# MONASH UNIVERSITY

## PRICE DETERMINATION IN THE U.S. OATS MARKET:

## RATIONAL VS. ADAPTIVE EXPECTATIONS

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## ABSTRACT

This paper develops a simultaneous rational expectations model of the U.S. oats market, with categories of agents which include hedgers, speculators and consumers. The post sample forecasts of the spot price derived from this model are employed to test the semi-strong form efficient markets hypothesis (EMH). These results are compared with those for a similar model which uses adaptive expectations. Forecasts derived from the rational model do not outperform the forward (futures) price as a predictor of the spot price, although an adaptive model-futures price composite predictor significantly outperforms the futures price, and hence contains evidence against the EMH.

# PRICE DETERMINATION IN THE U.S. OATS MARKET:

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## 1.    INTRODUCTION

In the United States, oats are the fourth most important crop, after corn, wheat and soybeans, according to area planted. The U.S. with 458 m. bush. in 1980-81, is an important world producer of oats, ranking second only to the U.S.S.R. In 1980-81 U.S. production of corn was 14.5 times that of oats, and for production of soybeans the ratio to oats was 3.9; yet in terms of volume of futures contracts traded at the Chicago Board of Trade, oats are proportionately far less important. Indeed, in 1980 oats futures contracts representing 1604 bil. bush. were traded, while trading in corn futures was 37 times that of oats, and in soybean futures the corresponding factor was 36.

In research on U.S. grains, the oats market has been neglected, and most studies have concentrated on wheat, corn and soybeans. This neglect of the oats market may be partly due to the consumption of a large proportion of the oats crop on the farm (34.9% in 1980-81), which in turn may be due to the high bulk:weight ratio and lower profitability of oats compared with corn (see Inkeles (1972, pp.129-30)). Lack of interest in the oats market may also be due partly to the lower speculative ratio which oats has attracted (see Appendix 1).

Oats are an important feed component for horses, dairy cattle, hogs and poultry, being high in protein and in fibre content, and they also play an important role in crop rotation programs. In 1975-76, 86% of the U.S. oats crop was fed to livestock (94% in 1980-81), while food uses typically comprise about 7% of the crop, seed comprises about 6%, and around 2% is exported. White oats are preferred in milling for feed, and the major U.S. states producing white oats are Minnesota, South Dakota, Iowa, Wisconsin and North Dakota.

In animal feed preparation there is strong substitutability between oats and corn, and in practice the price of corn has a strong influence on the price of oats. The weight of a bushel of oats is 57.14% of that of a bushel of corn, and corn has a higher feed value for a given volume. Hence the price of corn is usually significantly higher than that of oats.

The main trading location for oats futures contracts is the Chicago Board of Trade (CBOT), where the contract calls for delivery of 5,000 bushels in March, May, July, September and December. Oats have traded on the CBOT since 1877.

Peston and Yamey (1960) and Stein (1961, 1964) developed theoretical models of the simultaneous determination of spot and futures prices, while Dewbre (1981), Kawai (1983), Bray (1985), and Stein (1986) developed theoretical models of futures price determination with rational expectations, the model of Kawai (1983) being explicitly for non-storable commodities. Giles, Goss and Chin (1985) estimated a simultaneous rational expectations model of spot and futures price determination in U.S. corn and soybean markets, and Goss and Avsar (1991) presented an empirical model of Australian wool spot and futures markets with rational expectations.

Economists have studied the question of informational efficiency in futures markets for more than three decades. The methodology and results of investigations of the efficient markets hypothesis in equities markets have been summarized by Fama (1970). In the area of futures markets, weak form efficiency, that is efficiency with respect to information in own past prices, has been studied by Larson (1960), Stevenson and Bear (1970), Leuthold (1972), Cargill and Rausser (1975), Praetz (1975), Taylor (1985) and others using data from a wide range of commodity and financial futures contracts. Using methodologies borrowed from research on share prices, some dependence in past prices has been found, although it is not clear that this could have been used to generate returns in excess of transaction costs.

Semi-strong form efficiency in futures markets, that is efficiency with respect to publicly available information, has been studied using three different approaches. The forecast error approach exploits the idea that futures prices are market anticipations of

delivery date spot prices. Under the efficient markets hypothesis (EMH) there should be no systematic relationship between the current forecast error for a particular commodity and prior forecast errors for own and related commodities, which are assumed to form the set of publicly available information. This methodology was developed by Hansen and Hodrick (1980) for currencies, and has been employed by Goss (1986) and MacDonald and Taylor (1988) for non-ferrous metals, and Goss (1987) for wool, all of whom found some evidence against the EMH.

The second method used to investigate the semi-strong form EMH in futures markets is the model forecasting approach, which also exploits the predictive quality of futures prices. This approach employs a quantitative economic model of the market under review to predict the spot price. If the model outperforms the futures price as a predictor of the cash price, then the EMH must be rejected, for the model evidently contains information not reflected in the futures price. Non-rejection of the EMH, of course, is no proof of market efficiency, but may reflect simply the use of an inappropriate model. This method was developed by Leuthold and Hartmann (1979) for U.S. hogs, and has been employed by Rausser and Carter (1983) for the U.S. soybeans complex, Brasse (1986) for tin at the London Metal Exchange, Goss (1990) for Australian wool and Leuthold and Garcia (1991) for live cattle and hogs, all of whom found some evidence of inefficiency in the markets studied.

Semi-strong form efficiency in futures markets has also been investigated by the event studies approach, which analyses the behaviour of futures prices on days immediately prior, and subsequent, to a relevant announcement. Under the EMH prices should respond immediately to any unanticipated component of the announcement, and the expected component should already be reflected in prices. This approach has been employed by Chance (1985a, 1985b) who studied the responses of the GNMA and U.S. Treasury Bond futures prices to inflation rate announcements, and by Colling and Irwin (1990) who investigated the response of hog futures prices to information contained in USDA Hogs and Pigs Reports. The results in all three studies were consistent with the EMH.

In Section 2 of this paper a simultaneous rational expectations model of the oats market is developed and the specification of the equations of this model is discussed, while Section 3 discusses the data employed. In Section 4 the parameter estimates and intrasample simulations for this model are presented and compared with the results for a similar model of the oats market presented in Goss, Chan and Avsar (1991), where expectations are represented by the adaptive expectations hypothesis (see Nerlove (1958)). Post sample forecasts and tests of the efficient markets hypothesis are discussed in Section 5, and some conclusions are presented in Section 6.

## 2. A SIMULTANEOUS RATIONAL EXPECTATIONS MODEL OF THE OATS MARKET: SPECIFICATION OF EQUATIONS

The model presented in this paper has its theoretical foundations in Peston and Yamey (1960), and extends the empirical analyses of Giles, Goss and Chin (1985) and Goss, Chan and Avsar (1991). The model developed here comprises separate functional relationships for short and long hedgers, short and long speculators in futures, holders of unhedged inventories and consumers.

It is assumed that there are three submarkets for oats: one each for storage, futures and present consumption. Within each submarket, appropriate supply and demand functions may be distinguished. The storage and futures submarkets partially overlap, but the two are not synonymous: storage may be hedged or unhedged, and futures positions may be held for hedging or speculative purposes. Similarly, the consumption submarket is not the same as the spot market, because a spot purchase may be made for either storage or consumption purposes. It is assumed that in each period there is a given amount of the commodity (the available supply) for allocation between current consumption and storage.

### 2.1   Supply of Hedged Storage

Hedgers are assumed to pursue the joint objectives of risk reduction and profit. Working (1953, p.325) argued that hedging is normally done in the expectation of a

favourable change in the basis, and a decline in the forward premium will result in gains to short hedgers. Hence we would expect the volume of short hedging to vary directly with the current forward premium and the volume of inventories eligible for hedging, and inversely with the expected price spread (forward premium) and the marginal net cost of storage.

In the preliminary estimation of this model, inclusion of the price spread results in parameter estimates of the expected signs, but statistical significance and simulation performance of the model improve when spot and futures prices are included as separate variables, with expectations of the futures price (only) taken into account. The marginal net cost of storage was deleted from the equation for the same reason. Moreover, in the specification of this equation, as with the unhedged inventory relationship, employment of the rational expectations hypothesis resulted in parameter estimates and model simulation which were inferior compared with those produced under adaptive expectations. Therefore, in these two equations only expectations were represented by the adaptive hypothesis, which assumes that the current revision of expectations is a proportion of the prior expectational error. Hence the specification of the short hedging equation is:

$$SH_t = \alpha_0 + \alpha_1 P_t + \alpha_2 P^*_{t+1} + \alpha_3 A_t + \alpha_4 CK_t + e_{1t} \tag{1a}$$

where $\alpha_0$ = constant, $\alpha_1$, $\alpha_4 > 0$ ; $\alpha_2$, $\alpha_3 < 0$ ;

and $SH_t$ = supply of storage (and futures) by short hedgers;

$P_t$ = current futures price;

$A_t$ = current spot price;

$P^*_{t+1}$ = expectation of the futures price in period $(t+1)$, formed in period t.

$CK_t$ = measure of the quantity of oats eligible for hedging;

$e_{1t}$ = error term.

The adaptive expectations hypothesis assumes that:

$$P^*_{t+1} - P^*_t = \lambda(P_t - P^*_t), \quad 0 < \lambda < 1.$$

Hence $\qquad P^*_{t+1} = \dfrac{(1-\beta)P_t}{(1-\beta L)}$ $\qquad\qquad\qquad$ (1b)

where $\beta = (1-\lambda)$ and L is the lag operator. This hypothesis implies that the current expectation is a geometrically weighted average of past actual values, with backwardly declining weights; it will under-predict on a rising market and over-predict on a falling market.

Substitution from (1b) into (1a) yields the final specification

$$SH_t = \theta_1 + \theta_2 P_t + \theta_3 A_t + \theta_4 P_{t-1} + \theta_5 A_{t-1} + \theta_6 CK_t + \theta_7 CK_{t-1} + \theta_8 SH_{t-1} + u_{1t}$$

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ (1)

where $\theta_2 > 0$ if $\alpha_1 > |\alpha_2(1-\beta)|$, otherwise

$$\theta_2 < 0 ; \quad \theta_3 , \theta_4 , \theta_7 < 0 ; \quad \theta_5 , \theta_6 > 0 ; \quad 0 < \theta_8 < 1.$$

If $e_{1t}$ is independently and identically distributed (iid) then $u_{1t}$ follows a first order moving average process. This specification is the same as that for the oats short hedging relationship in Goss, Chan and Avsar (1991), (hereafter GCA).

## 2.2 Demand for Hedged Storage

Demand for hedged storage and for futures contracts is provided by long hedgers. A decline in the forward premium means a loss to long hedgers; hence long hedging has been regarded as the mirror-image of short hedging (see Stein (1961)), with one important qualification (Yamey (1971)). Long hedgers have a commitment to deliver oats or an oats product forward, and these commitments are transacted at the forward actuals price. In this model, the spot price has been used as a proxy for the forward actuals price, which is generally unobservable. Hence we would expect that the demand for hedged storage and futures by long hedgers (LH) would vary inversely with the current price spread and directly with the expected price spread and forward actuals commitments of long hedgers, measured here by planned exports in period (t+2), where the plans are assumed to be realized. Parameter estimates and model simulation improved when the price spread was replaced by

the ratio of the futures price to the spot price. Hence, the specification of the long hedging relationship is

$$LH_t = \theta_9 + \theta_{10}(P_t/A_t) + \theta_{11}(P_{t+1}/A_{t+1})^* + \theta_{12}X_{t+2} + u_{2t} \qquad (2)$$

where $(P_{t+1}/A_{t+1})^* = $ rational expectation of the ratio of the futures to the spot price for next period, formed in period t;

$X_{t+2} = $ exports of oats in (t+2);

and $\theta_{10}<0$ ; $\theta_{11}$ , $\theta_{12}>0$. (In GCA the variable $X_{t+2}$ had a negative impact on model performance and was deleted, hence the volume of long hedging is a function of the current and expected ratio of the futures price to the spot price.)

The concept of rational expectations originated with Muth's observation that mean expectations in an industry are as accurate as "elaborate equation systems" and his suggestion that "rational" expectations are the same as the predictions of the relevant economic theory (Muth (1961, p.316)).

The rational expectations hypothesis (REH) assumes first that agents use all relevant publicly available information at time t in forming their expectations about an economic variable at time t+1, and moreover, it is assumed that agents use such information efficiently (Minford and Peel (1986, pp.4-5)). Second, the REH assumes that agents correctly anticipate future prices, in the sense that the subjective probability distributions of agents are the same as the objective probability distribution of the system. This does not require identical expectations (see Muth (1961, p.317), Sheffrin (1985, p.10)).

Third, the REH implies that agents have the particular economic model, under review, in mind in forming their expectations, so that any test of the REH is a joint test of the REH and the economic model in question (Maddock and Carter (1982)). The REH implies, therefore, that the model which agents believe determines returns is the same as the model driving returns in practice; otherwise, abnormal returns would occur (Minford and Peel (1986, p.122)). Fourth, since the REH assumes that agents use all information efficiently,

expectational errors will have an expected value of zero, and will be uncorrelated with elements of the information set, and with past expectational errors.

On the question of how agents learn to form rational expectations, various answers have been given, such as by having a long history in the industry in question (Hirsch and Lovell (1969)), or by using the same forecasting rule consistently for a long period (Blume, Bray and Easley (1982)). On the likelihood of agents learning to form rational expectations, Bray and Savin (1986) are more optimistic than Frydman (1982).

There is experimental evidence to support the idea that markets achieve rational expectations equilibrium in a comparatively short period of time, as required by the model in this paper (see, for example, Friedman, Harrison and Salmon (1983), Plott and Sunder (1982)).

## 2.3    Unhedged Storage

Unhedged inventories are held by agents who purchase stocks spot in the expectation of a rise in the spot price. Following Brennan (1958) and Telser (1958), the demand for unhedged storage ($U_t$) is related directly to the expected spot price ($A^*_{t+1}$), and negatively related to the current spot price ($A_t$), the marginal risk premium ($r_t$) and the marginal net cost of storage ($m_t$). As mentioned in Section 2.1 above, the employment of the REH in this equation had a detrimental effect on the significance of parameter estimates, and so expectations in this equation were represented by the adaptive hypothesis. Moreover, the marginal net cost of storage was deleted for the same reason, although this is not a cause for concern.[1]  Hence the specification of this equation is

$$U_t = \alpha_5 + \alpha_6 A_t + \alpha_7 A^*_{t+1} + \alpha_8 r_t + e_{3t} \qquad\qquad (3a)$$

where $\alpha_6$ , $\alpha_8 < 0$ ; $\alpha_7 > 0$ ; and

$$A^*_{t+1} \;=\; \frac{(1-\gamma)A_t}{(1-\gamma L)} \qquad 0 < \gamma < 1 \qquad\qquad (3b)$$

Substitution from (3b) into (3a) yields

$$U_t = \theta_{13} + \theta_{14}A_t + \theta_{15}A_{t-1} + \theta_{16}r_t + \theta_{17}r_{t-1} + \theta_{18}U_{t-1} + u_{3t} \qquad (3)$$

where $\theta_{14}<0$ if $|\alpha_6|>\alpha_7(1-\gamma)$

otherwise $\theta_{14}>0$ ; $\theta_{15}$ , $\theta_{17}>0$ ; $\theta_{16}<0$ ; $0<\theta_{18}<1$ . (This is the same as the specification for the unhedged inventory equation in GCA.)

## 2.4 Demand for Futures by Long Speculators

Demand for futures contracts is provided also by long speculators, who purchase these contracts in the expectation of a rise in the futures price. Long speculators' demand for futures is assumed to vary inversely with the current futures price and the marginal risk premium, and directly with their expected futures price. Accordingly the specification of this equation is

$$LS_t = \theta_{19} + \theta_{20}P_t + \theta_{21}P^{**}_{t+1} + \theta_{22}r_t + u_{4t} \qquad (4)$$

where $\theta_{20}$ , $\theta_{22}<0$ ; $\theta_{21}>0$ ; and

$P^{**}_{t+1}$ = rational expectation of the futures price in (t+1) by long speculators, formed in period t.

(The specification of this equation in GCA included the price spread between oats and corn futures, to take account of the relative profitability of speculating in other grains. In preliminary estimation of the rational expectations model, that price spread performed less well than the specification in (4). In GCA $r_t$ was deleted for the same reason.)

## 2.5 Supply of Futures by Short Speculators

Futures contracts are also supplied by speculators who sell futures in the expectation of a fall in price. These agents may be seen as extending their short positions until the current futures price equals their expected futures price plus marginal risk premium, i.e. until $P_t = P'_{t+1} + r_t$ where $P'_{t+1}$ is a rational expectation of the futures price in (t+1) by short

speculators, formed in period t. We would therefore expect the positions of short speculators to vary directly with $P_t$ and negatively with $P'_{t+1}$ and $r_t$. In preliminary estimation the inclusion of the risk premium had a detrimental effect on model performance, and this variable was deleted, although again this is not a cause for concern.[1]  Hence the final specification of this equation is

$$SS_t = \theta_{23} + \theta_{24}P_t + \theta_{25}P'_{t+1} + u_{5t} \tag{5}$$

where $\theta_{24}>0$ ; $\theta_{25}<0$ ; and $SS_t$ is the supply of futures by short speculators.  (In the adaptive model of GCA, the specification of the short speculation equation includes the oats-corn futures price spread, which was deleted from (5) for the reason given in Section 2.4 above.)

## 2.6    Consumption Submarket

The consumption demand (C) by processors is a derived demand from the use of oats as a feed for dairy cattle, livestock and horses.  Hence consumption demand is assumed to depend on the parameters of demand for the end-products, the parameters of the supply of other inputs used in conjunction with oats, and the cash price of oats.  Corn is used extensively with oats in preparing livestock feed, and the cash price of corn ($A^c$) is included as a parameter of the supply of other inputs.  Whether corn is a complement to or a substitute for oats will be inferred from the sign of its coefficient (a negative sign indicates complementarity while a positive coefficient implies substitutability).  U.S. real personal income has been employed as a parameter of end-product demand, and in this model the rational expectations hypothesis has been extended to expected income in the consumption equation.  Hence the relationship is

$$C_t = \theta_{26} + \theta_{27}A_t + \theta_{28}A^c_t + \theta_{29}Y^*_{t+1} + e_{6t} \tag{6}$$

where $\theta_{27} < 0$ ; $\theta_{28} \gtrless 0$ ; $\theta_{29} > 0$ ; and $Y^*_{t+1}$ is a rational expectation of U.S. real personal income for period (t+1) formed in period t. (The consumption equation in the adaptive model of GCA employs the same explanatory variables.)

Supply in the consumption submarket is that part of available supply not allocated to storage.

### 2.7  Identities

The model, with eight endogenous variables, is completed with the identities

$$K_t \equiv U_t + HH_t \tag{7}$$

where $HH_t = \max[SH_t , LH_t]$

$K_t$ = total inventories of oats and is exogenous;

$$SH_t + SS_t \equiv LH_t + LS_t \tag{8}$$

The first identity states that the total quantity of stocks equals the quantity of unhedged stocks plus the quantity of hedged stocks; it is written in this form because this identity is employed to generate data on the variable U (see Section 3 below). The second identity states that total supply of futures contracts equals total demand for futures contracts. These are identities of observed values, and it is assumed that storage and futures markets clear every trading day, so that only equilibrium values are observed in monthly data. The eight endogenous variables are SH, LH, U, SS, LS, C, P, A.

With linear rational expectations models, the standard identification conditions do not apply (Pesaran (1987, p.119)). The model developed here fulfils the order condition developed by Pesaran (1987, p.160) for simultaneous rational expectations models with future expectations. (In the GCA model, each of the six structural equations is over-identified.)

3.    DATA

This section provides details of the collection and generation of data employed in the estimation of the model.    After allowing for lags up to four periods in the selection of instruments for estimation purposes (see below), the sample period dates from 1972(10) to 1978(9) resulting in 72 observations.    The post-sample forecast period dates from 1979(3) to 1981(8), giving 30 observations.

### 3.1    Endogenous Variables

Oats futures prices ($P_t$) are the closing prices in U.S. dollars per bushel for a six month future[2] on the median trading day of each month.    These prices are quotations from the Chicago Board of Trade *Statistical Annual,* 1972-81.    Spot price data ($A_t$) are daily cash prices for oats on the median trading day of each month in U.S. dollars per bushel (No.2 Extra Heavy White) at Minneapolis, published in the CBOT *Statistical Annual,* 1972-81.

The demand for and supply of hedged storage ($LH_t$ and $SH_t$ respectively) of oats are assumed to be measured by the end-of-month open interest of hedgers at the Chicago Board of Trade.    These open interest data (in thousands of bushels) are reported in the *Commitments of Traders* for the years 1972-1981 published by the U.S. Commodity Futures Trading Commission (CFTC).    The reporting level for oats was 200,000 bushels for the sample and post-sample periods.    The CFTC reports open positions data, both long and short, for large (reporting) hedgers, large (reporting) speculators and for non-reporting traders; the distribution of the positions of non-reporting traders between hedging and speculation is unknown.    How the positions of small traders should be distributed has been the subject of analysis by Peck (1982) who argued that 'virtually all' of the 'small traders' in corn and possibly soybeans were speculators for most of the 1970s.    The oats market, however, was not discussed in that paper and we assume that the distribution (between speculation and hedging) for non-reporting traders was carried out based on this assumption.

The demand for and supply of oats futures contracts by long and short speculators ($LS_t$ and $SS_t$) are also measured by end-of-month open interest for speculators calculated from the figures reported by the CFTC.

Data on the demand for unhedged storage ($U_t$) are unobservable, and $U_t$ is generated by subtracting $LH_t$ or $SH_t$ whichever is larger, from $K_t$. In some periods negative $U_t$ values[3] are generated by this procedure. Negative $U_t$ values are not consistent with this model, and so the following procedure is used to adjust these values: in periods when $U_t$ is negative, $LH_t$ or $SH_t$ whichever is larger,[4] has been reduced by the absolute value of $U_t$, and this absolute value has been added to $LS_t$ (if $LH_t$ is decreased) to $SS_t$ (if $SH_t$ is decreased). In this procedure, it is assumed that excess hedging is speculation rather than hedging. The signs and significance of the estimates of the structural parameters of the model are improved if commercial stocks (CK) rather than total stocks (K) are employed in the calculation of unhedged storage (see Section 4 below).

Oats consumption data ($C_t$) are quarterly observations, in thousands of bushels, on the total domestic use of oats published in the *Commodity Yearbook*, 1978 and 1983. These quarterly observations are interpolated to monthly data using the program TRANSF (Wymer (1977)).

## 3.2    Exogenous Variables

Data on U.S. total stocks of oats ($K_t$) are total stocks (in thousands of bushels) at end of month from the Chicago Board of Trade *Statistical Annual*, 1982, while data on U.S. commercial stocks of oats ($CK_t$) are in thousands of bushels at end of month, from the same source. The latter do not include stocks on farms.

The marginal risk premium $r_t$ is defined as the (90-day) Commercial Paper rate less the (90-day) Treasury Bill rate in per cent per annum, published in the U.S. *Federal Reserve Bulletin*, 1972-1981.

The marginal interest cost is the U.S. prime rate in per cent per annum divided by twelve and multiplied by $A_t$ ; the U.S. prime rate is published in the U.S. *Federal Reserve Bulletin,* 1972-1981.

The income variable $Y_t$ is U.S. total nominal personal income in billion U.S. dollars, from the *Federal Reserve Bulletin,* 1972-1981, divided by the Consumer Price Index (CPI) (base year = 1963) from *International Financial Statistics,* 1972-1981. While $Y_t$ data for the period 1972-1975 are monthly observations, data for total personal income for the years 1976-1981 are quarterly observations interpolated to monthly data using the program TRANSF (Wymer (1977)). Cash prices of corn ($A_t^c$) are daily prices in U.S. dollars per bushel, on the median trading day of each month, published in the CBOT *Statistical Annual,* 1972-82.

Corn futures prices ($P_t^c$) are the closing prices on the median trading day of each month for a corn futures contract approximately six months prior to delivery, where that contract is selected according to the rule in footnote 2. These prices are in U.S. dollars per bushel published in the Chicago Board of Trade *Statistical Annual,* 1972-1982.

## 4.    ESTIMATION AND RESULTS: SAMPLE PERIOD

The estimation of simultaneous rational expectations models has been discussed by McCallum (1979), Wallis (1980), Flood and Garber (1980), Wickens (1982), Cumby et al. (1983), Pesaran (1987) and others. While full information estimators are potentially more efficient than limited information methods, the former require a full specification of all economic processes affecting the model. In practice, as Pesaran (1987, p.162) points out, limited information estimators have the advantages first, that they are more robust to specification errors, and second, they are computationally less demanding.

The model presented in this paper has been estimated using the instrumental variable (IV) method of McCallum (1979), in which the instrument for the future expectation of an endogenous variable is estimated (by ordinary least squares) as a fitted value on the

information set of current endogenous and predetermined variables (including lagged endogenous variables) in the model. The structural equations of the model are then estimated by IV, the property of simultaneity being imparted by the definition of the rational expectations information set.

In equation (4) for example, the expected futures price is conditional on the set of publicly available information at time t, $\phi_t$, so that

$$P^*_{t+1} = E(P_{t+1}/\phi_t)$$

and $\quad P_{t+1} = E(P_{t+1}/\phi_t) + \eta_t$

where rational expectations requires that $E(\eta_t) = 0$ and $\eta_t$ is uncorrelated with the elements of $\phi_t$. A suitable proxy for $P^*_{t+1}$ is found by regressing $P_{t+1}$ on a representative sub-set of variables in $\phi_t$, using OLS. This yields a least squares prediction $\hat{P}_{t+1}$ which is a valid instrument for $P^*_{t+1}$.

Where the residuals of the structural equation are not serially correlated, that equation would be estimated by IV, with current values of exogenous variables acting as their own instruments, and lagged values of the endogenous variables in that equation acting as instruments for those variables. These instruments, together with the proxy for the expectational variable, derived as above, will yield consistent estimates.

Where the residuals of the structural equation are serially correlated, however, as in equations (2), (4), (5) and (6) in this model, a simple autoregressive (AR) correction with IV estimation will yield inconsistent estimates, as noted by Flood and Garber (1980). In this case the method of McCallum (1979) has been employed. This involves first making an autoregressive transformation of the relevant equation: in (4) for example, the equation was lagged one period, multiplied by $\rho_4$ (the AR coefficient), and the result subtracted from (4). Each of the variables in the transformed equation was then regressed on a representative subset of the elements in the relevant $\phi$, using OLS, to obtain fitted values of each, which were then substituted into the transformed equation. For equation (4) this gives:

$$LS_t = \theta_{19}(1-\rho_4) - \rho_4 L\hat{S}_{t-1} + (\theta_{20} - \theta_{21}\rho_4)\hat{P}_t - \theta_{20}\rho_4\hat{P}_{t-1} + \theta_{21}\hat{P}_{t+1} + \theta_{22}\hat{r}_t$$

$$-\theta_{22}\rho_4\hat{r}_{t-1} + (e_{4t} - \rho_4 e_{4t-1}) \tag{4.1}$$

Consistent estimates of the coefficients in (4.1) were obtained using the non-linear least squares option LSQ in TSP (Hall (1986)). This procedure was used for equations (2), (4), (5) and (6).

In the short hedging and unhedged inventory equations, ((1) and (3)), the expectational variables are represented by the adaptive hypothesis. In equation (1) there was no evidence of serial correlation of the residuals, while in equation (3) a correction for first order autocorrelation was made. The parameters of equations (1) and (3) were estimated by IV.[5].

In the totally adaptive model of GCA the parameters of the system were estimated by three stage least squares (3SLS), using the program TSP4.1B (Hall (1986)). The 3SLS procedure obtains IV estimates,[6] and these estimates are consistent and asymptotically efficient (Hall (1986, p.270)). In that model, there was evidence of serial correlation in the unhedged inventory equation only, where a correction for first order autocorrelation was made. The parameter estimates of the rational expectations model are presented in Table 1, together with their asymptotic t values. It will be seen that the signs of all estimated coefficients are as expected, although only 52 per cent of these estimates are significant at the 5 per cent level (one tail test). Support for the REH is strongest in the long hedging and consumption relationships, where the estimated coefficients of the expectations variables are clearly significant. There is support for the adaptive hypothesis in the short hedging equation, and especially in the unhedged inventory function.[7] The estimates $\hat{\theta}_8$ and $\hat{\theta}_{18}$ lie between zero and unity as the adaptive hypothesis requires. In the estimates of the consumption relationship, the estimate of $\theta_{29}$ suggests that oats are a superior good as one would expect, and the estimate of $\theta_{28}$ suggests that there is a substitution relationship between oats and corn in the production of livestock feed.

In the adaptive GCA model 63 per cent of the estimated coefficients of that model are significant, although one of those estimates ($\hat{\phi}_{11}$, the coefficient of ($P_{t-1}/A_{t-1}$) in (2)) has a sign contrary to expectations. This problem has been corrected in the switch to rational expectations. These comparisons suggest that the REH is more appropriate for the long hedging and consumption equations, while the adaptive hypothesis appears better suited to the short hedging and unhedged inventory relationships. There is apparently no clear support for either hypothesis in the futures speculation equations. This may be due partly to data difficulties with the LS and SS variables, and may suggest that it is inappropriate to allocate a portion of the non-reporting trader data to speculation.

The intra-sample simulation performance of the rational expectations model is evaluated in Table 2, while that of the GCA adaptive model is assessed in Appendix 2. It is clear that only in the consumption relationship, and perhaps the long hedging equation is the rational expectations model superior. In the short hedging equation, and in the simulation of spot and futures prices, the adaptive model of GCA is superior. In the remaining functions neither model seems to have the advantage.

In the rational model, while simulation of unhedged inventories is necessarily excellent (since these values are derived from identity (7)), the per cent RMSE for simulation of the cash price is moderately good, although not as low as the corresponding figure of 6.278% achieved by Goss (1990, p.984) with this type of model for the wool market. Tracking of the endogenous variables varies from excellent (for U) to moderately good, notwithstanding the lack of significance of the parameter estimates for the speculation functions (equations (4) and (5)).

Overall the adaptive model would seem to be superior to the rational expectations model in intra-sample simulation, at least for the sample period studied here. This may be because the oats market is perhaps slower to respond to market signals than the REH requires. This slowness in turn, may be due to the relatively large proportion of the oats crop

consumed on the farm, and the low speculation ratio of the oats market, compared with corn and soybeans.

If the results reported in Table 2 are compared with those in Giles, Goss and Chin (1985, p.758), where a similar model was applied to the corn and soybeans markets, it will be seen that generally the performance of the corn model is superior to that of the model developed here, although the long hedging and possibly the short speculation functions of the oats model perform better than their soybeans counterparts.

## 5.    POST SAMPLE FORECASTS AND MARKET EFFICIENCY

A more stringent test of the performance of a rational expectations model is its ability to forecast outside the sample period. The model developed here was used to forecast the cash price of oats six months ahead, during the post sample period 1979(03) to 1981(08) comprising 30 observations. In deriving these forecasts, the model was continuously updated by re-estimating the parameters for each successive forecast during the post sample period; the purpose of this updating was to place the model and the futures price on the same informational footing. The semi-strong form EMH was addressed by comparing the model derived forecasts of the cash price (AS) with the forecasts implicit in the futures price (P) (the unbiasedness hypothesis cannot be rejected for either predictor).

The post sample forecasts of the cash price by these two predictors are evaluated in Table 3 and illustrated in Figure 1. It can be seen that the futures price clearly outperforms the model as a predictor of the cash price, although the difference between the performance of these two predictors, according to the %RMSE criterion is not significant using the test in Granger and Newbold (1986, pp. 278-79). In any case, on the basis of this comparison, the EMH cannot be rejected.

Nevertheless, each of these predictors (AS and P) contains some information which the other does not (see Figure 1). Hence a linear combination of AS and P may be expected

to outperform the futures price as a predictor of A. Such a composite predictor was formed by estimating the equation

$$CP_{t-6,t} = \alpha AS_{t-6,t} + \beta P_{t-6,t} + e_t \tag{9}$$

where $\alpha + \beta = 1$. Equation (9) was estimated by OLS for the post sample period with

$$\hat{\alpha} = 0.41, \qquad \hat{\beta} = 0.60$$
$$\quad (2.52) \qquad\qquad (3.59)$$

(asymptotic t statistics in parentheses) and DW = 2.085 ($\alpha$ and $\beta$ were not constrained to add to unity).

The performance of the composite predictor as an anticipation of the cash price is summarized in Table 3 and illustrated in Figure 1. It is clear that the composite predictor marginally outperforms the futures price. This should not be used as evidence to reject the EMH however, because the difference between the per cent RMSE's of these two predictors is not significant, again using the test in Granger and Newbold (1986, pp. 278-79).

When the GCA adaptive model is used to predict the spot price, that predictor (AS') is superior to the futures price, although again the performance difference between these two is not significant. When a composite predictor (CP') is constructed as a weighted average of AS' from the adaptive model and the futures price, that composite outperforms the futures price, as can be seen from Appendix 3. Moreover, the difference in performance between CP' and P is significant at the 5 per cent level (although not at 1 per cent). This implies that the semi-strong form EMH could be rejected at the 5 per cent level for oats, if the GCA adaptive model were employed.[8]

6.    CONCLUSIONS

This paper has presented a rational expectations model of the U.S. oats market; the conclusions are as follows:

1.    There is support for the rational expectations hypothesis in all equations except the short hedging and unhedged inventory relationships; support is strongest in the long hedging and consumption functions.    While all estimated coefficients have the expected sign, only 52% are significant, compared with 63% for the adaptive model.

2.    Only in the long hedging and consumption functions is the rational model superior to the adaptive in intra-sample simulation; otherwise the adaptive model is the equal of or superior to the rational.  In particular, the adaptive model is superior in forecasting cash and futures prices within the sample period.

3.    In post-sample prediction of the cash price, the rational model is inferior to the futures price, although the difference in performance is not significant.  The adaptive model, on the other hand, outperforms the futures price as a predictor of the spot price in the post-sample period.

4.    A rational model-futures price composite surpasses the futures price as a predictor of the spot, but the difference is not significant.  Hence, the rational model does not provide evidence for rejection of the efficient markets hypothesis.  An adaptive-futures composite, however, outperforms the future significantly at 5%, and could be used to reject the EMH.

## TABLE 1

### OATS RATIONAL EXPECTATIONS MODEL: PARAMETER ESTIMATES

| Coefficient | Variable | Estimate | Asymp-t Value | Equation |
|---|---|---|---|---|
| $\theta_1$ | Const. | 4518.13 | 1.633 | 1 |
| $\theta_2$ | $P_t$ | 5217.9 | 0.680 | |
| $\theta_3$ | $A_t$ | -3170.9 | -0.365 | |
| $\theta_4$ | $P_{t-1}$ | -4410.6 | -0.733 | |
| $\theta_5$ | $A_{t-1}$ | 1034.0 | 0.141 | |
| $\theta_6$ | $CK_t$ | 0.325 | 2.152 | |
| $\theta_7$ | $CK_{t-1}$ | -0.319 | -2.100 | |
| $\theta_8$ | $SH_{t-1}$ | 0.795 | 8.110 | |
| | | | | |
| $\theta_9$ | Const. | -10909.0 | -3.132 | 2 |
| $\theta_{10}$ | $P_t/A_t$ | -9234.5 | -1.642 | |
| $\theta_{11}$ | $(P_{t+1}/A_{t+1})^*$ | 21367.0 | 3.629 | |
| $\theta_{12}$ | $X_{t+2}$ | 0.019 | 0.125 | |
| $\rho_2$ | | -0.828 | -5.804 | |
| | | | | |
| $\theta_{13}$ | Const. | 3555.9 | 0.981 | 3 |
| $\theta_{14}$ | $A_t$ | -9381.5 | -2.313 | |
| $\theta_{15}$ | $A_{t-1}$ | 6761.0 | 1.857 | |
| $\theta_{16}$ | $r_t$ | -808.3 | -0.830 | |
| $\theta_{17}$ | $r_{t-1}$ | 1837.0 | 1.882 | |
| $\theta_{18}$ | $U_{t-1}$ | 0.920 | 30.601 | |
| $\rho_3$ | | 0.193 | 1.669 | |

TABLE 1 (Continued)

| Coefficient | Variable | Estimate | Asymp-t Value | Equation |
|---|---|---|---|---|
| $\theta_{19}$ | Const. | 1606.6 | 0.894 | 4 |
| $\theta_{20}$ | $P_t$ | -6464.7 | -1.476 | |
| $\theta_{21}$ | $P^{**}_{t+1}$ | 5712.2 | 1.243 | |
| $\theta_{22}$ | $r_t$ | -236.4 | -0.613 | |
| $\rho_4$ | | -0.943 | -7.084 | |
| | | | | |
| $\theta_{23}$ | Const. | 115.9 | 0.095 | 5 |
| $\theta_{24}$ | $P_t$ | 1367.8 | 0.471 | |
| $\theta_{25}$ | $P'_{t+1}$ | -1358.8 | -0.460 | |
| $\rho_5$ | | -1.029 | -9.231 | |
| | | | | |
| $\theta_{26}$ | Const. | -46250.0 | -1.550 | 6 |
| $\theta_{27}$ | $A_t$ | -34634.0 | -2.709 | |
| $\theta_{28}$ | $A^c_t$ | 19857.0 | 2.952 | |
| $\theta_{29}$ | $Y^*_{t+1}$ | 78.684 | 2.080 | |
| $\rho_6$ | | -0.538 | -4.226 | |

TABLE 2

INTRA-SAMPLE SIMULATION ASSESSMENT
OATS: RATIONAL EXPECTATIONS

| Variable | Corr.Coeff. | Theil's IC | %RMSE |
|---|---|---|---|
| SH | 0.8957 | 0.1988 | 29.122 |
| LH | 0.7670 | 0.2738 | 29.896* |
| U | 1.0000 | 0.0000 | 0.0000 |
| LS | 0.7850 | 0.3793 | 70.173* |
| SS | 0.8851 | 0.3067 | 65.056* |
| C | 0.6918 | 0.2777 | 31.172 |
| P | 0.3026 | 0.4794 | 52.644 |
| A | 0.6245 | 0.2193 | 24.718 |

---

\*   Values of per cent RMSE are calculated with the following outliers deleted: for LH observations 1972(12), 1973(04,05,07); for LS 1972(10), 1973(01,02,03,12), 1974(08), 1975(08), 1977(08,12); for SS 1972(10), 1973(01,02,03,04,07), 1975(03,08), 1976(03), 1977(08).

TABLE 3

OATS: RATIONAL EXPECTATIONS MODEL
POST SAMPLE PREDICTION OF CASH PRICE*

| Predictor | Corr.Coeff. | Theil's IC | %RMSE |
|---|---|---|---|
| AS | 0.7797 | 0.1155 | 12.667 |
| P | 0.7922 | 0.1086 | 10.257 |
| CP | 0.8363 | 0.0955 | 10.036 |

---

\* AS is the model predictor with continuous updating during the post sample period; P is the futures price; CP is a composite predictor constructed as 0.41AS + 0.60P with OLS estimated weights (see Section 5).

FOOTNOTES

1. This is not necessarily a cause for concern. Since the equilibrium condition for holders of unhedged inventories is

   $$A^*_{t+1} - A_t - r_t = m_t$$

   the effect of $m_t$ is taken into account by the presence in (3) of the variables on the left side of this equilibrium condition. A similar statement can be made about the marginal risk premium in (5).

2. A six-month future is defined as follows:

   when the month is January/February, the future is July;

   when the month is March/April, the future is September;

   when the month is May/June/July, the future is December;

   when the month is August/September, the future is March;

   when the month is October/November, the future is May;

   when the month is December, the future is July.

3. A total of 22 such negative values are generated, of which 3 are in periods when LH>SH, 18 are in periods when LH<SH and 1 is in a period when LH=SH.

4. When $LH_t = SH_t$ , both $LH_t$ and $SH_t$ are decreased by half of the absolute value of $U_t$, while $LS_t$ and $SS_t$ are each increased by half the absolute value of $U_t$ .

5. The instruments employed in the estimation of equation (1) are $A_{t-2}$ , $CK_t$ , $CK_{t-1}$ , $P^c_t$, $P^c_{t-1}$ , $r_t$ , $r_{t-1}$ , $Y_t$ , $A^c_t$ , $A^c_{t-1}$ , $SH_{t-2}$ , $P_{t-2}$ , $LH_{t-1}$ , $U_{t-1}$ , $SS_{t-1}$ , $C_{t-1}$ , $LS_{t-1}$, where $P^c$ is the corn futures price.

6. The instrument set employed to obtain 3SLS estimates of the GCA model is $CK_t$ , $CK_{t-1}$ , $r_{t-1}$ , $r_{t-2}$ , $Y_{t-1}$ , $SH_{t-2}$ , $P^c_{t-1}$ , $A^c_{t-1}$ , $LH_{t-2}$ , $SS_{t-2}$ , $LS_{t-2}$ , $U_{t-2}$ , $C_{t-3}$ , $(P_{t-2} - A_{t-2})$.

7. Four of the estimated correlation coefficients are significant at the five per cent level (two tail test), and four are negative. Durbin-Watson statistics are not reported because this test is not accurate with IV estimation. While the value of $\hat{\rho}_5$ exceeds -1, it does not do so significantly.

8. Section 6.5 of GCA refers to a speculative trading program which yielded profits significantly different from zero, so long as the expense ratio was less than 25 per cent of gross profits. The program entailed selling a futures contract (as defined in footnote 2) if P>AS′ and buying the future if P≤AS′ . This resulted in 17 sell and 14 buy transactions.

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APPENDIX 1

AVERAGE MONTH-END RATIO OF LARGE
SPECULATORS TO TOTAL OPEN POSITIONS (%)

| | OATS | | CORN | | SOYBEANS | | WHEAT | |
| | Long | Short | Long | Short | Long | Short | Long | Short |
|---|---|---|---|---|---|---|---|---|
| 1970 | 24.5 | 17.3 | 28.7 | 27.1 | 31.2 | 33.5 | 37.9 | 31.2 |
| 1974 | 12.3 | 8.2 | 18.8 | 15.0 | 27.2 | 29.2 | 20.6 | 20.6 |
| 1975 | 13.1 | 9.1 | 18.5 | 15.2 | 30.0 | 33.8 | 16.7 | 20.6 |
| 1976 | 11.7 | 10.4 | 14.2 | 14.9 | 41.5 | 39.6 | 22.1 | 21.1 |
| 1977 | 4.3 | 4.1 | 13.9 | 16.3 | 41.2 | 35.6 | 24.4 | 22.8 |
| 1978 | 13.4 | 11.5 | 12.5 | 9.5 | 29.7 | 26.5 | 24.6 | 21.1 |

Source: CFTC, *Commitments of Traders* 1970-79.

## APPENDIX 2

### OATS ADAPTIVE MODEL

### INTRA-SAMPLE SIMULATION ASSESSMENT

| Variable | Correlation Coeff. | THEIL'S IC | %RMSE |
|---|---|---|---|
| SH | 0.9356 | 0.1445 | 23.378 |
| LH | 0.7034 | 0.3534 | 34.417* |
| U | 1.0000 | 0.0000 | 0.0000 |
| LS | 0.7707 | 0.4132 | 82.463* |
| SS | 0.8771 | 0.3365 | 81.707* |
| C | 0.5966 | 0.4666 | 50.328 |
| P | 0.5570 | 0.2131 | 22.815 |
| A | 0.7406 | 0.1542 | 17.308 |

---

\*     Values of per cent root mean squared error are calculated for LH with observation 1974(07) deleted, for LS with observations 1973(12), 1974(08), 1977(08), 1977(12) deleted, and for SS with observations 1975(03), 1975(08), 1977(08) deleted. The reason for these deletions is that this statistic can be greatly distorted by the presence of a few outliers.

# APPENDIX 3

## OATS ADAPTIVE MODEL

## POST SAMPLE PREDICTION OF CASH PRICE*

| Predictor | Corr. Coeff. | Theil's I.C. | %RMSE |
|-----------|--------------|--------------|-------|
| AS′ | 0.8663 | 0.0880 | 9.541 |
| P | 0.7922 | 0.1086 | 10.257 |
| CP′ | 0.8774 | 0.0829 | 8.625 |

* AS′ is the model predictor with continuous updating during the 31 observations of the forecast period; P is the futures price; CP′ is a composite predictor constructed as 0.71AS′ + 0.30 P, where the weights are estimated by OLS.

# Figure 1.
# POST SAMPLE SIMULATION