Asymmetric Information in Commodity Futures Markets: Theory and Empirical Evidence

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This article examines the theoretical and empirical implications of asymmetric information in commodity futures markets. In particular, it formulates and tests a theoretical model that recognizes two distinct categories of traders: hedgers, who participate in both spot and futures markets, and speculators, who participate only in the futures market. Speculators are assumed to possess differential information about the realized values of selected random variables. Multiperiod futures market equilibria are derived under competitive conditions, and the ability of futures markets to forecast changes in equilibrium spot market prices are examined. The key variable is shown to be the randomness and informational asymmetry in the aggregate supply by

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participating hedgers in the spot market, whose absence turns out to be the major determinant of the revelation of informational asymmetry.
Moreover, under the assumption of independence of error forecasts for prices and spot market supplies, it is shown that futures market equilibrium ends up with linear expressions for prices and futures contract volumes. These linear expressions are then used to develop empirically testable models. The main empirical implications in these models revolve around the role of the basis as a predictor of future spot price changes. The paper provides an empirical investigation of these implications, using three commodities traded on the Winnipeg Commodity Exchange (WCE). © 1998 John Wiley & Sons, Inc. Jrl Fut Mark 18:803–825, 1998

INTRODUCTION

Theoretical models of the determination of commodity futures prices have been presented in several studies,[1] for a variety of assumptions and market structures. The standard approach followed in these works is based on a partial market equilibrium situation, in which the futures price equates to one another the futures long and short positions of all participants. The existing literature on financial market equilibrium under asymmetric information has, however, mostly ignored market equilibrium in derivatives markets. Gould and Verrechia (1985), Glosten and Milgrom (1985), and Admati and Pfleiderer (1988) examine the incidence of asymmetry on stock market equilibrium. These studies have mainly focused on the well-known paradox, first presented by Grossman (1976, 1978) and Grossman and Stiglitz (1980), dealing with cases where observed prices reveal all privately-held information. If information acquisition is costly, and if prices are fully revealing, then there is no incentive to invest in acquiring information. Grossman and Stiglitz (1980) and Kyle (1985, 1989) have examined models of trading under asymmetric information under both perfect and imperfect competition that present solutions to this paradox. The driving force behind these solutions is the existence of independent sources of randomness, where private information exists but is not fully revealed by equilibrium prices.

, Futures market equilibrium models under asymmetric information were also examined in a series of articles by Khoury and Martel (1985, 1989). In these articles uninformed participants followed Bayesian decision rules in order to infer the values of important parameters in their

[1]The literature on futures markets and asymmetric information is too large to be cited in its entirety. For an early bibliography, see the references in Duffie (1989), Chapter 4.

own decision making. However, the models in these studies were incomplete, as there was no modeling of the decisions of informed agents, and no market equilibrium conditions. Consequently, no answer was given to the question of whether informed agents could be led to reveal the information in their possession.

Stock market equilibrium under asymmetric information is also the focus of several other studies that have reached a few results similar to those presented here, but only for the one and two period cases and without any empirical work. Thus Grundy and McNichols (1989) and Kim and Verrechia (1991a, 1991b) examine the impact of information asymmetry on both equilibrium price and volume of trade in models with two trading periods, while Brown and Jennings (1989) use a similar two-period model to deduce that technical analysis may have value in a world with informational asymmetry.

In this paper information is revealed over time during the sequential determination of futures market equilibrium, though earlier for some participants than for others. The revelation by informed traders (speculators) of the private information that they possess depends on the randomness and informational asymmetry of supply in the spot market,[2] and not on the futures market structure. Furthermore, the empirical results are strongly consistent with asymmetric information, while providing weak support for imperfect revelation in some cases.

The purpose of the assumption that speculators participate only in the futures market, while the hedgers participate in both futures and spot markets, is to rule out strategic participation in the spot market based on private information; it does not otherwise affect the results. Thus it is consistent with the existence of hedgers possessing private information as long as they are not large enough to affect the futures market equilibrium.[3,4] It may happen, as shown by Chang (1985) and by Leuthold, Garcia, and Lu (1994), that some large traders, particularly in some commodities in the United States, are as well informed as speculators. It is not always possible, though, to ascertain whether these traders are hedg-

[2]Similar results about the importance of the randomness of spot market supplies were also found by Grossman (1978) and Bray (1981).

[3]Note, however, that there is powerful support in early literature for the assumption that hedgers are less well-informed about market expectations than professional futures market traders or "speculators." Thus, R. G. Hawtrey wrote in 1940 about the hedger in futures markets that "... he regards the making of price as a whole time occupation for experts, and, in general, will not pit his fragmentary information against the systematic study at the disposal of the professional dealers". See also L. L. Johnson (1960).

[4]In fact, this model also allows speculators without specialized knowledge, by considering them as hedgers with zero spot market supplies. Similarly, it may be extended without reformulation to allow for hedgers with specialized knowledge, provided such knowledge is not sufficient to alter their spot market behavior.

ers or speculators. Information gathered from the WCE does not allow us to verify this fact in Canada[5] either.

THE GENERAL ASSUMPTIONS

This paper derives a system of simultaneous equations that characterize (i): a 2-period, 3-date equilibrium, and (ii): an n-period, (n + 1)-date equilibrium, and then performs an empirical test using data from the WCE. As in most earlier studies, it is assumed that all random variables are approximately normal. A mean-variance objective function for agents' decisions is adopted. Some of the results are also valid under a negative exponential utility function, which was used in most earlier studies. The two classes of agents in our model, hedgers and speculators, are denoted with the superscripts h and s respectively. The speculators are assumed to be better informed than hedgers about market conditions, implying that the errors in forecasting random variables are smaller for speculators than for hedgers.

It is assumed that there is one class of futures contracts expiring at the end of the horizon T. The spot market operates at all times, with prevailing prices P_t, with F_t denoting the corresponding futures price, t = 0, 1, 2, . . . ; P_t and F_t are random at any instant prior to time t, with $F_T = P_T$.

Let $R_i^h(t)$ and $R_j^s(t)$ denote the future cash flows[6] accruing from t to T, to the ith hedger and jth speculator respectively, where i = 1, . . . , I and j = 1, . . . , J, and I, J are supposed to be "large" (this term will be given a more precise definition later on). These cash flows are the only random income of both sets of agents. Hence, agents reach their decisions by maximizing *recursively* the expected utility of their cash flows.[7] This expected utility has the form $E[R_i^l] - r_i^l Var[R_i^l]/2$ or $E[-\exp(-r_j^l R_j^l)]$, $l = h, s$, under mean variance and negative exponential utility respectively. The two objective functions are strictly equivalent to each other only if the cash flows are linear in the random factors and these

[5]Likewise, even if it is true that several large U.S. commodity hedgers do possess private information, such hedgers do not necessarily participate on the WCE in canola, barley, and oats, the three commodities examined in the empirical work. Data supplied by the WCE in a private communication shows that 30% of the futures traders are pure speculators, 40% pure hedgers (producers, importers or exporters), and the remaining 30% are brokers trading on behalf of other parties. No data was, however, available as to the identity or size of the participants.

[6]Discounting is ignored, as in most futures market studies.

[7]In maximizing the objective functions of hedgers and speculators it is assumed that neither group possesses market power in the futures market. Hence, F_t is a constant for both groups in the maximization process. This is what is implied by the assumption of "large" numbers of agents on both sides.

factors are normal; the former condition, however, will not always be satisfied. Define also r_h and r_s as the harmonic means of the risk-aversion parameters of hedgers and speculators participating in the futures market during the life of the contract. They are given by the relations $1/r_h = \Sigma(1/r_i^h)$ and $1/r_s = \Sigma(1/r_j^s)$, and are assumed common knowledge.

The hedgers make spot market deliveries of $Q_i^t = [q_{it}, \ldots q_{iT}]$ till T, which may be positive, negative or zero, at spot market prices at times $t, \ldots, T$ respectively, yielding revenues of $q_{ik}P_k$, $k = t, \ldots, T$, for the ith hedger. They also hedge these revenues in the futures market. Let $W_i(t)$ the number of futures contracts written by the ith hedger and still outstanding at time t, and $X_i^t = [X_{it}, \ldots, X_{i,T-1}]$ the vector of contracts liquidated before expiration. $Z_j(t)$ and Y_j^t are the corresponding number of contracts held and liquidated by the jth speculator. The following relations obviously hold:

$$W_i(t+1) = W_i(t) - X_{i,t+1},\ Z_j(t+1) = Z_j(t) - Y_{j,t+1},$$
$$W_i(T) = Z_j(T) = 0 \tag{1}$$

The decision variables X_{it} and Y_{jt} are determined recursively at the end of period t. The market equilibrium condition $\Sigma_i X_{it} = \Sigma_j Y_{jt}$ determines the value of F_t at that time.[8] The spot market prices P_t are exogenously given, and so are the spot market deliveries q_{it}; the latter may or may not be known with certainty in advance. In other words, each hedger determines her spot market deliveries during the life of the contract on the basis of forecasts of spot market prices, in advance of the actual delivery time and independently from the hedging activity. Randomness in delivered individual quantities may reflect imponderable factors such as the weather.

This formulation recognizes the institutional features of actual commodity futures markets, in which commodities are produced and traded on a worldwide basis, while only a minority of commodity producers choose to hedge their sales in futures markets. Consequently, the futures market equilibrium is not supposed to affect the level of the future spot price, an assumption that is certainly satisfied for the commodities traded on the WCE, although not necessarily for the large U.S. futures markets.

[8]The futures market price is linked to the spot market price, in the absence of discounting, by the relation $F_t = P_t -$ (storage cost) + (convenience yield). On the other hand, the futures price is also linked, in the absence of asymmetric information, to the expected future spot price by means of the theories of normal backwardation, contango, or a capital market equilibrium model; see, for instance, Chang (1985). The model of this paper is in the spirit of the latter approach, under informational asymmetry. Note that both approaches are consistent with each other, with a proper definition of the convenience yield and the link between current and future spot prices.

For this reason the volume of spot deliveries is generally chosen ahead of actual deliveries and independently from the hedging activity. Randomness in aggregate quantities may also reflect varying numbers of hedgers participating in both spot and futures markets.

COMPETITIVE EQUILIBRIUM UNDER ASYMMETRIC INFORMATION

Assume at any time $t < T$ the spot prices form a martingale over time,[9] implying that $P_{t+1} = P_t + e_{t+1} + \varepsilon_{t+1}$, where e_{t+1} is an error term known to speculators but not to hedgers at time t, while ε_{t+1} is an error term unknown to both.[10] Clearly, from the point of view of the hedgers $E(e_{t+1}) = 0$, while for both hedgers and speculators $E(\varepsilon_{t+1}) = 0$. Hence, $P_t = E_h(P_{t+1})$, $E_s(P_{t+1}) = P_t + e_{t+1}$, and $E(e_{t+1}\, \varepsilon_{t+1}) = 0$ for both hedgers and speculators; similarly, $\mathrm{Cov}(e_{t+j}, e_{t+k}) = \mathrm{Cov}(\varepsilon_{t+j}, \varepsilon_{t+k}) = 0, j \neq k$ for both groups.

Ignoring discounting, future wealth (or, equivalently, total cash flow) of hedgers and speculators at time t, $R_i^h(t)$ and $R_j^s(t)$, is given by:

$$R_i^h(t) = P^{t+1}Q_i^{t+1} + W_i(t)\,[F_t - F_{t+1}] + \Sigma_k\, W_i(k)[F_k - F_{k+1}] \tag{2a}$$

$$R_j^s(t) = Z_j(t)[F_{t+1} - F_t] + \Sigma_k Z_j(k)[F_{k+1} - F_k], \tag{2b}$$

where Σ_k in (2ab) denotes summation for $k = t + 1, \ldots, T - 1$. In (2a) the first term is the revenue (or cost, since the vector Q_i^{t+1} can have negative elements) from the spot market deliveries. The remaining terms are cash flows from the marking-to-market and the successive revisions of the futures position till contract expiration. In (2b) the speculators' revenue comes only from their futures position.

The outstanding contracts $Z_j(t)$ and $W_i(t)$ are determined by maximizing the objective functions, $E[R_j^s(t)] - r_j^s\mathrm{Var}[R_j^s(t)]/2$ and $E[R_i^h(t)] - r_i^h\mathrm{Var}[R_i^h(t)]/2$ under mean variance, given the optimal numbers of subsequent contracts Y_{jk} and X_{ik} for all $k > t$. The model's assumptions imply that $P_{t+k} = E_s[P_{t+k}|t] + \varepsilon_{t+1} + \ldots + \varepsilon_{t+k}$ for all $k > 1$, and $\mathrm{Cov}_s(P_{t+1}, P_{t+k}|t) = \mathrm{Var}\varepsilon_{t+1} \equiv S_{t+1}$. Assume also that a futures market equilibrium will exist for all times $k \in [t + 1, \ldots, T - 1]$, implying that a positive market-clearing F_k exists.

[9]This assumption is only adopted for simplicity. In fact Propositions 1 and 2 hold for any linear Markovian assumption about the conditional expectation $E(P_{t+1} \mid t)$.

[10]Whenever possible, subscripts in error terms will indicate the time period at which the error is revealed to the *uninformed* agent.

A key determinant of the revelation of asymmetric information in this model is the nature of the vectors Q_t^i of spot market deliveries. Proposition 1 establishes the conditions for full revelation.

Proposition 1

If at any time $t < T$ all elements of the vector Q_i^t are known precisely, and if the risk-aversion parameters r_h and r_s of the participants in the spot market from t to T are also known, then there is full revelation at time t, and the futures price and optimal contracts are given by the following expressions:[11]

$$F_{T-1} = P_{T-1} + e_T - MS_Tq_T \tag{3a}$$

$$F_t = E[F_{t+1}|t] - MS_{t+1}(q_{t+1} + \ldots + q_T) \tag{3b}$$

$$X_{i\tau} = q_{i\tau} - Mq_\tau/r_i^h;\ Y_{j\tau} = Mq_\tau/r_j^s,\ \tau\varepsilon[t + 1, \ldots, T - 1] \tag{3c}$$

$$W_i(t) = \Sigma_k X_{ik};\ Z_j(t) = \Sigma_k Y_{jk}, \tag{3d}$$

where $M = [1/r_h + 1/r_s]^{-1}$ and $q_k = \Sigma_i q_{ik}$ for all $k \in [t, T]$.

Relations (3a)–(3d) form the benchmark case to assess the impact of information asymmetry in the empirical work of the next section.[12]

This full revelation result, however, does not survive the relaxation of the assumption of known future spot market deliveries. Moreover, since cash flows are no longer linear in the random factors, maximization of a negative exponential expected utility is not equivalent to mean variance maximization. In what follows proof of the existence of a nonrevealing equilibrium, as well as complete results, are first presented in Proposition 2 for the two-period model in the mean-variance case.[13]

The following assumptions are adopted in order to introduce randomness in spot market deliveries into the model:

(a) The vector Q_i^t of spot market supplies by the ith hedger is known to that hedger[14] (but not to other market participants) at time t. Further,

[11]The proof of all Propositions in this paper can be obtained from the authors upon request.

[12]Thus, (3b) implies that the formation of price expectations in the futures market [and, by a recursive application of (3a), in the spot market as well] must also incorporate a linear function of the net deliveries by hedgers in the spot market. Although these are unobservable, (3c) and (3d) can be used, under certain assumptions detailed in the next section, to express them as functions of the observable open interest in the futures market.

[13]Proof of the existence of such an equilibrium for the negative exponential does not seem to be available in the literature; see the comments in Brown and Jennings (1989, p. 532).

[14]The main points of both Propositions 2 and 3 would still be valid if the ith hedger faces some unanticipated errors in his own spot market deliveries. Such errors would, however, be positively correlated with the errors in aggregate spot market deliveries and, hence, would introduce extra covariance terms and complicate the analysis unnecessarily. For this reason they are omitted.

this vector contains zeroes for all but one entry, implying that each hedger participates in the market only once in $[t + 1, \ldots, T]$.

(b) The error terms in aggregate spot market supplies by hedgers participating in the futures market are mutually independent between periods and, without loss of generality, identically distributed. Let $q_k = q + x_k + y_k$, $k = t + 1, \ldots, T$, $\text{Var}x_k = \sigma_x^2$, $\text{Var}y_k = \sigma_y^2$, $\text{Cov}(x_k, y_l) = 0$, all k, l, $\text{Cov}(x_k, x_l) = \text{Cov}(y_k, y_l) = 0$, $k \neq 1$, where $E_s(q_{k+1}|k) = q + x_k$, $E_h(q_{k+1}|k) = q$ for all k.

(c) The error terms in aggregate spot market supplies by participating hedgers are independent of the error terms in spot market prices, that is, $\text{Cov}_s(x_k + y_k, e_l + \varepsilon_l) = \text{Cov}_h(x_k + y_k, e_l + \varepsilon_l) = 0$, all k, $l = t + 1, \ldots, T$.

Both (b) and (c) are consistent with assumption (a) and follow directly from it, given our assumptions that most hedgers do not possess private information, and that only a fraction of spot market participants also participate in the futures market. Assumption (b) follows from (a) given the presence of a "large" number of hedgers, each one a potential entrant to the spot market, with individual entry decision a private knowledge as to timing and quantity. Similarly, assumption (c) implies that hedgers decide their spot market deliveries on the basis of the expected spot market prices, not the prices' error terms; hence, there is no reason for the random errors of their aggregate decision variable to be related to these price error terms. Assumptions (b) and (c) are crucial for the empirical model of the next section. By contrast, the next assumption is adopted only for convenience, since it simplifies the recursive formulas in the multiperiod result.

(d) Speculators can forecast spot prices and quantities more accurately than hedgers for only one period ahead, implying that $E_s[P_{t+k}|t] = P_t + e_{t+1}$, $k \geq 1$, and $E_s(q_{t+k}) = E_h(q_{t+k})$, $k > 1$.

With these assumptions the futures market equilibrium in the two-period case can now be formulated. The absence of full revelation is well known from earlier studies, and will be treated rather briefly here. First replace q_0 by q, and set $\text{Var}e_k = S_1$, $\text{Var}\varepsilon_k = S_2$, $k = 1,2$; as before, conditional moments (means μ and variances σ^2) are denoted by the subscripts s or h. Next, the following notation is adopted in the remainder of this section, for all $k \in [t, T-1]$: $M_k = [(r_s \text{Var}_s F_{k+1})^{-1} + (r_h \text{Var}_h F_{k+1})^{-1}]^{-1}$; $a_k = M_k (r_s \text{Var}_s F_{k+1})^{-1}$; X^k and Y^k denote respectively the error vectors[15]

[15]The error vector X^k should not be confused with the subscripted vector X_i^k, denoting the contracts liquidated from k to $T - 1$ by the ith hedger. The vectors X^k and Y^k represent forecast errors at time $T - k$ in the aggregate spot market supplies, at time $T - k + 1, \ldots T$, during the recursive maximization of the objective function.

$[x_k, \ldots, x_T]$ and $[y_k, \ldots, y_T]$, and similarly a superscript k on a vector of coefficients denotes a vector of dimension $T-k$. Finally, for any vector A^k write $\Delta A^k = A^{k+1} - A^k$, where the first element of the vector A^{k+1} has been set equal to zero.

It is known from earlier studies that there is full revelation in a single period model, implying that (3a) also holds when the spot market q_T supply is asymmetrically random. Replacing and maximizing recursively (2a) and (2b), the prevailing price and volume in the futures market equilibrium are derived by aggregating and equating the total volume of futures market contracts for hedgers and speculators. Note that futures market equilibrium at $T-2$ reveals to speculators the quantity $\Omega_s = x_T + y_T + \Theta y_{T-1}$, where $\Theta = \mathrm{Cov}_h(P_{T-1}, F_{T-1})/\mathrm{Var}_h F_{T-1}$, and both Cov_h and Var_h are conditional on the information set available to hedgers at $T-2$. Hence, although the error terms x_T, y_T and y_{T-1} are not observable by speculators, their function Ω_s is. In deriving, therefore, the futures market equilibrium the s-subscripted moments of the error terms are conditional on Ω_s. Using the properties of conditional probabilities: $\mathrm{Var}_s(F_{T-1}|\Omega_s) = S_1 + S_2 + (MS_2\,\sigma_{s,x+y})^2$; $E_s(F_{T-1}|\Omega_s) = P_{T-2} + e_{T-1} - MS_2(\mu_{sx} + \mu_{sy})$; $\sigma^2_{s,x+y} = \Theta^2\sigma^2_y(\sigma^2_{x+y})/(\sigma^2_{x+y} + (\Theta\sigma_y)^2)$; $\mu_{sx} + \mu_{sy} = \Omega_s\sigma^2_{x+y}/(\sigma^2_{x+y} + (\sigma_y\Theta)^2) \equiv \lambda\Omega_s$, where $\lambda < 1$ if $\Theta \neq 0$. The aggregate volume of contracts is found by setting $K = M_{T-1}S_2[1 - 2S_2(M_{T-1}\sigma_{s,x+y})^2]$, and replacing the conditional means, we have

$$Z(T-2) = a_{T-2}M_{T-2}[P_{T-2} - Kq + e_{T-1} - \lambda K\Omega_s - F_{T-2}];$$

$$Z_j(T-2) = (r_j^s \mathrm{Var}_s(F_{T-1}|\Omega_s))^{-1}\,[P_{T-2} - Kq + \Omega_h - F_{T-2}], \qquad (4a)$$

where $\Omega_h \equiv e_{T-1} - \lambda K\Omega_s = e_{T-1} - \lambda K[x_T + y_T + \Theta y_{T-1}]$. This implies that for $K \neq 0$ observing Z reveals to hedgers Ω_h, as well as the quantity $U_h \equiv x_T + y_T + \Theta(x_{T-1} + y_{T-1})$. Hence, all h-subscripted moments are conditional on both Ω_h and U_h, as detailed below.

The expressions represented by K and Θ are key components of the non-revelation property, as discussed after the proof of Proposition 2. Indeed, for $K = 0$ it can be easily seen from (4a) that observing Z reveals to the hedgers at time $T-2$ the price error term e_{T-1}, while for $\Theta = 0$ $\sigma_{s,x+y} = 0$ and the speculators learn at $T-2$ the value of aggregate supplies two periods later. A nonrevealing equilibrium must, therefore, avoid such results.

For the evaluation of the conditional moments the following property $(\mathbf{P}_2)$ of conditional distributions of multivariate normal random variables[16] will be applied extensively in the remainder of this section. Let Z

[16]See, for instance, Tong (1990), Chapter 3.

denote an m-dimensional column vector of independent normal random variables with zero means, and $\mathbf{A}$ an nxm matrix, where $m \geq 5$, $n \geq 4$, and $\alpha_{n-1}\mathbf{Z} = \Omega_h$, $\alpha_n\mathbf{Z} = U_h$, where α_{n-1} and α_n are the last two rows of $\mathbf{A}$. Then if $\mathbf{AZ} = \mathbf{T} = [\mathbf{T}_1, \mathbf{T}_2]'$, where $\mathbf{T}_2 = [\Omega_h, U_h]'$, define $\Sigma = \text{Var}(\mathbf{T}) = \mathbf{AIA}'$, where $\mathbf{I}$ is a diagonal matrix of the variances of the elements of $\mathbf{Z}$. Partitioning Σ into an $(n-2)\times(n-2)$ and a 2×2 square matrices Σ_{11} and Σ_{22} respectively, as well as into the off-diagonal matrices Σ_{12} and Σ_{21} yields the following result:

($\mathbf{P}_2$) $(\mathbf{T}_1|\mathbf{T}_2)$ is normally distributed, with $E[\mathbf{T}_1|\mathbf{T}_2] = \Sigma_{12}\Sigma_{22}^{-1}\mathbf{T}_2$,

$$\text{Var}[\mathbf{T}_1|\mathbf{T}_2] = \Sigma_{11} - \Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21}$$

Applying ($\mathbf{P}_2$), set $\mathbf{Z} = [e_{T-1}, x_{T-1}, x_T, y_{T-1}, y_T]'$, and $\mathbf{AZ} = [e_{T-1}, x_T + y_T, \Omega_h, U_h]'$. Maximizing (2b) with respect to $W_i(T-2)$, using ($\mathbf{P}_2$) to evaluate the missing conditional moments, setting $\text{Var}_h(x_T + y_T|\Omega_h, U_h) \equiv \sigma^2_{h,x+y}$, $\text{Cov}_h(e_{T-1}, x_T + y_T|\Omega_h, U_h) \equiv \sigma_{e,x+y}$, and setting δ_i equal to 1 or 0 depending on whether the ith hedger participates or not in the market at $T-1$, yields the volume of futures contracts held by the ith hedger at time $T-2$:

$$\begin{aligned} W_i(T-2) = {} & (1-\delta_i)q_{iT} + \delta_i q_{i,T-1}\text{Cov}_h(P_{T-1}, F_{T-1}|\Omega_h, U_h) \\ & /\text{Var}_h(F_{T-1}|\Omega_h, U_h) + (r_i^h\text{Var}_h(F_{T-1}|\Omega_h, U_h))^{-1} \\ & [F_{T-2} - P_{T-2} - \mu_e + S_2M_{T-1}(q + \mu_{hx} + \mu_{hy}) \\ & + 2(q + \mu_{hx} + \mu_{hy})S_2M^2_{T-1}(\sigma_{e,x+y} - S_2M_{T-1}\sigma^2_{h,x+y})]. \end{aligned} \tag{4b}$$

The futures market equilibrium price is found by aggregating (4b), equating to (4a) and solving for F_{T-2}, yielding

$$\begin{aligned} F_{T-2} = {} & P_{T-2} - Ka_{T-2}q + a_{T-2}\Omega_h + (1 - a_{T-2}) \\ & [\mu_e - S_2M_{T-1}(q + \mu_{hx} + \mu_{hy})[1 + 2M_{T-1}(\sigma_{e,x+y} \\ & - S_2M_{T-1}\sigma^2_{h,x+y})]] - M_{T-2}(q(1 + \Theta) + U_h), \end{aligned} \tag{4c}$$

where, by ($\mathbf{P}_2$):

$$[\mu_e, \mu_{hx} + \mu_{hy}]' =$$

$$\begin{bmatrix} S_1(1 + \theta^2)(\sigma_x^2 + \sigma_y^2)/\kappa & KS_1\lambda(\sigma_x^2 + \sigma_y^2)/\kappa \\ -\lambda K\theta^2(\sigma_x^2 + \sigma_y^2)^2/\kappa & (S_1 + (\lambda K\theta\sigma_y)^2)/\kappa \end{bmatrix} \begin{bmatrix} \Omega_h \\ U_h \end{bmatrix} \tag{5}$$

$$\kappa = (\sigma_x^2 + \sigma_y^2)[(\lambda K\Theta)^2(\sigma_x^2 + 2\sigma_y^2 + (\Theta\sigma_y)^2) + S_1(1 + \Theta^2)],$$

$$S_{h1} = S_1 - S_1^2(1 + \Theta^2)(\sigma_x^2 + \sigma_y^2)/\kappa,$$

$$\sigma_{e,x+y} = -S_1\lambda K(\sigma_x^2 + \sigma_y^2)^2\Theta^2/\kappa,$$

$$\sigma_{h,x+y}^2 = (\sigma_x^2 + \sigma_y^2)[1 - (\sigma_x^2 + \sigma_y^2)(S_1 + (\lambda K\Theta)^2(\sigma_x^2 + 2\sigma_y^2))/\kappa].$$

The futures market equilibrium at time $T-2$ can now be shown to correspond to imperfect revelation by the following result.

Proposition 2

A two-period non-revealing equilibrium exists for mean-variance preferences of both hedgers and speculators for all but specialized values of the variance and risk-aversion parameters, and in that equilibrium the coefficient of the price error term e_{T-1} in (4c) is *different* from 1 for all but specialized values of these parameters.

A region of the parameter space in which the two-period futures market equilibrium reveals to hedgers the price information possessed by speculators can be identified by the condition $K = 0$ in (4)–(5); a similar effect takes place when the coefficient of e_{T-1} is equal to 1 in (4c).[17] In the empirical investigation of the next section, these parameter regions are indistinguishable from the full revelation case, where $\sigma_l = 0$, $l = x, y$.

The last theoretical result of this paper develops expressions for multiperiod recursive *nonrevealing* futures market equilibrium, in a manner similar to that of Propositions 1 and 2. The existence of such an equilibrium will be taken for granted if assumptions (a)–(c) hold. In the formulation that follows, all conditional moments are evaluated by applying property ($\mathbf{P}_2$). For economy of notation the following additional definitions are adopted: $\Delta F_k = F_{k+1} - F_k$, $k \in [t + 1, T - 1]$, $\mathrm{Var}(F_{t+1}|\Omega_{st}) = \mathrm{Var}_s F_{t+1}$, $\mathrm{Var}(F_{t+1}|\Omega_{ht}, U_{ht}) = \mathrm{Var}_h F_{t+1}$, where Ω_{st} and (Ω_{ht}, U_{ht}) are, respectively, the information sets (observable functions of the error terms) available at t to speculators and hedgers.

Proposition 3

Under assumptions (a)–(d) and for any $t < T$ the futures market equilibrium prices and volumes of contracts satisfy the following *linear* relations in P_t, e_{t+1}, q and the error term vectors:

[17]Similar parameter regions have also been found in other asymmetric information models. See, for instance, Brown and Jennings (1989, p. 534). These parameter regions have no obvious interpretation, in spite of their important implications.

$$F_t = P_t + m_t e_{t+1} - \alpha_t q - A^{t+1}X^{t+1} - B^{t+1}Y^{t+1}, \tag{6a}$$

$$W_i(t) = \beta_{t1} q_{i1} + \eta_{it} e_{t+1} + \gamma_{it} q + E_i^{t+1} Y^{t+1} + G_i^{t+1} X^{t+1}, \tag{6b}$$

$$\begin{aligned} Z(t) &= (r_s \mathrm{Var}_s F_{t+1})^{-1}[P_t + e_{t+1} - F_t - \phi_t q - K_t \Omega_{st}] \\ &= (r_s \mathrm{Var}_s F_{t+1})^{-1}[e_{t+1}(1 - m_t) + (\alpha_t - \phi_t)q + A^{t+1}\, X_{t+1} \\ &\quad + B_{t+1} Y^{t+1} - K_t \Omega_{st}], \end{aligned} \tag{6c}$$

where $1 \in [t + 1, \ldots, T]$, the observable error term functions are given by

$$\begin{aligned} \Omega_{st} &= \Theta_t y_{t+1} + \beta^{t+2}(X^{t+2} + Y^{t+2}),\ \Omega_{ht} = e_{t+1} - K_t \Omega_{st},\ U_{ht} \\ &= \Theta_t x_{t+1} + \Omega_{st}, \end{aligned} \tag{6d}$$

and the coefficients of (6abcd) are given by the recursive relations (A3)–(A5) in the appendix.

Proposition 3 shows quite clearly that under mean variance and for any time to contract expiration, both futures price and volume of outstanding contracts are linear functions of the speculators' private information, as well as of common expectations, about spot market prices and quantities. As already noted, the linearity of the results depends only on the independence assumptions (a), (b) and (c) above. Other assumptions, on the other hand, considerably simplify the recursive expressions (6) and (A3)–(A5), but are not essential for the empirical work of the next section. Expression (6a) shows that the speculators' private price information e_{t+1} enters into the futures price F_t with a factor that is generally different from one. This last remark, which forms the basis of the empirical work, was shown to hold in Proposition 2 for the two-period case. Although the proof will not be extended to more than two periods, it is noted that existence of equilibrium here implies the existence of a parameter vector (Θ_t, β^{t+2}) given by (A3b). In that solution the key parameter Θ_t must be *different from zero*. Otherwise, observing (Ω_{ht}, U_{ht}) is equivalent, from the perspective of (6d), to observing e_{t+1} and Ω_{st}, i.e. all the private information relevant to futures market equilibrium. The existence of such a solution constitutes an assumption underlying the empirical work of the next section, since the non-revealing equilibrium cannot be distinguished otherwise from that given by (3) for fixed spot market supplies.[18]

[18]Similarly, it is easy to see from (4a) and (6d) that there is full revelation if the futures spot market deliveries are random but *without* any informational asymmetry in quantities. This comes out clearly by setting the x-terms in the definitions of the information sets Ω_s, U_h and Ω_h equal to zero. U_{ht} then coincides with Ω_{st} in (6d), and observing U_{ht} and Ω_{ht} reveals to the hedgers e_{t+1}, the only privately known term.

EMPIRICAL INVESTIGATION

In this section, some of the empirical implications of the analysis presented in the previous sections are explored, using data on canola, barley and oats futures drawn from the WCE and covering the period 1982–1994. The data base consists of daily spot and futures prices, as well as open interest, for all the commodities traded on that exchange.

The WCE is Canada's oldest financial market. During all the period under study, it operated the only canola and barley futures markets in North America.[19] The WCE also conducts a market in oats, rye, wheat and flaxseed, as well as feed wheat, feed barley, and western domestic feed barley. From a structural point of view, during the years examined, the market for wheat and barley, and up to 1989 for oats, in Canada was strongly influenced by the policies of the Canadian Wheat Board, a public corporation that acts as the sole distributor and gives suppliers an equal opportunity to deliver grain through a quota system. By announcing a support price early in the season, and standing ready to adjust it if needed, the board smooths out supply and demand shocks in these markets. By contrast, canola, flaxseed and rye are marketed entirely by private traders. Further, while the bulk of the barley and oats production is consumed domestically, half the production of canola is exported, mainly to Japan. Tests were done for both canola and barley, the two commodities traded exclusively on the WCE.[20] Tests were also run with oats, for comparison purposes, in order to check for significantly different patterns.

Designated delivery months are an important consideration in this study, to avoid data overlapping. Delivery months for the canola contract are January, March, June, September, and December. For barley and oats contracts the delivery months are March, May, July, October, and December.[21] Delivery can occur only during the delivery month, up until the last day of the month, even though trading ceases eight business days before the end of the month. It should also be noted that Canadian contracts usually do not exceed 12 months.

It is assumed that the competitive model holds for all three commodities used in the tests. In addition, the martingale assumption, that $P_t = E(P_{t+1})$, is transformed into a random walk, by assuming independence and identical variances for all error terms e_t and ε_t for all t. Let T

[19]Carter (1989), however, reports that these two commodity futures are effectively arbitraged against corn and soybean futures in Chicago.

[20]Rye futures, which were also traded exclusively on the WCE, were discarded since their market is very thin, with no trades reported for many time periods. This violates the market existence assumption.

[21]November contracts were initiated on 25 January 1988 for wheat, oats and barley, but were later discontinued. These contracts are not included in the study.

denote the contract expiration date and t an earlier date. There are five contracts in each year, each one included as a separate observation. This implies the assumption that there is no seasonality in the data during the course of a year, an assumption that was tested and found justified for the commodities examined in an earlier study.[22] Let also the index k denotes any observation in our sample.

All error terms are assumed to have stationary distributions, independent of k. The vector of aggregate net supplies Q^t by hedgers participating in the spot market during the period [t, T] is not observable, and must be estimated from the futures contracts. Let also Z_{tk} and X_{tk} denote, respectively, the number of outstanding contracts and those liquidated in period k and time t before expiration; clearly, $X_{tk} = Z_{t-1,k} - Z_{tk}$.

There are three empirically relevant hypotheses, as far as symmetry of information is concerned, that can be derived from the theoretical results of the previous section:

I. *Symmetric information:* The error terms e and x are all equal to 0, and only the unanticipated error terms ε and y exist.

II. *Asymmetric information, known spot supply:* As shown in section III, this is the case of full revelation, covered in Proposition 1.

III. *Asymmetric information, random spot supply:* Information is only partially revealed at time t, as in Propositions 2 and 3.

Under hypothesis (II) it is known from (3bc) that[23] $X_{tk} = aq_{tk}$, $Z_{tk} = a\Sigma_\tau q_{\tau k}$, and that $F_t = E[F_{t+1}] - b\Sigma_\tau q_{\tau k}$, where a and b are parameters independent of both t and k by the stationarity assumption, and Σ_τ denotes the sum from t + 1 to T. Similarly, stationarity implies that $P_{Tk} - P_{tk}$ depends only on t and not on k, with $P_T - P_t = \Sigma_\tau(e_\tau + \varepsilon_\tau)$. Since $F_{T-1,k} = E(P_{Tk}) - bq_{Tk}$, a recursive application of the random walk hypothesis yields under (II) $F_{tk} = E[P_{Tk}|t] - b\Sigma_\tau(\tau - t)q_{\tau k}$.

The next assumptions are consistent with those already used in Propositions 2 and 3 of the previous section.

(i) Speculators can forecast only one period ahead, implying that $F_{tk} = P_{tk} + e_{t+1,k} + \varepsilon_{t+1,k} - b\Sigma_\tau(\tau - t)q_{\tau k}$.

[22] See Khoury and Yourougou (1993).

[23] In the model the term Z denotes the contracts held by speculators, which is equal to the *net* position of the group of hedgers. In the data only the open interest is observable, which may be larger if hedgers are both buyers and sellers in the spot market. Open interest is proportional to the net position if the proportion of buyers in the total spot market deliveries by participating hedgers is constant in every time period. The model continues to be valid if the error in using open interest instead of the net position is independent of the random error term in regression (8) below.

(ii) Spot market supplies in each period τ till contract expiration date T are a given fraction of the total supply in the period $[t + 1, \ldots, T]$ for all k. This implies that $q_{\tau k} = q_k c(\tau)$, $\tau \in [t + 1, \ldots, T]$, where $c(\tau)$ is a given proportionality factor independent of k.

Combining these assumptions yields, under (II):

$$F_{tk} - P_{tk} = e_{t+1,k} - c_t q_k, \; Z_{tk} = b_t q_k, \tag{7}$$

where the parameters b_t and c_t depend on the number of periods till expiration of the contract. Z_{tk} can now be used as an independent variable to measure q_k. From (7): $e_{t+1,k} = F_{tk} - P_{tk} + c_t Z_{tk}/b_t$. Replacing $e_{t+1,k}$ into the sum $\Sigma_\tau(e_\tau + \varepsilon_\tau)$ yields:

$$P_{Tk} - P_{tk} = A_t + B_t(F_{tk} - P_{tk}) + C_t Z_{tk} + \varepsilon, \tag{8}$$

where[24] the coefficient B_t should be equal to 1 under (II), and to 0 under the symmetry hypothesis (I), when all e_t's are 0.

Under hypothesis (III), setting $q = q_k$ in (6abc) and ignoring the error vectors X^{t+1} and Y^{t+1}, results, instead of (7), into $F_{tk} - P_{tk} = d_t e_{t+1,k} - c_t q_k$, $Z_{tk} = f_t e_{t+1,k} + b_t q_k$. Solving with respect to $e_{t+1,k}$ and q_k in terms of Z_{tk} and $F_{tk} - P_{tk}$, and replacing $e_{t+1,k}$ into the expression for $P_{Tk} - P_{tk}$ as before, yields again regression equation (8), with the difference that B_t is now a constant *different from both one and zero.* The constant term A_t represents any possible anticipated time trends in the formation of price expectations.

Hence, a test of the three hypotheses (I), (II) and (III) can now take place by running regression equation (8) for a fixed horizon t prior to contract expiration across the various periods for the thirteen years of observations.[25] The size and significance of the coefficient of the basis $(F_{tk} - P_{tk})$ would determine which one of the three hypotheses is consistent with the data. Hence, hypotheses (I)–(III) can be expressed as follows statistically, in terms of the null hypothesis H_0 and its alternative H_1:

Under (I) H_0: $B_t = 0$, H_1: $B_t \neq 0$.

Under (II) H_0: $B_t = 1$, H_1: $B_t \neq 1$.

[24] ε is the error term in the regression (8) and contains both the unanticipated e and the ε terms of the model.

[25] Note that equation (8) is very similar to equation (6) of Fama and French (1987), with the exception that open interest is not included in their model. As these authors indicate, their equation provides a direct test of the informational content of the basis and, equivalently, a test of the forecasting power of the futures price. This paper provides a theoretical justification for the use of such an equation in terms of the revelation of privately held information.

Under (III): both null hypotheses H_0 under (I) and (II) are rejected; hence, H_0: $B_t \neq 0$ and $B_t \neq 1$, while H_1: $B_t = 0$ or $B_t = 1$.

Note that the tests are conditional on the validity of assumption (ii) above and/or assumptions (a)–(c) of the previous section, since both fixed and random supply versions of the model depend on them. By contrast, assumption (i), or (d) of the previous section, can be easily replaced by an alternative linear model of spot price expectations formed by speculators. In that case, however, the basis $(F_{tk} - P_{tk})$ would become under hypothesis (III) a weighted sum of such expectations over the entire period $[t + 1, T]$, making the regression coefficient B_t hard to interpret. Note also that under all three hypotheses the regression coefficients depend on t, the time prior to contract expiration.

Futures volume usually declines sharply in the last few days before maturity. Also, futures prices during the delivery month are not generally considered as good indicators of true futures market conditions, because many traders attempt to get out of their positions without going through the delivery process. For this reason the futures settlement prices during the delivery month of the contract were discarded. This brought us to the beginning of the delivery month. Given the intrayear and interyear distribution of designated delivery months of the various contracts under study, and the fact that each contract is an independent observation in a regression, the data analyzed are non-overlapping. The number of observations declines, however, as one moves too far away from expiration, since in some instances no open interest exists at an early stage in the life of the contract. In such cases observations were deleted since the market does not exist.

Table I exhibits the ordinary least squares estimates of the coefficients B_t and C_t, together with the constant term A_t of regression equation (8) for the three commodities under examination. Since the model predicts that the coefficients of (8) generally differ by horizon (time to maturity), separate regressions were run for various horizons. These horizons $T-t$ varied from 30 to 180 working days prior to delivery month for all three commodities. As noted earlier, the number of observations declined as the horizon increased: 61 contracts were used for horizons from 30 to 90 days, while for horizons of 120, 150, and 180 days the number of contracts were, respectively, 60, 59, and 41. Although, for ease of exposition, only part of the results are presented in the table, the figures shown are quite representative of the results obtained for all times to maturity. The horizon of 180 days represents the maximum common time span for all contracts.

TABLE I

Tests of the Symmetry of Information in the Canola, Barley, and Oats Futures Markets Using Fixed Time to Maturity for the Various Contracts Traded between 1982 and 1994

Canola Working Days to Delivery Month	*A*	*B*	*C*	*DW*	*Adjusted R^{**2}*
30	−3.218	1.0285[a]	−0.000		
	(22.34)	(0.260)	(0.002)	2.226	0.103
60	−4.691	1.076[a]	0.0001		
	(11.90)	(0.084)	(0.0011)	1.815	0.424
90	−25.44	0.952[a]	0.003		
	(13.69)	(0.168)	(0.002)	1.602	0.1607
120	−21.50	0.8609[a]	0.003		
	(11.61)	(0.129)	(0.002)	1.338	0.1497
150	−27.02[a]	1.0317[a]	0.0059[b]		
	(12.37)	(0.129)	(0.0025)	0.928	0.2928
180	−19.25	0.8747[a]	0.0052		
	(13.44)	(0.130)	(0.004)	0.674	0.2359

Barley Working Days to Delivery Month	*A*	*B*	*C*	*DW*	*Adjusted R^{**2}*
30	−2.836[a]	0.758[a]	−0.000		
	(1.359)	(0.288)	(0.000)	2.019	0.086
60	−6.463[a]	1.419[a,b]	0.0003		
	(1.457)	(0.208)	(0.0004)	1.708	0.284
90	−11.92[a]	1.322[a]	0.0002		
	(2.738)	(0.193)	(0.001)	1.204	0.369
120	−9.743	0.8095[a]	0.0019		
	(5.176)	(0.338)	(0.003)	0.829	0.108
150	−9.496	1.0612[a]	0.0023		
	(5.413)	(0.303)	(0.005)	0.782	0.159
180	−7.989	1.273[a]	−0.0028		
	(4.191)	(0.297)	(0.006)	0.739	0.157

Oats Working Days to Delivery Month	*A*	*B*	*C*	*DW*	*Adjusted R^{**2}*
30	−4.5667	1.1787[a]	0.0042		
	(2.564)	(0.485)	(0.003)	2.052	0.0764
60	−0.6271	0.6053	−0.0002		
	(3.652)	(0.378)	(0.0025)	2.023	0.000
90	0.5749	0.7375[a]	−0.0042		
	(4.361)	(0.355)	(0.004)	1.045	0.0214
120	2.9244	−0.0072	−0.0087		
	(5.103)	(0.584)	(0.006)	0.848	0.0000
150	3.5298	−0.361[b]	−0.0134		
	(5.503)	(0.573)	(0.009)	0.789	0.0216
180	−1.1724	0.0567	−0.0174		
	(5.861)	(0.599)	(0.006)	1.101	0.0000

Newy-West Robust (to heteroskedasticity and autocorrelation) Standard Errors are shown between brackets.
[a]Significantly different from 0 at the 5% level.
[b]Significantly different from 1 at the 5% level.

The quality of the regressions conforms very closely to the model for all three commodities. For canola and barley, the two commodities that were exclusively traded at the WCE during the period under study,[26] all B_t coefficients are significantly different from zero and none of them, save one, is significantly different from one for all times to maturity, thus denoting asymmetric information with known spot supplies in those markets.[27] Note also that all but one C_t coefficients turned out not to be significantly different from zero for all three commodities.

The evidence for oats is weaker in terms of consistency with informational asymmetry: Two B_t coefficients are significantly positive, and one is significantly different from one, whereas the adjusted R^2's are much lower than for the other two commodities. The regressions for oats for horizons longer than 120 working days have coefficients that are not significantly different from zero. As noted in the beginning of this section, oats futures are not traded exclusively in Winnipeg, and the WCE market suffers greatly from the competition of the oats contracts traded in Chicago. Volume for oats at the WCE remains low because Canadian traders are in the habit of transacting mainly on the Chicago futures market, where liquidity is quite high.

As noted earlier, coefficients A_t, B_t and C_t depend on the time to contract expiration. This dependence can be examined systematically, by estimating equation (8) on a time-series basis, taking into account the entire data simultaneously. The time dependence of the regression coefficients can be taken into account by using time-varying coefficients in the estimation.[28] Thus, equation (8) becomes

$$P_{Tk} - P_{tk} = [a + b(T - t)] + [c + d(T - t)][F_{tk} - P_{tk}] + [e + g(T - t)]Z_{tk} + \varepsilon, \quad (9)$$

which is estimated for the entire period 1982–1994. Equation (9) focuses on short-term relationships, and the parameters b, d and g measure the one unit change in constants a, c and e as the contracts approach maturity. To construct this continuous price series, a nearby contract is used

[26]Barley futures are also traded in Minneapolis, but the contract there is not nearly as liquid as in the WCE.

[27]The regression results in Table I show autocorrelation in the residuals as the horizon increases above 120 for canola and above 90 for barley and oats, as evidenced by the DW statistic. This may be possibly due to other variables not accounted for in the model such as, for instance, contract liquidity.

[28]Because of the nature of pooled data, theory suggests that one time-varying coefficients regression may be superior to a set of fixed-horizon regressions. The latter, however, are also presented, since they are easier to interpret and their results are fully consistent with the time-varying model.

and, at the first day of the delivery month, the next nearby contract is used, and so on. The horizon $T-t$ varied from 0 to 60 days, rising to 90 days on rare occasions, in order to avoid contract overlapping. The time series for oats and barley contained 3114 observations, and that for canola 3069. Note that the coefficient B_t of equation (8) is now equal to $[c+d(T-t)]$. It is this last value that should be compared to 0 and 1 to assess the impact of information asymmetry.

Standard uniroot tests were also performed on the variables. The null hypothesis of nonstationarity was strongly rejected in all cases except for open interest, where the hypothesis was only marginally rejected. Thus, to avoid any potential problems with nonstationarity, all estimations were done on differenced data. Table II sets out the results of this regression for each of the three commodities under study for the period 1982–1994.

To assess the impact of the time trend on the estimated coefficients of (9), equation (8) was also estimated on the time series data, but with constant coefficients. Table III presents the results of this regression under the same procedures as before.

Overall, the results reported in Tables II and III are consistent with those of Table I. In the cases of canola and barley the coefficient of the basis in all tables is significantly different from zero, and not significantly different[29] from 1. This confirms the presence of asymmetric information with known spot supplies (hypothesis II) in those two markets. By contrast, the coefficient of the basis for oats is statistically different from both zero and 1, indicating asymmetric information with random spot supplies. Further, the significance of the regression is weaker for oats than for the other two commodities, indicating that the model is less well-suited to it.

CONCLUSIONS

This article has presented a theoretical model of futures market equilibrium under asymmetric information in a multiperiod context. The derived expressions were used to formulate an empirically testable model. The model was then tested with data on futures contracts for three commodities, canola, barley and oats, traded on the Winnipeg Commodity Exchange.

In the case of canola and barley, the empirical results show little evidence of imperfect revelation of information; hence, they are consis-

[29]Note that this is true for canola (the only commodity with a significant time trend coefficient c) for *all* horizons T-t from 0 to 60 days: the corresponding values of B_t vary from 0.70915 to 1.1341, with all values being not significantly different from 1.

TABLE II

Tests of the Symmetry of Information in the Canola, Barley, and Oats Futures Markets Using Pooled Data for the 1982–1994 Period and Time-Varying Coefficients

Coefficients	*Canola*	*Barley*	*Oats*
a	0.03649	−0.0009	−0.0031
	(0.1131)	(0.0349)	(0.0521)
b	−0.0733	−0.0832	0.06320
	(0.2823)	(0.0334)	(0.0731)
c	0.7351[a]	0.7980[a]	0.75164[a]
	(0.1614)	(0.1869)	(0.1807)
d	0.00665[a]	0.0047	0.00259
	(0.00336)	(0.0054)	(0.00568)
e	0.000365	−0.00097	0.00424
	(0.00665)	(0.00065)	(0.0023)
g	−0.000006	0.00001	−0.00012[a]
	(0.00003)	(0.00001)	(0.000056)
Adjusted R**2	0.5483	0.2642	0.1477
Mean B	0.9046[a]	0.9180[a]	0.8180[a,b]
	(0.1087)	(0.0757)	(0.04179)
DW	1.899	1.945	1.892

Newy-West Robust (to heteroskedasticity and autocorrelation) Standard Errors are shown between parentheses.
[a]Significantly different from 0 at the 5% level.
[b]Significantly different from 1 at the 5% level.

TABLE III

Tests of the Symmetry of Information in the Canola, Barley, and Oats Futures Markets Using Pooled Data for the 1982–1994 Period and Constant Coefficients

Coefficients	*Canola*	*Barley*	*Oats*
A	0.0517	−0.000	−0.003
	(0.114)	(0.035)	(0.052)
B	1.0677[a]	0.9296[a]	0.810[a,b]
	(0.142)	(0.075)	(0.098)
C	−0.0002	−0.0005	−0.001
	(0.0003)	(0.0003)	(0.001)
Adjusted R**2	0.5353	0.2373	0.126
DW	1.906	1.939	1.892

Newy-West Robust (to heteroskedasticity and autocorrelation) Standard Errors are shown between parentheses.
[a]Significantly different from 0 at the 5% level.
[b]Significantly different from 1 at the 5% level.

tent with the presence of asymmetric information with known spot supplies, or with random spot supplies but with informational asymmetry only in spot prices (see footnote 19). In the case of oats, however, the evidence points to imperfect revelation of information, or to absence of informational asymmetry.

These results are also consistent with the structure of the markets for these commodities over the period examined. As noted earlier on, the WCE was the only North American futures market for canola, and the primary such market for barley, whereas the main market for oats futures was Chicago, with which the WCE was competing. Equilibrium prices for oats futures at the WCE are, therefore, strongly influenced by the Chicago futures prices, which were not included in the model. Thus, it was to be expected that the regressions would be much more significant for canola and barley than for oats. Similarly, if private information about the randomness in spot market supplies exists, one would expect to find it among large traders in Chicago, thus influencing revelation in oats futures prices, rather than in a small local market like the WCE.

The implications of these results for traders and researchers, therefore, are that the basis does, indeed, convey information about future spot market prices, but that it does not always provide an unbiased estimate of these prices. This information stems from asymmetries in the accuracy of projections of future spot prices, which may be fully revealed by the basis. Further asymmetries, however, such as in the projections of future spot quantities, tend to obscure revelation.

There are several possible theoretical and empirical extensions of the work of this article, by relaxing some of its key assumptions. For instance, both theoretical and empirical work assumed stationarity in the distributions of both prices and quantities. This is an assumption that, although probably true on average over the long run, is probably not true over specific periods for the market for a given commodity. Similarly, the competitive assumption and the type of assumed asymmetry need to be re-examined when there are large hedgers, who may both possess private information and enter strategically the spot market in order to exploit it. Extending the model in such directions is a major undertaking for future research.

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