Transaction Frequency, Inventories and Hedging in Commodity Processing

by
Roger A. Dahlgran

Suggested citation format:

Dahlgran, R. A. 2004. "Transaction Frequency, Inventories and Hedging in Commodity Processing." Proceedings of the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. St. Louis, MO. [http://www.farmdoc.uiuc.edu/nccc134].

Transaction Frequency, Inventories and Hedging in Commodity Processing

Roger A. Dahlgran*

Paper presented at the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management
St. Louis, Missouri, April 19-20, 2004.

* *Associate Professor, Department of Agricultural and Resource Economics, Economics, Bldg#23, University of Arizona, Tucson, Arizona 85721-0023. Phone: (520)-621-6254, FAX (520)-621-6250, Email: dahlgran@u.arizona.edu.*

Transaction Frequency, Inventories and Hedging in Commodity Processing

Practitioner's Abstract

This study examines hedging strategies for commodity processors generally and soybean crushers specifically. Processors require hedging strategies built around processing multiple batches each year. Each batch requires the purchase of inputs, transformation of inputs into outputs, and sale of the resulting output. The more batches processed, the greater the transaction frequency, the smaller each batch's size. Increased transaction frequency reduces risk because of the smaller batch size. This study distinguishes between batch (accounting) profits and periodic profits (cash flows). Traditional hedging models have focused on batch profits but we argue that hedging cash flows are also a legitimate hedging target because (a) discounted cash flow is the capital investment decision criterion, (b) costs are associated with managing working capital, (c) cash flow and profits converge in annual aggregation, and (d) stabilizing periodic cash flow stabilizes annual profits but the converse does not hold. Weekly cash and futures prices from 1990 through 2003 are used to compare averages and standard deviations of direct-hedged and unhedged profits and cash flows with transaction frequencies of 1, 2, 4, 13, 26 and 52 weeks. Our findings are as follows. (1) Increased transaction frequency reduces the variance of unhedged profits and cash flows. Two effects account for this. Both profit and cash flow risks are reduced by smaller batch size associated with increased transaction frequency but only profit risk is reduced by closer integration of input and output markets as transaction frequency increases. (2) As transaction frequency increases, the amount of hedgeable risk declines (finding 1) and the effectiveness of traditional hedges also declines. (3) Anticipatory hedging of soybean processing does not offer much risk protection. (4) Traditional hedging of batch profits tends to destabilize periodic cash flows. Several areas meriting additional investigation are also discussed.

Keywords: risk management, process hedging, soybean crushing.

Introduction

One sage bit of agricultural marketing advice is "if you want to get the annual average price for your crop, sell one twelfth each month." While the logic of this advice is unassailable business strategies are typically not so simple. More specifically, transaction and marketing costs might make this strategy uneconomical. However, the strategy might be more practical for processing firms because they continuously purchase inputs, continuously transform inputs into outputs, continuously sell outputs, and deal in quantities where transaction cost economies are less important.

To envision the transaction frequency effect, suppose a firm produces y units of output annually over T sub-annual periods and the output price, p_t, follows a random walk. If all output is sold at the year's end, the variance of revenue is $V(y\, p_T) = y^2\, T\, \sigma^2$. If instead annual production is sold uniformly through N transactions at intervals of T/N, the variance of revenue is

$y^2 T \sigma^2 (N+1)(2N+1) / 6N^2$.[1] This variance decreases as the number of transactions (N) increases and approaches one-third that of a single year-end transaction as the number of sub periods becomes large.

Rather than following a random walk, cash commodity prices have generally been found to display serial correlation. Accordingly, suppose $p_t = \mu (1 - \rho) + \rho p_{t-1} + e_t$ for t = 1,2,3, ..,T. Table 1 shows revenue variances for ρ values of -0.8, -0.4, 0, 0.4, and 0.8 and T=120. This table demonstrates that increased sales frequency decreases the revenue variance over a broad range of conditions and that this variance drops dramatically as the first few transactions are added.

The optimal inventory model (Ravindran, Phillips, and Solberg, 1988) further illustrates the importance of this problem. Continue assuming that y units are produced annually and sold through N transactions. Also assume the firm's annual average inventory of y/2N is carried at a constant marginal cost of c per unit. Suppose each transaction costs a + b (y/N) where y/N expresses the transaction size. Total transaction costs are therefore a N + b y. Finally, suppose the firm separately values price risk exposure at a constant marginal cost of χ per unit and the random walk revenue variance derived in the preceding paragraph, $y^2 T \sigma^2 (N+1)(2N+1) / 6N^2$, measures these risks. The firm's total inventory cost is thus

$$c\, y / (2N) + (a N + b y) + \chi y^2 T \sigma^2 (N+1)(2N+1) / 6N^2.$$

Table 1. Revenue variance (times $\sigma^2 y^2$) by serial correlation of prices (ρ) and number of transactions (N).[a]

		ρ					
N	Cycle[b]	-.8	-.4	0	0.4	0.8	1
1	E	77.16	20.04	1	20.04	77.16	120
2	E	28.98	7.62	.25	7.62	28.98	75
3	E	17.19	4.55	.111	4.55	17.19	62.22
4	E	12.11	3.21	.0625	3.21	12.11	56.25
6	E	7.65	2.01	.0278	2.01	7.65	50.56
8	E/O	5.15	1.45	.0156	1.46	5.75	47.81
30	E	2.99	.376	1.11×10^{-3}	.376	2.99	42.02
40	E/O	.342	.236	6.25×10^{-4}	.302	2.87	41.51
60	E	2.79	.241	2.78×10^{-4}	.241	2.79	41.01
120	E/O	.0388	.0381	6.94×10^{-5}	.201	2.72	40.50

a/ Prices follow $p_t = \mu (1 - \rho) + \rho p_{t-1} + \varepsilon_t$ over 120 observations. $\varepsilon_t \sim IID(0,\sigma^2)$.

b/ E indicates the transaction cycle always falls on even periods. E/O indicates the transaction cycle alternates between even and odd periods. This distinction matters when $\rho < 0$.

[1] If p_t follows a random walk, then $Cov(\mathbf{p},\mathbf{p}^T) = \sigma^2 M$ where $M = \{ m_{ij} \mid m_{ij} = \min(i,j), i = 1,2...T, j=1,2, ...T\}$. If observations are drawn at intervals T/N then the covariance matrix of the periodic prices is $\sigma^2 (T/N) M$ where $M = \{ m_{ij} \mid m_{ij} = \min(i,j), i = 1,2...N, j=1,2, ... N\}$. $Var(Rev) = Var((y/N) \Sigma_{\tau=1}^{N} p_{(T/N)\tau}) = (y/N)^2 (T/N) \sigma^2 N(N+1)(2N+1)/6 = (y/N)^2 \sigma^2 (T/N) \Sigma_{\tau=1}^{N} \tau^2$.

The cost minimizing number of transactions is not a simple expression but application of the implicit function theorem of calculus reveals that the optimal number of transactions (N^*) is inversely related to χ and σ^2.

The overall objective of this paper is to examine the outcomes of hedging strategies for agricultural processing firms that continuously purchase inputs, transform these inputs into outputs, and sell outputs. This study addresses several questions, including: (1) Is the transaction frequency effect significant for agricultural commodity processors? (2) Is the transaction frequency effect mitigated or enhanced by hedging? (3) Is the transaction effect important enough to be part of a risk management strategy? To answer these questions we will examine the impact on profit variability of input procurement and product sales frequency both using and not using futures markets to hedge price risk.

The soybean-processing sector provides an opportune setting in which to study these issues because product transformation occurs with known, fixed coefficients, the sector is economically important, and the abundant cash and futures prices for soybeans, soybean oil, and soybean meal provide hedging opportunities for all transaction cycles. Consequently, hedging can alter risk levels so that the tradeoffs between price risk and transaction frequency can be studied. While our attention focuses on soybean processing, we note that our findings can be generalized to other agribusinesses that engage in continuous production such as cottonseed processors, meat packers, fertilizer manufacturers, and cereal manufacturers. Likewise, many traditional agricultural livestock production enterprises, such as hog and broiler production long ago adopted continuous production modes.

Soybean processing consists of crushing and flaking soybeans then removing the oil with hexane (Chicago Board of Trade, 1985). The hexane is evaporated from the oil then reused. This process yields eleven pounds of oil per sixty-pound bushel of soybeans. After extracting the oil and solvent, the remaining material is toasted and ground into 47 pounds of soybean meal (44 percent protein if hulls are not removed prior to processing, 49 percent if the hulls are removed). Thus, the fixed production coefficients for soybean processing describe the yield of eleven pounds of oil and 47 pounds of meal from each bushel of soybeans processed. The gross processing margin is the difference between the revenue from the soybean meal and oil and the cost of the soybeans.

Tzang and Leuthold (1990) describe a three-step hedge that soybean processors use to reduce price-induced variation in the gross processing margin. The steps are (1) at the beginning of the planning horizon, buy soybean futures and sell soybean meal and soybean oil futures, (2) when processing is initiated, buy soybeans, and sell the soybean futures contracts, and (3) when processing is complete, sell soybean oil and meal, and buy soybean oil and meal futures to close the hedge. Now consider how these transactions would be implemented on a continuous basis to support ongoing processing. Define continuous hedging as the futures transactions that correspond to the periodic cash market transactions required for continuous processing. As an example, table 2 illustrates the procession of Tzang and Leuthold hedging transactions to hedge quarterly cash market transactions. This table assumes that processing future batches of

Table 2. Cash and futures transactions for continuous processing with a quarterly transaction cycle.

	Cash Market (Batch)		Futures Market (Batch)			
Time	Soybeans	Meal & Oil	Soybeans		Meal & Oil	
			Buy	Sell	Buy	Sell
A. Continuous hedging in nearby contract for cash transaction, quarterly anticipatory period.						
Sept	Buy(Dec)	Sell	***Dec(Mar)***	Sep(Dec)	Sep(Sep)	***Mar(Mar)***
Dec	***Buy(Mar)***	Sell	***Mar(Jun)***	***Dec(Mar)***	Dec(Dec)	***Jun(Jun)***
Mar	***Buy(Jun)***	***Sell***	***Jun(Sep)***	***Mar(Jun)***	***Mar(Mar)***	***Sep(Sep)***
Jun	***Buy(Sep)***	***Sell***	***Sep(Dec)***	***Jun(Sep)***	***Jun(Jun)***	***Dec(Dec)***
Sept	***Buy(Dec)***	***Sell***	Dec(Mar)	***Sep(Dec)***	***Sep(Sep)***	Mar(Mar)
Dec	Buy(Mar)	***Sell***	Mar(June)	Dec(Mar)	***Dec(Dec)***	Jun(Jun)
B. Continuous hedging in nearby contract for cash transaction, no anticipatory period.						
Sept	Buy(Dec)	Sell			Sep(Sep)	Dec(Dec)
Dec	***Buy(Mar)***	Sell			Dec(Dec)	***Mar(Mar)***
Mar	***Buy(Jun)***	***Sell***			***Mar(Mar)***	***Jun(Jun)***
Jun	***Buy(Sep)***	***Sell***			***Jun(Jun)***	***Sep(Sep)***
Sept	***Buy(Dec)***	***Sell***			***Sep(Sep)***	***Dec(Dec)***
Dec	Buy(Mar)	***Sell***			***Dec(Dec)***	Mar(Mar)
C. Cumulative hedging, one quarter anticipatory period.						
Sep	Buy(Dec)	Sell	***Dec, Mar, Jun, Sep***	Sep	Sep	***Mar, Jun, Sep, Dec***
Dec	***Buy(Mar)***	Sell		***Dec***	Dec	
Mar	***Buy(Jun)***	***Sell***		***Mar***	***Mar***	
Jun	***Buy(Sep)***	***Sell***		***Jun***	***Jun***	
Sept	***Buy(Dec)***	***Sell***	Dec, Mar, Jun, Sep	***Sep***	***Sep***	Mar, Jun Sep, Dec
Dec	Buy(Mar)	***Sell***		Dec	***Dec***	

soybeans is continually anticipated and hedged one quarter ahead and that contract maturities are available to match the timing of cash market transactions.[2]

Under scenario A (table 2), the processor anticipates in September purchasing soybeans in December, crushing them, and selling the resulting meal and oil in March. This batch is

[2] Contract maturities for soybeans are Jan, Mar, May, Jul, Aug, Sep, Nov and contract maturities for soybean meal and oil are Jan, Mar, May, Jul, Aug, Sep, Oct, Dec. The maturities in table 2 are for illustrative purposes only. Our analysis uses the nearby contracts at the time of the hedge removal.

identified with the time of the output sale in parentheses (March). The Tzang and Leuthold approach to hedging this batch consists of (1) in September hedge the December purchase of soybeans with the purchase of a December soybean futures contract and sell March soybean meal and soybean oil futures contracts to hedge the March sale of the resulting output, (2) in December, when the soybeans are purchased, sell the soybean futures contracts, and (3) in March sell the soybean oil and soybean meal and close the respective futures positions. Table 2 shows similar transactions for other quarters. For this scenario hedging consists of establishing an intertemporal crushing spread (in September, buy December soybeans, sell March meal and oil) and executing a reverse crush spread at the time of each cash market transaction (in September, sell September soybeans and buy September meal and oil). The intertemporal aspect of the crush spread is governed by the frequency of the cash transaction cycle (one quarter) and the maturity of the soybean futures contract is governed by the anticipatory period.

Panels B and C of table 2 show other hedging configurations. In panel B the anticipatory period is eliminated and as a result the crush spread is not used. Panel C assumes variable anticipatory periods as hedge positions for the coming year are established in September. Under scenario C, intertemporal (quarterly) crush spreads are established for each anticipatory period in September then removed with a reverse crush spread at the time of the cash market transaction. Scenarios such as the non-simultaneous soybean meal and oil sales, and meal and oil sales that do not correspond to the purchase of soybeans are not shown in table 2. Nonetheless, table 2 presents a structure for considering these and other transaction cycles. At issue is how well do traditional hedging methods work with continuous hedging

Literature Review

The foundation of hedging theory is the treatment of a commodity market position as part of a portfolio that may also contain a futures market position (Johnson 1960; and Stein 1961). Portfolio returns are

$$\pi = x_s (p_1 - p_0) + x_f (f_1 - f_0) \qquad (1a)$$

where x_s is a predetermined spot market position, x_f is the attendant futures market position, p_0 and p_1 are spot prices at the beginning and end of the time period, and f_0 and f_1 are futures prices at the beginning and end of the hedge period. Initial spot and futures prices are assumed given while the ending period prices are assumed to be random variables. Risk is defined as the variance of returns,

$$V(\pi) = x_s^2 V(p_1\text{-}p_0) + x_f^2 V(f_1\text{-}f_0) + 2 x_s x_f \mathrm{Cov}(s_1\text{-}s_0 , f_1\text{-}f_0), \qquad (1b)$$

and hedging involves setting x_f so as to minimize risk. The solution is

$$x_f^* = - x_s \mathrm{Cov}(s_1\text{-}s_0 , f_1\text{-}f_0) / V(f_1\text{-}f_0). \qquad (1c)$$

Effectiveness measures the risk reduction attributable to hedging and is measured as

$$e = 1 - [V(\pi_h) / V(\pi_u)] = [\mathrm{Cov}(s_1\text{-}s_0 , f_1\text{-}f_0)]^2 / [V(f_1\text{-}f_0) V(s_1\text{-}s_0)] = (r_{\Delta s,\Delta f})^2 \qquad (1d)$$

where $r_{\Delta s,\Delta f}$ is the correlation between spot and futures price changes. Ederington (1979) reports that for a wide variety of commodities, the portfolio-risk minimization approach is more effective than the one-unit futures to one-unit cash approach.

Anderson and Danthine (1980, 1981) generalized earlier approaches by including multiple futures contracts in the portfolio. Their profit function (1980) is

$$\pi = x_s (p_1 - p_0) + \mathbf{x_f} (\mathbf{f_1} - \mathbf{f_0}) \quad (2a)$$

where the terms are as define under (1a) except that $\mathbf{x_f}$ represents positions in multiple futures contracts, and $\mathbf{f_1}$ and $\mathbf{f_0}$ are vectors of initial and terminal futures contract prices. The agent chooses a futures position to

$$\max_{\text{wrt } \mathbf{x_f}} U(\pi) = E(\pi) - (\lambda/2)\, Var(\pi). \quad (2b)$$

Letting $\Sigma_{\Delta f,\Delta f}$ and $\Sigma_{\Delta f,\Delta s}$ represent covariance matrices of the indicated price changes, the solution,

$$\mathbf{x}_{\mathbf{f}}^{*} = \lambda^{-1}\Sigma_{\Delta f,\Delta f}{}^{-1}(\bar{\mathbf{f}}_1 - \mathbf{f}_0) - \Sigma_{\Delta f,\Delta f}{}^{-1}\Sigma_{\Delta f,\Delta s}\, \mathbf{x_s}, \quad (2a)$$

provides for multi-contract hedging (1980) and cross hedging (1981). Assuming $\lambda = \infty$ or $\bar{\mathbf{f}}_1 = \mathbf{f_0}$ results in risk-minimizing hedge ratios, estimated by regressing the change in the spot price on the changes in the price of the futures contracts. Hedging effectiveness is estimated by the regression multiple correlation statistic. Myers and Thompson (1989) examined whether hedge ratios are most appropriately estimated from price levels, changes, or returns. They derive a generalized hedge ratio estimator based on deviations from the conditional mean at the time the hedge is implemented.

The Johnson and Anderson and Danthine methods have been frequently employed in agricultural production and storage hedging. Some examples of production hedges that resemble processing hedges include the cattle feeding hedge using corn, feeder cattle, and live cattle futures (Leuthold and Mokler, 1979; Shafer, Griffin and Johnson, 1978), and the hog feeding hedge using live hog, soybean meal and corn futures (Kenyon and Clay, 1987).

The soybean-processing hedge is similar to production hedges but with increased transaction frequency. Several methods for determining futures positions have been discussed in the soybean processing hedging literature (Tzang and Leuthold, Fackler and McNew). In a *one-to-one hedge*, each unit of cash market commitment is matched with a corresponding unit of futures market commitment. In a more general risk minimizing *direct hedge*, each unit of cash market commitment is hedged with a risk-minimizing futures commitment in the same commodity. In a *multi-contract hedge*, each unit of cash market commitment is hedged with risk-minimizing commitments in several futures contracts.[3] These futures contracts may differ by maturity, may

[3] Fackler and McNew (1993) refer to this as a multi-commodity hedge. Because the processor has a multi-commodity cash market position without hedging, we define this as a multi-contract hedge where the "multi"

specify a different commodity (i.e., a cross-hedge), or may specify non-commodity financial instruments (currencies, securities, indices, or weather). Other hedging strategies are defined in terms of the speculative soybean futures crush spread.[4] In a *one-to-one crush hedge*, the processor is long one bushel in a soybean crush spread for each anticipated bushel to be processed. This strategy is the identical to a one-to-one hedge if the soybean oil and soybean meal are sold simultaneously. A generalization of the one-to-one crush hedge is the *proportional crush hedge* whereby the soybean processor employs a risk-minimizing crush spread that is proportional to the cash soybean market position.

These hedging approaches have been used in various process hedging studies. Tzang and Leuthold (1990) use weekly cash and futures prices from January 1983 through June 1988 to investigate multi- and single-contract soybean processing hedges over 1-, 2-, 6-, 9-, and 15-week hedging horizons. Fackler and McNew (1993) use monthly average cash and futures prices to examine three soybean processing hedging strategies: multi-contract hedges, single-contract hedges, and proportional crush-spread hedges. Garcia, Roh and Leuthold (1995) find that time varying hedge ratios "provide minimal gain to hedging in terms of mean return and reduction in variance over a constant conditional procedure." Collins (2000) reports that multivariate hedging models offer no statistically significant improvement over "naive equal and opposite hedges." The multi-contract approach has recently been extended to cross hedging in the cottonseed-processing sector (Dahlgran, 2000; Rahman, Turner, and Costa, 2001).

These process-hedging studies typically follow Johnson, Stein, and Anderson and Danthine in using a two-period model. In doing so, inputs and outputs are priced at temporally separated points corresponding to the transformation cycle. The notion of batch processing is implicitly adopted as profits are defined as output(s) valued at the terminal price(s) less input(s) valued at the initial price(s). The hedger's assumed objective is the minimization of the variance of batch profits.

With the consideration of continuous processing, periodic profits are defined as outputs valued at current-period prices less inputs also valued at current-period prices. The variance of periodic profits represents periodic variation in cash flows and differs from the variance of accounting profits under the batch processing approach.

Cash flow stability is a concern for several reasons. First, discounted cash flow is the criterion in used in the decision to buy or build a processing plant. The use of cash flow as a hedging target is consistent with its use in the capital investment decision. Second, costs are associated with managing operating capital, so that stabilization of cash flow is a cost-reducing objective. And finally, we will see that with frequent transactions, accounting profits and cash flows converge in annual aggregation even though the sub-annual components behave differently. We will further observe that the stabilization of cash flows stabilizes annual accounting profits but the stabilization of batch accounting profits does not stabilize periodic cash flows.

---

refers explicitly to the futures markets. An additional advantage of this definition is that it allows consideration of multiple maturities in the same futures contract.

[4] The crush spread involves a long soybean futures position, and short soybean meal and soybean oil futures positions in the ratios of 47 pounds of meal and 11 pounds of oil for each bushel of soybeans.

Empirical Analysis

The analysis of periodic profits and cash flows requires first specifying a period, which returns our focus to transaction frequency. Our analysis will examine the interplay between transaction frequency and the amount of risk to be hedged and the comparison of the stability of accounting profits to the stability of cash flows when profits are unhedged as well as hedged by conventional approaches. We begin by establishing definitions.

Suppose at one point in time a processor decides on the amount of input to be purchased and processed at a future time with the product to be sold later still. We designate the time between the decision point and the input purchase as the anticipatory period (A) and the time between the input purchase and output sale as the transformation period (B). The anticipatory period may be fixed, variable or nonexistent as illustrated in table 2. During the transformation period, commodity is successively held as input inventories, goods in process, then output inventories. The timing of the movement between the various inventories is unimportant. The key aspects are that input inventories are determined by the frequency of input purchases, output inventory accumulation is determined by the rate of transformation, and output sales are determined by the size of output inventories.

Batch or accounting profits in cents per bushel for production sold in period t are

$$\pi_{u,t} = 48\ Sm_t + 11\ So_t - Sb_{t-B} \qquad t = 1 + B\ \tau,\ B= (52/N),\ \tau=1,2,3,\ .... \qquad (3a)$$

where and Sm_t, So_t, and Sb_t respectively represent spot or cash prices of soybean meal (cents per pound), soybean oil (cents per pound) and soybeans (cents per bushel) in week t. N, the number of transactions per year, determines the sampling frequency, the length of the transformation cycle (B), and the temporal separation between pricing inputs at time t-B and outputs at time t. Collins points out that there is no advantage to more complex hedging methods so according to the one-to-one Tzang and Leuthold hedging approach, hedged profits are

$$\begin{aligned}\pi_{h,t} = & [48\ Sm_t + 11\ So_t - Sb_{t-B}] \\ & - [48\ (Fm_{t-B} - Fm_{t-B-A}) + 11\ (Fo_{t-B} - Fo_{t-B-A}) - (Fb_{t-B} - Fb_{t-B-A})] \\ & - [48\ (Fm_t - Fm_{t-B}) + 11\ (Fo_t - Fo_{t-B})] \qquad t = 1 + B\ \tau,\ B= (52/N),\ \tau=1,2,3,\ .... \qquad (3b)\end{aligned}$$

The bracketed terms respectively represent unhedged accounting profits, per (3a), hedge profits for the anticipatory period (t-B-A to t-B) and hedge profits for the processing period (t-B to t).

Periodic profits or cash flows for period t from unhedged processing are

$$\phi_{u,t} = 48\ Sm_t + 11\ So_t - Sb_t \qquad t = 1 + B\ \tau,\ B= (52/N),\ \tau=1,2,3,\ .... \qquad (3c)$$

This expression assumes that commodity purchases and sales are on a cash basis and occur simultaneously, or that the accounts payable and receivable have identical terms. The cash flows attributable to the Tzang and Leuthold hedges are

$$\phi_{h,t} = [48\ Sm_t + 11\ So_t - Sb_t] - [48\ (Fm_t - Fm_{t-B-A}) + 11\ (Fo_t - Fo_{t-B-A}) - (Fb_t - Fb_{t-A})]$$
$$t = 1 + B\ \tau,\ B= (52/N),\ \tau=1,2,3,\ ... \qquad (3d)$$

The first bracketed term represents cash flows from spot market transactions while the second represents the cash flows from hedging. These terms generate one observation per transaction cycle and the observation is at the end of the cycle. The variance (or standard deviation) computed from these data, estimates Var($\phi_{h,t}$) which is the variance of cash flows within the cycle. Margin is assumed deposited initially and as positions are closed the margin freed up is used to open new positions to support the continuous hedging. Hence, except for the start-up, margin requirements do not cause cash flows.

The data used to compute the series defined by (3a) through (3d) were obtained from the online brokerage service BarChart.com. These data consist of daily cash prices for soybeans (#1 yellow, central Illinois), soybean oil (crude, Decatur Illinois), and soybean meal (48% protein, Decatur, Illinois) for the 14 years from January 1, 1990 through December 31, 2003. Daily cash crushing margins computed from these data are shown in figure 1. Daily futures prices (open, high, low, and settlement) for each soybean, soybean oil, and soybean meal futures contract traded on the Chicago Board of Trade during this time period were also obtained from this source and used to compute hedged profits and the corresponding cash flows.[5] Roughly 28,000 futures-market price observations on each commodity were available.

Several transaction frequencies were considered as N was set at 1, 2, 4, 13, 26 and 52 transactions per year. All transaction frequencies specify integer multiples of weekly observations (i.e. every week, every two weeks, etc) so observations on (3a) through (3d) were computed over the sample period using Wednesday's prices. However, if Wednesday was a holiday, then Thursday prices were used.

The futures prices used in (3b) and (3d) were for the nearby contract at the time of the cash market transaction provided that the contract was at least one week from maturity. Three hedging strategies are examined. These were no hedging, hedging just product transformation (i.e., B determined by N and A = 0), and hedging both anticipated and actual product transformation (i.e., i.e., B determined by N and A ≠ 0). For the third strategy, the length of the anticipatory period was set to the length of the transaction cycle (A = B).

The comparison of hedged versus unhedged outcomes can involve profits, comparing (3a) to (3b), or cash flows, comparing (3c) to (3d). The structure of table 3 facilitates these comparisons for various transaction frequencies. Table 3 reports averages and standard deviations for profits and cash flows in cents per bushel processed. Where appropriate the effectiveness of the hedge is also reported, as is the effect of hedging on the variance of cash flows.

5 The futures contract delivery locations correspond to the cash price locations so concerns about spatial price relationships and spatial price risk are removed from the focus of this analysis.

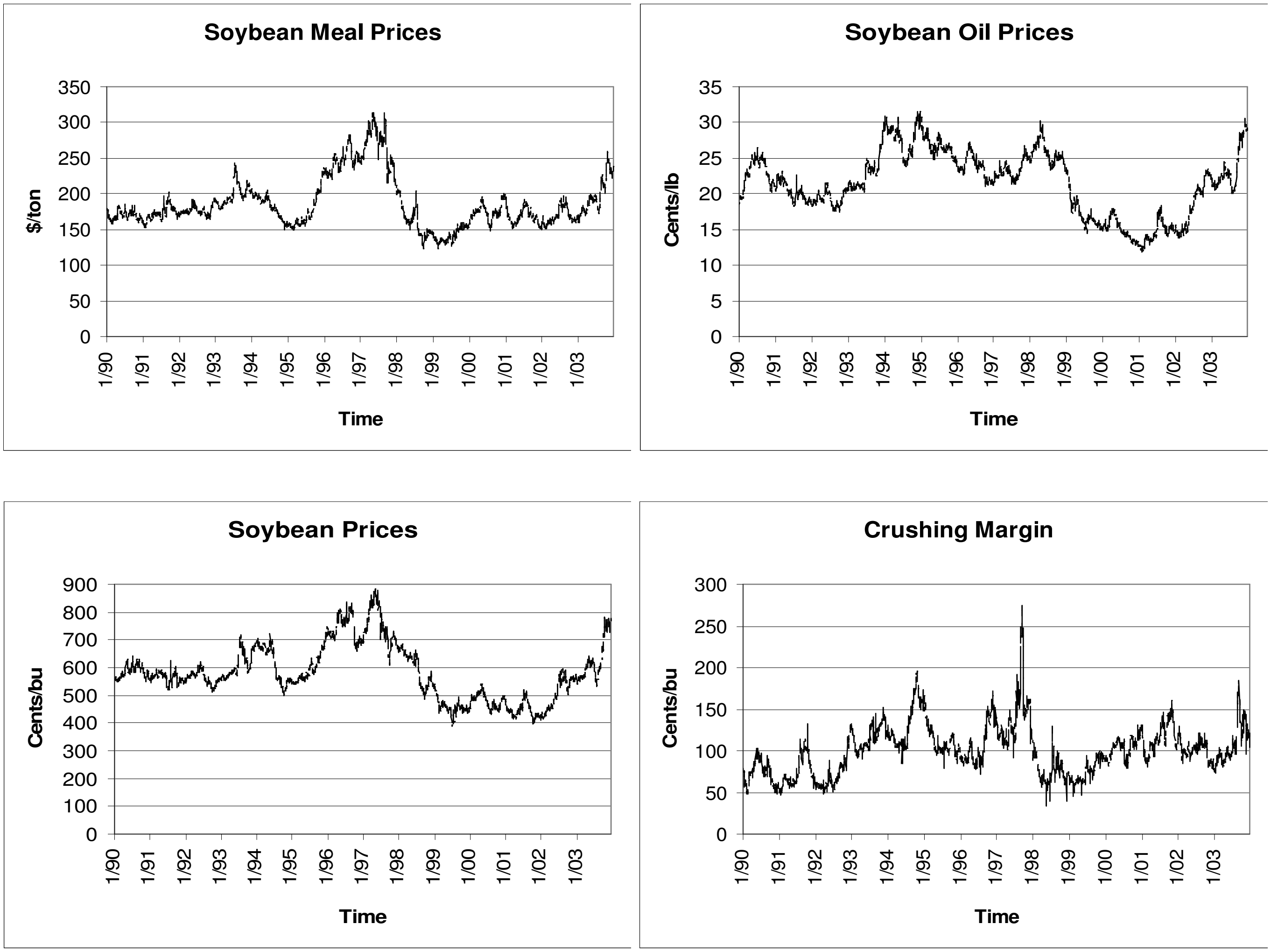

Figure 1. Historical data; cash prices for soybean meal, soybean oil, and soybeans, and the gross crushing margin.

Table 3. Hedging outcomes (in cents per bushel) by transaction cycle.

Outcome	Hedge Type		Transactions per year					
			1	2	4	13	26	52
Periodic Returns		Periods:	14	28	56	182	364	728
Profit	Unhedged	Average	122	107	107	102	101	101
		StdDev	115.38	78.11	61.50	43.97	36.96	33.98
	Transformation	Average	106	97	101	100	100	100
		StdDev	27.61	34.28	21.95	24.85	26.79	28.63
		Effectiveness	0.943	0.807	0.873	0.681	0.475	0.290
	Anticipation &	Average	92	96	101	99	99	100
	Transformation	StdDev	23.04	25.04	21.72	23.97	25.55	28.02
		Effectiveness	0.960	0.897	0.875	0.703	0.522	0.320
Cash Flow	Unhedged	Average	106	99	103	101	100	101
		StdDev	29.66	26.50	36.08	30.10	29.97	30.34
	Transformation	Average	91	89	97.62	99	99	100
		StdDev	113.33	69.56	58.85	38.31	34.11	32.91
		Effect	-13.598	-5.889	-1.660	-0.620	-0.295	-0.177
	Anticipation &	Average	109	98	101	98	99	100
	Transformation	StdDev	72.99	51.10	53.15	39.80	32.61	32.06
		Effect	-5.055	-2.717	-1.169	-0.748	-0.183	-0.116
Annual Aggregate								
Profit	Unhedged	StdDev	115.38	62.96	41.22	26.03	24.35	23.90
	Transformation	StdDev	27.61	22.51	15.20	19.54	21.29	22.41
		Effectiveness	0.943	0.872	0.864	0.437	0.236	0.121
	Anticipation &	StdDev	23.04	19.30	15.61	18.99	20.65	22.04
	Transformation	Effectiveness	0.960	0.906	0.857	0.468	0.281	0.149
Cash Flow	Unhedged	StdDev	29.66	21.47	25.56	23.43	23.33	23.46
	Transformation	StdDev	113.34	58.25	28.14	20.15	21.05	22.15
		Effect	-13.601	-6.363	-0.212	0.261	0.186	0.108
	Anticipation &	StdDev	72.99	38.70	23.61	18.86	20.20	21.66
	Transformation	Effect	-5.055	-2.250	0.146	0.352	0.250	0.148

This table reveals several relationships. First, except when there is only one transaction per year, the average gross crushing margin is slightly more than one dollar per bushel. With one transaction per year, it widens to $1.22 per bushel because of the substantial time lag between input purchases and output sales.

Second, table 3 reveals a consistent risk-return relationship for profits in that within each transaction frequency, lower profit risk is associated with lower average profits. This relationship is apparent, for example, with one transaction per year where unhedged processing has average profits of 122 cents per bushel and a standard deviation of profits of 115.38 cents per bushel while hedged processing has average profits of 106 cents per bushel and a standard deviation of profits 27.61 cents per bushel. This risk-return relationship also holds in the comparison of transformation hedging with combined anticipatory and transformation hedging, as the standard deviation falls from 27.61 to 23.04 cents per bushel while average profit falls from 106 to 92 cents per bushel. This risk-return tradeoff exists for profits across transaction frequencies but not for cash flows. The cash flow section of the table shows that transformation hedging reduces average cash flow and increases its standard deviation, regardless of frequency. When anticipatory hedging is added to transformation hedging, the cash flow impact is ambiguous with the average cash flows increasing for one, two and four transactions per year, and cash flow variability declining in all cases except for thirteen transactions per year. In all cases, the cash flow risk associated with anticipatory and process hedging exceeds the cash flow risk of unhedged processing.

The third finding from table 3 is that profit variability declines as transaction frequency increases. Two factors account for this. First, cash market arbitrage ensures that prices are jointly dependent. This dependency or market integration is stronger the less the temporal separation between input and output prices. Because increased transaction frequency reduces the temporal separation of input purchases and output sales, crush margin variability declines with increased transaction frequency. This effect is shown in table 3 where the standard deviation of periodic returns declines as transaction frequency increases. Not shown in table 3 is that increased transaction frequency reduces the quantity per transaction. These two effects reinforce each other because the standard deviation of periodic profits (or cash flows) is the product of volume times the standard deviation of the processing margin per bushel.

The standard deviation of periodic profits or cash flows cannot be determined directly from table 3 because total annual processing volume (y) is indeterminate. However, relative comparisons are possible by assuming a given total annual processing volume divided among the varying number of transactions. We can state, for example, that the standard deviation of unhedged profit with weekly transactions is 0.56 percent of the standard deviation of unhedged profit with one annual transaction ($0.56 = 100\times[33.96\times(y/52) \ / \ 115.38\times(y/1)]$). The effect of reduced periodic processing volume with increased transaction frequency is significant.

Hedging effectiveness and the effect of hedging on cash flows provide another view of the results. By definition, hedging effectiveness compares profit variances for hedged versus unhedged outcomes and can be interpreted as the proportionate reduction in profit variance due to hedging, given the transaction frequency. The effect of hedging on cash flow can be similarly defined as the proportionate reduction in cash flow variation due to hedging. However, hedging effectiveness differs from the effect of hedging on cash flows in that the hedging strategy is designed to minimize the variance of profits but its effect on cash flows is indeterminate. Table 3 shows that the effectiveness of transformation hedges declines as transaction frequency increases. Table 3 also indicates that the incremental effect of anticipatory hedging is relatively small.

Table 3 shows the effect of hedging on cash flows. These results are interpreted as follows. Suppose a processor has a four-week transaction cycle (13 transactions per year) and attempts to hedge profits with a transformation hedge. While this strategy reduces profit variability by 68 percent, it increases cash flow variability by 62 percent. This reduction in the variability of profits and increase in the variability of cash flows applies across all frequencies.

Finally, table 3 shows the standard deviations of annual aggregations of periodic profits and cash flows. On an annual basis, all hedging strategies and frequencies have the same annual processing volume so standard deviations are directly comparable. These results reveal that the standard deviations of profits and cash flows converge as transaction frequency increases though with few transactions per year, hedging destabilizes annual cash flows.

Summary and Conclusions

Figure 3 brings together the pertinent findings of this study by showing the impacts of both hedging and transaction frequency on periodic outcomes (figure 3a) and annual aggregates of the periodic outcomes (figure 3b). Figure 3a shows an index of the variance of unhedged periodic profit, Var(Prof). This index equals 100 for one transaction per year and drops dramatically with higher transaction frequencies. Generally, doubling the transaction frequency more that halves the standard deviation of unhedged profits because periodic volume is halved and the standard deviation of the per-unit processing margin falls due to increased cash market price integration. The periodic cash flow variance, Var(CF), is also indexed relative to the unhedged profit variance at one transaction per year. The periodic cash flow variance is less than the periodic profit variance because cash market price integration is fully incorporated into cash flows, regardless of the transaction frequency. Hence, as transaction frequency increases, the standard deviation of periodic cash flows declines because of reduced periodic volume but not because of falling standard deviations of per unit processing margins.

Figure 3a also shows the effectiveness of hedging during the transformation period, E(Prof,B), and during both the transformation and anticipatory periods, E(Prof,A&B). This figure demonstrates that the increment in effectiveness from anticipatory hedging is relatively small and that as transaction frequency increases, hedgable profit risk falls along with hedging effectiveness. Figure 3a also demonstrates the effect of hedging on periodic cash flows. The negative variance reduction indicates that while hedging reduces the variance of profits, it increases the variance of cash flows. This finding applies to both transformation hedging and transformation and anticipatory hedging.

Figure 3b shows an index of the variance of annual unhedged periodic profits, Var(Prof), where the index equals 100 for one transaction per year. This variance declines rapidly as transaction frequency increases. Also shown is the variance of annual unhedged cash flows indexed against the variance of unhedged profits with one transaction per year, Var(CF). Annual unhedged cash flows are less variable than annual unhedged profits, though both decline and converge as transaction frequency increases. As transaction frequency passes 13 transactions per year, hedging reduces the variance of annual profits and reduces the variance of annual cash flows and the amount of the reduction is approximately the same because cash flow and profits converge (E(Prof,B), E(Prof,A+B) versus E(CF,B) and E(CF,A+B) in figure 3b).

The three questions raised in the introduction can be addressed in light of the findings summarized in figure 3. First, is the transaction frequency effect significant for agricultural commodities? We have determined that the transaction effect arises from two sources. More transactions mean less volume per transaction and increased integration between input and output prices. The volume effect is primary but the price integration effect also plays a significant role in variance reduction. Traditional profit hedging approaches address the lack of price integration but interfere with existing price integration that is the source of cash flows stability.

Second, is the transaction frequency effect mitigated or enhanced by hedging? We have shown that hedging reinforces the transaction frequency effect by reducing the variance of periodic and annual profits but it increases the variance of periodic cash flows. Stockholders would apparently favor hedging as a profit assurance mechanism while managers might favor not hedging as a cash flow management strategy. However, stockholders receive profit reports annually and the income stabilizing effect of hedging an annual profits is limited.

Third, is the transaction frequency effect important enough to be part of a risk management strategy? The answer here is that multiple transactions represent a major source of risk reduction. Hedging strategies that fail to recognize the risk protection afforded by multiple transactions vastly overstate the amount of risk protection achieved. Furthermore, given the findings of this paper, the pertinent question is why would a processor hedge? The stabilization of periodic profits would be unrecognized by stockholders while the more variable cash flows would have to be dealt with by managers. On an annual basis, the variation of hedged profits and cash flows are about the same whether or not product transformation is hedged.

This paper represents a preliminary investigation into these issues and raises many questions. These questions include (1) How long should the anticipatory period be? Our attention focused on no anticipatory period and on anticipatory periods equal to the transformation period. Other anticipatory periods are available for investigation. (2) Is the risk reduction from anticipatory hedging statistically and economically significant? Figure 3 shows only a modest amount of risk reduction from the anticipatory periods examined. And finally, (3) Should cash flows be hedged instead of profits?

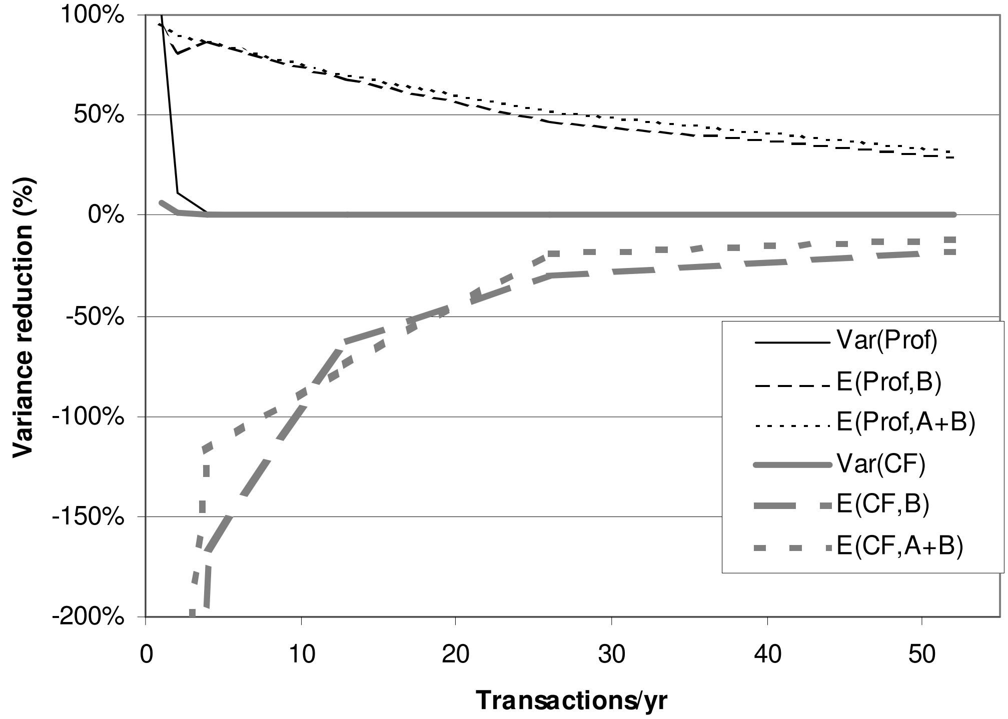

Fig 3a. Hedging's Effectiveness and Its Effect on Periodic Cash Flows.

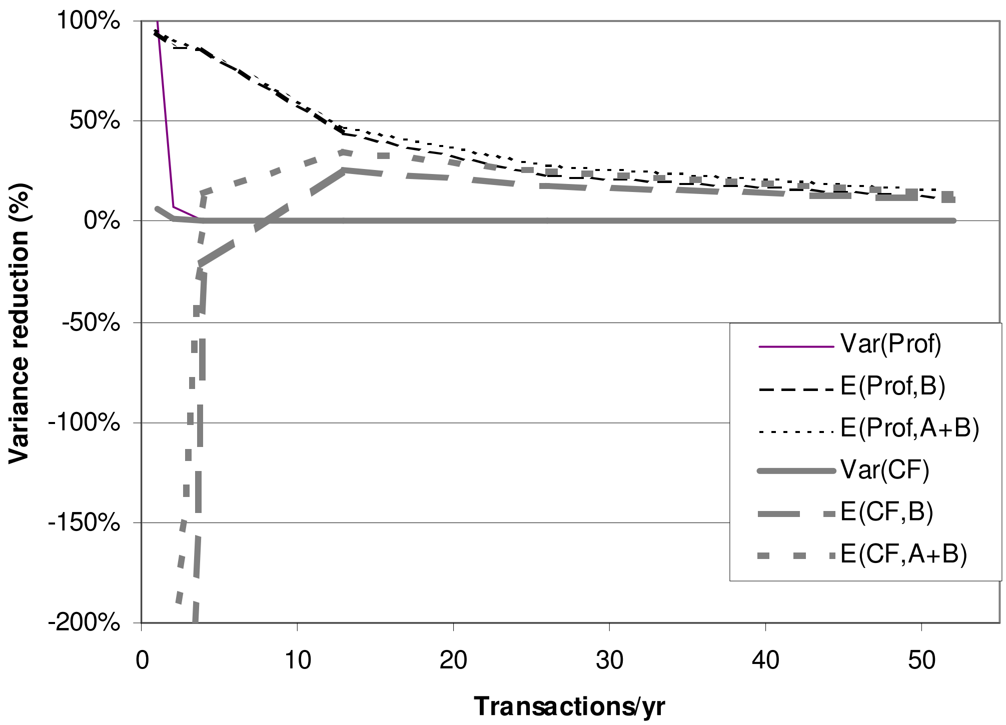

Fig 3b. Hedging's Effectiveness and Its Effect on Annual Cash Flows.

Figure 3. Hedging's Effectiveness and Its Effect on Cash Flows.

References

Anderson, R.W. and J. Danthine. "Hedging and Joint Production: Theory and Illustrations." *Journal of Finance* 35(1980):487-501.

Anderson, R.W. and J. Danthine. "Cross Hedging." *Journal of Political Economy* 89(1981):1182-96.

BarChart.com, Inc. Advanced Commodities Service. (data source). http://www.barchart.com.

Chicago Board of Trade. *Commodity Trading Manual*. Chicago Board of Trade, Chicago, IL, 1985.

Collins, R.A. "The Risk Management Effectiveness of Multivariate Hedging Models in the U.S. Soy Complex." *Journal of Futures Markets* 20(2000):189-204.

Dahlgran, R.A. "Cross-Hedging the Cottonseed Crush: A Case Study." *Agribusiness* 16(2000):141-158.

Ederington, L.H. "The Hedging Performance of the New Futures Markets." *Journal of Finance* 34(1979):157-170.

Fackler, P.L. and K.P. McNew. "Multiproduct Hedging: Theory, Estimation, and an Application." *Review of Agricultural Economics* 15(1993):521-535.

Garcia, P., J.S. Roh, and R.M. Leuthold. "Simultaneously Determined, Time-varying hedge ratios in the soybean complex." *Applied Economics* 27(1995):1127-34.

Johnson, L.L. "The Theory of Hedging and Speculation in Commodity Futures." *Review of Economic Studies* 27(1960):131-59.

Johnson, R.L., C.R. Zulaf, S.H. Irwin, and M.E. Gerlow. "The Soybean Complex Spread: An Examination of Market Efficiency from the Viewpoint of a Production Process." *Journal of Futures Markets* 11(1991):25-37.

Kenyon, D. and J. Clay. "Analysis of Profit Margin Hedging Strategies for Hog Producers." *Journal of Futures Markets* 7(1987):183-202.

Leuthold, R.M. and R.S. Mokler. "Feeding Margin Hedging in the Cattle Industry." *International Futures Trading Seminar Proceedings,* Chicago Board of Trade 6(1979):56-67.

Myers, R.J, and S.R. Thompson. "Generalized Optimal Hedge Ratio Estimation." *American Journal of Agricultural Economics* 71(1989):858-868.

Rahman, S.M., S.C. Turner, and E.F. Costa. "Cross-Hedging Cottonseed Meal." *Journal of Agribusiness* 19(2001):163-171.

Ravindran, A., D.T. Phillips, and J.J. Solberg. *Operations Research Principles and Practice*, 2nd ed. John Wiley and Sons, New York, N.Y. 1987.

Stein, J.J. "The Simultaneous Determination of Spot and Futures Prices." *American Economic Review* 51(1961):1012-1025.

Shafer, C.E., W.L Griffin, and L.D. Johnson "Integrated Cattle Feeding Hedging Strategies, 1972-1976." *Southern Journal of Agricultural Economics* 10(1978):35-42.

Tzang, D. and R.M. Leuthold. "Hedge Ratios under Inherent Risk Reduction in a Commodity Complex." *Journal of Futures Markets* 10(1990):497-504.