{t-1}E[P_t]\alpha + e_t \tag{13}$$

where P_t is defined by (4), F_t is the soybean futures price, and O_t is the futures price for ocean freight.

The optimal ratios for the importer are found in the same fashion. For example, for the importer who buys at Illinois, the optimal hedge ratios are determined by:

$$P_t = b_1\Delta F_t SE_t + b_2\Delta O_t SE_t + b_3\Delta E_t({}_{t-1}E[P_t]/E_{t-1}) + {}_{t-1}E[P_t]\alpha + e_t \tag{14}$$

where P_t is defined by (8). Note that the first difference terms are now in DM units and that the number of units hedged in the exchange rate market is ${}_{t-1}E[P_t]/E_{t-1}$. An alternative specification is to set this term to one, allowing the regression coefficient, b_3, to represent the number units hedged. However, the specification of (14) was chosen to provide consistency between full hedge (b_3=1) and optimal hedge results, and because the hedge units must be determined a priori in practice.

Regression equations (13) and (14) are altered, depending on the scenario being considered. The scenario defined by an importer who buys at Rotterdam, for example, does not obtain a position in the ocean-freight market and thus b_2 of (14) is not estimated. Other scenarios involve other locations, the use of only commodity futures, and perfect foresight of barge and ocean rates.

Data

Corn and soybean cash prices were collected by the Illinois Market News Service. For confidentiality reasons, the exact location of the elevator used for this study can not be identified; however, the elevator is approximately 20 miles from the Illinois River in central Illinois. Closing futures prices for corn and soybeans were collected from either CBOT tapes or the *Wall Street Journal*. Gulf prices were taken from *USDA Grain and Feed Market News*. Barge rates are those reported in Midco Commodities' *Merchandisers Fact Sheet*. Rotterdam prices were collected from *Oil World*. Exchange spot rates and futures are from the *CME Yearbook* and the *Wall Street Journal*.

Two sources of spot rates for ocean freight were used. The first set of rates was provided by the USDA. These rates are published by Maritime Research, Inc. Only rates for 40,000-60,000 metric ton shipments were used. These data extended over the entire 1981-89 period of study. The second set of rates are conversions of the BFI spot index for Gulf-Rotterdam grain shipments reported in the *Journal of Commerce*. The BFI futures index (converted to ¢/cwt.) was also collected from the *Journal of Commerce*. All BFI data are from July 1985 - December 1989.

Thursday prices and rates were used when possible. If Thursday prices were not available, Wednesday prices were used. However, the 1981-85 ocean rates represent weekly averages, and barge rates are mid-week estimates.

Results

Table 1 presents the 1985-89 price uncertainty results for the exporter. At the first stage of the marketing channel (Illinois), three scenarios are considered for each crop -- (1) unhedged (open) sale, (2) full hedge (hedge ratio = 1), and (3) optimal hedge. The variance estimates in the OPEN column is the variance of the difference between expected and realized price when the futures market is not used. The variances under the HEDGE column apply to this difference when futures contracts are included. The "hedge effect" statistic measures the reduction in price uncertainty resulting from adding the futures contract(s); i.e., it is equal to 1 - (HEDGE variance/OPEN variance).

For soybeans at Illinois, the open variance of 7730 is reduced to 615 through full hedging. The optimal hedge (HR=.945) yields virtually the same hedge variance as the full hedge. For corn at Illinois, the open variance of 1513 is much smaller than the open soybean variance of 7730, indicating that price uncertainty based on expected minus realized prices is much smaller for corn than for soybeans. However, the hedge variances for corn are about the same as for soybeans. Consequently, the hedge effect is much smaller for corn than soybeans (about .62 for corn versus .92 for soybeans). This comparison illustrates an important caveat for hedging effectiveness studies. The hedge-effect statistic is analogous to the R^2 measure of hedging effectiveness from regressions of cash on futures (e.g., Ederington). However, if differences in the variance of the dependent variable are large, comparisons of hedging effectiveness estimates (R^2 values) are meaningless. Likewise, comparison of the hedge-effect statistics in Table 1 across scenarios with different open variances should be done with care. A more meaningful comparison across different open-variance scenarios is with the hedge variances. (This is similar to comparing the mean-squared error of traditional hedging effectiveness regressions.) For example, the fact that the hedge variances for corn and soybeans at Illinois are about the same suggests that price uncertainty across these crops at Illinois is about the same even though "hedging effectiveness" is much larger for soybeans.

The Gulf results in Table 1 indicate that price uncertainty facing the exporter does not increase as grain moves through the marketing channel from Illinois to the Gulf. The open and hedge variances for the Gulf are slightly lower than for Illinois for both corn and soybeans. In other words, the Gulf price does not present more price uncertainty than the Illinois price in either the unhedged or hedged situation.

Another scenario examined for the Gulf measures the remaining price uncertainty after the uncertainty caused by fluctuating barge rates is removed. This is done by assuming that the realized barge rate is the expected barge rate; i.e., perfect foresight in barge rates. The purpose of this scenario is twofold: (1) to get an idea of the amount of risk reduction which could be resolved through forward contracting barge freight, and (2) to provide a means for comparing risk across transport modes (barge versus ocean vessel). The hedge-variance reduction caused by perfect barge-rate forecasts is about 30% in each case. The results of perfect ocean-rate forecasts are discussed below.

Table 1. **1985-89 Price Uncertainty Facing Illinois Exporter**

	Soybeans					Corn				
	Hedge Ratio[a]		Variance[b]		Hedge Effect[c]	Hedge Ratio		Variance		Hedge Effect
	FUT	OCN	OPEN	HEDGE		FUT	OCN	OPEN	HEDGE	
Illinois										
HR=1	1	--	7730	615	.920	1	--	1513	581	.616
Optimal	.945	--	7730	597	.923	.935	--	1513	577	.619
	(17.32)[d]					(6.33)				
Gulf										
HR=1	1	--	7696	610	.921	1	--	1416	485	.657
Optimal	.943	--	7696	585	.924	.937	--	1416	481	.660
	(17.42)					(6.94)				
HR=1, E[B]=RB[e]	1	--	7382	433	.941	1	--	1351	346	.744
Opt, E[B]=RB	.935	--	7382	400	.946	.972	--	1351	345	.745
	(20.89)					(8.50)				
Rotterdam										
HR=1	1	-1	7235	1112	.846	1	-1	1918	658	.657
Optimal	.890	.119	7235	930	.871	.957	-1.777	1918	626	.674
	(12.66)	(0.14)				(5.99)	(-2.47)			
HR=1, E[O]=RO	1	-1	7103	1114	.843	1	-1	1709	523	.694
Opt, E[O]=RO	.895	.879	7103	810	.886	.991	-1.002	1709	523	.694
	(13.65)	(1.08)				(6.78)	(-1.53)			
HR=1, Only FUT	1	0	7235	1029	.858	1	0	1918	788	.589
Opt, Only FUT	.889	0	7235	931	.871	1.029	0	1918	787	.590
	(13.01)					(5.97)				

[a] Hedge ratio for commodity futures (FUT) or ocean freight futures (OCN); equal to one (HR=1) or determined by regression (Optimal).

[b] Variance of differences between expected and realized outcomes without using futures (OPEN) and with futures (HEDGE).

[c] 1 - (HEDGE variance/OPEN variance).

[d] t statistic from optimal hedge regression.

[e] E[B]=RB: Perfect foresight in barge rates. E[O]=RO: Perfect foresight in ocean rates.

The exporter who sells at Rotterdam faces uncertainty about commodity price, barge rate, and ocean rate. For soybeans during 1985-89, the open variance at Rotterdam (7,235) is less than the open variance at the Gulf (7,696). However, the full-hedge variance at Rotterdam (1,112) is considerably higher than the full-hedge variance at the Gulf (610). The optimal hedge variances are also much different (930 versus 585). These results suggest that as soybean marketing moves from the Gulf to Rotterdam, the level of total price uncertainty does not increase; however, the amount of this total uncertainty that can be eliminated by using futures contracts decreases.

The use of ocean-freight futures is of little help in reducing the 1985-89 soybean price uncertainty. This non-effect is reflected in the t statistics of the optimal hedge ratios, and by the fact that the optimal hedge variance when using both soybean and ocean futures (930) is virtually equal to the optimal hedge variance when using only soybean futures (931). Furthermore, the optimal ocean hedge ratio (.119) implies short hedging ocean freight in a situation which one would expect the covariances to lead to a long hedge.

Perfect expectations of ocean freight do not reduce the Rotterdam hedge variance for soybeans. (The slight increase will be explained below with a more pronounced case.)

There are two important factors determining whether ocean-freight hedging will reduce price uncertainty as defined here. The first factor is the correlation between the Rotterdam-Gulf price spread and ocean-freight rate. The second factor is the "hedging effectiveness" of the freight futures market. Table 2 presents simple correlation coefficients for price spreads and freight rates. Weekly data are used, and correlations are estimated annually. The ocean rate correlations with the soybean spread vary from -.220 in 1983 to .738 in 1982. The correlations for ocean rates and corn spreads tend to be higher than the correlations for soybeans. In general, (1) the ocean rate correlations vary considerably from year to year, (2) they are lower than what might be expected in an "integrated" market, and (3) the corn correlations are generally higher than the soybean correlations. There are many possible explanations for these general results. The Rotterdam price is being determined by many grain flows (not just U.S.-Rotterdam), and other economic and political factors; ocean rates are determined within a very competitive industry which can serve many different markets; and it is not clear that integration in a competitive market implies high correlation (Faminow and Benson), and thus the corn versus soybean results may reflect the fact that relatively little corn was shipped to Rotterdam during the 1980s. Although further work is being done on these issues, the simple correlation coefficients reveal one reason why the soybean price uncertainty at Rotterdam is not reduced through hedging ocean freight. Another reason is reflected by the regression fit of ocean spot-rate changes on ocean futures-rate changes. Using the 27 eight-week-interval prices for 1985-89, this regression has a slope coefficient of 0.83 and an R^2 of 0.35. This R^2 (one measure of hedging effectiveness) may underestimate hedging effectiveness of alternative time periods and/or selective hedging techniques; however, its low value for the data used here to measure price uncertainty indicates that the contract may not provide much help in reducing the portfolio variance being studied.

Table 2. Simple Correlation Coefficients for Price Spreads and Freight Rates.

	Rotterdam-Gulf Spread with Ocean Rate			Gulf-Illinois Spread with Barge Rate		
		Soybeans	Corn		Soybeans	Corn
	n[a]	ρ	ρ	n	ρ	ρ
1981	36	.639	.766	52	.786	.874
1982	45	.738	.819	52	.747	.662
1983	37	-.220	.026	52	.814	.810
1984	38	.184	.549	52	.649	.801
1985F[b]	13	.239	.727	21	.556	.849
1985L	31	.058	.638	31	.515	.681
1986	53	.076	.206	53	.822	.837
1987	52	.375	.265	52	.668	.770
1988	52	.075	-.162	52	.705	.731
1989	52	.641	.363	52	.697	.904
Average		.281	.420		.696	.792

[a] Number of observations (weeks) used; for 1981-1985F, observations for ocean rates did not exist for every week.

[b] 1985F: January-May, 1985; 1985L: June-December, 1985.

Returning to Table 1, both the open and hedge variance for <u>corn</u> at Rotterdam are higher than the respective variance at the Gulf. However, the hedge variances (658 and 626) are at about the same level as the Illinois hedge variances for corn (581, 577) and soybeans (615, 597). Thus, the results at the Rotterdam level suggest that the uncertainty for corn is higher than at the Gulf, but much closer to the uncertainty at Illinois than soybeans. The sign of the optimal ocean-freight hedge for corn is negative, as expected, but much larger in absolute terms than a full hedge. With perfect foresight of ocean rates, the optimal hedge variance is equal to the full hedge variance. And, unlike soybeans, the hedge variance increases by about 20% when only commodity futures are used in the hedge.

Table 3 presents the exporter results for 1981-85. For this period, however, the use of ocean-freight futures could not be considered. The general implications of Table 3 are similar to those of Table 1. The hedge variances for soybeans decrease slightly from Illinois to the Gulf, and then increase by more than twofold from the Gulf to Rotterdam. For corn, relatively small increases in hedge variances occur at each stage.

Note that the variances associated with perfect ocean-rate forecasts are slightly larger than the other Rotterdam variances. Since the variance is of the difference between expected and realized prices, it can be broken into